Written evidence from Dr David Lowry, Dr James France and Dr Rebecca Fisher (MET0038)

Here we summarise our views, informed by 30 years of experience of measurement of atmospheric methane and source identification in the UK and globally by the Royal Holloway Greenhouse Gas Research Group. Our research uses measurements of the different stable isotopic ratios of methane and ratios of methane with other tracers such as ethane for source attribution as well as mobile measurements to map emissions.

Data, Measurement and Monitoring

Status of methane accounting, monitoring and reporting in the UK

The monitoring programme in the UK is held in high regard globally. Atmospheric measurements using the tall tower network and inverse modelling have shown good agreement with the trend recorded in the overall UK methane emission inventories since 2013 (Lunt et al., 2021) although cannot verify the sharp decrease in emissions in the 1990s in the inventories. Spatial distribution of emissions and source attribution at local scale is not so well known. Long term measurements of the stable isotopic ratio of atmospheric methane can provide information about the sources of emissions (see Woolley Maisch et al., 2023 for UK measurements, and Nisbet et al., 2023 for global measurements). Further work to refine UK specific emission factors for many subsectors of emissions would assist the assessment of inventory products using inventory data. Closer working relationships between industry, government and researchers making quantitative measurements of emissions by source category are needed. The NERC MOMENTUM (Mobile Observations and quantification of Methane Emissions to inform National Targeting, Upscaling and Mitigation - NE/X014649/1) will address some issues related to inventory reporting by using direct measurement of emission sources.

Progress on methane monitoring and data collection in the UK using technologies such as satellite data and drones

Satellites can quantify very large emissions but currently overpasses are infrequent. Emissions estimates can be verified by ground surveys (Dowd et al., 2024). Satellites can detect super-emitters, but this methodology will not detect the myriad of smaller urban emissions that come from gas leaks and wastewater pipes or agricultural emissions.

Most UK landfill site emissions and other point and area sources are too small to be quantified by current satellites but emissions can be measured using high precision gas analysers on a drone or mobile platforms on other vehicles downwind of a site. The cost of high precision (ppb level) analysers currently prevents deployment at all sites.

Many companies are beginning to utilise drone technologies to monitor sites, such as offshore oil and gas. However, this information is commercial and not available to the wider community, and much of it anonymised if it is reported under voluntary frameworks such as OGMP (Oil and Gas Methane Partnership).

We recommend implementation of a framework for the regulation, standards and traceability of those commercial companies undertaking methane emission assessment, with funding allocated so that the UK has an emission centre of excellence for technology testing and demonstration, utilising its world class academic expertise. There are facilities in other parts of the world (such as METEC and TADI in the US and France respectively) that are being run as commercial enterprises. It would be timely and prudent for the UK to utilise its world class academic expertise to develop an equivalent and be overseen by an independent non-commercial operator (i.e., something like a NERC facility). This could be designed with not just methane in mind but be suitable for many other gases such as nitrous oxide, ammonia, and hydrogen.

Significant methane leakages in the UK

Significant leaks can be super-emitters, such as those detected by satellites, but many may be missed if not specifically targeted. For example, a large gas pipeline leak detected in 2023 by GHGSat and subsequently remediated (Dowd et al., 2024) would not have been detected if a neighbouring landfill site was not the target of a focussed investigation.

Significant leaks can also be clusters of gas leaks along roads; often these are in very busy traffic locations where is it difficult to facilitate the road closures necessary for pipeline replacement. Work by the Royal Holloway group using mobile atmospheric methane measurement identified 925 gas pipeline leaks across London. Multiple small or medium sized leaks along a stretch of road add up to significant emissions. Our estimate is that half of the emissions came from multiple small leaks of < 6L/min. A recent paper (Vogel et al., 2024) uses mobile atmospheric methane measurements to compare methane leakage in London, Birmingham and Swansea with other cities in Europe and Canada. The leak rate per km of pipeline in London was the second highest of the 13 cities in this study, but lower than has been found in many US cities.

Atmospheric measurements using Royal Holloway's mobile methane laboratory have identified leakages also from gas terminals, offtake stations and other above ground gas infrastructure such as roadside gas governors which vent methane (Zazzeri et al., 2015; Lowry et al., 2020). Leaks of methane are also identified at biogas facilities (Bakkaloglu et al., 2021). Measurements by aircraft have quantified emissions from North Sea gas facilities (France et al., 2021; Pühl et al., 2024). The large range in emissions across all these facilities suggests that emissions can be low if technologies and leak detection are well implemented.

UK Methane emissions and sectors

Progress in emission reduction

Many reductions in emissions in the UK have been made since the 1980s through closure of coal mines, capture of landfill gas and reduction in organic material sent to landfill, and partial replacement of cast iron with plastic gas pipes, but there is scope for further reduction in fossil fuel, waste and agricultural sectors.

Sectors most promising for further emissions reduction

In the fossil fuel sector: Further reduction in emissions can occur with replacement of existing metal pipes and inclusion of offtake stations as part of the national point source inventory with regular leak checks. Mobile measurements can identify key methane emitting sites for further on-site investigation to pinpoint leak sources, and these can be remediated by replacing faulty components. Gas leaks, particularly road sections with multiple leaks, could be identified by mobile measurement. Pinpointing the exact location below ground and facilitating pipeline replacement is the most complex of these mitigation steps.

In the waste sector: Anaerobic digestors (AD) need better regulation and a requirement for annual leak assessments for all sites, including non-permitted energy crop AD sites. Remediation should consider capture of additional biogas from digestate lagoons by covering these over and using the gas rather than venting to the atmosphere.

In the agricultural sector: Emissions can be reduced by covering slurry tanks and utilising the biogas produced to run farm machinery, such as tractors. Enteric fermentation will be the most difficult to mitigate and more research is needed on feed supplements. Emissions from animal waste (manure and slurry) can be mitigated more easily.

All these improvements will have an associated cost, but in the long term may be profitable to the operators by capturing otherwise fugitive emissions.

Regulation

Gas Distribution – if regulation only applies to identified point sources (compressor stations and larger), then the problem lies with smaller infrastructure where there is no incentive to mitigate.

Waste – regulation generally works well for landfill with gas extraction systems and gas engines as identified point sources, but some older closed landfills are emission hotspots and these are more challenging to mitigate. AD biogas production needs more stringent regulation for all sites with limits on emissions for all components of the site including gas upgrading and digestate lagoons. Biogas AD at wastewater treatment plants may have similar issues also. Biogas / landfill gas producing electricity directly, produces less CO_2 and CH_4 emissions as the gas engines can cope with the mix percentages produced by AD, but purification of gas to make it grid compatible results in significant additional fugitive emissions.

Agricultural - emissions are not regulated.

Targets for Remediation

Agriculture

Within agriculture animal waste is the easiest target for reduction. Animals in fields produce waste that is wet and anaerobic (and therefore producing methane) only for a short time. The addition of water to remove waste from barns creating a slurry exacerbates the issue by creating an anaerobic environment for organic digestion. Capturing the slurry in a closed system and capturing the biogas produced is a developing technology, but utilisation of the gas is a key technological development. One example is the methane tractor developed by New Holland in association with Bennamann. What is required are farm activities that can be powered directly by the biogas, without the requirement to purify the methane, which is introducing extra points of leakage to the atmosphere.

As well as capture emissions from slurry by having impermeable covers over their lagoons, it is also necessary to provide incentives to use the gas, or set up facilities to bottle and sell the gas. Capture without additional incentives will eventually lead to leaks of gas to the atmosphere, some of which may otherwise have been removed due to soil uptake of degradable organic matter. We recommend policies to incentivise use of biogas in farms, and to prioritise and incentivise the production of biogas from animal slurry.

Additional subsidies for willingness to take part in scientific trials for methane quantification and long-term tracking of methane emissions in real-world environments would be useful. There is a paucity of data for emission factors derived on working farms which would help us really understand the impact of new technologies (such as feed additives).

Waste and waste management

Enforcement of gas capture on sites was the main reason for the rapid reduction of waste methane emissions from landfill sites. This does not apply to sites / cells that closed before these regulations came into force, and these will continue to emit until the end of the lifetime of methane generation (up to 50 years) and they cannot easily be remediated any quicker. Gas capture at landfill sites is not perfect, and leaking boreholes and gas wells, from above ground gas infrastructure and from the uncovered active cell remain a source of methane.

The diversion of organic waste to AD plants has created a new less well-regulated industry. Better engineering (joins and seals) of AD biogas plants, and enforced annual leak checks would reduce emissions. Regulation requiring capture and recycling of slow-produced biogas in digestate lagoons (with impermeable covers) would lead to further reductions. Utilisation of biogas for onsite electricity generation only, rather than gas upgrading to reach grid purity would remove other sources of fugitive emission. AD biogas plants at wastewater treatment plants have many of the same features and can be subject to similar requirements, but potentially lagoons at smaller sites can be covered and the produced methane captured.

Fossil fuels

Further methane reductions should be possible with complete replacement of metal pipes with plastic ones. Offtake stations should be included as emission point sources and require annual fugitive emission monitoring and mitigation of the 110+ sites of this category in the UK by the regional gas companies. Alternative technologies to venting of methane at roadside gas governors should be considered.

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