



Methane regulation in the EU: Stakeholder perspectives on MRV and emissions reductions



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ABSTRACT

Methane is potent greenhouse gas (GHG) accounting for 11% of all EU emissions, but in contrast to CO₂ it has received relatively little attention. Although methane is regulated under the EU Effort Sharing framework, this policy lacks methane-specific regulations or targets, leaving the Member States considerable discretion over whether to prioritize methane reduction or not. The European Commission presented a proposal for EU methane regulation on 15 December 2021. However, our understanding of how to design measurement, reporting and verification (MRV) regulation for methane is limited. MRV involves many stakeholders at different steps in the process (policymakers, industry, civil society, MRV service providers, etc.), whose perspectives may differ, and our study aims to gain an insight into what constitutes an effective MRV by garnering the different stakeholders' perspectives. The study reveals that: (1) the limits of voluntary MRV initiatives justify regulatory intervention, (2) the major barrier to the implementation of methane-specific MRV is not economic, but relates to an incomplete understanding of methane sources and available measurement technologies, (3) verification is likely to be the most challenging MRV element to implement, partly due to the limited number of accredited verifiers and overlapping tasks (4) MRV needs to be accompanied by methane mitigation policies incentivising continuous improvement of companies' performance. The study recommends enhancing the proposed regulation by: introducing equal requirements for operated and non-operated assets; an obligation to report measurement uncertainties; a closer integration of MRV and LDAR; clear verification rules; and an introduction of minimum and optimum methane control standards.

1. Introduction

Methane is a potent but short-lived greenhouse gas contributing ~25% to the warming since pre-industrial times (Saunois et al., 2020). Methane concentrations in the atmosphere have more than doubled between 1750 and 2021, reaching 1900 ppb (Dlugokencky, 2021; Nisbet et al., 2019). This increase is mostly driven by agriculture and fossil fuel use (IPCC, 2021a, 2021b). Reducing emissions associated with coal, oil and gas offers a fast and cost-effective opportunity to slow down the rate of global warming (Anon, 2021). Hence, keeping the 1.5 °C target within reach requires "strong, rapid and sustained reductions" in CO₂ and methane emissions (IPCC, 2021a, 2021b, p. 27).

During the UN Climate Change Conference (COP 26), the US and the European Union (EU) together with over 100 other countries launched the Global Methane Pledge (GMP) with an objective to reduce man-

made methane emissions by at least 30% from 2020 levels by 2030 (European Commission, 2021a). GMP signatories also commit to improving inventory methodologies to quantify methane emissions, especially from high emitting sources. In this context, the EU Methane Strategy and proposed regulation was published in Anon (2021), including compulsory measurement, reporting, and verification (MRV) for all energy-related methane emissions based on the voluntary Oil and Gas Methane Partnership (OGMP 2.0) (European Commission, 2021b). MRV involves direct emissions measurement, modelling or calculations ('measurement'); data collection, recording and disclosure to the relevant authority ('reporting'); evaluation of the report's accuracy and compliance by the third party (Bellassen and Stephan, 2015).

More accurate measurement and reporting of emissions by the companies is expected to improve the robustness of national GHG inventories, which form the EU GHG inventory submitted annually on

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behalf of 27 Member States to the UNFCCC Secretariat. The current reliance on Tier 1 and Tier 2 methods in national reporting leads to a high degree of uncertainty and a risk of inaccurate emission accounting (Cooper et al., 2021).

Methane abatement efforts in the oil and gas sector have often been held back by a lack of reliable methane emissions inventories (Anon, 2021). A significant stream of the scholarly literature on methane incorporates the results of measurement campaigns demonstrating the discrepancies and gaps in GHG inventory estimates (Alvarez et al., 2018; Zimmerle et al., 2015) or provides a comprehensive compilations of existing estimates (Balcombe et al., 2017). Other researchers investigate rapidly evolving detection and measurement technologies (and their limitations), improve the understanding of individual emission sources (Atherton et al., 2017; Barchyn et al., 2018; Coburn et al., 2018; Conley et al., 2016; Connolly et al., 2019; Golston et al., 2018; O'Connell et al., 2019; Ravikumar et al., 2019), and assess economic and policy incentives to reduce methane releases (Calel and Mahdavi, 2020; Hausman and Muehlenbachs, 2016; Konschnik and Jordaan, 2018; Lade and Rudik, 2017; Roshchanka et al., 2017; Silvia et al., 2021).

However, peer-reviewed literature addressing methane policy instruments, such as MRV, and their implementation remains limited (Mar et al., 2022; Rabe et al., 2020). There are few examples of effective MRV for methane in other regions, whilst existing experience with CO₂-oriented MRV systems is less applicable as methane emissions are typically smaller and more difficult to measure. Consequently, there is little understanding of what makes an effective MRV regulation for methane where our current understanding stems from a few countries' recent experience, e.g. US, Norway, and voluntary initiatives.

Given this lack of understanding, it is important to assess the perspectives of different stakeholders, including direct stakeholders relating to EU methane as well as those with prior MRV experience. Therefore, the aim of this study is to make recommendations to enhance prospective EU methane regulation and MRV via the elicitation of perspectives from a comprehensive range of stakeholders. This article focuses on the oil and gas-related emissions only. This study conducts a series of semi-structured interviews with: those involved in the policy formulation and implementation process, those required to create the information and those that may use the new information. By combining and contrasting these different perspectives the study identifies barriers to the development of an MRV system; investigates differences in the stakeholders' perception of the barriers; and identifies strategies to overcome the barriers to MRV and to effectively reduce methane emissions.

2. The current status of EU methane policies

In the EU, the first methane strategy covering emissions from agriculture, waste and energy was adopted in 1996. Methane emissions in Europe decreased by 39% between 1990 and 2019, from 729 to 443 Mt CO₂ equivalents (EEA, 2021), but the achieved reductions can only partly be attributed to the strategy and following legislation (Olczak and Piebalgs, 2019). Methane emissions are covered under the Effort Sharing framework, which sets general GHG reduction targets for Member States, but leaves them flexibility as to which emissions and sectors to address. But this issue re-emerged on the EU policy agenda with the adoption of the Governance of the Energy Union Regulation and the European Green Deal setting a climate neutrality objective by 2050 (European Commission, 2019; Anon, 2018).

In 2020, the European Commission presented a new EU strategy to reduce methane emissions setting the improvement in the quality and accuracy of methane emissions reporting, both at a corporate and national level, as a priority. On 15 Anon (2021), The European Commission proposed a regulation targeting methane emissions in the energy sector. On the MRV, the oil and gas operators will be required to gradually move from emissions estimates using standard EFs towards direct emissions measurement at the source- and site-level. This approach is

largely aligned with the voluntary OGMP2.0 reporting framework. The OGMP2.0 member companies commit to moving towards direct measurement-based reporting rather than default EFs gradually increasing data granularity and accuracy (Anon, 2020).

Under the emission mitigation measures, the European Commission suggested the harmonisation of Leak Detection and Repair practices. It sets rules as to their frequency (every 3 months), emissions detection threshold (500 ppm), repair time (within 5 days after detection), re-inspection (within 15 days) record-keeping and reporting obligations.

LDAR has historically been aimed at safety, minimising leaks of flammable gases. For this reason the focus has been on detection and then repairing of leaking components rather than quantification of the emissions. But LDAR has recently aligned with reductions of climate and air pollutants with the state of Colorado mandating the operators to conduct LDAR at wells and compressor stations and progressively extending emissions monitoring and reporting obligations (Anon, 2021, 2014). Since the introduction in Colorado, LDAR requirements have been increasingly adopted in the US and beyond.

In Europe, LDAR programmes are conducted by mid- and downstream companies, mostly on a voluntary basis. According to the 2020 industry survey, binding LDAR requirements already exist in at least 13 countries, but the majority of surveyed companies perform LDAR on voluntary basis (Anon, 2021). LDAR practices in Europe involve methane detection with soap spray, gas detectors and sensors, Optical Gas Imaging (OGI) cameras, with quantification using mainly high flow samplers and flame ionization detectors (FID) via EN51446 (Anon, 2021).

But how much measurement is actually needed to understand methane emissions enough to reduce? And what measurement technologies are the most effective for different types of facilities, given a rapid development of methane monitoring systems and evolving regulations? This paper seeks to further understand these issues, which are central to effective methane measurement and reduction, by: investigating what motivates the voluntary industry efforts to report and reduce methane emissions; critically assessing and evaluating barriers related to the establishment of a regulatory MRV for the oil and gas companies; suggesting measures to overcome the identified barriers and to enhance prospective methane regulation. To address these questions, a qualitative approach using semi-structured interviews has been applied. The next section explains the data collection and data analysis method.

3. Methodology

3.1. Analytical framework

This research is underpinned by the grounded theory method (GTM), an inductive method for conducting qualitative research with the goal of developing a theory or suggesting a new conceptualisation of the phenomenon using frameworks, conceptual schemes or models. (Bryant, 2017; Timonen et al., 2018). Grounded theory method, introduced by Glaser and Strauss (1967), is now one of the most widespread qualitative research methods used across various disciplines and subject areas (Bryman, 2012).

GTM involves an iterative process where data collection and analysis occurs in parallel, which requires moving back and forth between empirical data and emerging analysis. The inductive approach implies that hypotheses and theories emerge through collecting and analysing data, in contrast to deductive reasoning that starts out with a general statement or hypothesis. In other words, an emerging theory is "grounded" in empirical data (Timonen et al., 2018; Urquhart, 2019).

The GTM is used in this study to investigate different perspectives and expectations of different stakeholders involved in the development of an EU MRV system for methane emissions. Moreover, GTM offers a systematic approach to the analysis of a large quantity of interview data, ensuring reliability and validity of research findings (Charmaz and

Thornberg, 2021).

3.2. Stakeholder interviews

In total 48 organisations took part in the study, including 19 organisations located outside EU/European Economic Area: Russia, the United Kingdom, Ukraine, US, Canada, and Mexico. Some of those countries are important suppliers of natural gas to EU or transit countries and hence are impacted by new EU regulations. Others, like US, Canada and Mexico, were selected due to the experience in regulating methane emissions, at national and subnational level.

For mid- and downstream stakeholders, the study focused on the emissions from natural gas infrastructure only. Fig. 1 presents the breakdown of study participants by headquarters location and part of the value chain represented.

Interviewees were identified based on their expertise in the field as well as their involvement in various initiatives and thematic workshops, conferences, and webinars. Many of them were approached as a result of their engagement in public events on methane mitigation and so are naturally highly engaged in the topic. It is important to note that the sample is not necessarily representative of their sectors. The study did not seek a representative sample but instead sought perspectives from those with expertise and understanding of the topic across the different industrial, policy, civil society sectors. As a result, those organisations that are less engaged in the discussions at the EU level may be underrepresented.

Study participants have been divided into two categories: information providers and information users (Fung et al., 2004). Information providers include oil and gas companies, whose assets produce the emissions, whereas users refer to all stakeholders advocating for more transparency on corporate methane emissions, e.g. via academic publications, position papers, opinion pieces. In total, 30 participants representing the information providers and 29 users participated in the study. The former group involved: International Oil Companies (IOCs), National Oil Companies (NOCs), midstream companies, downstream companies, and industry associations – including international, regional and national associations. The latter group included: the public sector (international organisations, national regulatory authorities, policymakers, public investors and research institutes), the private sector (consulting companies, MRV service providers, private investors) and the civil society (academia and non-governmental organisations, NGOs).

Any research ethics concerns were investigated via the Research Ethics Application and approved by the Queen Mary Ethics of Research Committee. The interviewer followed the following ethics protocol: prior to the interview each participants received Participant Information

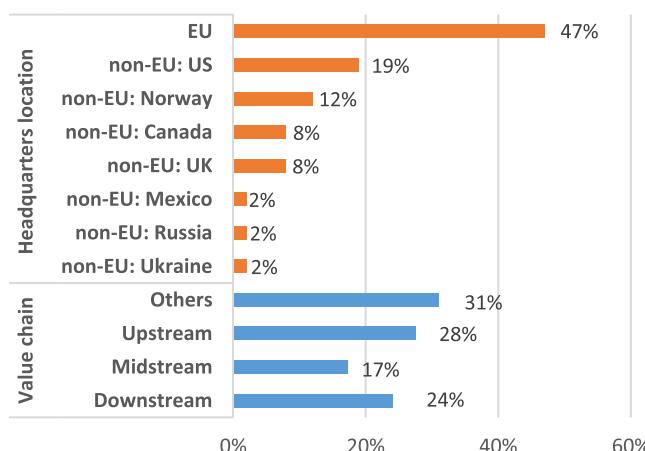


Fig. 1. Information on study participants: headquarters location (% of all study participants), part of the value chain (% of interviewed oil and gas companies). Others = Industry Associations.

Sheet with information on: the objectives and the main features of the design, possible risks and benefits for the participants, confidentiality, the right to withdraw from the study, anonymity as well as data protection and storage policies and provided their written consent. The interviews, lasting 30–60 min, were conducted between January and June 2021 via video calls.

After a brief introduction to the study, the interview commenced with questions concerning the role of the interviewee and experience within the organisation they represent. The core interview questions were split into four thematic areas and a list of interview questions are included in the *Supplementary Information*. Most interviews were video recorded and transcribed verbatim, except five interviews. In two cases the interviewees did not agree for recording – the detailed notes were used instead; two interviews were audio recorded, one interview consists of written responses only. The transcripts were subsequently analysed and coded.

3.3. Data analysis

The process of data analysis is composed of three steps: open coding, axial coding and selective coding (Urquhart, 2013). Open coding encompasses line-by-line coding where the individual concepts are identified and subsequently moved into sub-categories and categories. The data from each study participant is compared for similarities, differences and variations. Axial coding involves the identification of relationships between the categories. Selective coding led to the identification of core category – the key phenomena around which the theory is generated – and linking it to other categories.

Open coding began with the analysis of the first two transcripts, which resulted in the identification of the main concepts and common themes. Subsequently, seven overarching coding themes were identified: voluntary industry initiatives; opportunities related to mandatory MRV; methane detection and quantification technologies used by the industry; barriers to mandatory; the most challenging element of an MRV system; the link between MRV and fugitive emissions reduction (LDAR programmes); suggestions on accelerating methane emissions reduction.

4. Results

4.1. Descriptive analysis

In total, 52 interviews were conducted. In 11 cases, either more than one person representing the organisation took part in the interview or 2 separate interviews were recorded with the employees of the same organisation. Consequently the total number of interviewees was 59, representing 48 different companies and organisations. The breakdown of study participants by different subcategories as a percentage of total number of interviewees is presented in Fig. 2 below.

To categorise the interviewees and their representation, they were

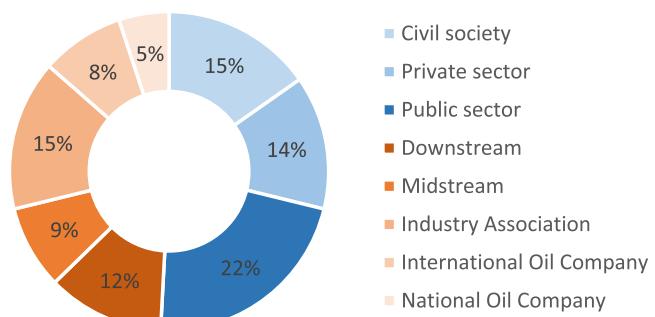


Fig. 2. Study participants disaggregated by subcategories. Data users (blue), data providers (orange) (% of total).

divided into three categories depending on their functional areas, years of professional experience within given organisation and seniority level within the organisations they represent. The results are presented by Fig. 3 below.

4.2. Limits to voluntary initiatives

Interviewees were first asked what prompts companies to report their emissions voluntarily or to join the voluntary disclosure initiatives, e.g. the OGMP2.0. The willingness to maintain the social license to operate (SLO) and to contribute to energy transition were the two most popular answers among the surveyed companies, accounting for 70% of responses provided by Data providers. Fig. 4 below presents the summary of responses. As SLO depends on the company relations with other stakeholders, follow-up questions were asked to identify them. Pressure from investors did not appear to be a motivation to join voluntary initiatives, but investors were mentioned twice as frequently by the data users than by the companies. This may indicate that users overestimate the investor pressure. The study results suggest that companies are more likely to signal their environmental responsibility to regulators (5 responses), civil society (5 responses) and to general public (4 responses) than to investors and gas consumers (3 and 2 responses respectively). Three interviewees, including 2 company representatives, mentioned the company own staff, which suggests that the source of pressure is not always external.

The interviewees were also asked about the expected benefits related voluntary emissions disclosure programs, e.g. whether they foster abatement measures. Out of 22 companies and industry associations that participated in the study, 4 companies' representatives (18%) raised doubts if quantification of emissions is even necessary to minimise emissions and two different approaches were distinguished across the data providers. The first, based on a historical safety philosophy, is focused on the detection and reduction of emissions instead of quantification: "the focus in our business is always on finding and fixing, not so much worrying about how much exactly has been leaked" [Interview 15]. The second is shared by data users and part of the industry who consider quantification key to better understand the problem and guide subsequent mitigation measures (Anon, 2020) and to increase the credibility of the industry's environmental claims.

The interviewees representing the 'detect only' approach were against setting up methane reduction targets or high reduction targets on the grounds that they are infeasible. Moreover, they typically question the viability of climate targets announced by other companies on the grounds that they lack the scientific basis and the understanding of baseline emissions [Interview 27]. The 4 companies operate in different parts of the value chain and regulatory regimes. Even though their share in the study was small, it may be more prevalent given that the study sample is not representative of the industry and we may assume that companies representing the first approach are less likely to join

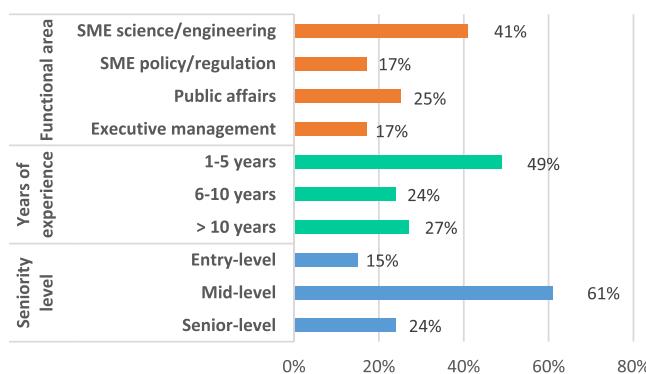


Fig. 3. Information on study participants (% of total). SME = subject-matter expert.

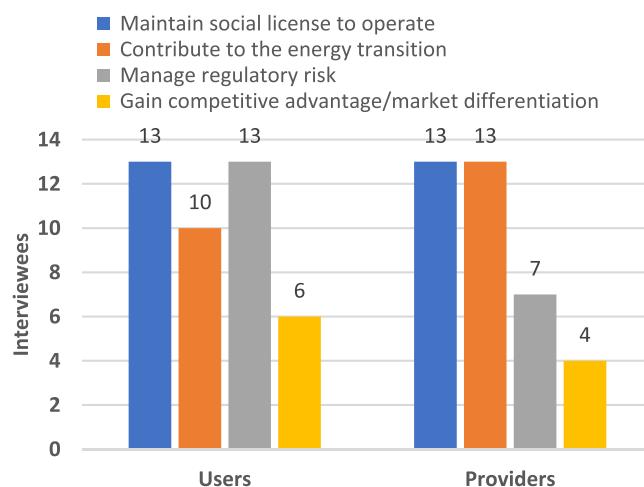


Fig. 4. Motivation to join voluntary GHG reporting initiatives by participant category.

voluntary reporting programmes. The second part of the interview focused on the barriers to an effective MRV.

4.3. Barriers to an effective MRV

Five groups of barriers, which may impede or delay the creation of an effective MRV, were identified and listed in Table 1 with a distinction between revenue-regulated gas network operators and non-regulated companies. The entities which are subject to economic regulation perform activities that are not open to competition including transmission, distribution, storage. In the EU, such companies are subject to the rules prescribed in Directive 2009/73/EC and their revenues are usually set through tariffs. Non-regulated companies are engaged in competitive activities such as the production and supply of energy.

A breakdown of responses by study participants is presented in Fig. 5 is followed by a brief description of each barrier category.

Incomplete understanding has been indicated as a major barrier by all categories of study participants, except Civil society. Data providers more frequently highlighted incomplete understanding and economic as the two major barriers, whereas more data users pointed to corporate culture (74% of all responses), regulatory barriers (65% of all responses) and accountability gap (64% of all responses). The major difference between groups were with regards to corporate culture, where data providers accounted for only 26% of all responses, in contrast to 74% of data users.

Incomplete understanding of the technologies and methods to

Table 1
Barriers to MRV for non-regulated and regulated companies: comparison.

Category	Specific	Non-regulated	Regulated
Incomplete understanding	of methane emission sources of emission measurement technologies	✓ ✓	✓ ✓
Economic	Cost-benefit analysis Opportunity cost Cost recovery	✓ ✓ ✓	✓ ✓ ✓
Corporate culture	Data confidentiality Gap between corporate strategy and culture	✓ ✓	✓
Regulatory	Lack of a uniform regulatory approach Overlaps with existing reporting frameworks	✓ ✓	✓ ✓
Accountability gap	Operatorship barrier Ownership barrier	✓ ✓	✓

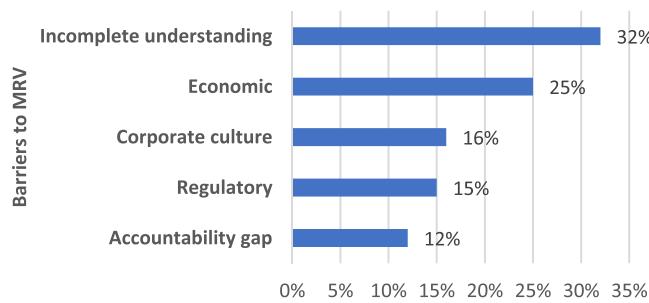


Fig. 5. Barriers to MRV (% of all responses).

measure and quantify methane emissions is a barrier to MRV framework. While some companies questioned the suitability of existing methane measurement technologies, the majority of the interviewees pointed out that they are not a barrier anymore. The challenge is that different measurements systems exist and there is no one way to do the measurements. Hence, the companies need to inquire which are the most suitable to measure emissions at their facilities ensuring sufficient accuracy. So some companies prefer to avoid investing in technologies that may be outdated soon. Consequently these companies may prefer to wait until certain technologies are prescribed by regulation and become an industry standard.

Economic barriers to conducting an effective MRV and to mitigating methane emissions were cited by 25% of interviewees. Methane measurement often requires an upfront investment in technology and expertise, and the immediate financial benefits are uncertain: savings depend on how much methane can be mitigated, natural gas prices and whether a social cost of emissions is internalised. Measurement technologies could be double or more expensive than devices used to detect emissions for safety (Anon, 2020) and there are additional costs: capacity-building among the employees, e.g. trainings, the costs related to planning and procurement, the digitalisation of data gathering process. In effect, smaller companies may not have sufficient financial capabilities to purchase, test and choose methane monitoring technologies [Interview 35]. The opportunity cost of methane measurement also serves to increase the economic barrier, that is where investment elsewhere may yield a higher return.

Regulated companies face a different set of economic barriers. In the absence of a consistent regulatory approach to methane abatement costs recovery an organisation's additional investment in methane MRV and mitigation may not be recovered as allowed revenue. Hence, the regulated companies have limited incentives to reduce methane emissions: compliance with safety requirements or minimisation of network gas losses, but up to a point where the cost of lost gas is borne by system operators (Anon, 2021). Lastly, one operator mentioned political pressure to keep the gas retail prices down, despite increasing wholesale prices, as a factor which may discourage regulated entities from making additional investment.

Barriers akin to corporate culture relate to the sharing of confidential data and instilling a 'methane mitigation mindset'. One data provider (and 8 data users) raised the concern that more methane emissions reporting may lead to revealing proprietary information, such as the efficiency of their operations or the cost of extraction. This may be particularly salient for non-operated assets, where confidentiality could prevent getting or sharing the data [Interview 40]. Currently, many companies disclose data on overall company methane-intensity rather than asset-level. However, unwillingness to publish such data creates suspicion among stakeholders "that they're simply trying to hide information that makes them look bad." [Interview 31].

Similarly, a lack of awareness of methane emissions across each company is a barrier to effective mitigation. The management of methane emissions by an organisation requires "involvement and engagement from every person in the chain who actually does it"

[Interview 28]. In some companies, the drive comes from the senior management level, who may find it challenging to ensure the buy-in from the middle management. In other, the managers may struggle to attract the attention of the senior management: "There are loads of risks and I think methane is just one of them" [Interview 24].

Another group of barriers relates to existing policy and regulatory frameworks, including a lack of a uniform regulatory approach and overlaps with existing reporting frameworks. According to 15% of all respondents, methane emissions is the result of regulatory failure, because "we haven't required [companies] to do enough on methane." [Interview 33].

There were several factors underpinning regulatory barriers at each stage of the regulatory process. Five data users suggested that without the engagement of the governments, regulators may not have a mandate to regulate methane emissions or to ask the companies for additional information. Regulators may also be constrained by information asymmetry (equipment count and production accounting, inconsistent reporting terminology). Two data providers highlighted a lack of coordination between national GHG reporting framework (UNFCCC) and the OGMP2.0 in terms of reporting templates and EFs used in those two frameworks. Finally, two data users suggested that limited regulatory resources (staff, financial, technical) impeding enforcement of the regulations.

Finally, the accountability gap relates to where the responsibility for methane emissions is not clearly established or diffused among several entities. That may be the case for Joint Ventures (JVs), where multiple companies share ownership, returns and risks, and management. Non-operated JVs (NOJVs) are also common, where a company is an owner but the operation is managed by another. The key obstacles highlighted by data providers include a perception that methane emissions is an operational issue and the responsibility of operators only. One NOJV interviewee had requested methane emissions data only in the last 2–3 years: "in some cases we didn't have a response and we don't know why, maybe it's about confidentiality or maybe it's a lack of interest." [Interview 40]. Companies that have received access to such data highlighted the issues with the quality of the inventory, e.g. methane emissions sources included/excluded from reporting. One company mentioned they receive the data from the operators, but current contractual arrangements prevent reporting them.

The interview participants were asked to point out the most challenging MRV element. Their responses were split between verification and measurement with 48% and 45% of all responses, in some cases the interviewees have chosen more than one. The summary of responses is presented in Table 2 below.

One concern relates to the verifiers and their ability and competence to verify data reported by the companies. Verification of methane emissions requires technical competence and 5 interviewees raised the doubts whether the accounting companies are qualified for this task. Two interviewees highlighted that national public authorities also may not have sufficient staff and competence. Verification is considered as

Table 2
The most challenging aspect of Measurement (M) Reporting (R) and Verification (V).

Challenges	M	R	V
Technical challenges: accuracy vs practicality vs costs	16		
Technology-related challenges	8		
Lack of standardised measurement system	7		
Data handling	1		
Standardised reporting template		2	
Disaggregation		2	
Reluctance to report problems		1	
Verification input			1
Reconciliation of source-level and site-level measurements	4		5
Verification output			6
Lack of verification standard for methane			16
Verifiers and their competence/ability to verify			16

the least mature part of MRV: “that’s probably a challenge to get the common understanding of what the verification is” [Interview 45]. There is uncertainty around whether verification should include the reconciliation between site level and source measurements were part of ‘measurement’, whereas others as a part of ‘verification’.

4.4. Is MRV enough to reduce methane emissions?

Lastly, the interviewees agree that MRV would not be sufficient to reduce methane emissions and indicated three potential pathways for accelerating further methane emissions reductions:

- 1) 8 interviewees suggested setting a clear trajectory for methane emissions reductions, which could translate into a set of mandatory targets for individual companies.
- 2) 7 interviewees suggested introducing regulatory standards for reductions, e.g. prescriptive regulations, performance-based regulations, and tightening them overtime.
- 3) 4 interviewees suggested introducing a mix of policy instruments combined with diplomatic action.

5. Discussion

Based on the interview results, a set of critical factors regarding the set-up of an effective MRV regulation have been identified: limits to voluntary initiatives, the role of technology, verification, and the role of other policy instruments. These are discussed in this section to draw recommendations to enhance the proposed EU methane MRV framework.

5.1. Are voluntary initiatives enough to reduce emissions?

The findings of the interviews confirmed the necessity to introduce mandatory MRV framework in lieu of voluntary OGMP2.0 framework. While interviewees largely agree that voluntary efforts are worthwhile, there are several limitations, which MRV regulation could address: economic, limited participation, limited scope, limited use for other stakeholders.

The major barrier to the effectiveness of voluntary efforts is that measurement of emissions is expensive and the costs related to quantification outweigh the expected benefits – the mitigating impact. As a result, some firms believe that it is more important to focus investment and company’s efforts on mitigation, instead of on accurate quantification: “We have a very well organized program for the LDAR and result is that we find very little leaks, so spending a lot of money on quantifying those would be a waste of money and a waste of opportunity to do other mitigating measures.” [Interview 38]. Moreover, the reductions which those companies consider as achievable are lower than what is expected, e.g. 60–75% reductions by 2030 or a ‘near zero’ emissions intensity suggested by the OGMP2.0.

There is also a limited participation in these programmes as voluntary initiatives tend to attract the companies that have already undertaken efforts to reduce methane emissions. Other firms fear that efforts to measure emissions more accurately and publish results may lead to negative reactions from other stakeholders, affecting their reputation. There is a risk that firms are criticised for polluting more, should their GHG inventories increase as a result of more measurement. This may have implications for how MRV is set up, to prevent companies being penalised for better measurement. However, it should be noted that some default emission factors are inherently conservative and so better measurement often results in reduced inventory, as well as the opportunity to eliminate the emission once it is found. Hence, the proposed regulation could be enhanced by introducing the obligation to report the measurement uncertainty, which would provide an incentive to improve the measurement overtime.

The introduction of mandatory MRV would alleviate both economic

and membership barriers by eliminating the cost-benefit trade-off and by introducing the same requirements, hence levelling the playing field. The lack of methane regulations in place particularly prevents regulated companies from investing in methane management: “the relationship we have with our regulator is you don’t do anything that they haven’t asked you to do because you won’t get paid” [Interview 24]. Once a mandatory MRV is established, the role of the national regulatory authorities (NRAs) becomes key in creating incentives for the regulated companies to reduce methane emissions.

Another shortcoming of voluntary efforts is their limited scope. Up to now, methane emissions from NOJVs have typically not been reported or have been reported only partially (Anon, 2017, 2018, 2016). However, NOJVs accounted for 48% of the oil and gas majors’ production (between 19% and 66%), and revenues (19–65%) in 2018 (Block and Watson, 2020). The inclusion of both JVs and NOJVs in the mandatory MRV framework would eliminate these limitations. The MRV requirements in new JV agreements could alter the design of new facilities, helping to avoid methane emissions in the first place. Currently, the proposed EU regulation makes a distinction between operated and non-operated assets, allowing the latter more time for reporting. The interview results suggest that those assets should be treated equally.

Additionally, the interviews revealed that the companies used participation to signal their environmental responsibility to regulators, civil society and general public but not to gas buyers and consumers. This is consistent with the literature (Antweiler and Harrison, 2007; Broule and Harrington, 2010) suggesting that voluntary GHG disclosure mechanisms have greater use to regulators than to other data users, particularly consumers. While the information gathered through GHG disclosure aides the regulators to create and implement better regulatory instruments, the benefit to diverse groups of consumers acting voluntarily upon this information is less evident. This demonstrates both the potential and limitations of using information disclosure in reducing methane emissions, highlighting the necessity to combine MRV with other mitigation measures in line with the European Commission proposal.

5.2. The major barrier to mandatory MRV is not economic: technologies in MRV

While the costs of emissions measurement may discourage some companies to join voluntary initiatives, the major barrier to mandatory MRV is related to a lack of common understanding of what ‘measurement’ should entail, which methane quantification technologies are the most effective and how to reconcile source-level and site-level emissions. Despite a rapid measurement technologies development in the last few years, it is still impossible to measure all emissions all the time with high accuracy and precision.

In case of fugitive emissions the EU MRV regulation could build on existing safety practices, capitalizing on the rapid development of emission measurement technologies though linking LDAR programs with emissions quantification. Traditional LDAR programmes involve detection devices such as: infrared cameras (IR), Flame Ionisation Detectors (FID), carpet probe methane detectors. Yet, the majority of the 29 interviewed companies already links LDAR programs with fugitive emissions quantification, either by following the leak detection with direct measurement or by using quantification technologies, that is laser-based Cavity Ring-Down Spectroscopy (CRDS).

There are several benefits of linking LDAR with emission quantification. Firstly, it enables the companies to gather information on the state of infrastructure, which can serve more than one purpose, reducing the monitoring costs, reduction of fugitive emissions, compliance with safety regulations and compliance with quality of service and supply requirements, e.g. continuity of gas supply.

Despite these benefits there are several caveats that the EU methane regulation should take note of. Firstly, practical experience with using methane quantification technologies, especially at site level, is still

limited as there is no one-size-fits-all technology. This is due to different weather conditions (wind, humidity, snow coverage), security and safety policies (drone fly-overs), as well as local regulations, permitting and approval process.

Secondly, there are significant differences in the current European LDAR practices in terms of the scope and frequency of LDAR campaigns, and repair time. During the interviews, only 4 companies noted that they conduct annual LDAR programs on all their networks, others do it either less regularly or conduct LDAR at specific elements of the grid such as compressor stations, depending on national regulations. The frequency of LDARs is either fixed e.g. annual inspection or varies depending on the type of facility, gas pressure, and pipeline material. Lastly, some companies categorise and prioritise leaks to be repaired based on safety considerations (Anon, 2018), while others have a predefined maximum repair time, e.g. one year. This is likely to have an impact on the consistency of leak detection surveys in the EU following the adoption of regulation, as highly experienced surveyors detect more leaks than those who had completed fewer surveys (Ravikumar et al., 2020; Zimmerle et al., 2020). EU methane regulation should complement and build on existing foundations to ensure no conflicts between safety and climate regulations exist. This requires the harmonisation of diverse company practices (Anon, 2021) and may require targeted training for the crews conducting LDAR surveys.

Lastly, there must be consideration over the design of MRV regulations that enhances benefits of the currently rapid technology development, instead of hampering it. One answer, reiterated by 11 of interviewees, is that regulation should be technology-agnostic and allow the companies to explore different quantification technologies. The drawback of this strategy is that companies are then burdened with the decision of what technologies to use and the knowledge gap comes into play: “The legislation would be fantastic (...) but it can't just be about here's the legislation – comply, because people will panic and possibly take the wrong decisions” [Interview 42]. If a technology-agnostic approach is chosen, regulators and the Commission should work with industrial experts to raise awareness of the different technology options across the entire industry.

One example is an ongoing project, which has been undertaken by the European Gas Research Group (GERG) assessing different site-level measurement and quantification technologies among midstream and downstream gas companies (Anon, 2021). The involvement of regulators, codification of learnings into best available technologies documents and international standards, combined with the dissemination of such results among the industry via existing voluntary initiatives will help to enable better technology investment decisions and to raise technology awareness. In the future, the EU MRV framework could also set a basis for the validation and certification of different measurement technologies.

In summary, MRV should be fully integrated into the existing company practices, such as LDAR programs. Safety philosophy became a success, because it has been integrated into the O&G operations at every step, it is likely that the same process needs to take place in terms of methane emissions management.

5.3. What kind of verification is needed?

The study participants indicated verification as the most challenging element of MRV for methane emissions and provided diverging perspectives on what verification or validation should entail. For instance, there was a confusion whether the reconciliation of source- and site-level measurements is a part of measurement or verification process. As a result, the development of a verification standard would help to clarify the scope. Hence, a key question to MRV setters is: how should methane emissions be verified most effectively and by whom?

The study participants were against allowing accounting companies to verify methane reporting, on the grounds that they lack the expertise in measurement and in the oil and gas sector. Moreover, the study

participants highlighted the necessity to verify the robustness of the entire process put into the reporting, not only if the final reported values are correct. The study participants were also divided whether verification should always entail on-site measurements and to which extent, the verification results should be publicly available.

The proposed EU MRV framework aligns with most of the requirements suggested by both data providers and data users, especially in terms of the qualifications that verifiers should have, so that their work is credible and the necessity to verify the robustness of the entire process, tools and technologies to get the methane emissions inventory. In terms of the governance structure the proposed verification framework involves both private and public entities: independent verifiers accredited by a national accreditation body, national competent authorities and International Methane Emissions Observatory.

However, the analysis of the information available on the webpages of the national accreditation bodies reveals that the number of verifiers with an expertise in both GHG validation and verification in line with international standards (ISO14065: 2013) in the oil and gas sector is currently limited and in some countries where there are no such verifiers yet. Additionally, the proposed regulation does not specify the sampling strategy, which the competent authorities should choose to conduct routine inspections and there is a risk of a duplication of tasks of independent verifiers and IMEO, as both entities have been tasked with the verification of methodologies and statistical processes used by the operators.

Hence, an effective EU MRV could include a set of minimum requirements for verifiers (understanding of methane emission quantification and the oil and gas sector operations) and clear verification rules. One data user suggested the development of verification form or checklist, explaining the steps undertaken by verifiers with a publicly available verification report [Interview 50]. The EU regulation supports the development of European and international standards for methane emissions quantification, which may be incorporated into the EU legislation through a delegated act, when they will be adopted. It also demonstrates that it is rather a beginning of a standardisation of methane verification process and the Commission has chosen to leave some flexibility to verifiers and Member States. The EU regulations may be enhanced by differentiating the verification requirements and frequency depending on the size of the companies and or by introducing sampling strategy based on the magnitude of discrepancies between source-level and site-level measurements.

5.4. The role of other policy instruments

While the interviewees broadly agree that MRV will need to be complements by other policy instruments, there is no agreement on the best way to proceed. But the responses provided by the stakeholders raise a pertinent question – how to keep a right balance between efforts to improve emissions quantification and actual emissions reductions? Improved quantification of emissions is essential, but it should not delay emissions prevention and control, which is the ultimate objective of methane policies. Therefore, one suggestion could be to oblige the operators to report the measurement uncertainty (Bellassen and Stephan, 2015; Jonas et al., 2019). For instance, the Norwegian measurement regulations, which form the basis of the calculation of CO₂ tax applying to methane emissions, specify an allowable measurement system uncertainty at 95% confidence level (e.g. 5% of standard volume for flare gas metering, please note that the ‘flare gas’ is defined in these regulations as “natural gas burnt off or vented to the atmosphere”), as well as the maximum uncertainty limits at measurement systems’ individual components (Anon, 2001). The advantage of such an approach is that it helps to prioritize the reduction of emissions, which could be measured the most accurately.

Since, the EU methane tax is unlikely, due to the unanimity requirement in the Council, the EU Commission could define a set of minimum and optimum methane reduction standards in the regulation.

This approach would ensure the regulators that all regulated entities meet at least a minimum performance standard (e.g. avoid compressor venting) with penalties for non-compliance, whilst allowing companies flexibility (e.g. use mobile highly efficient flares or better - recompress and use methane instead of flaring it). If this information is reported along with methane emissions, it could provide an immediate incentive to the companies to aim for higher reduction standards, signaling a better performance than their peers to other stakeholders, e.g. financial community.

6. Conclusions and policy implications

This paper has investigated the critical attributes of, and barriers to an effective MRV in the oil and gas sector through a series of 52 interviews with 59 professionals representing: the companies operating in different parts of the oil and gas supply chain, regulators and policy-makers, civil society, international organisations, MRV service providers and financial community.

The key findings are: voluntary initiatives have important, but limited role in addressing methane emissions highlighting the need for a regulatory intervention. A mandatory MRV system could foster: standardization of industry approaches, definitions and measurement and quantification methodologies; the acceptance of additional costs; integration of existing regulatory reporting frameworks and templates e.g. national GHG inventories.

The major challenge related to the establishment of a mandatory EU MRV system for methane emissions in the EU is not economic, but relates to the complexity of a task at hand. A significant knowledge gap exist in terms of the understanding of methane emission sources and measurement technologies, which are rapidly evolving. Taking into account the learning effort required, MRV should not be technology-specific regarding measurement, but must provide a framework to enable innovation and learning, whilst also removing the incomplete understanding barriers. Hence, there is an important role for the industry and the regulators to raise awareness of the different technology options and lessons learned.

Verification is the most challenging element of the methane-specific MRV framework, partly because there are diverging perspectives on how stringent it should be. The proposed EU regulation splits the verification process between independent accredited verifiers and public organisations with a broader remit such as the competent authorities and International Methane Emissions Observatory (IMEO). But clear rules are required to make a distinction between the tasks of independent verifiers and IMEO. Moreover, the sampling strategy used by the competent authorities for routine inspections has not been defined. The EU regulations may also differentiate the verification requirements depending on the size of the companies and the size of discrepancies between source-level and site-level measurement. One important thing to consider is whether there will be enough accredited verifiers in Member States to do the verification without any delay and about the capabilities of competent authorities in EU countries.

The Commission proposal could be enhanced on several instances by introducing: equal requirements for operated and non-operated assets; an obligation to report measurement uncertainties; a closer integration of MRV and LDAR programs; clear verification rules to avoid potential overlaps between the tasks of private and public verifiers; and an introduction of a set of minimum and optimum methane prevention and control standards. The standards could be adjusted overtime (e.g. every 5 years) and should be higher for new and modified sources.

This study has several limitations. It presents challenges to the implementation of an MRV system for methane emissions in the oil and gas sector in the EU, which is dominated by the mid- and downstream companies. Hence, the findings are less applicable to natural gas exporting countries with different industry structure. Moreover, the study sample is not necessarily representative, as it focuses on the stakeholders, which have been active in the EU decision-making process,

hence those less active or represented at national level are underrepresented. Finally, we identify that more research is needed into MRV in other methane emitting sectors: coal, agriculture and waste and available methane policy options, and the effectiveness of methane policies.

CRediT authorship contribution statement

Maria Olczak: Conceptualization, Methodology, Writing – original draft. **Andris Piebalgs:** Supervision. **Paul Balcombe:** Supervision, Validation, Writing – review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data Availability

The authors do not have permission to share data.

Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.envsci.2022.09.002.

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