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Agricultural Methane Framework

The Methane Framework Series

When released into the atmosphere, methane causes intense but short-term warming, with immediate effects more than 80 times greater than that of carbon dioxide. Due to this gas's powerful warming effect and short lifetime, cutting methane emissions is critical to slow the climate crisis and limit global warming to 1.5 degrees Celsius. Recognizing this opportunity, more than 110 countries have endorsed the Global Methane Pledge, which aims to cut worldwide methane emissions by at least 30 percent by 2030, compared to 2020 levels. The Methane Framework series serves as a guide for local, provincial, and regional governments to commit to methane emission reduction, rapidly scale up jurisdictionally appropriate action, and join a coalition with other leading governments across each of the three largest sources of human methane emissions: agriculture (e.g. cattle and rice production), energy (e.g. natural gas, coal, and oil), and waste (e.g. landfills and wastewater).

Introduction

The Agricultural Methane Framework introduces governments of all levels to techniques for tracking, managing, and reducing methane emissions from livestock and rice operations. Agriculture is responsible for over 40 percent of human-caused methane emissions and presents a major opportunity to slow the pace of near-term global warming. Agricultural methane releases result from the storage of organic energy in oxygen-free conditions, including rice paddies, livestock manure storage lagoons, and the digestive systems of some animals. When methane escapes these systems, it both causes global warming and represents a loss of energy that could otherwise be used productively (e.g. for animal or rice growth, as fertilizer, or as a fuel source). Agricultural methane reduction techniques can control emissions, and, in some cases, redirect this energy for productive uses, often boosting the profits of herds and farms.[1]

Agricultural methane presents a rich but challenging climate opportunity. Research in this domain is ongoing; jurisdictions have varying levels of authority; and economic, cultural, and local environmental factors must be considered. This framework first presents six governance components: (1) inventorying agricultural emissions sources; (2) calculating emissions; (3) setting an emissions reduction target; (4) introducing incentives and/or regulations; (5) implementing monitoring, reporting, and verification; and

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[1] This framework does not address issues of meat supply or demand reduction, which may be key components of long-term emission reduction strategies. Policymakers crafting strategies pursuant to this framework should be careful to avoid creation of perverse incentives or locking in programs that could inhibit future efforts.

(6) sharing information, technology, and policy best practices. It then provides a series of strategies and considerations that jurisdictions may wish to consider when addressing agricultural methane.

Governments that endorse this framework commit to implementing these actions, as appropriate to their jurisdiction, in order to quickly address agricultural methane emissions. Strategies will vary by jurisdiction based on the nature of agricultural operations and scope of government authority, and should be adjusted as techniques and institutions evolve. This framework is intended to orient policymakers and is not exhaustive.

Inventory methane-emitting livestock and rice facilities *to compile an active, jurisdiction-wide database.*

Identify and create an inventory of all agricultural facilities that could be subject to methane initiatives in the jurisdiction. For livestock, include headcounts of methane-producing animals (e.g. cattle, sheep, goats) and manure management facilities at large livestock operations. For crops, include rice fields by acreage. Where possible, the source inventory should incorporate data from environmental permits; land use and corporate registrations; and aerial observations. These inventories should be updated regularly to reflect changes in operations. This data should be made publicly available in an easily accessible and analyzable form, with anonymization as appropriate.

Inventory total methane emissions from agricultural sources *and develop an emissions baseline.*

Track and inventory methane emissions from all operations in the source inventory and determine a baseline for emissions reduction, including emissions data for major operations and the jurisdiction overall. The emissions inventory may incorporate both aerial observations (e.g. from satellites and airplanes) and statistical estimates (e.g. from animal headcounts). The inventory should be updated regularly to detect emissions changes. Note that many agricultural operations have cyclical emissions based on planting seasons and animal production schedules. Where possible, regulators should make emissions baselines publicly available in an intuitive format.

Set a jurisdiction-wide emissions reduction target *and design strategies to achieve it.*

Establish an agricultural methane reduction target based on the breakdown of agricultural operations, current emissions levels, and broader climate change mitigation goals. The agricultural methane target should be ambitious and feasible. It may be structured as a total, mass-based emission reduction or as a percentage reduction compared to a baseline. The target should account for the capacity of operators to adapt to emerging agricultural methane strategies. It is important to establish frequent benchmarks to evaluate progress. Targets and policies should be adjusted regularly to maintain ambition.

__Implement regulations, performance standards, or incentives__ *for individual facilities and operations, applicable as necessary in the jurisdiction.*

Establish requirements or incentives for operators to achieve the emission reductions established for the jurisdiction. Governments may deploy a combination of regulations, subsidies, and trading schemes. Direct incentives promote methane reduction through payments, tax deductions, or technical assistance. Regulations or performance standards would require the reduction of agricultural emissions where appropriate in accordance with regulatory authority and capacity. Trading schemes, meanwhile, can provide a credit market that rewards operators for capturing or reducing agricultural methane, either independently or in concert with other incentive or regulatory schemes. All policies should account for the impacts of methane emission reduction actions, both positive and negative, on animal health, crop yield, water, air quality, and economic development.

__Conduct monitoring, reporting, and verification__ *of emissions and emissions reductions.*

Implement monitoring, reporting, and verification (MRV) best practices to verify facility- and jurisdiction-scale emission reductions pursuant to the target and selected regulatory or incentive strategies, recognizing that MRV for agricultural emissions poses challenges. MRV can include satellite-based imaging; measurement at individual facilities where available; operator documentation and compliance reporting; and inspection and enforcement where appropriate.

__Participate in information and technology sharing forum.__

Framework endorsers participate in a forum to share policy best practices, technological developments, and regulatory analyses. The forum can provide research updates, model provisions for legislators and regulators, and regular contact between industry, regulatory, research, and NGO leaders.

Expert Assistance

Expert assistance from the Climate and Clean Air Coalition (CCAC) is available, for free, to governments of all levels. Previous CCAC agricultural methane projects have involved a livestock emissions inventory in Vietnam, rice strategies for Pakistan, and manure management techniques in China.

Baseline and Monitoring Strategies

After compiling a list of agricultural methane emitters, framework participants establish an emissions baseline. As with other pollutants, an agricultural methane baseline allows a government to assess progress and adjust policies accordingly.

For jurisdictions, methane inventories are best established through three basic approaches:

1. **Aerial observations** measure jurisdiction-level emissions of all types, agricultural and otherwise, using sensors from above (e.g. aboard satellites or airplanes). Aerial observations are considered a “top-down” technique because they take an aggregate measurement and allow operators to input further information to refine their estimates.
2. **Statistical modeling** uses ground-level factors like (e.g. cattle herd size and feed, or rice paddy acreage and composition) to estimate methane emissions across a region. Statistical modeling is considered a “bottom-up” technique, meaning that it builds a total emissions estimate by combining ground-level data.
3. **Direct sampling** of methane sources can supplement statistical modeling by providing precise local data. Through this process, professionals carefully measure the methane released by a select group of methane sources (e.g. by placing cattle in a chamber) that are representative of those within a jurisdiction. These data are then fed to statistical models to improve their accuracy.

In monitoring emissions, governments should consider that uncertainties in methane estimates may stem from several factors, including data quality, model design, and changes in emissions over time. To minimize uncertainties, the above approaches are often combined so that the granularity of statistical modeling may complement the holistic nature of aerial observation.

Aerial Observation

Aerial observations accumulate local or regional atmospheric methane data. While these approaches capture emissions from most sources, they might struggle to provide details on specific emitters. Once captured, this information might be used to determine likely emissions sources using models or by incorporating other data. Once collected, aerial data can be used in three ways: (1) a simplified, or “box,” model of the atmosphere can attribute methane to sources, (2) chemical measurements can attribute emissions to certain sources, or (3) top-down measurements can be augmented by ground-level information (e.g. statistical modeling).

Examples:

1. **Satellites:** Satellites use space-based spectrometers to assess methane emissions across entire regions or at targeted locations. As technology improves, these systems will be able to detect smaller concentrations of methane at higher resolutions, making it easier to pinpoint specific emitters. In 2022 and 2023, a new generation of methane hunters are expected to launch into orbit, some of which promise to offer free or low-cost emissions data.
2. **Overflights:** Like satellites, airplanes can be fitted with methane-sensing spectrometers. These devices, flown at various altitudes, can provide detailed insights into specific sources of methane. This method is often more sensitive than satellite observations but may be more cost-intensive.

Statistical Modeling

Statistical modeling uses readily measurable factors (e.g. cattle mass, feed quality, and milk productivity; rice yields, water usage, and crop acreage) to build a picture of total emissions. While this approach can approximate emissions from specific, documented operations, it cannot account for all sources within a jurisdiction. Although jurisdictions can use readily available data to form their estimates, some may choose to incorporate data specific to their area. In either case, the accuracy of each estimate will depend on the quality of data collected, the generalizability of samples, and the settings of the mathematical model.

Examples:

1. **GLEAM-i for livestock:** The Global Livestock Environmental Assessment Model (GLEAM-i) is a modeling tool developed by the UN's Food and Agriculture Organization. It allows users to develop emissions baselines for free using variables like species herd size, animal weights, mortality, production, feed, and manure management. For national jurisdictions when these values are unknown, GLEAM-i will provide its own estimates.
2. **SECTOR for rice:** The Source-selective and Emission-adjusted GHG CalculaTOR (SECTOR) is a spreadsheet-based model developed by the International Rice Research Institute. With this tool, users must determine inputs like crop area, yield, fertilizer, and season length. There is no estimation feature for SECTOR.

Direct Sampling

This method involves careful, scientifically rigorous evaluations of emissions sources within a jurisdiction. When used properly, direct sampling improves the accuracy of statistical models, but the high cost and operational difficulty of these practices makes them unlikely candidates for jurisdiction-wide monitoring or baseline setting. Strategies include **closed chamber systems**, which enclose an area to measure the buildup of gases and can be used for enteric, manure, and rice emissions; and enteric techniques for monitoring animals using hoods, lasers, and other methods, where each has its own advantages.

Learning from Kenya

In 2020, Kenya used statistical modeling to prepare a greenhouse gas inventory for its dairy sector. Using relatively advanced (Tier 2) modeling, the country's State Department for Livestock accounted for enteric and manure-based emissions. This involved a stocktake of five categories of cattle (cows, heifers, adult males, growing males, and calves), further sorted by different grazing and feeding scenarios. Having established a detailed inventory, Kenya is now employing a suite of initiatives to lower agricultural methane emissions.

Livestock Enteric Emission Reduction Strategies

When ruminant animals (e.g. cows and sheep) eat, their food travels to an internal chamber called the rumen. There, microbes aid digestion in oxygen-free conditions, leading to the venting of methane through the mouth. These releases—called enteric emissions—have accounted for nearly 40 percent of overall agricultural greenhouse gas emissions in recent decades. Some strategies have shown great promise to reduce emissions (i.e. methane released per product unit) while simultaneously improving profitability (production cost per unit) for operators. Effective interventions–and policy programs to support them–will likely use a range or combination of techniques with different applications depending on livestock breed, facility type, conditions, and economics. While these interventions show great promise, in some cases questions persist regarding cost, animal yield, feed efficiency, animal and human health, long-term efficacy, and supply availability.

Enteric emissions reduction techniques can be categorized as follows:

1. **Feed additives** can counter the organisms that generate methane within the rumen of an animal. They include seaweeds, nitrates, fatty acids, and 3-nitrooxypropanol, among others.
2. **Diet quality modifications** are designed to ensure that animals gain nutrition that is optimized to lower methane emissions. Recommended approaches include the feeding of young and processed forages; C3 (i.e. cold-weather) grasses, more protein, and less fiber.
3. **Selective Breeding** is an evolving strategy that could simultaneously select for animals that are both productive and low-emitting. This technique could permanently lower methane emissions among successive generations within a population of animals.

When evaluating enteric emissions strategies, governments should consider that some additives may not yet be produced at a cost or quantity to enable widespread use. Furthermore, additives like red seaweed, tannins, and certain essential oils are still being vetted for safety. Long-term studies are also evaluating whether the methane-reducing effects of feed additives remain steady over time. In addition, some vaccine-based strategies have shown potential enteric emissions reduction, but researchers are still working to evaluate their effectiveness.

Feed Additives

Feed additives work to alter the processes by which methane is produced in the rumen. They are classified as either methane inhibitors or rumen modifiers. Methane inhibitors directly counter methane production (e.g. with 3-nitrooxypropanol and red seaweeds) while rumen modifiers alter conditions within the rumen so that methane production is reduced (e.g. with essential oils).

Examples

1. **3-NOP:** The compound 3-nitrooxypropanol (3-NOP) is another methane inhibitor, designed for the purpose of blocking the generation of methane. 3-NOP may lower methane production by 36 percent in dairy and 50 percent in beef cattle. This system has not been shown to improve animal productivity and has been slow to be adopted. In late 2021, an additive consisting of 3-NOP received authorization for use in the European Union.

2. **Red seaweeds**: Red seaweeds are methane inhibitors that have achieved methane reductions of up to 55 percent in dairy and 98 percent in beef cattle. Research suggests possible benefits to animal production and health. As of 2022, red seaweed is not yet produced at commercial scale.
3. **Nitrates**: High levels of hydrogen in the rumen contribute to methane production. Nitrates act to absorb hydrogen, thereby reducing methane production. This strategy has shown a 16 percent reduction in dairy and a 12 percent reduction in beef cattle. Nitrate levels must be closely monitored to prevent toxicity.
4. **Tannins**: When included in animal diets, tannins help bind proteins, limiting the role of microbes and reducing the production of methane. This technique can lower emissions by 13 to 16 percent in dairy cattle but can reduce animal productivity if overused.
5. **Essential oils:** Essential oils can be blended together to reduce methane and significantly boost animal productivity. Commercially available essential oil blends include Mootral and Agolin, of which the former has been shown to reduce methane intensity by up to 20 percent per kilogram of milk. When used in isolation, garlic oil has shown a 12 percent methane reduction with horseradish oil achieving a 19 percent cut.

Diet Quality Modifications

Forages are plants consumed by livestock as pasture, hay, or silage. In the rumen, forages that are younger, chopped, or ensiled can aid digestibility, thereby reducing methane production. Furthermore, grasses that are adapted to cooler, dryer climates (C3 grasses) result in less methane than those that are adapted to warmer, hotter environments (C4 grasses). In conjunction with an optimized diet, the above techniques are projected to lower methane emissions between 45 and 75 percent. Each of these elements should be considered in the context of the complete diet and with the knowledge that some dietary modifications may not be sustainable due to problems with toxicity or increases in emissions of other greenhouse gasses like nitrogen oxide.

Selective Breeding

Animals within a population naturally vary in methane production, a quality that is hereditary. Early research has shown that low-emitting animals could be selectively bred to produce a cumulative and enduring improvement of livestock emissions. Practically, this would require analysis of the genetic makeup and methane production of a large number of animals. Then, methane emissions could be incorporated into existing livestock industry breeding indices that select for traits like milk yield, longevity, health, and fertility. A study looking at Dutch cattle found that this could achieve a 24 percent reduction in population-wide methane emissions by 2050 while simultaneously boosting animal productivity.

Livestock Manure Emission Reduction Strategies

Methane is generated when manure is pooled in oxygen-free environments, as is commonly done at larger livestock operations. These situations have accounted for nearly 7 percent of global agricultural greenhouse gas emissions in recent decades. The primary greenhouse gases produced during manure decomposition are methane and nitrous oxide, another highly potent greenhouse gas. Unlike other agricultural methane sources, improvements in animal productivity have little effect on manure emissions; however, in some cases the gas from manure operations can be gathered and used for energy production, displacing other fossil fuels.

The following manure management strategies may be used in isolation or combined to optimize methane reductions:

1. **Anaerobic digesters** are typically used at larger facilities to capture manure, which can then be burned to generate heat or electricity. These systems can be profitable to operators but have raised serious air and water quality concerns among environmental justice advocates.
2. **Cooling** is a low-cost tactic that can significantly reduce manure-based methane emissions in some climates. This can be accomplished by storing manure outside or by lowering its temperature through irrigation.
3. **Solid-liquid separation** reduces methane production by limiting the oxygen-free conditions required to produce methane. While this method typically requires an upfront investment, operators may benefit from selling the resulting byproducts.

When designing manure emissions policies, governments should consider environmental justice concerns that may result from incentives for biogas collected from anaerobic digesters. The production of biogas can degrade local air and water quality, often disproportionately harming lower-income communities. Moreover, some argue that biogas incentives delay a complete transition to renewable energy, while others see the practice as a key interim measure. The usefulness of anaerobic digesters is further complicated by gas leaks, which are common, and high upfront costs for grid-connected models.

Anaerobic Digesters

For larger livestock operations, where manure is typically pooled in oxygen-free conditions, a large portion of gases can be captured by anaerobic digesters. Once collected, these gases, which include high volumes of methane, can be burned to generate heat or electricity. Different types of anaerobic digesters can be deployed with different background infrastructures, including versions that connect to the larger power grid and others that generate heat or power for local use. Anaerobic digesters may result in a 68 percent reduction in methane emissions. The production of usable gas provides an incentive to implement anaerobic digesters, but upfront expenses can be high. This is especially true of grid-connected, technologically advanced models. Costs are much lower for facility-scale digesters, which could be utilized in developing countries. Some environmental justice advocates argue that policies promoting the use of anaerobic digesters can harm local air and water quality while thwarting a complete transition to renewable energy.

Cooling

Methane production is a temperature-dependent process where manure tends to produce lower emissions in colder temperatures. In cooler climates, quickly moving manure to outdoor storage facilities can achieve up to an 86 percent decrease in methane emissions with minimal cost. Furthermore, methane emissions may be reduced by using groundwater to cool the slurry surface, which has been shown to reduce methane emissions by up to 50 percent. Note that these techniques are both heavily dependent on the local climate and may not be feasible in warmer areas.

Solid-Liquid Separation

At larger operations, liquids and solids from manure are often stored together, limiting oxygen and creating the conditions for methane generation. Solid-liquid separation seeks to reduce the volume of solid manure stored in liquid, thereby reducing methane potential. Through this process, methane emissions reductions of up to 93 percent are possible. A variety of separation methods exist for facilities of different sizes. Once separated, the solid manure stream may be used to improve the nutrients and water retention of nearby soils, while the nitrogen-rich liquid stream can be used as fertilizer. In both cases, operators may return a profit. The annual cost of manure separation can range from $5 USD per cow in simpler systems to $75 per cow in more sophisticated systems.

Rice Emissions Reduction Strategies

Methane generated as a byproduct of global rice production has accounted for about 10 percent of global agricultural greenhouse gas emissions in recent decades. Rice is grown in diverse environments around the world, including both naturally and flooded and irrigated fields and commercial and small-scale operations. Strategies targeting rice emissions work to alter rice's properties or growing environment to achieve lower emissions. Its role as a staple crop in many regions may affect the applicability of some strategies.

Key strategies include the following:

1. **Water management** strategies seek to introduce more oxygen into the rice-growing process to reduce methane production. The two primary tactics are a midseason water drawdown, which is practical for most operations, and the alternate wet-dry method, which typically requires reliable irrigation.
2. **Plastic film mulching** increases oxygen in the soil to lower methane generation. This system can be labor-intensive but often results in cost savings from pesticide and fertilizer reductions.
3. **Breeding and variety** tactics employ rice types that are lower-emitting. In some cases, this takes the form of higher-yield rice, while in others, it may involve genetic modification.

When implementing rice emissions strategies, governments should understand that releases of nitrogen oxide, a greenhouse gas and local air pollutant, are likely to occur in water management scenarios. Furthermore, while low-water techniques often boost yield, they can result in dramatic yield reductions when fields are dry for too long and may invite problems with nematodes and weeds. Plastic film mulching, meanwhile, can be labor-intensive, despite showing promise to result in overall savings. Finally, some rice breeds that reduce methane emissions have a different flavor and nutritional profile.

Water Management

Methane production occurs under oxygen-free conditions, including those in flooded paddy soils. As a result, methane emissions can be substantially reduced by periodically introducing oxygen through water management.[1] When used properly, these practices can improve yield, but they can have the opposite effect when fields are left dry for too long. Note that fertilizer use must be coordinated with water management to prevent increases in nitrogen oxide, another powerful greenhouse gas.

Examples:

1. **Single midseason water drawdown:** Through this method, a field is drained for five to ten days. This is typically viable for both rainfed and irrigated operations, achieving up to a 40 percent reduction in methane emissions. The midseason drawdown has historically been used in China and Japan to boost crop yields, though studies in the US have not found such gains.
2. **Alternate Wet-Dry method**: Where more precise water management is possible, particularly in irrigated systems, a paddy can be managed through alternating cycles of flooding and drainage. This practice can achieve methane emissions reductions ranging from 48 to 93 percent and may result in an improved rice nutritional profile, reductions in toxic minerals, and yield increases.
3. **Dry seeding**: Dry seeding involves drilling seeds directly into dry fields, resulting in decreased flooding time. Compared to the alternate wet-dry method, this can result in a 47 to 66 percent reduction in CH_4 emissions during the growing season. Dry seeding is likely possible on most farms and can produce significant water savings.

Breeding & Variety

Methane emissions per unit can vary widely among rice varieties, or “cultivars.” High-yield rice can generate about 10 percent less methane, while rice modified with barley genes has been shown to produce 90 percent less methane. Note that cultivar selection for methane emissions may have an effect on rice productivity, and genetically altering rice can affect its flavor and nutritional profile.

Plastic Film Mulching

When placed over rice beds, thin plastic films can increase the oxygen in soils, improve the productivity of water, and reduce methane emissions, all while maintaining or improving rice yields. This method can achieve up to a 50 percent total greenhouse emission reduction per acre. Crop yield increases of 5 to 20 percent have been achieved in cooler climates, with water savings of up to 84 percent per hectare. In warmer climates, ridge-ditch cultivation (a similar practice without the plastic film) has suggested the potential for significant methane reductions alongside yield increases of up to 46 percent. This occurs alongside co-benefits to yield, soil aeration, and nutrition. Note that plastic film mulching can be labor-intensive. Farmers may be hesitant to invest in this system, even though it demonstrates overall savings through pesticide and fertilizer reductions.

Existing Agricultural Methane Policies

Agricultural methane mitigation policy may take the form of emissions regulations, direct incentives, trading schemes, and advisory programs. At present, policies targeting agricultural methane—and methane generally—are uncommon, but a small group of jurisdictions, led by California, have begun to act. Reductions in agricultural methane emissions may fall within existing programs that broadly target greenhouse gas emissions, but sector-specific policies are essential for near-term methane emissions reductions. The examples below are not exhaustive but provide a cross-section of agricultural methane efforts thus far.

California's Senate Bill 1383: A Landmark Methane Regulation

Passed in 2016, California's short-lived climate pollutant strategy is the world's first regulatory initiative specifically targeting livestock emissions. By 2030, the California Air Resources Board (CARB) must achieve a 40 percent reduction in dairy manure methane emissions, compared to 2013 levels. Per CARB's plan, California will "work to support improved manure management practices through financial incentives, collaboration to overcome barriers, and other market support." SB 1383 directs CARB to develop incentive programs for manure management emission reduction and to promulgate regulations starting in 2024, if technologically and economically feasible. The law also creates the potential for enteric emission reduction programs.

Agricultural methane policies may be categorized as follows:

1. **Regulations and binding targets** for agricultural methane directly require the reduction of enteric and rice emissions to meet a set target, typically through mechanisms set by an air quality or agricultural regulator. To date, only California has taken this step with specific application to agricultural emissions.
2. **Subsidies and financial incentives** include jurisdiction-sponsored aid programs to encourage private facilities to implement methane reduction mechanisms.
3. **Trading schemes** provide sellable credits for emission reductions to create a financial incentive for operators to reduce emissions–often in concert with regulatory programs–and can provide additional government revenue which can be used to fund environmental programs.

While policy mechanisms are ultimately the backbone of methane emission reduction and framework participation, the scope and composition of legal authority–as well as financial and regulatory capacity–across jurisdictions will necessarily result in a range of diverse, iterative policy approaches. Approaches that incorporate a locally appropriate mix of regulatory, incentive, trading, and advisory strategies may be most effective.

Regulations and Binding Targets

Regulations may require that agricultural methane emissions be reduced by delegating an agency to ensure their enforcement. Such a regulation may be paired with other measures to aid compliance, including subsidies, incentives, and technical assistance. As of 2022, only California has taken this step.

Examples

1. **Climate Change Response Amendment Act of 2019 (New Zealand):** This law establishes a 2050 target of at least a 24 percent reduction from 2017 levels of biogenic methane emissions. It also

includes an interim 2030 target of a 10 percent reduction. Implementing regulations have not yet been issued.

2. **Senate Bill 605 (California)**: This law required the state's air regulator to develop a comprehensive short-lived climate pollution reduction strategy inclusive of methane. The regulator must perform baseline inventories, identify research gaps, and prioritize methods with benefits to water and air quality.
3. **Senate Bill 1383 (California)**: This law requires a 40 percent reduction in total anthropogenic methane emissions relative to 2013 levels by 2030. It covers agricultural sources and specifically calls for a 40 percent reduction in dairy manure emissions. Enforcement will occur through the state's air regulator, which will develop an economically and technologically feasible incentive program. It also requires the development of biomethane pilot systems and recommendations for biomethane and biogas use.
4. **Senate Bill 1122 (California):** This law promotes bioenergy production from agricultural sources by requiring utilities to collectively procure at least 250 megawatts of generating capacity from developers of bioenergy projects, of which 90 megawatts must be produced from dairy and agricultural bioenergy.

Subsidies and Financial Incentives
Direct incentives work to reduce barriers to methane reduction strategies. They may take the form of payments or tax deductions, which enable operators to reduce emissions profitably.

Examples:

1. **Feed-in Tariffs (Argentina, Bulgaria, China, Germany, the United Kingdom, and some US states)**: These programs provide a guarantee that utilities will purchase energy generated from anaerobic digester biofuel, often at a premium, to encourage the reduction of manure emissions.
2. **Dairy Digester Research and Development Program (California)**: Funded through cap-and-trade revenue, this initiative offers financial aid for anaerobic digesters. It is expected to reduce the equivalent of 12.8 million metric tons of carbon dioxide over a ten-year period from its first 64 projects.
3. **Alternative Manure Management Practices Program (California)**: This program, funded through the state's cap-and-trade revenue, provides financial incentives to implement non-digester manure management schemes. It supports "pasture-based management; alternative manure treatment and storage; and solid separation or conversion from flush to scrape in conjunction with…drying or composting." Over five years, the program is expected to fund 114 projects to achieve a greenhouse emissions cut equivalent to 1.1 million metric tons of carbon dioxide.

Trading Schemes

The inclusion of agricultural methane in new or existing trading schemes can provide a powerful incentive for operators to reduce or capture methane. Through these arrangements, agricultural operators are able to monetize emissions reductions on a credit market.

Examples:

1. **Climate Change Response Act of 2002** (**New Zealand):** This emissions trading scheme accounts for emissions relating to livestock and fertilization. It further requires officials to report on alternative schemes to apply to agricultural emissions.
2. **The Federal Emissions Reduction Fund (Australia):** This system authorizes a standard carbon credit scheme. A variety of agricultural practices qualify for credits, including treating beef cattle with nitrates, treating dairy cattle with feed additives, herd management, and effluent management.
3. **Other Carbon Credit Systems (Mexico and the European Union)**: Under these programs, methane reductions via anaerobic digestion of manure may qualify, though agricultural methane is not specifically targeted.
4. **Transportation Fuel Programs (the US and Belgium):** Through these initiatives, credits may be granted for renewable fuel containing anaerobic digester biogas.
5. **Cap-and-Trade Program (California)**: This system requires operators of qualified greenhouse gas-emitting facilities to reduce annual emissions in line with a regulatory cap or purchase credits from other low-emitting operators. California's program allows a percentage of a firm's obligation to be met via offset programs, which can include the implementation of dairy digesters or methane reductions in rice agriculture.