EUROPEAN
COMMISSION

Brussels, XXX
[…](2020) XXX draft

COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE AND THE COMMITTEE OF THE REGIONS

on an EU strategy to reduce methane emissions

I. INTRODUCTION

Methane is the second most important greenhouse gas contributor to climate change following carbon dioxide. It has 28[1] times greater global warming potential than carbon dioxide on a 100-year timescale and is a potent precursor to air pollution contributing to ozone formation, which itself causes serious health problems.[2] Reducing methane emissions therefore contributes both to improving air quality, as well as to slowing down climate change, and can be achieved in a cost effective way, exploiting new business opportunities.

The **Regulation on the Governance of the Energy Union and Climate Action**[3], adopted in 2018, calls on the Commission to deliver a strategic plan for reducing methane emissions. Furthermore, in the **European Green Deal** Communication[4], the Commission indicated that decarbonisation of the gas sector would be facilitated as part of the commitment to reach climate neutrality by 2050, including by addressing energy-related methane emissions. In this way, policy action to reduce methane emissions will contribute to the **EU's decarbonisation efforts towards the 2030** Climate Target Plan and to the **zero pollution ambition** for a toxic-free environment.

The EU's **2030 Impact Assessment for non-CO_2 emissions** found methane to be the dominant non-CO_2 greenhouse gas in the EU, and that stepping up the level of ambition for greenhouse gas emission reduction from 50-55% by 2030 will require an accelerated initiative on methane emissions. Current baseline non-CO_2 emissions scenarios already anticipate a decrease of methane emissions in the EU by 45% compared to 1990 by 2030. However, modelling suggests that reductions of 53-55% will be necessary to meet climate targets by that date.[5] Moreover, in the EU's **Long Term Strategy** scenarios, projections indicate that methane emissions could rise again from 2030 to 2050.[6] It is therefore important that the EU sets out a methane strategy with an enduring impact beyond medium-term objectives. At a global level, reducing methane emissions associated with human activity by 50% over the next 30 years could mitigate global temperature change by **0.18 degrees** Celsius by 2050.[7]

The EU has reduction targets for 2030 across all greenhouse gases, with overall methane emissions covered in the Effort Sharing Regulation.[8] However, there is currently no specific regime in place for the reduction of anthropogenic methane emissions. Approximately 41% of global methane emissions come from natural sources, like wetlands or wildfires.[9] The remaining 59% is the result of human activity (anthropogenic), of which the largest sources are agriculture (40-53%), fossil fuel production and use (19-30%), and waste (20-26%). In the EU, 53% of anthropogenic methane emissions come from agriculture, 26% from waste and 19% from energy. The specific allocation of emissions per sector continues to evolve as reporting

[1] IPCC AR5, (2014).
[2] In the EU, premature deaths due to ozone exposure are estimated between 14,000 and 16,000 per year for the years 2015 to 2017 (EEA). JRC modelling results estimate that by 2030, depending on levels of methane emissions, the difference in associated premature deaths would be between 1,800 and 4,000, annually. These results are likely under-estimated as they do not take into account recent re-evaluation of mortality risks associated with long-term ozone exposure, which suggest a factor 2.3 times higher.
[3] (EU) 2018/1999.
[4] COM(2019) 640 final.
[5] [EU 2030 Impact Assessment for non-CO_2 emissions, (2020)].
[6] COM(2018) 773.
[7] Shindell, (2020).
[8] Anthropogenic methane emissions are currently covered by the overall reduction targets for Member States under the Effort Sharing Regulation, (EU) 2018/842
[9] IEA, World Energy Outlook, (2018), https://edgar.jrc.ec.europa.eu/overview.php?v=50_GHG.

and data collection improve. Nevertheless, these three sectors account for up to 95% of global anthropogenic methane emissions, and therefore should be the focus of mitigating action.[10]

In view of the urgency of the problem, and to contribute to the EU decarbonisation objectives, this document sets out a new EU strategy to reduce methane emissions, based on a holistic approach combining concrete horizontal and sector-specific actions, and promoting similar action internationally. While the EU contributes only 5% of global methane emissions[11], it can leverage its position as the largest global importer of fossil fuels and a strong player in the agriculture sector to support similar action from global partners.

The strategy encourages voluntary and business-led initiatives to immediately close the gap in terms of emissions monitoring verification and reporting and reduce methane emissions in all sectors. Building on this, legislative initiatives will be considered in 2021 and beyond to provide a robust, reliable and comprehensive framework for reducing methane emissions.

II. A NEW STRATEGY TO REDUCE METHANE EMISSIONS: COMBINING HORIZONTAL AND SECTOR SPECIFIC ACTIONS

The EU first addressed methane emissions with the strategy adopted in 1996.[12] In the following years, some specific regulatory initiatives such as in the waste sector - to address site management, including landfill gas - have taken into account methane emissions. These measures contributed to emission reductions in key sectors. Energy sector methane emissions have halved relative to 1990 levels, whilst emissions from waste and agriculture have fallen by a third and just over one fifth, respectively. Yet, methane emissions remain a significant challenge in each of these sectors.

In the **energy sector**, methane can leak from coal, oil, and natural gas production sites, transmission systems, ships and distribution systems, be vented (released intentionally) into the atmosphere. Even when flared or burnt, methane can still escape due to incomplete combustion. According to current estimates, 40% of methane emissions in the energy sector come from solid fuels, 31% from fuel combustion and 29% from leaks in the production and transport of oil and gas.[13] The EU's **2030 Impact Assessment for non-CO_2 emissions** indicates that the most cost-effective methane emissions savings are from the energy sector. Upstream oil and gas operations generally show a variety of negative cost mitigation options, while a large number of mitigation options at near zero cost are available throughout the whole sector.[14] Targeted intervention can therefore fully exploit methane mitigation potential in the energy sector.

Agriculture is the sector with the second highest cost-effectiveness of abatement, with potential synergies for mitigating abatement cost through production of saleable biogas.[15] Methane emissions originate mainly from the rumen of livestock (enteric fermentation)[16] (80.7%), manure management (17.4%), and rice cultivation (1.2%). Methane emissions sources are often diffuse, with numerous actors (farm holdings, farmers, processors), which makes the methane monitoring, verifying and reporting more challenging. Nevertheless, technologically

[10] Shindell, (2020).
[11] Climate Watch Data, (2016).
[12] COM(96) 557 final.
[13] [Insert source]
[14] [EU 2030 Impact Assessment for non-CO_2 emissions, (2020)].
[15] [EU 2030 Impact Assessment for non-CO_2 emissions, (2020)].
[16] Ruminant animals are a subset of mammals that ferment food in their 'rumen' (first stomach) using bacteria, before further digestion in subsequent stomachs. This 'enteric fermentation' generates methane which the animal releases. The largest sources of methane emissions in the EU agricultural sector are from cows and sheep.

feasible mitigation solutions and practices do exist and their deployment as well as reporting of their mitigation should be facilitated.

In the **waste** sector, the main identified sources of methane are the uncontrolled emissions of landfill gas in landfill sites (which account for the vast majority of waste methane emissions), the treatment of sewage sludge, and leaks from biogas plants due to poor design or maintenance. Emissions from landfilling of waste dropped by 47% between 1990 and 2017[17], following better compliance with EU waste legislation regarding emissions from landfill. This has been achieved primarily by diverting biodegradable waste to other waste treatment options higher in the waste hierarchy, such as composting and anaerobic digestion, as well as ensuring the stabilisation of biodegradable waste before disposal. However, more stringent compliance practices are needed to further reduce methane emissions from waste.

An effective EU strategy to reduce methane emissions must therefore provide stronger measures to address methane emissions in each sector but also rely on a wider use of synergies across sectors. Adopting a holistic approach brings clear advantages, as it allows for more cost-effective and evidence-based mitigation of methane emissions. It also allows to build an enabling framework and to reinforce the business case for capturing methane emissions from waste and agriculture. Lifestyle and diet changes could also contribute substantially to reducing EU methane emissions.

Furthermore, lack of agreed measurement methodologies and reliable comprehensive data hampers a clear view of the problem and constrains policy action. Filling in this gap across the board, with representative and verifiable measurement and reporting of emissions, lays the ground for well-targeted policy responses in each sector.

1. CROSS SECTORAL ACTIONS WITHIN THE EU

a. Improve the data

A priority objective is to ensure that private entities apply considerably more accurate measurement and reporting methodologies across sectors, thereby providing a better understanding of the problem and better informing subsequent mitigation measures.[18] At the level of Parties, the United Nations Framework Convention on Climate Change (UNFCCC) has a three tier reporting framework for methane emissions, which is applicable across all relevant emitting sectors. Tier 1 constitutes the most basic approach, involving simple estimations based on activity data and emission factors; Tier 3 (specific, individual measurement) is the most demanding in terms of methodological complexity and data requirements, whilst Tier 2 (specific emissions factors) combines elements of both Tiers 1 and 3.

Currently, the level of monitoring and reporting between sectors and between Member States varies considerably, with very few Member States consistently reaching Tier 3 standards. One of the key objectives of this strategy is to make Tier 3 reporting the new benchmark standard across the EU. This does not exclude applying certain level of flexibility to account for the different challenges to improving monitoring and reporting across the different sectors.

In the energy sector, Tier 3 reporting is considered widely achievable for the industry and will therefore be the EU target standard. Widespread adoption of the measurement and reporting framework developed under the United Nations Environment Programme (UNEP) **Oil and Gas Methane Partnership** (OGMP) will accelerate this transition. The OGMP is a voluntary

[17] https://www.eea.europa.eu/publications/european-union-greenhouse-gas-inventory-2020.
[18] Measurement, reporting, verification (MRV), integrity and validation (IV).

initiative that currently covers only oil and gas upstream companies, but the Commission, in cooperation with UNEP, will work to extend the OGMP framework to more companies in the gas upstream, midstream, downstream as well as to the coal sector and abandoned sites.[19] The OGMP has a 3 to 5-year implementation process to reach the required level of reporting.

In the agricultural sector, the challenges associated with a higher number of different actors involved in adjusting to new targets justifies a temporary objective of maintaining Tier 2 standards, with improving disaggregation of emission factors and a final objective of achieving Tier 3. In the waste sector, the quality of reporting is already robust for waste disposal, with the majority of improvements to be made in the area of wastewater.[20]

b. International methane emissions monitoring

The Commission will promote the establishment of an **independent and qualified international methane emissions mechanism** [name to be agreed]. It will be tasked with collecting, reconciling, verifying, and publishing anthropogenic methane emissions data at a global level anchored in the United Nations Environmental Programme (UNEP). Furthermore, the Climate and Clean Air Coalition hosted by UNEP (UN CCAC) has indicated its willingness to support the establishment of this structure through their political endorsement and engagement. This international methane emissions mechanism will incorporate a number of work streams such as the Oil and Gas Methane Partnership and the Global Methane Science Studies implemented by UNEP, within the framework of the Climate and Clean Air Coalition.

As a first step, the international methane emissions mechanism will cover methane from the energy sector. The extension of the mechanism to cover **waste and agriculture** will be considered once monitoring and reporting methodologies are defined for those sectors. For the purpose of data verification and reconciliation of energy related methane emissions, company reporting needs to be complemented by data from national emission inventories, scientific research, remote sensing verified by ground-level observations, as well as satellite observations. The mechanism will be tasked with testing new technologies through its' scientific pillar and validate their equivalence with existing methodologies, as well as assessing the level of improvement they provide to the quality of data submitted by companies.

The Commission is ready to mobilise funding from the Horizon 2020 programme to kickstart the establishment of such an international methane emissions mechanism. In cooperation with UNEP and the UN Climate and Clean Air Coalition, the Commission will organise a **donor conference** to encourage national governments in Europe and around the world to contribute, so as to ensure the necessary sustainable financing for the functioning of the mechanism.

c. Satellite Detection and Copernicus

The EU's earth observation programme 'Copernicus', can provide a key capability to enhance air surveillance and monitoring of methane emissions. In particular, Copernicus can contribute

[19] Ongoing coordination with relevant stakeholders is supporting the development of revised MRV methodologies, adapted for these sectors and sections of supply chains.

[20] The UNECE Air Convention also has a three tiers reporting framework for air pollutants emissions which is used under Directive (EU) 2016/2284 on the reduction of national emissions of certain atmospheric pollutants (the NEC Directive), where air pollutant emissions are commonly reported under Tier 2, and this forms the basis for compliance checking and further policy decisions.

to an EU-coordinated global super-emitter[21] detection and monitoring capability, principally via its Atmosphere Monitoring Service (CAMS).[22]

When launched in 2025, the Copernicus CO_2 Monitoring (CO2M) mission, which involves a constellation of three satellites, will be capable of measuring smaller and more prevalent sources of emissions as well as global atmospheric methane. This will represent a significant improvement compared to the capabilities of the CAMS and the Tropospheric Monitoring Instrument (TROPOMI), which are limited to larger emission sources.

d. Review and possible revisions of relevant environmental and climate legislation

In the European Green Deal, the Commission has announced it will review and propose the revision of a number of measures covering methane emissions[23], including measures to address pollution from large industrial installations in 2021. The Commission will assess whether the role of the Industrial Emissions Directive[24] in preventing and controlling methane emissions could be enhanced, as well as the potential to strengthen the role of the European Pollutant Release and Transfer Register (E-PRTR) regulation[25] with regard to monitoring, reporting, and verification of methane emissions.

The Commission will consider including methane into the zero pollution-monitoring framework to be developed under the Zero Pollution Action Plan announced for 2021 and in the third edition of the EU Clean Air Outlook in 2022. Moreover, the Commission will also review the NEC directive by 2025 and, in this context, explore the possible inclusion of methane among the regulated pollutants.

e. Valorisation of methane waste and residues streams from agriculture and waste sectors in biogas production

The valorisation of non-usable and non-recyclable human and agricultural organic waste[26] (i.e. manure) and residue streams in closed biogas reactors can effectively reduce methane emissions from anaerobic decomposition processes in nature. It can also generate additional revenue streams for farmers and provide opportunities for development and investment in rural areas. To that end, cooperation among farmers, as well as cooperation between farmers and local communities is essential. This will improve local economies and promote circularity. National Common Agricultural Policy Strategic Plans can offer support for such initiatives.

The biogas resulting from such processes is a source of highly sustainable and useful renewable energy with multiple applications, while the material that remains after anaerobic digestion (digestate) can be used as a soil improver, such as fertiliser. Moreover, in line with the waste hierarchy, the biodegradable input into biogas plants can count towards municipal waste recycling targets as set out in Directive 2018/98/EC on waste. The role of sustainable biogas

[21] The term 'super-emitter' in this general context refers to a specific site or facility with disproportionately high-emissions for a site or facility of that kind. In specific sectors there are individual definitions of super-emitters, in the natural gas supply-chain for example the term can refer to sites with the highest proportional loss rates, i.e the greatest loss of methane emitted for methane produced/ processed (Zavala-Araiza, et al., 2015).
[22] CAMS analyses global fluxes of methane on a daily and monthly basis and can provide full emissions datasets with comparisons between main global and regional inventories. CAMS methane products are reconciled with other independent measurement sources such as surface monitoring stations, ships, and aircraft programmes, in order to derive more accurate data.
[23] Relevant legislation includes the EU Emissions Trading System (ETS) and the Effort Sharing Regulation.
[24] Directive 2010/75/EU.
[25] Regulation (EC) No 166/2006 on the establishment of a European Pollutant Release and Transfer Register.
[26] Communication COM(2017) 34 final.

production in contributing towards the EU's decarbonisation objectives has been recognised in the recently published EU strategies for energy system integration and hydrogen.[27]

Biogas can be exploited on-site to lessen dependence on fossil-based energy, for instance to produce heat and electricity in farms, or to produce high-value renewable hydrogen via the reforming of biogas (as a substitute for natural gas). Biogas can also be purified or upgraded into pipeline-quality biomethane and then compressed or liquefied to be used as a transport fuel. Extracting CO_2 from biogas can also be used for the production of renewable hydrogen with negative greenhouse gas emission properties.[28]

According to the EU's long-term decarbonisation strategy[29], the EU's consumption of biogases (biogas and biomethane) is projected to amount to between 54 and 71 Mtoe, from around 17 Mtoe today. This growth in production is necessary to support the cost-effectiveness of methane mitigation in the agricultural sector, and for the EU to meet emission mitigation and climate targets as modelled in the long-term strategy.

Collecting and using high methane emitting organic wastes from farming into biogas substrates can also provide revenue for farming communities from material, which could otherwise be left unused. Such opportunities should be further incentivised, for instance by identifying best practices for collection and/ or harvesting of sustainable wastes and residues or by incentivising use of digestate to deliver organic alternatives to mineral fertilisers and to enhance soil quality sustainably. Sequential cropping has multiple benefits for sustainable biogas production as well as sustainable farming practices, which could be further incentivised.[30] Other means of incentivising sustainable biogas production could be explored, such as through renewable gas targets or prioritising injection of biogas into the grid. As outlined in the EU strategy for energy system integration[27], the Commission will re-examine the regulatory framework so as to facilitate the uptake of renewable gases.

In order to support the development of cross-sectoral synergies in this area as well as rural development, the Commission will consider leveraging support from the Next Generation EU (**NGEU**) and Common Agricultural Policy (**CAP**) Strategic Plans to fund sustainable biogas production. However, any supportive measures to biogas production must be carefully assessed to avoid perverse incentives that could lead to an overall increase in emissions from the waste and agriculture sectors. Actions promoted in the context of the methane strategy should be in line with the general sustainability criteria for bioenergy developed in the context of energy legislation and the taxonomy.

[27] COM(2020) 299 and 301; https://ec.europa.eu/commission/presscorner/detail/en/ip_20_1259.
[28] Solothurn site of the Horizon 2020 Store&Go project: Sewage sludge derived biogas was upgraded to pipeline specifications in a cost effective and easily scaleable bioreactor with the help of electrolysis hydrogen in a methanization process. (Technology: http://www.electrochaea.com/technology/).
[29] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52018DC0773.
[30] Stakeholder workshop organised by the Commission on the 17th of July 2020 titled "The opportunities and barriers to achieving methane emission reductions in waste and agriculture through biogas production".

Cross-sectoral actions

- The Commission will propose legislation to improve measurement, reporting, verification, integrity, and validation through sector-specific initiatives for all sources of methane emissions to the atmosphere. The Commission will also provide support for global voluntary, business-led initiatives in the energy sector.
- The Commission will promote the establishment of an independent, government-led international methane emissions mechanism anchored in UNEP, in cooperation with international partners.
- The Commission will strengthen satellite-based detection and monitoring through the Copernicus programme.
- The Commission will review and potentially revise relevant environmental and climate legislation, including the National Emission Reduction Commitments (NEC) Directive, in 2021.
- The Commission will propose pilot projects to support rural areas and farming communities in building projects and accessing funds for biogas production from agricultural waste, as well as receiving potential support from Next Generation EU (NGEU) and the Common Agricultural Policy (CAP) Strategic Plans.

2. ACTIONS IN THE ENERGY SECTOR

The scope of actions regarding energy-related methane covers the entire oil, gas, and coal supply chains, including LNG, storage of gas, and bio-methane introduced into natural gas systems. Achieving emissions savings in this sector is feasible, with at least one third of reductions possible at no net cost to industry.[31] The greatest benefits, in terms of net economic, environmental, and social costs would be achieved from reducing vented gas[32], reducing leaks in natural gas transmission, combustion, and reducing methane leaks from coalmines.[33] Flaring and venting, occurs at coal, oil, and natural gas production sites, as well as (to a much lower extent) at landfill gas and biogas facilities. Venting and routine flaring should be restricted to unavoidable circumstances, for example for safety reasons or at landfill sites.[34]

Globally, 5% of methane leaks in the coal, oil, and natural gas sectors contribute to 50% of sectoral emissions.[35] Based on a first analysis of EU emissions data, a similar pattern emerges for the EU.[36] Addressing these **super-emitters** is a cost-effective action that is feasible with currently available data and with established leak detection and repair measures.

[31] IEA, Methane Tracker, (2020).
[32] Vented from gas and oil installations during or before production, or for safety reasons. See UN CCAC SAP.
[33] (unintended leaks from all equipment).
[34] Flaring is the controlled burning of gasses produced or released in association with fossil fuel extraction and transportation as well as certain agriculture and waste practices. Venting is the controlled release of unburned gases directly into the atmosphere. Venting is arguably more harmful to the environment as the released gas typically contains high-levels of CH4, whereas flaring converts the CH4 into less harmful CO_2 (Emam, 2015). Nevertheless, the process of flaring can release other emissions such as SO_2 and NO_2 that when combined with moisture in the atmosphere can form acid rain. There are also links between flaring and serious health conditions (Ajugwo, 2013). All venting and flaring should be avoided where at all possible.
[35] Brandt, Cooley, Heath, (2016). (DOI: 10.1021/acs.est.6b04303).
[36] 10-20% of sites are responsible for 60-90% of emissions. Source: study: "Tackling energy-related methane emisisons", 2020. Consortium led by Wood.

Support voluntary initiatives

In the energy sector, the strategic approach is to support immediate industry-led voluntary initiatives in parallel with preparing relevant EU legislation to build on and consolidate the progress made through voluntary actions.

As part of this approach, the Commission actively promotes the widespread implementation of the UN **Oil and Gas Methane Partnership** measurement and reporting framework, as the best vehicle for enhancing MRV capability in the energy sector. The Commission calls on **companies** in the oil, gas, and coal sectors to set up more robust leak detection and repair (**LDAR**) programmes in preparation for upcoming legislation that would make such programs mandatory.

Upstream companies have a financial incentive to implement leak detection and repair programs, as they can sell the gas that they prevent from escaping. However, transmission, storage, and distribution system operators, including many LNG terminals are **regulated businesses** and do not own the gas. For this purpose, the Commission encourages **National Regulatory Authorities** (NRA) to **recognise leak detection and repair** related and **methane reduction investments** as **allowed costs** for regulated entities in transmission, storage and distribution. This is a short to medium-term measure until corresponding legislation is proposed that mandates these emission abatement measures. Similarly, National Regulatory Authorities should review rules, where those exist, with a view to eliminating **system losses in gas** as allowed costs in order to incentivise its minimisation. In the framework of the ongoing revision of the trans-European energy networks (TEN-E) Regulation, the Commission will also consider possible ways of identifying methane emissions-related projects. Sharing leak detection equipment at different segments of the supply chain to facilitate further the accessibility and effectiveness of leak detection and repair is another avenue worth exploring.

As EU oil and gas production is steadily decreasing, the importance of emissions from transmission, storage, and distribution within the oil and gas supply chains is likely to increase relative to upstream sources. Ensuring effective policy action in these segments of the supply chain is therefore key to the success of the strategy moving forwards.

Legislative action

The Commission intends to table in 2021 a legislative proposal on compulsory **measurement, reporting, and verification for all energy-related methane emissions**, building on the **OGMP methodology**. Improved quality of emission data through mandatory higher tier reporting on private entities enables Member States to also improve their reporting to UNFCCC and may therefore lead to an increased share of 'higher tier' reporting for the concerned key categories, also in the EU inventory. In addition, the Commission will propose **an obligation to improve leak detection and remedy leaks on all natural gas infrastructure,** as well as any other infrastructure that produces, transports or uses natural gas, including as feedstock. Moreover, the Commission will explore feasibility and added value of possible performance targets or standards for natural gas as means to further incentivise methane emission reduction in the EU.

When the proposed revision of the Non-Financial Reporting Directive (NFRD) leads to the development of European non-financial reporting standards, then the development of such standards will take account of OGMP standards in the case of oil, natural gas, and coal supply chains, with the aim of ensuring appropriate alignment.

The EU will consider enforcing an effective stop of all routine venting and flaring in the EU energy sector by 2025.[37] This will come ahead of the 2030 objectives of the World Bank Zero Routine Flaring (ZRF) initiative[38], which the Commission also intends to support, along with the World Bank Global Gas Flaring Reduction partnership (GGFR).[39] Moreover, a more precise standard for combustion efficiency will also be explored as a priority, with the objective of further reducing fugitive emissions as well as emissions from incomplete combustion of fuels. These mitigation options are generally cost-effective, and a key component of methane mitigation in the energy sector, with combustion accounting for a significant portion of EU emissions.[40]

Further improve transparency

The EU is the single largest gas importer in the world. Estimates show that external carbon or methane emissions associated with EU natural gas consumption, for example, are between three and eight times the number of emissions occurring within the EU.[41]

In order to enhance transparency on the total emissions related to the fossil fuels consumed in the EU, the Commission will task the international methane emissions mechanism to compile and publish a **Methane Supply Index (MSI)** at EU and international level.

Initially, the index can be compiled and published using existing and reported data in countries' emission inventories as submitted to the UNFCCC. It will rely on global data from the international methane emissions mechanism, empowering buyers to make informed choices when purchasing fuels. Participation in measurement programmes either within OGMP or according to other techniques equivalent to the OGMP will be further encouraged. The European Commission will propose to use a default value within the EU for natural gas volumes that have no adequate monitoring, reporting and verification systems in place. This will be designed to encourage accurate measurement, reporting and verification.

Address coalmines and abandoned production sites

The Commission encourages remedial work to eliminate methane emissions in the EU **active or unused coalmines and abandoned oil and gas sites**. Experience in third countries and certain Member States shows that these sites can have a high-concentration of emissions.[42] However, at present, there are no EU-wide rules on checking, measuring or exploiting methane leakage from coalmines or oil and gas wells after their closure. The Commission aims to support the utilisation of residual methane from coalmines, rather than flaring it or allowing it to leak unmitigated. Technologies to achieve this are available and operational in certain parts of Europe already, and their wider implementation can be supported by EU funds, such as pillar 2 of the Just Transition Mechanism, EFSI or LIFE. The forthcoming reform of the Research Fund for Coal and Steel also supports research in this field. The initiative for Coal Regions in Transition, now part of the Just Transition Platform, can serve as a forum for discussing good practices and best available techniques.

As part of the Just Transition Platform, the Commission will propose to Member States that decommissioned wells and mines are either closed and effectively sealed or are used for residual energy production (collecting methane for local use). This will require a local

[37] This would not be withstanding flaring that is necessary, for example for safety reasons.
[38] https://www.worldbank.org/en/programs/zero-routine-flaring-by-2030#1.
[39] https://www.worldbank.org/en/programs/gasflaringreduction.
[40] [EU 2030 Impact Assessment for non-CO_2 emissions, (2020)]
[41] Environmental Defence Fund (EDF), (2019).
[42] Kholod, et al., (2020). (https://doi.org/10.1016/j.jclepro.2020.120489).

workforce in these areas, such as South Poland and central and North Romania to be trained, funds to underpin non-commercial definitive closure, and accelerated opportunities for commercial companies to collect methane from abandoned sites. The Commission will bring forward recommendations for best practices and/or enabling legislation if necessary.

Actions in the energy sector

- In the short-term, the Commission encourages voluntary measurement, reporting, and verification initiatives by global industry, in particular through OGMP, leveraging its role as a co-chair.
- The Commission, in cooperation with UNEP, will work to extend the OGMP framework to more companies in the gas upstream, midstream, downstream as well as to the coal sector and abandoned sites.
- The Commission will promote remedial work under the Coal regions in transition initiative and advise project promoters on the use of available funds to support it. Best practice recommendations and/ or enabling legislation will be brought forward, if necessary.
- The Commission will work towards sector-wide implementation of leak detection and repair (LDAR) programmes by industry and, in the short-term, encourage national regulatory authorities (NRAs) to recognise related costs for regulated businesses until corresponding legislative action is proposed.
- The Commission will consider in the TEN-E Regulation revision the inclusion of methane emission reduction projects
- The Commission will propose legislation in 2021 regarding LDAR and monitoring, reporting and verification of data in the energy sector.
- The Commission will consider legislative action to prohibit routine venting and flaring by 2025, as well as prioritising precise standards for combustion efficiency.
- The Commission will task the international methane emissions mechanism to compile and publish a methane supply index for oil, gas, and coal at EU and international level.

3. ACTIONS IN THE AGRICULTURAL SECTOR

Overall, methane emissions from EU agriculture have decreased by approximately 22% since 1990, although in the past five years, herd sizes have increased again, leading to an upturn in methane emissions in that period. The methane emission intensity of meat and milk production has been lowered over time, and in order to avoid production challenges for the sector, emissions should be further decoupled from livestock populations for achieving effective future decreases. This would best be achieved through a strategic vision that balances technology, markets, facilitation and ensures at the same time farmer incomes and the fundamentals of the EU's food policy, such as described under Farm to Fork strategy.[43]

Reducing methane emissions in the EU's **agricultural** sector and their accurate monitoring, verification and reporting face inherent **complexities**. Trade-offs in mitigation actions must be minimised. For example, increasing confinement housing and dedicated grain and protein feeds may typically lead to reduced methane emissions, but are likely to increase carbon dioxide emissions through energy use in transport and animal housing. This invariably has implications for biodiversity and water consumption through the requirement of additional feed production. Moreover, grazing cattle can have a positive effect on local grassland and shrub land as well as

[43] COM(2020) 381.

through the carbon sequestration associated to maintenance of grassland, which is lost through a transition to confinement housing.

A range of mitigation technologies and practices with the potential to deliver emission reductions decoupled from production are available. These are mainly related to improvement of animal diets, herd management, manure management, in particular the application as fertiliser and biogas generation, breeding and herd health, productivity and animal welfare.

In particular, as far as reducing the emission intensity from **enteric fermentation** is concerned, the best approaches[44] are those enhancing health, fertility, animal welfare and productivity of the herds, the improvement of animal diets, feed additives, and feeding techniques, such as precision feeding as well as modernisation of stables. Approximately 7-10% of the energy in the feed of ruminants is metabolised into methane. The biggest potential to reduce the emission intensity is seen in novel feeding concepts, as mentioned in the Farm to Fork Strategy, which can achieve a very substantial methane reduction. All these measures, on top of reducing emissions, could also benefit farmers and animals. Their wide application needs to rely on a comprehensive public programme both at national and regional level with the involvement of professional advisors and sectoral relevant bodies in support of the breeders.

Reduction of emissions from manure represents a major win-win for farmers. The change from wet to dry manure practices is the most accessible and attractive mitigation action. Successful deployment of other measures depends mainly on investments in storage coverage and biogas installations. These help in 'capturing' methane from manure, while retaining the nutrients that can be used as organic fertilisers, while contributing to decarbonising the energy system and providing farmers with additional income

Methane from **rice fields** can be reduced by rewetting, drying, and other appropriate agricultural practices. Their high costs and the required reorganisation of the farm management need to be addressed.

The **uptake** of measures for methane reduction across the EU is uneven and in some regions still rather low.[45] Anaerobic digestion (for biogas production) is also an example of how policy frameworks across the Union vary in encouraging such a well-established and important technology that reduces methane emissions while providing renewable energy, valorising the waste streams, and additional income to farmers. Several of these technologies and practices can be applied at low cost for farm owners, but barriers such as insufficient knowledge and expertise may prevent their wider uptake. This underlines the need for a more systemic promotion of the related know-how and enabling frameworks, taking into account the specifics of different Member States and production systems.

Some promising technologies are being tested and are already commercially available. Novel feeding concepts could reduce to a large extent the energy lost in the feed of ruminants. In this respect, the Farm to Fork Communication envisages actions to facilitate the authorisation of new types of feed or feed additives.

In order to promote a wider uptake, **by end of 2021** the Commission, in cooperation with sectoral experts, key stakeholders and Member States, will develop an inventory of best

[44] https://ec.europa.eu/jrc/en/publication/eur-scientific-and-technical-research-reports/economic-assessment-ghg-mitigation-policy-options-eu-agriculture-ecampa-2.
[45] https://ec.europa.eu/eip/agriculture/sites/agri-eip/files/eip-agri_fg_livestock_emissions_final_report_2017_en.pdf.

practices, available technologies, including innovative ones, and keep it up to date with technologies gradually coming into the markets.

New technology that can be effective in different circumstances and with lower trade-off is however much needed to continue in a longer term reducing methane emissions in the sector. In this respect, the Commission will push its research agenda in this area, and in particular through targeted research on technology-based and nature-based solutions in its **Strategic Plan 2021-2024** of Horizon Europe.

Some of these actions and technologies are captured by current national **monitoring and reporting** of greenhouse emissions (e.g. the impacts of herd health, productivity, and welfare on emissions). However, other mitigation measures would require an improvement in the reporting methodology under the greenhouse inventory and more detailed data available to Member States. Science, technology and policy need to combine together to provide workable and long-term solutions on these aspects.

In order to encourage improvement of reporting and better collection of observation data on livestock management, feed management, feed characteristics, manure management and methane conversion factors for new technologies and practices, the Commission will set up, in the **first half of 2021,** a focus/ expert group in cooperation with sectoral experts and Member States. Moreover, to help data collection and measurement, the Commission **by 2022** will come out with a digital carbon navigator template and will encourage their development and use at farm level. This will also improve farmers' awareness of greenhouse gas emissions and of the effects of mitigation technologies on their farms.

Other initiatives stemming from the **Green Deal** accompanied by a reformed **Common Agricultural Policy** will further contribute to an effective and steady decrease in the overall methane emissions from the EU livestock sector. The specific objective to reduce greenhouse gas emissions in agriculture in the future Common Agricultural Policy and the wider flexibility provided to Member States in designing and combining various policy interventions would allow a better targeting of methane emissions at national and regional level. It will also allow for the organisation of comprehensive schemes supporting a wide range of measures encompassing the enabling infrastructures, such as technical support, farm advisory services, knowledge transfer, relevant training, and the specific mitigation technologies.

In this respect, the Commission will encourage Member States to include in their Common Agricultural Policy Strategic Plans effective schemes, such as **carbon schemes including the animal sector**, which would reward farmers based on the mitigation achieved. Common Agricultural Policy Strategic Plans will also support investments into biogas plants. Such investments can contribute to the EU's economic recovery and increase quality of life in rural areas. The focus should be put on cooperation among farmers and local communities to maximise added-value, and to prevent undesired consequences stemming from over concentration. The Common Agricultural Policy Strategic Plans will also look at ways Members States could account for the emission reduction achieved in their greenhouse gas reporting.

Mitigation measures will support a more balanced transition with all developments for the sector and rural areas, including an expected societal shift to more balanced diets, with less red and processed meat and with more fruits vegetables, and plant based protein sources, in line with the EU Farm to Fork Strategy. These lifestyle changes can "reduce not only risks of life threatening diseases, but also the environmental impact of the food system."[46]

[46] Farm to Fork Strategy (COM(2020) 381).

Actions in the agricultural sector

- In the first half of 2021, the Commission will set up a focus/ expert group, in cooperation with sectoral experts and Member States, on improving Member States' reporting of emissions through better collection of data on livestock management, feed management, feed characteristics, manure management and methane conversion factors for new technologies and practices.
- By 2022, the Commission will provide a digital carbon navigator template and guidelines on common pathways for the quantitative calculation of greenhouse gases emissions and removals in order to encourage carbon balance calculation at farm level.
- By the end of 2021, the Commission, in cooperation with sectoral experts, key stakeholders and Member States, will develop an inventory of best practices and available technologies in order to explore and promote a wider uptake of innovative mitigating actions with a special focus on methane from enteric fermentation.
- The Commission will also promote the uptake of mitigation technologies such as anaerobic digestion, feed and breeding changes (special focus on small-scale technologies and collective business models) through a wider deployment of "carbon schemes" by Member States in their Common Agricultural Policy Strategic Plans, as from 2021.
- In the Strategic Plan 2021-2024 of Horizon Europe, the Commission will include targeted research on methane emission reduction focused on technology-based and nature-based solutions.

4. ACTIONS IN THE WASTE AND WASTEWATER SECTOR

In **waste management**, the Landfill Directive[47] adopted in 1999, requests landfill operators to manage landfill gas by either utilising it for the generation of energy or flaring it. The latter practice still generates pollutants and CO_2. As a result of recent changes to the EU waste legislation (2018) which introduced the obligation to collect biodegradable waste separately by 2024, and set a new target of maximum 10% landfilling of waste by 2035, it is expected that the methane emissions from landfills will decrease further. Minimising the disposal of biodegradable waste in landfills is critical to avoid the generation of methane. For these reasons, the enforcement of existing legal requirements such as the landfill diversion targets for biodegradable waste, and the treatment of biodegradable waste prior to disposal[48] in order to neutralise its degradability, should be reinforced, as well as, clamping down on the operation of illegal landfill sites. In addition, enhanced monitoring, reporting and verification in this field is necessary to forecast the impacts towards the climate ambitions for 2030, and beyond.

More data and information is necessary to ascertain the need and scope of further action. Ideally, all landfill sites should utilise the gas they produce, until the energy content drops below a useful value. Once the utilisation of landfill gas is no longer viable, it may be recommended

[47] Directive 1999/31/EC.
[48] As interpreted by the EUCJ ruling Case C-323/13, European Commission v. Italian Republic. http://curia.europa.eu/juris/liste.jsf?language=en&num=C-323/13.

to use bio-oxidation technology[49] in "hot spots" identified across the site in order to neutralise the remaining methane.

With respect to the treatment and use of wastewater and sewage sludge, the current regulatory framework, namely the Urban Waste Water Treatment Directive and the Sewage Sludge Directive, do not tackle specifically emissions of greenhouse gases. The Urban Waste Water Treatment Directive is currently being reviewed. Over the past 30 years, the Directive has facilitated the avoidance of significant methane emissions due to collection and treatment of wastewater in efficient centralised facilities, which emit significantly less methane and other greenhouse gases than alternative treatment approaches. As part of the ongoing review of the Urban Waste Water Treatment Directive, the potential to further reduce greenhouse gas, and in particular methane emissions, will be considered, notably through a better management of sewage sludge.

The Sewage Sludge Directive, adopted more than 30 years ago, regulates the use of sewage sludge to protect the environment, and in particular soil, against the harmful effects of contaminated sludge when used in agriculture. The Commission will carry out a study starting in the third quarter of 2020, to support the evaluation of the Directive, as well as a further study that will assess the scope for further action on greenhouse gas emissions, including methane from sewage sludge. Based on the outcomes of the evaluation, the Commission will consider the revision of the Directive and the introduction of measures to limit the emission of greenhouse gases from sewage sludge by 2023.

In the review of the Landfill Directive required for 2024, the Commission will consider several actions related to landfill gas management. Firstly, emerging techniques to reduce methane emissions. This may include, *inter alia*, aeration of landfill mass to inhibit the generation of methane, improving the effective and efficient utilisation of landfill gas to generate useful energy or (when depleted) the use of (bio)oxidation techniques, including the use of bio-filters, bio-windows, and flaring. Secondly, as stated above, enhanced monitoring, reporting and verification is key to gauge impacts and improve performance in this field over time. Therefore, the assessment of cost-effective estimating, measuring, and monitoring of methane emissions in sites can provide useful tools for that purpose. Thirdly, the Commission will consider best available techniques to extract useful energy from the flaring of landfill gas through, for example, heat exchangers. Finally, following from the above actions and where necessary, the existing guidance document on the implementation of the Landfill Directive on gas control requirements[50] will be updated accordingly.

[49] LIFE Project RE MIDA - Innovative Methods for Residual Landfill Gas Emissions Mitigation in Mediterranean Regions LIFE14 CCM/IT/000464. The project demonstrated the technical and economic viability of two technologies (biofiltration and biowindows) implemented for the biological oxidation of landfill biogas with low calorific value, resulting in gains related to oxidation efficiency, abatement of odorous compounds, minimization of the risk associated with emissions of carcinogen compounds and the reduction of the cost of landfill post treatment, when compared to a conventional combustion system.

[50] https://ec.europa.eu/environment/waste/landfill/pdf/guidance%20on%20landfill%20gas.pdf.

Actions in the waste and wastewater sector

- The Commission will continue to pursue unlawful practices and to provide technical assistance to Member States and regions. This includes sub-standard landfills and the stabilisation of biodegradable waste prior to disposal, as well as its diversion for biogas production.

- The Commission will review the Landfill Directive in 2024, including possible further actions to improve the management of landfill gas, minimise its harmful climate effects, and harness any potential energy gains.

- Based on the outcome of an ongoing review of the Urban Waste Water Treatment Directive and possible review of the Sewage Sludge Directive in 2023, the Commission will assess further action to reduce greenhouse gas emissions, including methane, notably through improved management of sewage sludge

III. INTERNATIONAL ACTION

To achieve significant global atmospheric methane reduction, the EU will work internationally with diplomatic partners, international agencies and other governments, leveraging its position as the world's largest natural gas import market, its leadership in the circular economy and its advanced agricultural practices that balance animal welfare with productivity. Using this, the EU will lead the way in international fora, such as a re-invigorated UN Climate and Clean Air Coalition (UN CCAC) or the United Nations Environment Programme and engage with multilateral aid agencies and development banks. The Commission will provide support to the [mechanism] and will support global action by making its satellite data available to partners. This will be complemented by specific actions in each sector, as described below.

1. ENERGY

Given that the majority of EU energy-related methane emissions are released outside its borders, the EU must aim to tackle methane emissions throughout the supply chain. Moreover, as the world largest importer of natural gas and oil, the EU has the influence to promote improved performance not only downstream in a domestic context, but also midstream and upstream with third countries. The Commission and the External Action Service (EEAS) will work together to deliver a strong international dimension to the methane emissions policy of the European Union.

a. Reach out to international energy supplier and buyer countries and support multilateral co-operation

The EU will lead a diplomatic outreach to producer countries and companies, and urge them to become active in OGMP.[51] Furthermore, closer cooperation with US, Canada, and Mexico (countries with existing methane regulation and country-level methane reduction targets) will be pursued in order to share experience and identify joint actions. Russia, one of world's largest gas producers and the biggest gas supplier to the EU, has an important role to play in reducing methane emissions.

[51] Current members are: BP, Ecopetrol, Eni, Equinor, Neptune Energy International SA, Pemex, PTT, Repsol, Shell, and Total.

Under international partnerships and cooperation, the Commission will explore the possibility of providing partner countries with gas and oil production technical assistance on enhancing methane regulatory frameworks and monitoring, reporting and verification capacity. Through diplomacy, the Commission and the High Representative will advocate the need to properly measure and reduce methane emissions at a global level.

The scope for coordinated international action among **buyer countries** in reducing methane emission in the natural gas sector is particularly large. The EU, together with China, South Korea and Japan account for more than 75% of the global trade in natural gas.[52] The EU will reach out to these partners in order to create a coalition amongst buying countries to support the monitoring, reporting and verification standard, hence contributing to a global uptake of emission reduction technologies. This would also increase the transparency of the majority of international gas trades.

The EU will join and actively support other initiatives, in particular the UN CCAC, the Global Methane Initiative (GMI), the World Bank Global Gas Flaring Reduction partnership (GGFR), and World Bank Zero Routine Flaring (ZRF) by 2030 initiative. Greater participation in such initiatives is widely supported by stakeholders. EU collaboration with UNEP and UN CCAC on the international methane emissions mechanism is a core component of multilateral efforts across and between these organisations to tackle global methane emissions in the short-term.

Beyond this, the Commission will also propose to the EU Member States and then to the United Nations a series of actions designed to rapidly reduce global atmospheric methane emissions in the decade 2021 - 2031 and support the adoption of milestones and key performance indicators accordingly. Such an approach should be presented and endorsed in time for the 2021 United Nations General Assembly.

b. Satellite data sharing regarding super-emitters

The EU will promote the extension of the **super-emitter detection and monitoring capability** of the international methane emissions mechanism to a global level, offer it to international partners and will take **energy diplomacy action** to monitor and work to achieve reductions in emissions from super-emitters globally. This information will be based on satellite data reconciled with bottom-up detection processes. This detection and monitoring capability will form the basis for the establishment of a procedure that alerts the EU and national governments about major emission sources as of 2021. Further improvements in detection capability will be available from 2023.[53]

The EU is a technical leader in satellite imagery and methane emission leak detection through Copernicus, in particular, the global and freely available CAMS and Sentinel 5P products. Satellites will be launched by the US and Japan in the coming years covering the same chemical spectrum as Sentinel 5P. Data sharing amongst international actors will set an example of international collaboration to improve global methane emission monitoring and mitigate climate change.

2. AGRICULTURE

A significant portion of global methane emissions in the agriculture sector originate outside of the EU, and this share is projected to increase. As a result, an international vision and promotion of mitigation actions abroad is paramount. The Commission and Member States have been and

[52] IEA, (2019).
[53] The launch of satellites Sentinel 4 and 5 will provide higher frequency observations, increasing the likelihood of capturing intermittent sources.

will continue to be very active in various international fora for improving mitigation of agricultural and agro-food systems emissions.

The EU will **intensify collaboration with third countries in the framework of the Koronivia Joint Work on Agriculture**[54] (KJWA) as part of the UNFCCC. This framework covers a range of interrelated topics, such as soil, livestock, nutrient and water management, food security and socio-economic impacts of climate change across agriculture as well as methods for assessing climate change. At COP 26, the EU will work towards extracting best practices and knowledge from the KJWA work programme so as to benefit global implementation of food system sustainability.

As an active member of the UN Food and Agriculture Organization (FAO)-led **Thematic Working Group on agriculture**[55], the EU will help to foster collaboration, exchange of knowledge and best practices to improve implementation of climate action in agriculture. This will cover livestock and focus on improving the implementation of Nationally Determined Contributions (NDCs) pledged by countries as part of the Paris agreement.

The UN CCAC agriculture initiative[56] also aims to increase ambition of NDCs, focusing on reducing methane (from enteric fermentation, manure management) from livestock and paddy rice production. As a main partner, the Commission will ensure that the agriculture initiative will continue to help third countries with knowledge exchange, best practices, and establishing pilot projects to better manage methane emissions from agriculture. Future work will focus on best practices and technologies to reduce enteric fermentation globally.

EU-international partnerships on research and cooperation will continue to provide support for climate action in agriculture related projects, covering livestock and grazing land management as well as forestry.[57] Forestry includes reducing the conversion, draining and burning of peatland forests[58], managing and restoring forests in a way that reduces the incidence and severity of uncontrolled forest fires[59], and reducing firewood and charcoal use (switching to non-biomass fuels for cooking).[60] Other target areas are cropland and manure management and other land use and ecosystems (managing prescribed/ controlled fire[61], agricultural development in urban and peri-urban areas, and drying of wetlands).

The huge mitigation potential in the rice cultivation sector in Asia will be promoted, including the modification of water management practices in rice paddies such as, dry seeding, periodic or mid-season draining of flooded fields, intermittent irrigation, "ridge and furrow" system. Moreover, reducing anaerobic decomposition of fertilisers and crop residues, modifying rice crop residue management (crop residue removal, avoidance of burning, residue application in dry conditions) can also mitigate methane emissions in the Asian rice cultivation sector.

[54] https://unfccc.int/topics/land-use/workstreams/agriculture.
[55] http://www.fao.org/climate-change/our-work/what-we-do/ndcs/twg/en/.
[56] https://ccacoalition.org/en/resources/ccac-agriculture-initiative-infosheet.
[57] EU Communication on Stepping up EU Action to Protect and Restore the World's Forests; 23 July 2019
[58] IPCC, (2019).
[59] Forest conservation and sustainable management also reduces flood risks, and thereby the methane emissions associated with flooding.
[60] From the perspective of methane emissions, a switch to other biomass fuels, even if sustainably produced, is not ideal as all biomass burning generates methane.
[61] Prescribed fires are used for a variety of purposes, including rangeland management (stimulation of grass re-sprouting, maintenance of perennial grasses, inhibition of woody plant growth), landscape management, natural woodland restoration, and infrastructure/ property protection (through a reduction in hazardous fuel loads near developed areas).

These projects will be established and monitored according to EU climate tracking procedures and in line with NDCs and National Adaptation plans.

3. WASTE

Regarding waste, the Commission is actively participating in the revision of guidance on the landfilling of waste, including landfill gas management, under the Basel Convention. The guidance has been aligned with the existing EU waste legislation.

International actions

- In the context of the EU diplomatic and external relations action, the Commission will address methane emission reductions in all relevant sectors with partner countries and mobilise international partnerships and cooperation instruments to support global methane emission reduction.
- The Commission will reach out to international energy suppliers and buyers to strengthen global coordination of efforts to address energy sector methane emissions.
- The Commission will support the establishment of a methane super-emitter detection and alert process using EU satellite capability and share this information internationally through the international methane emissions mechanism.
- The Commission will support cooperation with UNEP, GGFRI, IEA, and propose actions to reduce global atmospheric methane in the decade 2021 – 2031 in time before the UN General Assembly in New York in September 2021.

IV. CONCLUSIONS

This Strategy identifies a set of actions that will achieve significant reductions to methane emissions across the energy, agriculture, and waste sectors at the EU and international level. These measures will contribute to delivering on the EU's commitments under the European Green Deal and the Paris agreement towards climate-neutrality, as well as reducing air pollution. Effective emission reductions will require resolute action by Member States, third countries and stakeholders.

The Commission will report on progress as regards the implementation of this strategy as part of the EU inventories in relation to methane emissions, while reporting under the UNFCCC and UNEP frameworks will monitor progress at international level.

The Commission invites the European Parliament, Council, and the Committee of the Regions, the European Economic and Social Committee, Member States, third countries, international organisations and stakeholders at the EU and international level to support and cooperate on the further development of this strategy to urgently address methane emissions across the energy, agriculture, and waste sectors.