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Report:
Biogas as an Agricultural Methane Mitigation Strategy

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Abstract:

This paper will explore agricultural methane technology as a potential methane mitigation strategy with a focus in biogas production. In our research, we will contextualize the issue by examining agricultural methane trends in general before focusing on the impact of a subsidy policy in India to encourage biogas technology adoption. We then examine implications for various stakeholders and conclude with a look at the future of biogas technology.

Section 1: Overview of Agricultural Methane

Agriculture is often regarded as the basis of human civilization and economic activity. Now, it is a worldwide industry that “is two to four times more effective in raising incomes among the poorest as compared to other sectors” (World Bank, 2022). Many developing countries rely on agriculture to sustain their economy and, in particular, to generate income for the most vulnerable populations in rural and semi-urban areas. In fact, “in some least developing countries, it can account for more than 25% of GDP” (World Bank, 2022), providing them with food and income security and further creating job opportunities.

Despite clear socio-economic benefits, there is a trade-off that has a significant atmospheric impact, and more alarmingly, on climate change. Methane is “the second biggest contributor to human-caused global warming after carbon dioxide” (NOAA, 2022). Although many climate initiatives focus on CO₂ reductions, various studies have stressed the severity of methane. While carbon dioxide has a longer life-span, “methane is roughly 25 times more powerful at trapping heat in the atmosphere, and has an important short-term influence on the rate of climate change” (NOAA, 2022). Methane is a molecule that can be broken down much faster than carbon; however, acting now to reduce methane-derived emissions will have immediate benefits to the climate that reductions in CO₂ cannot provide on their own (EPA, 2022; Olczak et al., 2021).

The COP26 negotiation has stressed this in its “methane moment” pledge to reduce CH₄ emissions by 30% as of 2030 (Olczak et al., 2021). Given that agriculture is the predominant source of methane emissions, numerous developing countries decided not to take part in it as they feared it would limit their economic potential and threaten vulnerable populations whose safety depended on it. A prime example of this paradigm is India, which has the highest agricultural methane, as seen in *Appendix A Figure 1*. The graph illustrates that in 2019, agricultural methane emissions in India were about 500.22 thousand metric tons of CO₂ equivalent accounting for 14.34% (found by $500.22\text{Mt}/3.49\text{Gt} * 100\%$) of the world's agricultural methane emissions.

Section 2: Sources of Agricultural Methane

Methane is emitted from natural resources as well as various anthropogenic (human-influenced) activities. The largest source of anthropogenic methane emissions is agriculture and is responsible for about 1/4 of total emissions (IEA, 2020). Within agricultural methane emissions, most are a product of enteric fermentation, which is responsible for about 90% of all livestock-derived methane emissions (*Appendix A Figure 2*). Enteric fermentation is the digestive process by which microbes in the guts of ruminant livestock (hoofed herbivore grazing animals) break down plant matter, enabling it to be absorbed into the animal's bloodstream, and producing methane as a by-product. Livestock then expels that methane (Lynch, 2019). Additionally, the breakdown of manure releases significant amounts of methane when stored. Outside of livestock, methane is also emitted when rice is grown in flooded paddies and created from the burning of agricultural wastes (Lynch, 2019).

Section 3: Available Technologies that Tackle Agriculture-Methane Emissions

A. Feed Additives: Reducing Enteric Fermentation Emissions

Promising research has emerged in the last few years that can have positive impacts in reducing enteric emissions through feed additives. Feed additives work by inhibiting methanogens in the rumen (the largest and first compartment of the digestive process in ruminant livestock) and decreasing methane generated inside the animal. While these can take many forms, the most practical so far has been to add fats and oils to cow feed for a resulting 15-20% reduction in exhaled methane — though studies in March 2021 have presented strong evidence that feeding cows red algae can reduce methane by up to 82% (Nelson, 2021). Symbrosia, a leading company in the use of red algae, has estimated that it would cost farmers \$1.60 USD per cow per day to include this in livestock diets, a figure that may still be cost prohibitive to many farming operations.

B. Manure Management: Cover and Flare

Investment in manure management systems can also mitigate methane released from storage. Commercial farms often require solutions for long-term manure storage to be able to process and use manure as compost and bedding material, and consequently create conditions favorable to the production of methane. A study focusing on manure lagoons in Idaho found that lagoons emitted methane in a range between 30 to 126 kg/ha per day or 22 to 517 kg/d (A.B Leytem et al, 2017).

To combat emission, cover and flare systems can be installed to cover manure pits and trap the methane produced by the stored manure. Then, since methane is combustible, flares will burn off

the methane and convert it to carbon dioxide – a strategy that effectively mitigates GHGs by converting methane into a less powerful agent of climate change (Cornell CALS, 2020). Exact costs for this type of solution is difficult to determine exactly as it is dependent on size, choice of material, location, and other factors, but it is a relatively costly solution that requires maintenance and design upkeep fees (typically by employing a licensed engineer). A cover can last between 10-20 years and does have additional benefits, mainly a decrease in odors produced on the farm as well as preventing precipitation from falling into the pit, which decreases overall manure storage capacity and requires extra labor to separate out (Peter et al, 2019).

C. Biogas Production

Biogas is a mixture of different gasses, mostly methane and carbon dioxide, produced by the breakdown of organic matter like agricultural waste in the absence of oxygen. Unlike natural gas, biogas is a renewable source and produces a nutrient-rich fertilizer as a by-product, which farmers can use on their own land or sell in the market.

After grinding and slurrifying biowaste, it is placed inside an anaerobic digester, which should be constantly maintained around 37°C for optimum microbes behavior. In around three weeks, the process is completed. The biogas product can then be purified by removing carbon dioxide, water vapor, and other gasses from the product for a higher quality gas.

Biogas as a methane mitigation strategy will be the focus of this paper as, unlike the other technologies mentioned, it has the potential to be an essentially limitless renewable source of energy in addition to reducing methane emission. Biogas and its byproducts can also be monetized on a household level as well as commercial one, making it highly scalable. The versatility of this technology as well as potential to be a cost-effective solution for different market participants will be explored by first examining its application in global policy before looking at the future of biogas.

Section 4: The New National Biogas and Manure Management Program (NBMMP)

A. Introducing the Policy

Biogas technology has been implemented in many countries – however, financial aid is often needed to subsidize the processes. In India, the government launched **the New National Biogas and Organic Manure Program (NBMMP)** in 2018. In this policy, the government provides financial aid (in between 30 to 35% of the project costs) for the setting up of family-type biogas plants, of 1 to 25 Cubic Metre capacity, mainly for rural and semi-urban households.

The lifespan of these types of biogas plants is around 7 years. And while it is active, there are

further benefits from this project, such as saving households' time (ie. women do not need to walk long distances to get firewood), improving sanitation, and increasing energy independence for households; while helping reduce environmental degradation and preventing methane emissions. To date, India has installed over 5 million small-scale biogas plants, each of which (without including land) can cost between 50-75 US Dollar per m^3 capacity.

Even though the program was discontinued in 2020, this report examines the effects of this policy before its discontinuation, with an emphasis on how adoption of this technology can be an effective methane mitigation strategy.

B. Stakeholder and Economic Theory Analysis

By analyzing the environmental, and socio-economic impact of India's adoption of biogas technology under the NBMMP policy, a few conclusions can be drawn with regard to the efficacy of biogas technology in lowering agricultural methane in agro-dominant economies/regions around the world. The NBMMP policy involved four major stakeholders – the environment, the rural household/farmers, the government (of India), and the private sector.

B.1 The Environmental Impact of Biogas Technology

Biogas technology can lower agricultural methane by reducing the negative externality associated with agriculture. *Figure 1* illustrates the externality created by agricultural activities. The socially desirable level of agriculture (Q^*) after accounting for the external climate cost borne by society due to CH_4 emissions is less than the current equilibrium level of agriculture (Q_e). By installing a biogas plant on their farm, farmers can continue producing at Q_e while also reducing the externality associated with their agricultural activity.

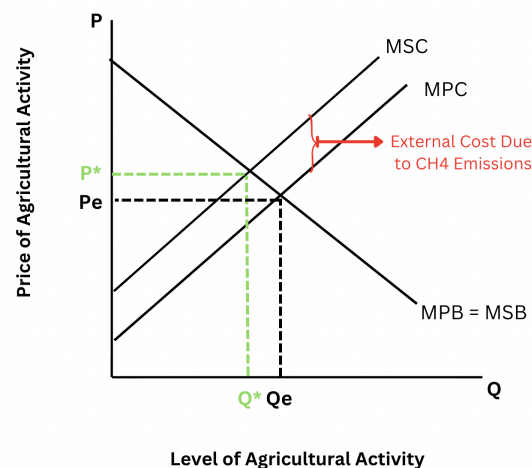


Figure 1: Negative Externality due to CH_4 Emissions

Thus, biogas production is a dependable adaptation strategy for capturing agricultural methane for economies/regions that depend on agriculture for economic growth.

Biogas technology can also indirectly reduce the concentration of other GHGs in the atmosphere (Desta et al, 2020). With biogas plants on the farm, farmers have access to biogas – a renewable resource to meet their energy needs, thus lowering their dependence on conventional electricity that eventually comes from burning fossil fuels. Increased use of biogas as a substitute for conventional energy can reduce aggregate carbon emissions if biogas technology is successfully implemented on a large scale.

Biogas technology also promotes a circular economy. Digesters decrease greenhouse gas emissions and find higher-use purposes for waste. In addition to biogas that can be used for generating heat and electricity, they also produce valuable digestate byproducts that can be used as a nutrient-rich fertilizer on farms to improve crop yield. *Figure 2* includes a detailed representation of a circular economy driven by the use of biogas.

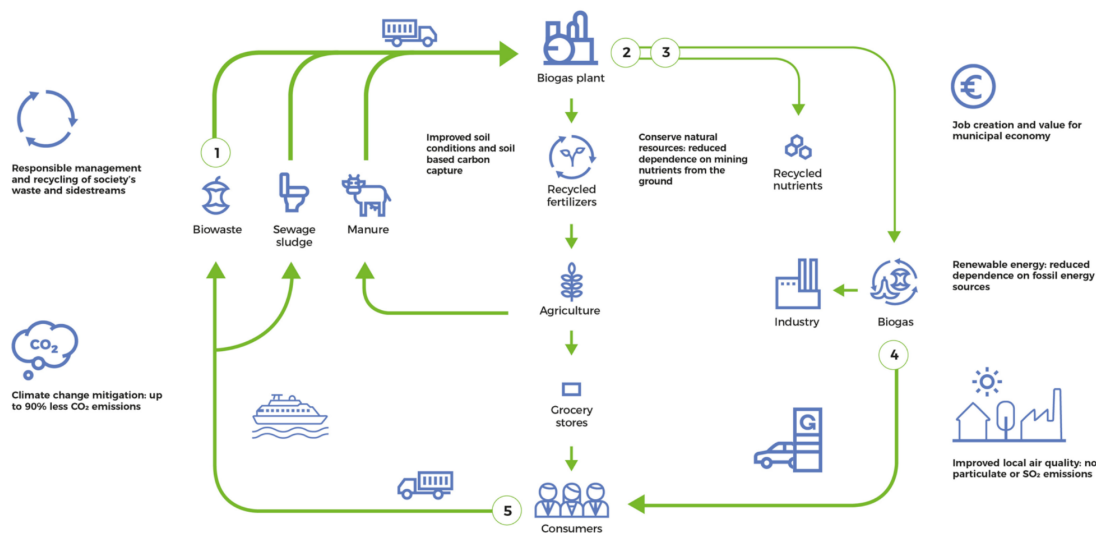


Figure 2: Biogas plants and Circular Economy

Source: Gasum

B.2 Implementation Caveats affecting the effectiveness of Biogas technology

While there are notable environmental benefits to a policy that promotes biogas technology, there are certain caveats to the implementation of the policy that could reduce the dependability or effectiveness of biogas technology in capturing agricultural methane. More specifically, under the NBMMP policy in India, studies have pointed out that the benefits of the policy were lopsided in that some regions benefited more as compared to others. This is primarily due to limited technology diffusion and accessibility to remote regions in rural India. Another potential

issue is the installation of defective biogas digesters. Due to the government of India's ambitious targets under the policy to provide rural households with biogas plants, private contractors, in order to meet their capacity targets, would often install defective plants (Dey et al, 2019). This would mean that the plant would not produce biogas as intended and would simply capture and release methane without lowering CH₄ concentrations.

B.3 The Socio-economic Impact of promoting Biogas Technology

The promotion and use of biogas technology under the NBMMP policy has had notable socio-economic impacts in the country.

Utilizing biogas from livestock waste helps families to save money that can be spent otherwise. Digestate can help reduce costly synthetic fertilizers and can increase plant growth by 10-30% compared to synthetic fertilizers. This improves crop productivity. The time-efficient aspect of using biogas has also been observed to help improve the socio-economic status of families. Instead of spending time trying to find suitable firewood, surveyed individuals claim that they are spending more time doing other activities, including social and community work and income-generating activities, among others (Thomas et al, 2017). Additionally, 1 m³ of biogas equals 0.43 kg of LPG, and a family in rural India can save about Rs 1821 (32-33 CAD) by using biogas instead of purchasing LPG, which is a significant portion for lower-income families (Ghosh et al, 2019). In addition, users have also been reported to sell digestates to farmers for a price of 200 Rupees/50 kg.

Traditionally, many households in rural India rely on burning firewood for cooking fuel. Using biogas fuel reduces the drudgery of women, as it is a less time-consuming and healthier alternative (VNV Advisory, 2020). Additionally, substituting biogas for solid fuels (like coal and firewood) reduces the emissions of smoke and other harmful substances (carbon monoxide and nitrogen oxide) by about 60%, which not only improves air quality but greatly depletes indoor and outdoor pollution. This improves the standard of living and quality of life in rural India.

B.4 Policy Impact on the Private Sector

The NBMMP has several implications for the private sector, particularly in how efficient it is for private businesses. There are several factors that affect this, with the first being the availability of feedstock. The primary input for biogas production is manure, which is abundantly available in India for use as digester feedstock. On a country scale, India had a cattle population of 306.7 million in 2022 (Statista, 2022). Pair this with the knowledge that the average cow produces around 29.5 kilograms of feces daily, and it is clear to see the potential that biogas and, subsequently biomethane, holds not only as an energy source but also as a revenue stream. Additionally, the production process has also provided an entrepreneurial avenue for farmers.

Farmers in Mizoram have been observed to sell digestates, a by-product of the digestion process, to others for a price of 200 rupees/50 kg, if not using it themselves for fertilizers (Dey et al, 2019).

The policy also provides an opportunity for businesses to transition into using a renewable source of energy. This is true for many industries in India, including manufacturing and real estate, shopping malls, and perhaps most importantly, heavy industries like chemicals and fertilizers. With the country estimated to be a \$2.5 billion market for compressed biogas by 2030, firms and businesses can begin lowering production costs by switching to biogas as a cost-effective and less carbon-intensive alternative to meet this energy demand.

Ultimately, the policy promotes large-scale production and provision of biogas digesters. Further advancements and improvements in biogas production technology can improve methods of capturing agricultural methane and lower concentrations at an increased pace over the long run. Through this, India can achieve dynamic efficiency in biogas production.

B.5 Policy Impact on the Public Sector

On the other hand, the NBMMP has several different implications for the public sector. In addition to the higher quality of life and economic stimulus that it could create, biogas production holds immense potential for trade. As the world transitions towards renewable energy, the government of India can benefit from the sheer size of the agricultural sector. Biogas is a potentially cheaper source of energy for export, roughly undercutting LPG by 80% (The Economic Times, 2020). This showcases that biogas could be a lucrative source of international trade in a quickly expanding global market.

However, the NBMMP has incurred several direct and indirect costs to the government. Costs to the government from the NBMMP mainly come from investment and construction costs, but may also arise from negligence and deterioration. Surveys have shown that state officials have failed to conduct post-installation assessments and that most digesters are non-functional, due to a variety of reasons including improper installation and operational defects (Dey et al, 2019).

Additionally, there is an issue of asymmetrical information. As a part of the NBMMP, the central government of India has assigned nodal agencies for farmers and households to report any defects that may be affecting their digesters. Despite this, surveys have shown that farmers were not aware that this was an option they had, resulting in non-functioning, obsolete digesters (Dey et al, 2019).

C. Competing Business Models for the future of Biogas in India - Privatisation vs Government Intervention

The Government of India has recently discontinued the subsidies under the NBMMP program in 2020. One of the objectives behind this step was to promote neoliberal policies that aim at greater privatization in India (The Tribune, 2020).

For the future of biogas and its success in reducing agricultural methane, it is worthwhile to discuss whether privatization could achieve similar or more efficient results as compared to government intervention in producing and expanding biogas technology in rural India.

Even if the private sector achieves dynamic efficiency for producing and installing biogas plants in the long-run, their ability to target the remote and alienated households of rural India is questionable. This is primarily due to the clashing objectives of the private and public sectors. The willingness of corporates or private contractors to enter the rural market would depend on the demand for biogas plants at the market price they offer. Given the huge income disparities across rural households in India, it is quite possible that a few regions remain untapped by the private sector resulting in lopsided environmental and socio-economic benefits in the country.

The time horizon of implementation and climate adaptation through biogas is another important aspect for selecting a business model. India aims to reach net zero by 2070. However, the Climate Action Tracker (CAT) rates India's current policies as "Insufficient" to be consistent with the 1.5C temperature limit. That said, an appropriate business model – private/public/hybrid – must be chosen in alignment with the main objective of reducing and capturing as much agricultural methane as possible as fast as possible while ensuring minimal reduction in agricultural activities that supports economic growth.

Section 5: Limitations and Risks of Biogas Technology

As biogas is made out of biowaste, handling animal manure might contain bacteria that can transmit diseases and can threaten the health of people directly involved in the process. Moreover, if there is a lack of safety standards and procedures, biogas production process can present a fire hazard, given that methane is flammable (Farm Energy, 2019). Furthermore, as manure is stored in an enclosed space, there might be a risk of asphyxiation for those working in large-scale, commercial biogas facilities.

It is also important to note that biogas production involves chemical processes that may be inhibited by impurities and the composition of the digester feedstock, which may limit the efficacy of this technology. For example, the quality and quantity of biogas output may be limited by quantities of ammonia over 3000 mg/L, a ratio between volatile acids and alkalinity

greater than 0.35, concentrations of heavy metals, and other factors (Biogas World, 2022). Quality of inputs can be a potential limitation to biogas production, as the method of husbandry, waste type (chicken, hog, and cattle manure differ in composition and reactivity), and location can create variability within the production process. Biogas operations in colder climates may also have to take special precautions to keep the internal temperature of a biogas digester in optimal operating range. Ultimately, biogas production involves sensitivity to local factors and may require location-specific research and experimentation to fully realize production capacity in different regions.

Section 6: Future of Biogas

Biogas is currently being utilized by a variety of projects in Canada and is growing rapidly. As of 2020, 279 biogas facilities existed in Canada, 45 of which utilized agricultural digesters (Canadian Biogas Association, 2020). In British Columbia, a local pilot project in Abbotsford called Eco Dairy became the first plant in North America to extract gas from cow manure and sell it to utility from a farm in 2010.

While the pilot facility struggled financially in 2012, they're currently operating with about \$5 million worth of equipment and operate as a research facility. Eco Dairy experiments with different compositions of digester feedstock to test the resulting quality and quantity of biogas output. As an agricultural operation, they've demonstrated that a 50-cow farm can reduce the equivalent of 150 tonnes of CO₂ emissions per year in addition to saving 33% of their electricity costs by combining agricultural activities with biogas production. As a pilot-scale biogas facility, they also power 1,000 homes and businesses in their area.

This pilot is especially important to the future of Canadian biogas as it is the inspiration behind a larger-scale facility currently being built in Chilliwack called Dicklands Farms. This \$40 million project will be the largest biogas plant in Canada and plans to be fully operational by April 2023. In addition to creating 200,000 gigajoules of RNG to power 4,000 homes, it will also "recover nine million gallons of water per year from manure remnants via reverse osmosis and mineral rebalancing," (Cyr, 2022), a project that is especially promising for the utilization of agricultural waste on a larger scale for Canadian energy needs.

Section 7: Conclusion and Recommendations

Global biogas energy capacity has steadily increased since 2009, with a 4.6 increase in 2021 from the previous year, and is likely to continue to rise as biogas technology becomes more efficient and available. Ultimately, biogas production has the potential to be an effective methane mitigation strategy as well as a renewable fuel for the future. It is a particularly promising direction for research, as the implementation of this technology can be made accessible on an

individual, rural scale (as evidenced by the NBMMP policy in India) as well as large industrial facilities – differentiating it from technologies like solar and wind power, which may be too cost prohibitive for developing regions to access. When paired with fitting incentive structures and reliable regulation and implementation processes, biogas production and its byproducts can be versatile and cost-effective solutions to help meet clean global energy needs.

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Appendix

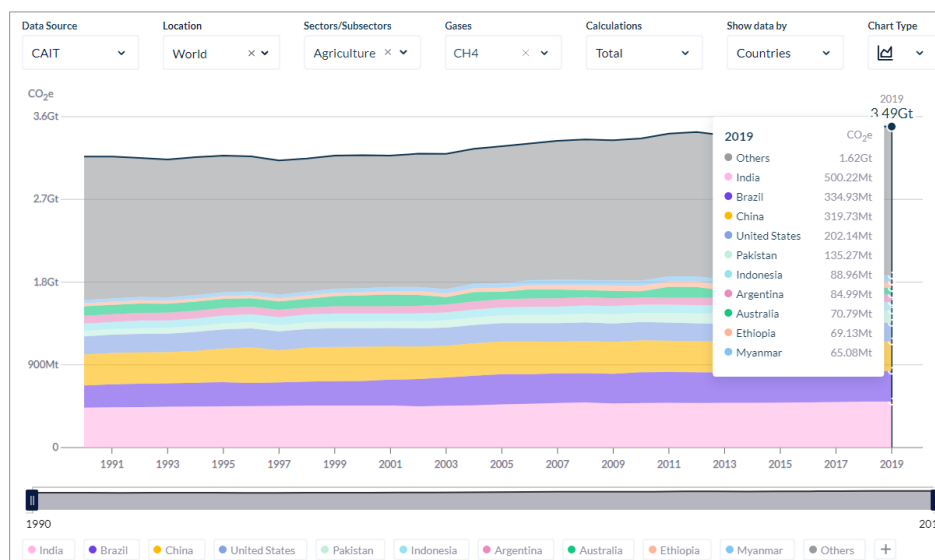


Figure 1

Source: <https://www.wri.org/insights/interactive-chart-shows-changes-worlds-top-10-emitters>

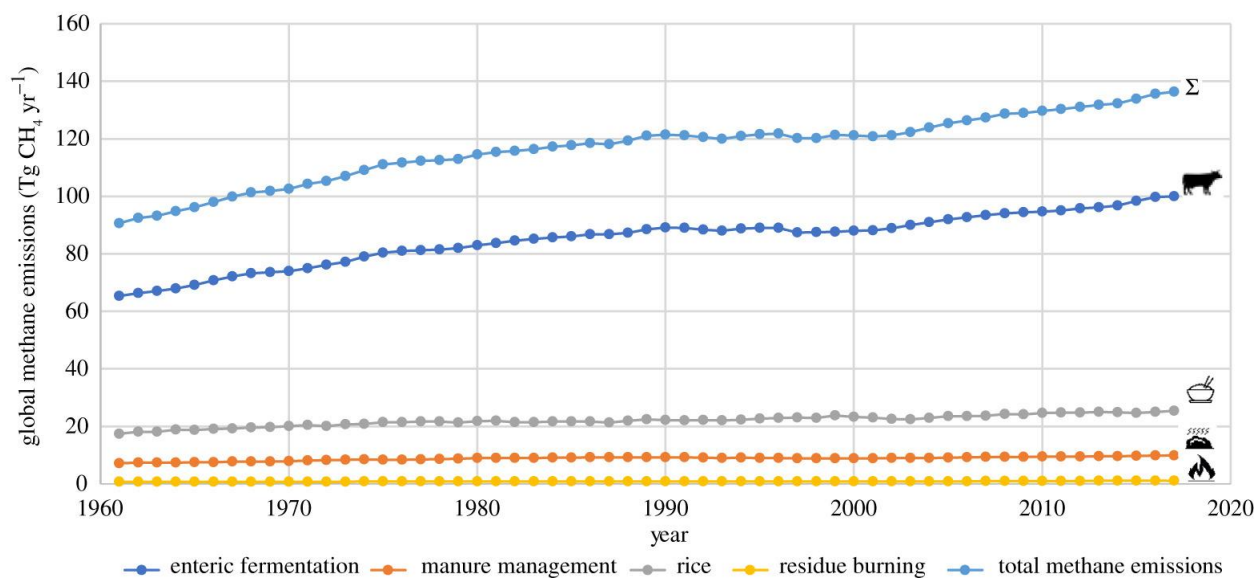


Figure 2

Source: <https://royalsocietypublishing.org/doi/10.1098/rsta.2020.0451#RSTA20200451F2>