Possible regulation of methane emissions abatement

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ABBREVIATIONS

Acronyms & Abbreviations	
ACR	Annual Compliance Report
ASEA	Agency for Safety, Energy and Environment of Mexico (esp. Agencia de Seguridad, Energía y Ambiente
ACER	The European Union Agency for the Cooperation of Energy Regulators
BAT	Best available techniques
CAMS	Copernicus Atmosphere Monitoring Service
CATF	Clean Air Task Force
CCAC	Climate and Clean Air Coalition
CCAP	Center for Clean Air Policy
CDP	Carbon Disclosure Project
CEPA	Canadian Environmental Protection Act
CH4	Methane
CHP	Combined heat and power
CO2	Carbon dioxide
DSO	Distribution System Operator
EC	European Commission
Eq.	Equivalent
EU	European Union
EU-KP	EU-27, United Kingdom and Iceland
GHG	Greenhouse gas
IEA	International Energy Agency
IOGP	International Association of Oil and Gas Producers
IPCC	Intergovernmental Panel on Climate Change

Acronyms & Abbreviations	
IPIECA	International Petroleum Industry Environmental Conservation Association
ISO	International Organization for Standardization
LDAR	Leak Detection and Repair
LNG	Liquefied Natural Gas
MARCOGAZ	Technical Association of the European Natural Gas Industry
MGP	Methane Guiding Principles
MRV	Monitoring, Reporting and Verification
MS	Member State
MT	Megatonnes
NECP	National Energy and Climate Plan
NIR	National Inventory Reports
NRA	National Regulatory Authority
OGCI	Oil and Gas Climate Initiative
OGMP	Oil & Gas Methane Partnership
PPCIEM	Program for The Prevention And Comprehensive Management Of Methane Emissions Within The Hydrocarbon Sector
R&D	Research and Development
TSO	Transmission System Operator
UK	United Kingdom
UNFCCC	United Nations Framework Convention on Climate Change
VOC	Volatile Organic Compounds
VRS	Vapour Recovery System

1 Introduction

1.1 Objective & key outcomes

The European Green Deal published on December 2019, identified energy-related CH_4 emissions as an important issue for the facilitation of the decarbonization of the gas sector that requires an accelerated initiative from the EC[1]. The global community cannot reach climate targets addressing only CO_2 emissions, therefore reducing CH_4 emissions in the energy sector could be a valuable contribution to the increased ambition of the EC to reduce GHG by some 50-55% by 2030. CH_4 emissions harm the credibility of natural gas today as a transition fuel towards a decarbonized energy system and puts in jeopardy the potential of renewable and decarbonized gases in the longer term as gas infrastructure may be abandoned as a consequence[2] .

Since the mid-1990s, CH_4 emissions have been decreasing partly due to the adoption of the first EU methane strategy published in 1996. However, this strategy was not a complete success, since it failed to bring about the expected level of emissions' cuts. Today, the "Effort Sharing Regulation"[3] covers CH_4 on MS level, with binding targets for a variety of sectors. However, there is no specific policy or regulatory framework across the natural gas value chain. Under existing legislation CH_4 emissions are expected to drop by about 25% by 2030 relatively to 2005 levels.

Regulation (EU) 2018/1999[4] requires the EC to propose a new EU strategic plan for CH4, which will become an integral part of the EU long-term climate strategy. The Florence School of Regulation suggests that the new adopted EU CH_4 strategy should adopt a holistic approach keeping in mind the specifics of each sector/sub-sector based on the following key elements:

- a more transparent framework at international, EU and national levels;
- the better coordination of policy measures targeting emissions in agriculture, waste and energy sectors, given that captured CH_4 is a source of energy;
- setting an EU CH_4 intensity target, which could be included in the revised EU climate pledge – Nationally Determined Contribution – which needs to be submitted by 2025;
- specifically for the gas industry, the entire gas value chain including gas transmission, distribution, storage and regasification facilities, should be covered;
- cooperation with key EU gas suppliers to obtain accurate estimates of gas industry emissions across the entire gas supply chain is essential. It is important that these data are aggregated not only at a corporate, but also a national level to ensure that national policies and regulations are based on accurate CH_4 estimates[5].

Within this context, the present paper aims at collecting and reviewing EU wide material, including policies, reports and studies, needed for the analyses and the assessments of ways of using regulation by NRAs to reduce

[1] Source: European Commission, COM(2019) 640 final, Communication from the Commission to the European Parliament, the European Council, the Council, the European Economic and Social Committee and the Committee of the regions, The European Green Deal, Brussels, 11.12.2019. https://eur-lex.europa.eu/resource.html?uri=cellar:b828d165-1c22-11ea-8c1f-01aa75ed71a1.0002.02/DOC_1&format=PDF

[2] Source: STAKEHOLDER MEETING ON A STRATEGIC PLAN TO REDUCE METHANE EMISSIONS IN THE ENERGY SECTOR 20 March 2020, https://ec.europa.eu/info/sites/info/files/energy_climate_change_environment/events/documents/stakeholder_meeting_invitation_methane_20march2020.pdf

[3] REGULATION (EU) 2018/842 of 30 May 2018 on binding annual greenhouse gas emission reductions by Member States from 2021 to 2030 contributing to climate action to meet commitments under the Paris Agreement and amending Regulation (EU) No 525/2013

[4] Regulation (EU) 2018/1999 of the European Parliament and of the Council of 11 December 2018 on the Governance of the Energy Union and Climate Action, amending Regulations (EC) No 663/2009 and (EC) No 715/2009 of the European Parliament and of the Council, Directives 94/22/EC, 98/70/EC, 2009/31/EC, 2009/73/EC, 2010/31/EU, 2012/27/EU and 2013/30/EU of the European Parliament and of the Council, Council Directives 2009/119/EC and (EU) 2015/652 and repealing Regulation (EU) No 525/2013 of the European Parliament and of the Council

[5] Source: Maria Olczak and Andris Piebalgs, How far should the new EU Methane Strategy go?, Florence School of Regulation, April 2019. https://cadmus.eui.eu/bitstream/handle/1814/62188/PB_2019_07_FSR_Energy.pdf?sequence=1

methane emissions in transmission, distribution, storage and liquefied natural gas facilities. To that end, focus is placed on: a) transparent reporting of methane emissions by the operators of such facilities to NRAs and verification of the reported emissions by NRAs, b) regulation by NRAs in pursuit of methane emissions abatement, and c) acknowledgement by NRAs of efficiently incurred cost by the operators in abating methane emissions. The paper concludes on possible energy transition regulatory solutions to address the gaps and areas for improvement to allow the abatement of methane emission from transmission, distribution, storage and LNG facilities.

1.2 Structure of the Background Paper

The present paper is structured as follows:

Chapter 2. *Methane emissions abatement in the gas sector in the EU,* provides the contextual background of the paper. It discusses the key features of natural gas infrastructure relevant to methane abatement.

Chapter 3. *EU current Policy and Regulatory Framework relevant to methane emissions abatement,* provides an overview on the current EU framework applicable to the methane emissions abatement in the gas sector. This chapter contains a summary of EU Directives and Regulations, and global practices, to obtain an understanding of how conducive a framework is to methane emissions abatement.

Chapter 4. *Review and meta-analysis,* gathers a list of key recent papers and reports, EU-wide or Member State-specific, as well as global-wide, that answer key questions related to the regulatory aspects of methane emissions abatement in the gas sector. This chapter also includes an analysis of the material according to the key regulatory aspects that need to be addressed for creating a conducive EU framework methane emissions abatement.

Chapter 5. *Methane emissions abatement gap analysis* feeding from the results of the preceding chapters, presents the gap analysis and identification of areas that need to be addressed in the current regulatory framework and provides a summary of the key outcomes and recommendations from our analysis.

2 Methane emissions abatement in the gas sector

2.1 Current status of methane emissions in the gas sector in the EU

All EU-MS are required to monitor and report their GHG emissions including CH_4 emissions under the EU's Climate Monitoring Mechanism, which sets the EU's own internal reporting rules on the basis of internationally agreed obligations (IPCC[6] Guidelines). The EU inventory[7] developed as a compilation of the National Inventory Reports (NIR) submitted by the EU-MS under this mechanism includes all the available information on the EU level emissions.

In 2018, methane emissions were estimated at 456 Mt CO_2 eq. accounted for 11% of total EU-KP[8] GHG emissions in 2018 and decreased by 38 % since 1990. The two largest key sources are enteric fermentation and anaerobic waste, whereas CH_4 emissions from natural gas operations were calculated at approximately 21 Mt CO_2 eq. corresponding to a percentage of 5% of the CH_4 emissions produced in EU as shown in Figure 1 (a).

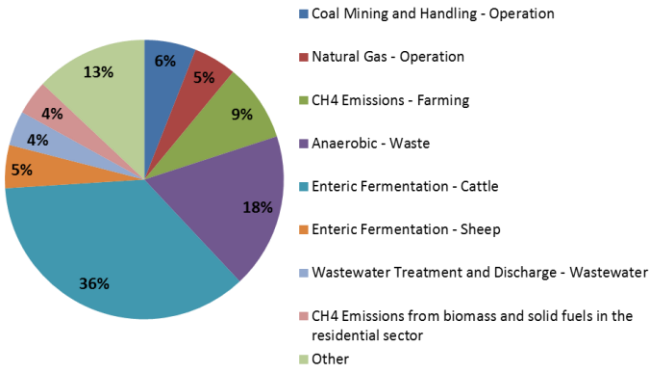
Methane emissions from natural gas operations include all emissions from exploration, production, processing, transmission, storage and distribution of natural gas (excluding utilization). In the preceding period 1990-2018, a 58% decrease of CH_4 emissions in the sector was reported amounted to an absolute decrease of 30 Mt CO_2 eq. compared to 1990 CH_4 emissions' level. More specifically, CH_4 emissions in the transmission and storage systems cover a rate of 25% (Figure 1 (b)) of the total CH_4 emissions in the gas value chain (exploration, production, transport, refining and storage, distribution, other). Thus, it is clear that transmission, distribution and storage stages of the gas value chain need further actions for handling with CH_4 emissions. It is noted that methane emitted at distribution level accounts for 57% of the total emissions from natural gas operations across gas value chain, due to the network length and congestion that provokes fugitive emissions.

In the same period (1990-2018), the gross inland natural gas consumption in EU-KP augmented from 3,454,067 GWh to 4,562,192 GWh (increase of 32%)[9] and the length of the gas network has been increased. This indicates the efforts taken place to improve the different initiatives, regulations and measures for monitoring, reporting, verification and addressing directly or indirectly the methane emissions in EU. A wide dispersion of CH_4 emission levels along the gas value chain and across regions appears, and the quality of available data should be improved. It is important for the industry to continue to work on improving data and transparency. These issues are discussed in Chapter 4 of this report with main focus on regulatory aspects.

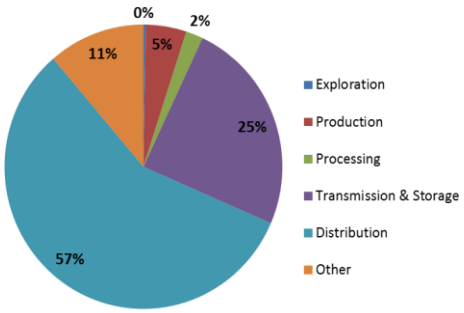
[6] The Intergovernmental Panel on Climate Change
[7] EEA, Annual European Union greenhouse gas inventory 1990–2018 and inventory report 2020, Submission to the UNFCCC Secretariat, 27 May 2020. https://www.eea.europa.eu/publications/european-union-greenhouse-gas-inventory-2020/#additional-files
[8] EU-KP includes EU-27, United Kingdom and Iceland
[9] Source: Eurostat Energy Balances-June 2020 edition. https://ec.europa.eu/eurostat/web/energy/data/energy-balances)

Figure 1: CH_4 emissions across the EU-KP gas value chain in 2018[10]

(a) Share of key CH_4 emissions' sources



(b) CH_4 emissions from natural gas operations across gas value chain



2.2 Existing activities in methane emissions in the natural gas value chain

The gas industry has been conducting identification, detection, quantification, monitoring, reporting and verification, and mitigation of methane emissions for a long time, as a safety requirement.

2.2.1 Identification/Categorization of the CH_4 emissions

Broadly, methane emissions across the different stages of the gas value chain can be divided into three categories as follows:

- Fugitive (accidental) emissions resulting from CH_4 leaking from equipment or components (for example because of a faulty seal or leaking valve), which are rather challenging to estimate;
- Vented (deliberate) emissions, which are intentional for safety considerations (due to the design of the facility or equipment (e.g. pneumatic controllers)) or operational procedures (e.g. venting a pipeline for inspection and maintenance); and
- Incomplete combustion emissions which can occur when natural gas that cannot be used or recovered economically is burned instead of being sold or vented. The vast majority of the natural gas is converted into CO_2 and water, but some portion may not be combusted and is released as CH_4 into the atmosphere.

Table 1 provides an overview of the CH_4 emissions occurred in the different components of the transmission and storage stages of the gas value chain and more specifically in the gas transmission systems, liquefied natural gas terminals and underground storage facilities.

Table 1 Methane emissions in the gas value chain[11]

[10] Source: EEA, Annual European Union greenhouse gas inventory 1990–2018 and inventory report 2020, Submission to the UNFCCC Secretariat, 27 May 2020. https://www.eea.europa.eu/publications/european-union-greenhouse-gas-inventory-2020/#additional-files

[11] Source: GIE and MARCOGAZ, Potential ways the gas industry can contribute to the reduction of methane emissions, Report for the Madrid Forum, 5-6 June 2019. https://www.gie.eu/index.php/gie-publications/methane-emission-report-2019/27786-gie-marcogaz-report-for-the-madrid-forum-potential-way-gas-industry-can-contribute-to-the-reduction-of-methane-emissions/file

Methane Emissions Category	Components
Fugitive emissions	**Production** • Components (valves, flanges, connectors, etc.)
	Liquefaction • Components (valves, flanges, connectors, etc.) • Compressor seals
	LNG carriers • Components (valves, flanges, connectors, etc.)
	Biomethane production • Open digestate storage • Separator • Storage of solid fraction • Biofilter • Valves
	Transmission & Storage • Components (valves, flanges, connectors, etc.)
	Regasification • Components (valves, flanges, connectors, etc.)
	Distribution • Components (valves, flanges, connectors, etc.) • Permeability of materials
Vented emissions	**Production** • Flaring • Tank storage • Compressors • Maintenance • Failure/Emergency • Glycol regeneration • Produced water handling • Pneumatic controllers
	Liquefaction • Flaring • Tank storage • Vessels and truck loading • Maintenance • Failure/Emergency • Start-up / shutdown activities
	LNG carriers • Tanks • Compressors • Gas freeing for dry-dock • Start & stops
	Biomethane production • Flaring • Closed digestate storage • Reactor maintenance

Methane Emissions Category	Components
	Transmission & Storage • Compressors • Maintenance • Failure/Emergency • Pneumatic controllers • Devices for on-line gas quality sampling
	Regasification • Flaring • Vessels and truck loading • Vessels unloading • Maintenance • Failure/Emergency • Pneumatic controllers
	Distribution • Maintenance • Failure/Emergency • Operational
Incomplete combustion emissions	**Production** • Flaring • Stationary combustion devices (e.g., engines, boilers) • Turbo compressors
	Liquefaction • Flaring • Stationary combustion devices (e.g., engines, boilers)
	LNG carriers • Engines (e.g., methane ships)
	Biomethane production • Flaring • CHP
	Transmission & Storage • Stationary combustion devices (e.g., engines, boilers) • Engines/turbines for gas compression • Flaring
	Regasification • Stationary combustion devices (e.g., engines, boilers) • Vaporisers • Flaring
	Distribution • Stationary combustion devices (e.g., boilers)

2.2.2 Detection of the CH_4 emissions

Detecting and measuring CH_4 emissions in a comprehensive and cost-effective manner **r**emains a fundamental challenge because of the high cost of detection systems. Technologies that can prevent vented and fugitive emissions are reasonably well-known. The challenge is to incentivise the deployment of these abatement technologies via voluntary or regulatory means but this is further analysed in Chapter 4. In many cases, investment in abatement technologies is economic, thus regulatory incentives should be adopted. Where reduced emissions do not pay for themselves—or where barriers prevent companies from taking action that would otherwise be cost-effective—policy and regulatory interventions may serve to incentivise companies to take steps to reduce their emissions.

Vented and incomplete combustion emissions are clearly detected at the facility through equipment/process mapping. On the other hand, due to their unplanned nature, fugitive emissions require different methodologies to be identified and detected.

The Leak Detection and Repair (LDAR) is a detection and management concept of locating and repairing fugitive leaks consisting of monitoring plant, scheduling maintenance, repairing and controlling elements. A typical LDAR programme involves the comprehensive scanning of infrastructure and their equipment and components, from which fugitive gas emissions may occur. Any part of the infrastructure is inspected (e.g. though infrared cameras making CH_4 leaks visible), in order to detect leakages at the component level.

The most common policy approach currently deployed to address fugitive emissions is to require inspection at a facility at regular intervals. While many companies already undertake LDAR, the practices and standards vary widely.

2.2.3 Quantification of the CH_4 emissions

With respect to CH_4 emissions' quantification, the industry has developed two main approaches "bottom-up" and "top-down" based on a source-specific quantification and on an aggregate assessment of an area (usually at regional scale), respectively:

- **"Bottom-up"** approach: the emissions from each identified source are individually quantified. Total emissions are calculated by adding each type of emission source data.
- **"Top-down"** approach: it is used by the industry to quantify and report its emissions allowing the quantification of the emissions of specific sources and aggregating them for the calculation of total figures.

"Bottom-up" approach is the preferred-one by the EU gas industry for the quantification of the CH_4 emissions, as it is offered as a basis for the successful emissions' management. The quantification of the emissions at the individual source level provides a better understanding of the components and systems of the gas value chain that appear larger quantities of CH_4 emissions. Subsequently, the evaluation of the emission reduction opportunities could be provided.

The CH_4 emissions from an installation could be quantified either by

- Measurement: field data are measured via methane detectors (data can also be collected through instrumentation like online connected flow meters or pressure meters)
- Calculation: field data are utilised to directly calculate the emissions of a given source, e.g., in case of the vent of a pipe section, the level of methane emission can be accurately derived from the pipe section volume and the pressure condition in that particular pipe section during that event.
- Modelling: emissions are modelled using emission factor multiplied by activity factor, i.e., the number of the emitting components or the number of events.

Currently, the methods to quantify methane emissions have not been implemented homogenously yet all over the gas value chain.

2.2.4 Reporting of the CH_4 emissions

Reporting of the CH_4 emissions by the European gas industry is essential for addressing them. The methane emissions can then be reported through national inventory reports to national authorities, or voluntary reporting

initiatives (e.g. CDP[12]), partnership and associations (CCAC OGMP[13], OGCI[14], IOGP[15], IPIECA[16], MARCOGAZ[17]), and via companies' annual sustainability and carbon footprint reports.

The Methane Guiding Principles (MGP) established in 2017 is a multi-stakeholder collaborative platform incorporating over 20 institutions from industry, intergovernmental organisations (including the IEA), academia, and civil society. The principles aim to advance understanding and best practices for CH_4 emissions reduction and to develop and implement methane policy and regulation.

Voluntary initiatives can play a vital role in developing new approaches to abatement and in demonstrating what is possible and practicable. However, there are limits to what can be achieved by voluntary action because the pool of those willing to take such action is limited, and because the actions themselves may fall short of what is desirable from a public policy perspective. Effective targets, policies and regulations established by governments and regulatory authorities are also therefore essential.

The format and the methodology for reporting vary among the different initiatives. Reporting within NIR, which is used for the UNFCCC, is in many cases not transparent, and there are large differences in methodologies and procedures among EU-MS.

The gas industry has developed its own reporting methods to improve the accuracy and transparency of the data. However, these vary between companies and organizations, and are difficult to be combined. More work towards harmonisation of the different methodologies used is required, ensuring that they are specific for the gas sector, and the entire gas chain and all types of emissions are covered.

2.2.5 Validation/verification of the CH4 emissions

CH_4 emissions need to be assessed following general criteria from the most reliable standards, guidelines and frameworks, which include agreed procedures for collating emission data and intensity, whilst ensuring the integrity and confidence of these data are replicable and verifiable by a third party.

Currently, a large number of gas companies use existing recognized standards and guidelines to assess and verify the methane emission inventories in order to improve accuracy and reduce uncertainty in the data. The most common ones in Europe are GHG Protocol, EN 15446 (to detect and quantify VOCs[18], but not all types of methane emissions), ISO 14064 (to verify carbon footprint), the high-level ISO 14001 (environmental certification), ISO 50001 (energy efficiency) and ISAE 3000 (sustainability standards). However, some additional work is needed in order to identify and quantify all different kind of methane emissions and to report them along the entire gas value chain.

2.2.6 Mitigation of the CH_4 emissions

Through increased efforts to identify, quantify and report CH_4 emissions, the industry is continuously improving the management and reduction of CH_4 emissions. A large number of best available techniques (BAT) exists to reduce CH_4 emissions and the gas industry implements these on a voluntary basis. The BATs are related to engineering

[12] Carbon Disclosure Project (CDP) is a not-for-profit charity that runs the global disclosure system for investors, companies, cities, states and regions to manage their environmental impacts
[13] The Oil & Gas Methane Partnership, an initiative of the Climate and Clean Air Coalition (CCAC OGMP), provides protocols for companies to survey and address emissions and a platform for them to demonstrate results. It consists of group of 10 oil and gas companies, governments, UN Environment, World Bank, and the Environmental Defense Fund
[14] The Oil and Gas Climate Initiative (OGCI) aims to improve methane data collection and develop and deploy cost-effective methane management technologies; it consists of thirteen major international oil and gas companies.
[15] The International Association of Oil and Gas Producers
[16] The International Petroleum Industry Environmental Conservation Association
[17] The Technical Association of the European Natural Gas Industry
[18] Volatile Organic Compounds - including methane

design, commissioning and operation, including maintenance and repairs, and decommissioning, whereas applying the BATs requires a case by case practical, economic, environmental and technical consideration

3 EU existing Policy & Regulatory Framework relevant to methane emissions abatement in the gas sector and best practices

3.1 EU Directives and Regulations relevant to methane emissions abatement in the gas sector

Table 2. EU Legal Acts relevant to the CH_4 emissions abatement in the gas network

Number	Title	Date
1.	REGULATION (EU) 2018/1999 on the Governance of the Energy Union and Climate Action	December 11, 2018
2.	REGULATION (EU) 2018/842 on binding annual greenhouse gas emission reductions by Member States from 2021 to 2030 contributing to climate action to meet commitments under the Paris Agreement and amending Regulation (EU) No 525/2013 ("Effort Sharing Regulation")	May 30, 2018
3.	Decision 406/2009/EC on the effort of MS to reduce their GHG emissions to meet the Community's GHG emission reduction commitments up to 2020 ("Effort Sharing Decision, ESD")	April 23, 2009
4.	REGULATION (EU) No 525/2013 on a mechanism for monitoring and reporting greenhouse gas emissions and for reporting other information at national and Union level relevant to climate change and repealing Decision No 280/2004/EC ("Monitoring Mechanism Regulation (MMR)")	May 21, 2013
5.	Directive 2009/30/EC of the European Parliament and of the Council amending Directive 98/70/EC as regards the specification of petrol, diesel and gas-oil and introducing a mechanism to monitor and reduce greenhouse gas emissions and amending Council Directive 1999/32/EC as regards the specification of fuel used by inland waterway vessels and repealing Directive 93/12/EEC	April 23, 2009
6.	Paris Agreement	2015
7.	Kyoto Protocol to the United Nations Framework Convention on Climate Change	December 11, 1997
8.	United Nations Framework Convention on Climate Change ("UNFCCC")	1992

Regulation (EU) 2018/99 sets out the necessary legislative foundation for reliable, inclusive, cost-efficient, transparent and predictable governance of the Energy Union and Climate Action (governance mechanism), which ensures the achievement of the 2030 and long-term objectives and targets of the Energy Union in line with the 2015 Paris Agreement on climate change following the 21st Conference of the Parties to the United Nations

Framework Convention on Climate Change (the 'Paris Agreement'), through complementary, coherent and ambitious efforts by the Union and its Member States, while limiting administrative complexity.

Regulation (EU) 2018/842 forms part of the implementation of the Union's contributions under the Paris Agreement adopted under the United Nations Framework Convention on Climate Change ('UNFCCC'). The Paris Agreement was concluded on behalf of the Union on 5 October 2016 by Council Decision (EU) 2016/1841. The commitment of the Union to economy-wide greenhouse gas emission reductions was set out in the intended nationally determined contribution submitted in view of the Paris Agreement by the Union and its Member States to the Secretariat of the UNFCCC on 6 March 2015. The Paris Agreement entered into force on 4 November 2016 and replaces the approach taken under the 1997 Kyoto Protocol which will not be continued beyond 2020.

Decision 406/2009/EC lays down the minimum contribution of Member States to meeting the greenhouse gas emission reduction commitment of the Community for the period from 2013 to 2020 for greenhouse gas emissions covered by this Decision, and rules on making these contributions and for the evaluation thereof. This Decision also lays down provisions for assessing and implementing a stricter Community reduction commitment exceeding 20 %, to be applied upon the approval by the Community of an international agreement on climate change leading to emissions reductions exceeding those required pursuant to Article 3, as reflected in the 30 % reduction commitment as endorsed by the European Council of March 2007.

Regulation (EU) No 525/2013 establishes a mechanism for:

(i) ensuring the timeliness, transparency, accuracy, consistency, comparability and completeness of reporting by the Union and its Member States to the UNFCCC Secretariat;
(ii) reporting and verifying information relating to commitments of the Union and its Member States pursuant to the UNFCCC, to the Kyoto Protocol and to decisions adopted thereunder and evaluating progress towards meeting those commitments;
(iii) monitoring and reporting all anthropogenic emissions by sources and removals by sinks of greenhouse gases not controlled by the Montreal Protocol on substances that deplete the ozone layer in the Member States;
(iv) monitoring, reporting, reviewing and verifying greenhouse gas emissions and other information pursuant to Article 6 of Decision No 406/2009/EC;
(v) reporting the use of revenue generated by auctioning allowances under Article 3d(1) or (2) or Article 10(1) of Directive 2003/87/EC, pursuant to Article 3d(4) and Article 10(3) of that Directive;
(vi) monitoring and reporting on the actions taken by Member States to adapt to the inevitable consequences of climate change in a cost-effective manner;
(vii) evaluating progress by the Member States towards meeting their obligations under Decision No 406/2009/EC.

Directive 2009/30/EC sets, in respect of road vehicles, and non-road mobile machinery (including inland waterway vessels when not at sea), agricultural and forestry tractors, and recreational craft when not at sea technical specifications on health and environmental grounds for fuels to be used with positive ignition and compression-ignition engines, taking account of the technical requirements of those engines; and a target for the reduction of life cycle greenhouse gas emissions.

The Paris Agreement sets out a global framework to avoid dangerous climate change by limiting global warming to well below 2°C and pursuing efforts to limit it to 1.5°C. It also aims to strengthen countries' ability to deal with the impacts of climate change and support them in their efforts. The Paris Agreement is the first-ever universal, legally binding global climate change agreement, adopted at the Paris climate conference (COP21) in December 2015.

Kyoto Protocol to the United Nations Framework Convention on Climate Change operationalizes the United Nations Framework Convention on Climate Change by committing industrialized countries and economies in transition to limit and reduce greenhouse gases (GHG) emissions in accordance with agreed individual targets.

The Convention itself only asks those countries to adopt policies and measures on mitigation and to report periodically. The Kyoto Protocol is based on the principles and provisions of the Convention and follows its annex-based structure. It only binds developed countries, and places a heavier burden on them under the principle of "common but differentiated responsibility and respective capabilities", because it recognizes that they are largely responsible for the current high levels of GHG emissions in the atmosphere.

The UNFCC entered into force on 21 March 1994. Today, it has near-universal membership. The 197 countries that have ratified the Convention are called Parties to the Convention. Preventing "dangerous" human interference with the climate system is the ultimate aim of the UNFCCC. The ultimate objective of the Convention is to stabilize greenhouse gas concentrations "at a level that would prevent dangerous anthropogenic (human induced) interference with the climate system." It states that "such a level should be achieved within a time-frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened, and to enable economic development to proceed in a sustainable manner."

3.2 Global best practices

3.2.1 Canada's methane regulations for the upstream oil and gas sector

Natural gas is composed almost entirely of methane (CH4), a colourless, odourless and flammable gas. Methane is considered toxic under the Canadian Environmental Protection Act, 1999 (CEPA). As a greenhouse gas (GHG), it has a global warming potential more than 70 times greater than carbon dioxide (CO2) over a 20-year period.

When oil and gas are extracted and processed, natural gas can leak accidentally or be released intentionally into the environment. These emissions contribute significantly to global warming and climate change and also cause smog and other negative impacts on air quality.

Oil and gas facilities are the largest industrial emitters of methane in Canada. They release 44% of total methane emissions. Upstream activities such as exploration, drilling, production and field processing contribute close to 90% of methane emissions and account for 26% of Canada's total GHG emissions.

There are many cost-effective opportunities such as gas capture, clean combustion and fixing leaks that can help to reduce this loss and promote sound industry practices.

The federal regulations that apply to methane in the upstream oil and gas sector aim to control methane emissions and also reduce the amount of volatile organic compounds (VOCs) released into the air, as shown below in Table 3. VOCs are found with methane and are known to have adverse health effects and contribute to smog formation[19].

These regulations apply generally to facilities that handle significant volumes of gas. They cover key fugitive and venting emission sources in the upstream oil and gas sector described below.

[19] While CH4 upstream emissions is an interesting topic, it is generally outside of scope of NRAs responsibilities. However, as there are no relevant examples and case studies of practices on midstream and downstream sectors of oil and gas, the chosen case study of Canada has been presented, in terms of this study.

Table 3. Requirements in Canada's methane regulations related to emission sources

Emission Source	Requirements	Date of implementation
Fugitive (leaks)	• Implementation of a leak detection and repair (LDAR) program to stop natural gas leaks	January 1, 2020
	• Inspections for leaks three times per year	
	• Corrective action when leaks are found	
General facility production venting	• Venting limit of 1,250 m3 of natural gas per month (15,000 m3 per year)	January 1, 2023
	• Conservation of natural gas for re-use on site or for sale, or flaring / clean incineration of natural gas	
Venting from pneumatic devices	• Venting limit of 0.17 m3 of natural gas per hour for pneumatic controllers	January 1, 2023
	• Conservation of natural gas for re-use on site or for sale, or replacement with non-emitting or low-bleed pneumatic device	
Venting from compressors	• Annual measurements of emissions of natural gas from compressor vents	January 1, 2020
	• Corrective action when emissions are higher than the applicable limit	
Venting from well completions involving hydraulic fracturing	• No venting	January 1, 2020
	• Conservation of natural gas for re-use on site or for sale, or flaring / clean incineration of natural gas	

3.2.2 Methane Regulatory Framework in Mexico

Just over six months after the adoption of methane regulations in Canada, the Mexican methane regulations were published on the 6th of November 2018, and entered into force on the following day.

It should be noted that the process of developing regulations in Mexico was led by the Agency for Safety, Energy and Environment of Mexico (esp. Agencia de Seguridad, Energía y Ambiente, ASEA) and supported by an international community of experts. The Center for Clean Air Policy (CCAP) jointly with Clean Air Task Force (CATF) organised a series of workshops, which looked at best practices and regulatory experience on methane emissions in the US and Canada, including the provincial and state regulations.

In contrast to the US and Canada, Mexican regulations cover the entire value chain, including natural gas transmission and distribution. They are applicable to both new and existing onshore and offshore sources. The regulations introduce the bottom-up system building upon special programs (PPCIEMs), in which oil and gas companies specify their reduction targets and how they are going to achieve them. The scheme resembles the Governance of the Energy Union and Climate Action system with National

Energy and Climate Plans (NECPs), which monitors the EU Member States' progress towards the achievement of EU energy and climate targets.

The NECPs are submitted to the European Commission, which assesses the plans and has the right to issue recommendations if the national plan in question is not in line with EU targets. Whereas, the plans prepared under the Mexican methane regulations are verified by an Authorised Third Party. The regulation itself does not specify if ASEA has the right to issue binding recommendations to companies, and more importantly, what actions ASEA could undertake in case aggregated targets submitted by the companies are insufficient to meet the regional pledge. In principle in such situations, ASEA has a power to issue recommendations and to impose administrative penalties (fines).

The Mexican Program for the Prevention and Integral Control of Methane Emissions (PPCIEM) is developed in three steps:

- **Step 1: Emission assessment.**

Firstly, the companies identify the (potential) sources of emissions and divide them into three groups: equipment, well operations or non-scheduled activities. Then the types of emissions are categorised as:

- destruction equipment (flaring);
- fugitive leaks in well operations, equipment and components; or
- venting emissions.

Once the emissions are identified and classified, the regulated companies are required to quantify their emissions based on one of the methodologies listed in Article 18, including: mass balance, mathematical models, engineering calculations or emission factors. The choice of the methodology needs to be justified.

- **Step 2: Program for the Prevention and Integral Control of Methane Emissions (PPCIEM).**

The programs prepared by the regulated companies constitute a basis of prevention and control cycle. The regulated companies set out their percentage reduction target using the emission assessments from the first step as a baseline. They have a maximum of six years to achieve those objectives, counting from the time they submit their PPCIEMs to the Agency. The information and data provided to ASEA is considered public information. The regulation sets different obligations for new (constructed after the 7th of November 2018) as opposed to existing facilities. The new facilities are required not to exceed the level of emissions from the base year, whereas existing facilities are only required to decrease their emissions by the amount specified in their targets. The companies need to specify how they are going to achieve these targets and they can choose from the list of technologies and best practices suggested. For instance, the facilities using reciprocating compressors are required to replace seals on the compressor rods, or adjust and align the rod packing systems, capture the emissions and direct them to a Vapour Recovery System (VRS).

- **Step 3: Continuous improvement.**

Every year, the regulated companies outline their annual reduction objectives and actions per facility. They are required to keep track of their progress by evaluating the PPCIEM implementation and preparing the Annual Compliance Report (ACR) at least once per year (internal evaluation). As part of the ACR, the companies re-quantify their methane emissions and include the data in the report. The final ACR is then validated by an Authorised Third Party and handed in to the Agency along with the opinion issued by the external evaluator in the first quarter of every calendar year and annexed to the Performance Report applicable to the hydrocarbon sector.

4 Review and meta-analysis of material relevant to methane emissions abatement

A systematic review has been carried out to identify all material whose primary focus is the regulatory aspects of methane emissions abatement in transmission, distribution, storage and LNG terminals in gas value chain. Particular care was taken in selecting material that reflects current progress (topicality – focusing on material dated between 2017-2020), and whose lead organization is an official EU entity or other top-tiered institution/organization.

4.1 Methodology

The following database contains publications, reports, proceedings and other papers of major organizations and institutions pertinent to the regulation of methane emissions abatement. The initial screening of the material focused on identifying topical reports, papers and other relevant material. The list was cross-checked and is still being enriched by key stakeholders during consultation sessions.

We then shortlisted the papers, by considering material that focuses on methane emissions abatement in natural gas value chain. The shortlisted material was examined in terms of the information it contains, considering certain assessment areas. The material used was further shortlisted to include papers that contained regulatory implications on at least two of the assessment areas. The resulting core list consists of 9 papers and it is presented in Table 4. The assessment areas are illustrated in Table 5.

Table 4: List of material used for the purpose of systematic analysis

Report No	Title	Country/Region	Lead organization	Publication year
1.	EU strategy to reduce methane emissions	EU-wide	European Commission	October 2020
2.	Strategic plan to reduce methane emissions in the energy sector	EU-wide	European Commission	March 2020
3.	Potential ways the industry can contribute to the reduction of methane emissions - Report for the Madrid Forum	Global	GIE and MARCOGAZ	5-6 June 2019
4.	Limiting the climate impacts of the EU's gas supply - Key issues and opportunities in the 2020 European Gas Framework.	EU-wide	EDF	N/A
5.	Environmental Defense Feedback to the sector integration consultation	EU-wide	EDF	N/A
6.	Methane policy recommendations for the European Union	EU-wide	BP, ENI, Equinor et al.	May 2020

Report No	Title	Country/Region	Lead organization	Publication year
7.	Methane emission reduction - an important step in strengthening the sustainability dimension of gas network companies	EU-wide	Florence School of regulation - European University Institute	April 2020
8.	Can the current EU regulatory framework deliver decarbonization of gas?	EU-wide	The Oxford Institute for Energy Studies	June 2020
9.	Methane Emissions in the Gas Sector	EU-wide	GIE, MARCOGAZ, Energy Community	June 2020

The review sought to identify material related to the regulatory aspects of the accelerated refurbishment of the existing energy infrastructure and the development of new ones, relevant to methane emissions abatement. Because the collected material differs in scope, focus was placed on the following assessment areas to be examined in each paper.

Table 5. Key assessment areas and respective considerations

Assessment Area	Key Assessment Considerations
Acknowledgement of infrastructure adaptation costs incurred by the network operators and gas facilities, specifically with respect to transmission, distribution, storage and liquefied gas facilities	• Infrastructure governance (responsibility and planning network infrastructure)
	• Provisions for infrastructure investments and adaptations
	• Incentives and support for innovation to TSOs/DSOs
The time horizon of the regulatory period	• Identification of the priority levels
	• Timeframes and objectives
	• Sandbox frameworks and trial periods
	• Strategies, policies, etc.
Evaluation of infrastructure investments	• Cost-Benefit-Analysis
	• Other investment appraisal approaches
Benefits expected from the adaptations needed to enable handling of CH4 emissions abatement	• Sector integration benefits;
	• System flexibility and security of supply
	• Environmental benefits
	• Job creation and other socio-economic benefits
	• Barriers to market entry

Market, economic and financial terms and conditions to be accounted by regulators regarding CH4 emissions abatement	• Enablers of market entry
New technologies, products and measured with a focus on those who address cross-border barriers for methane emissions abatement handling	• Guarantees of origin for hydrogen and other green certificates
	• Other solutions that are compatible with cross-border trade (gas quality inventories etc.)
	• R&D and other projects of cross-border relevance

The regulatory aspects covered, consider the interplay between technological innovations, infrastructural needs and market prospects, hence why they represent the backbone of our analysis. For the scope of this work, we first determined the degree to which each of the assessment areas was addressed across the list of papers. Table 6 illustrates the frequency these areas were encountered across the reports examined so far:

Table 6. Frequency of assessment areas addressed in the shortlisted material

Assessment Area	Addressed	Not addressed
Acknowledgement of infrastructure adaptation costs incurred by the network operators and gas facilities, specifically with respect to transmission, distribution, storage and liquefied gas facilities	6	3
Time horizon of the regulatory period	4	5
Evaluation of the financial return on infrastructure investments	2	7
Benefits expected from the adaptations needed to enable handling of CH4 emissions abatement	3	6
Market, economic and financial terms and conditions to be accounted by regulators regarding CH4 emissions abatement	5	4
New technologies, products and measured with a focus on those who address cross-border barriers for methane emissions abatement handling	5	4

In the following sections, we perform a systematic review, discussing each assessment area individually. The analysis contains the relevant key information which is either directly or indirectly addressed in each paper.

4.2 Acknowledgement of infrastructure adaptation costs

In the material included in our analysis, the acknowledgement of infrastructure adaptation costs is being fairly represented, although there is variation in the way it is addressed. Amongst the material reviewed, 6 out of 9 papers address the issue. Table 7 summarizes the relevant key considerations discussed in each paper.

Table 8. Key aspects covered with respect to the acknowledgement of infrastructure adaptation costs

Material	Key regulatory aspects covered
EU strategy to reduce methane emissions	• Recognition by National Regulatory Authorities (NRAs) of LDAR and methane reduction investments as allowed costs for regulated entities in transmission, storage and distribution, including through possible guidance to regulators • Priority to explore a more precise standard for flaring efficiency, with the objective of further reducing both venting emissions and emissions from incomplete combustion of fuels
Potential ways the industry can contribute to the reduction of methane emissions	• Industry should be engaged early and often in any new policy development • Cost-effectiveness tests should be applied to all proposed measures, ensuring that regulations have a net benefit • Policies should encourage the industry to maximise the value of reductions
Limiting the climate impacts of the EU's gas supply	• Opportunity for the EU's regulatory approaches to influence others through the "Brussels effect"
Methane policy recommendations for the European Union	• Working practice standards would be applied for the EU natural gas downstream infrastructure operators, through amendments of existing EU regulations or new regulations if necessary
Methane emission reduction - an important step in strengthening the sustainability dimension of gas network companies	• A regulation to limit methane emissions by the gas sector should be established at the European level, striving to establish dynamic targets, creating a robust and transparent MRV framework and incentivizing the network companies to establish and realize ambitious action plans
Methane Emissions in the Gas Sector	• Organizations that have not previously invested in energy and other GHG reductions should be capable of meeting more aggressive reduction levels

EU strategy to reduce methane emissions envisages that achieving emissions savings in the energy sector is feasible, with at least one third of reductions possible at no net cost to industry. Upstream gas companies have a certain but limited financial incentive to implement LDAR programmes, as they can sell the gas that they prevent from leaking[20]. Transmission, storage, and distribution systems operators (including many LNG terminals) are regulated businesses and do not own the gas. For this reason, the Commission will promote the recognition by National Regulatory Authorities (NRAs) of LDAR and methane reduction investments as allowed costs for regulated entities in transmission, storage and distribution, including through possible guidance to regulators. The

[20] However, this would only reduce leakage if (and to the extent that) the cost of abatement is lower than the additional sale price achievable. However, as these companies do not own the resource they are using (those are generally owned by the country of production) and not accountable for losses, they often have little interest in reducing them.

Commission will also make it a priority to explore a more precise standard for flaring efficiency, with the objective of further reducing both venting emissions and emissions from incomplete combustion of fuels. These mitigation options are generally cost-effective, and a key component of methane-emission mitigation in the energy sector, with combustion accounting for a significant portion of EU emissions.

Potential ways the industry can contribute to the reduction of methane emissions considers that the industry should be engaged early and often in any new policy development to ensure that proposed measures are workable and effective, policies should be economically and administratively efficient – balancing regulation with market-based mechanisms. Cost-effectiveness tests should be applied to all proposed measures, ensuring that regulations have a net benefit. Additionally, policies should encourage the industry to maximise the value of reductions, by allowing enough flexibility to identify opportunities for investment to achieve the highest reductions at the lowest cost.

Limiting the climate impacts of the EU's gas supply highlights the fact that there is an opportunity for the EU's regulatory approaches to influence others through the "Brussels effect", where other countries track EU legislation to spare their companies the cost of following more than one set of rules. There is a significant opportunity for the EU to put climate at the core of its energy policy and diplomacy, setting positive examples for other major gas importing countries such as China, Japan and Korea to follow.

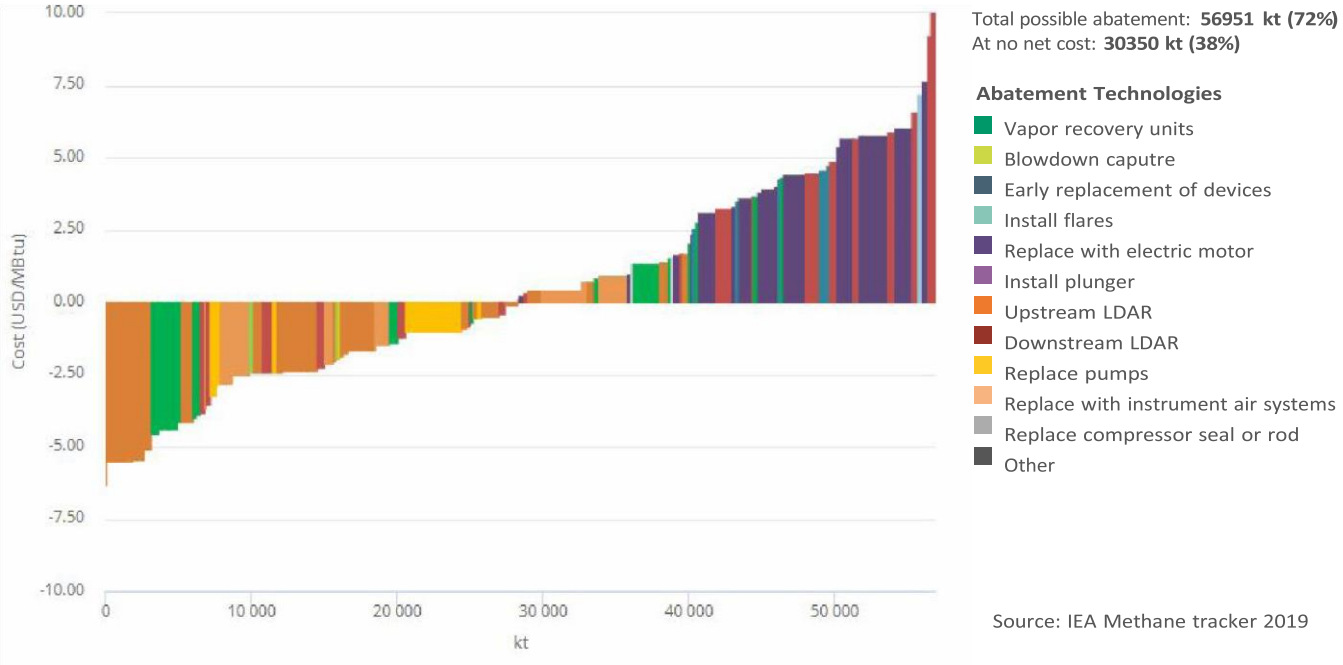


Figure 2 Estimated global oil and gas sector methane abatement potential (2017 estimate)[21]

Methane policy recommendations for the European Union foresees that the working practice standards would be applied for the EU natural gas downstream infrastructure operators, through amendments of existing EU regulations or new regulations if necessary. Costs efficiently incurred by the regulated companies during the improvement of MRV and the successful implementation of mitigation measures should be recoverable and accordingly incentivized. Policy makers and regulators should maximize synergies between the MRV standard and the working practices/technology standards (e.g., LDAR informing methane emissions data and reporting on factors such as leak prevalence, leak recurrence, leak distribution, and over time emissions quantification)

[21] Limiting the climate impacts of the EU's gas supply, Key issues and opportunities in the 2020 European Gas Framework

and made consistent across the EU, recognizing the industry is comprised of different oil and gas assets which will require a tailored approach.

Methane emission reduction - an important step in strengthening the sustainability dimension of gas network companies envisages that the European Green Deal envisages an important role for gas in the energy transition. To follow this pathway, the gas value chain should be more oriented towards sustainability. Methane emission reduction should also be strongly pursued by gas network companies. A regulation to limit methane emissions by the gas sector should be established at the European level. It should strive to establish dynamic targets, create a robust and transparent Monitoring, Reporting and Verification (MRV) framework and incentivize the network companies to establish and realize ambitious action plans. The creation of a European Methane Emissions Observatory could provide an efficient tool for substantially reducing methane emissions. The Observatory would be well-placed to reconcile data from bottom-up corporate reporting and top-down aerial surveys and satellite measurements, creating the necessary transparency in the results obtained. National Regulatory Authorities should recognize the efficiently incurred costs for regulated entities. A form of incentive-based regulation oriented to minimizing network losses based on the experiences of the electricity sector could provide a promising approach.

Methane Emissions in the Gas Sector mentions that organizations that have not previously invested in energy and other GHG reductions should be capable of meeting more aggressive reduction levels because they would have more cost-effective reduction opportunities.

4.3 Time horizon of the regulatory period

Under this assessment area, we examined the time horizon of the proposed or existing regulatory period. To this end, we considered specific timeframes, but also priority levels, relevant strategies and policies which refer to target years and trial periods within regulatory sandboxes. Table 9 lists the relevant key considerations addressed in each paper.

Table 9. Key aspects covered with respect to the time horizon of the regulatory period

Material	Key regulatory aspects covered
EU strategy to reduce methane emissions	• Options available in view of proposing legislation on eliminating routine venting and flaring in the energy sector covering the full supply chain, up to the point of production, complementing the 2030 objectives of the World Bank's Zero Routine Flaring initiative
Strategic plan to reduce methane emissions in the energy sector	• Phasing out of fossil fuels should be the outstanding priority and that reduction of mineral methane emissions remain a component of that wider objective
Environmental Defense Feedback to the sector integration consultation	• A core feature of the gas market reform should be a mandatory methane performance standard consistent with what the industry considers feasible: 0,2% methane intensity by 2025
Methane Emissions in the Gas Sector	• Fixed target base year • Year-on-year rolling target • Target based on average emissions over a period of time

According to the *EU strategy to reduce methane emissions,* the Commission will table in 2021 a legislative proposal on compulsory measurement, reporting and verification for all energy-related methane emissions,

building on the Oil and Gas Methane Partnership (OGMP) methodology. Improving the quality of emissions data through mandatory higher-tier reporting by companies will also help Member States to improve their reporting to the United Nations Framework Convention on Climate Change (UNFCCC). It may therefore also lead to an increased share of higher-tier reporting for the concerned key categories in the EU inventory. Additionally, the Commission will examine the options available in view of proposing legislation on eliminating routine venting and flaring in the energy sector covering the full supply chain, up to the point of production. This would complement the 2030 objectives of the World Bank's Zero Routine Flaring initiative, which the Commission intends to support alongside its support for the World Bank's Global Gas Flaring Reduction Partnership.

In the *Strategic plan to reduce methane emissions in the energy sector,* across stakeholder responses there were overwhelming calls for swift and decisive action, with the majority of stakeholders stressing the importance of a short-medium term approach to this issue (1-10 years). Different justifications were offered for taking such a pro-active approach, including the EU's strong but diminishing position in global fossil fuel markets (particularly natural gas). Moreover, two stakeholders raised concerns that a slow and/or weak approach could facilitate fossil fuel lock-in. Within this context, multiple stakeholders emphasised that the phasing out of fossil fuels should be the outstanding priority and that reduction of mineral methane emissions remain a component of that wider objective. Conversely, two stakeholders opposed the notion that methane emissions undermined the credibility of natural gas, citing arguments that it is the cleanest conventional fuel and remains necessary for balancing energy supply in Europe.

Environmental Defense Feedback to the sector integration consultation highlights that according to the Commission's own modelling natural gas use will continue well into 2050, albeit in a reduced role. Considering how cheap gas is, it is believed that the biggest cost-efficiency potential lies in internalizing the environmental externalities of gas, notably methane emissions, in the gas price to level the playing field with low-carbon electricity. A core feature of the gas market reform should be a mandatory methane performance standard consistent with what the industry considers feasible: 0,2% methane intensity by 2025.

Methane Emissions in the Gas Sector mentions that organizations, in the context of target setting, can have:

- Fixed target base year
- Year-on-year rolling target
- Target based on average emissions over a period of time (e.g. 5-year average)

Best practices for GHG targets include the setting of at least two targets to cover both the medium (5-15 years) and long-time frames (>15 years). For methane targets, International initiatives such as the Global Methane Alliance refers to 2025 and 2030. Generally, long-term targets depend on uncertain future developments. Adding intermediate targets and/or milestones increases the credibility of these long-term commitments by giving investors more clarity on how this vision is going to impact the short-term.

4.4 Evaluation of infrastructure investments

Any regulatory decisions on investments must be supported by systematic planning early on. This section discusses the extent to which methane emissions abatement is discussed within the context of optimal investment decision. Hence, under this section, we are looking into the investment appraisal methods, either those that have been conducted and presented in the papers or those that the material recommends to be considered for future investment decisions. Table 10 lists the investment appraisal methods covered in the material reviewed.

Table 10. Key aspects covered with respect to the evaluation of infrastructure investments

Material	Key regulatory aspects covered
EU strategy to reduce methane emissions	• Methane reduction investments will be promoted as allowed costs for regulated entities in transmission, storage and distribution, including through possible guidance to regulators
Potential ways the industry can contribute to the reduction of methane emissions	• Methane emissions management across the gas value chain should enable the role of natural gas in the future energy mix

EU strategy to reduce methane emissions pinpoints the fact that methane reduction investments will be promoted as allowed costs for regulated entities in transmission, storage and distribution, including through possible guidance to regulators.

According to the *Potential ways the industry can contribute to the reduction of methane emissions,* methane emissions management across the gas value chain should enable the role of natural gas in the future energy mix by helping governments achieve their climate goals, instilling stakeholder confidence with respect to gas' environmental value and providing long-term predictability that allow industrial planning and investment. It is also noted that blending hydrogen into the existing natural gas infrastructure has national and regional benefits for methane emissions reductions.

4.5 Benefits expected from the adaptations needed to enable handling of CH4 emissions abatement

In terms of expected benefits resulting from the implementation of the adaptations needed to enable the handling of methane emissions, it is noted that this thematic area is more broadly represented in most papers. Under this assessment area, we have considered the acknowledgement of benefits from an environmental perspective, as well as in terms of security of supply, strengthening of the gas sector and socio-economic benefits.

Table 11. Key aspects covered with respect to the benefits expected from the adaptations needed to enable handling of CH4 emissions abatement

Material	Key regulatory aspects covered
EU strategy to reduce methane emissions	• Reducing venting and flaring • reducing leaks in fossil gas transmission • Venting and routine flaring
Strategic plan to reduce methane emissions in the energy sector	• A clearinghouse could create benefits for information sharing within the field
Potential ways the industry can contribute to the	• Excessive methane emissions along the value chain can reduce the climate benefits of natural gas

Material	Key regulatory aspects covered
reduction of methane emissions	

EU strategy to reduce methane emissions considers that the greatest benefits in net economic, environmental and social terms would be achieved by reducing venting and flaring, reducing leaks in fossil gas transmission. Venting and routine flaring should be restricted to unavoidable circumstances, for example safety reasons, and recorded for verification purposes.

According to the *Strategic plan to reduce methane emissions in the energy sector,* there was strong backing from a diversity of stakeholders for the Commission's proposal to establish an independent methane data clearinghouse, with all seven of the responses that referred to the clearinghouse voicing their support. One representative from academia highlighted the benefits a clearinghouse could create for information sharing within the field, both through seconding experts as well as through informing future stakeholders via an internship program.

Based on the main findings of *Potential ways the industry can contribute to the reduction of methane emissions,* natural gas generates about half as much CO2 as from coal for the same quantity of energy generated. It is the most heat intensive and highly efficient fuel, particularly when used directly. However, excessive methane emissions along the value chain can reduce the climate benefits of natural gas. Natural gas has also other important environmental benefits; during the combustion of natural gas, the emissions of nitrogen oxides are very low and it produces close to zero particulate matter and sulphur dioxide emissions.

4.6 Market, economic and financial terms and conditions to be accounted by regulators regarding CH4 emissions abatement

Under this section, we look into enablers and barriers to market entry, including institutional and legal issues, financial and administrative burdens and proposed ways to address them. Table 12 lists the key aspects covered in each paper.

Table 12. Key aspects covered with respect to the market, economic and financial terms and conditions to be accounted by regulators regarding CH4 emissions abatement

Material	Key regulatory aspects covered
Strategic plan to reduce methane emissions in the energy sector	• International pillar with the EU leading international efforts through bilateral and multilateral cooperation • Standard-setter in global gas markets
Potential ways the industry can contribute to the reduction of methane emissions	• Company organization and culture innovation
Limiting the climate impacts of the EU's gas supply	• Adequate funding to continue long-term background ozone and methane observations. • Measurements of methane emissions • Support for top-down approaches to provide valuable information

Material	Key regulatory aspects covered
	• Support for facility wide measurements
Environmental Defense Feedback to the sector integration consultation	• Lack of level playing field – decarbonization has thus far focused on the power sector while the gas sector continues to operate with no sustainability requirements in terms of either CO2 or methane emissions
Methane Emissions in the Gas Sector	• Relationship between methane emissions and business metrics, investment and growth strategy

According to the *Strategic plan to reduce methane emissions in the energy sector,* an ambitious methane policy should have a strong international pillar with the EU leading international efforts through bilateral and multilateral cooperation. Concerning the international dimension, the majority of stakeholders (9 out of 16) agreed with the Commission approach, one regarded it cautiously and six refrained from an explicit position. For those calling for the EU to take the role of a standard-setter in global gas markets, this would not only support global climate ambitions but also ensure equal treatment between internal and external market players and help maintain security of supply in the EU.

Potential ways the industry can contribute to the reduction of methane emissions pinpoints innovation in terms of company organization and culture to empower every employee to contribute to methane emission reduction. New initiatives are tested as:

- Employee Engagement Programme that set financial incentives paid to employees for the highest reductions achieved by improvements in operations and technologies.
- Executives' remuneration linked to carbon emissions reduction.
- Employee Engagement Programme which sets financial incentives for:
  - Using natural gas at home
  - Performing works to improve their housing energy efficiency

Limiting the climate impacts of the EU's gas supply considers that the EU should use the gas market reform to ensure the following:

- Adequate funding to continue long-term background ozone and methane observations.
- Measurements of methane emissions from the oil and gas system at different scales.
- Support for top-down approaches to provide valuable information
- Support for facility wide measurements to improve bottom-up approaches of estimating emissions, which typically rely on multiplying activity data

Environmental Defense Feedback to the sector integration consultation highlights that the main barriers to energy system integration to be addressed are:

- The dominant role of gas molecules, mostly fossil, in the EU's energy mix and lack of alternatives for industrial processes and heating is a significant market and technological barrier.
  - In market terms, gas is cheaper than electricity and this makes it difficult for both households and industrial energy systems to switch to electricity.
  - In technology and physical system terms, lack of availability of Large-Scale Power Storage means that direct electrification will not necessarily act as an enabler for building more renewable capacity which is intermittent.
- Infrastructure costs - building cables is more expensive than building pipelines. Infrastructure lock- in effects and general difficulty of making binary infrastructure choices in an uncertain environment are an additional market and physical system barrier.

- Structure of energy and market system which currently prioritizes security of supply and affordability over sustainability, volume over value. This represents an enormous market risk for new, lower carbon technologies.
- Lack of level playing field – decarbonization has thus far focused on the power sector while the gas sector continues to operate with no sustainability requirements in terms of either CO2 or methane emissions.
- Geopolitics – gas dependence makes Europe interdependent with Russia but renewables and electrification are likely to still keep Europe dependent but this time on China, Africa and the Middle East.

Methane Emissions in the Gas Sector mentions that the main factors to determine the level of ambition include:

- Methane reduction potential based on the implementation of BATs or improvement of operational activities
- Drivers affecting methane emissions, this is, the relationship between methane emissions and business metrics, investment and growth strategy
- International/national initiatives with a specific level of ambition (e.g. MGA ambition level: reduce by 45% by 2025 and 60%-70% by 2030)
- Alignment with other companies (benchmarking of methane targets with similar organizations)
- Science based targets scenarios to ensure that targets are in line with IPPCC scenario toward Paris Agreement goals

4.7 New technologies, products and measured with a focus on those who address cross-border barriers for methane emissions abatement handling

Under this section we examine the material in terms of inclusion of relevant regulatory aspects geared towards new technologies, products, measures, especially those that offer opportunities for enhancing cross-border flows. The majority of papers reviewed do not refer to specific technologies per se, or regulations regarding such technologies, hence our focus has shifted more on new products and measures with cross-border implications. Table 13 lists the relevant key elements included in the material reviewed.

Table 13. Key aspects covered with respect to the new technologies, products and measured with a focus on those who address cross-border barriers for methane emissions abatement handling

Material	Key regulatory aspects covered
EU strategy to reduce methane emissions	• Independent international methane emissions observatory, tasked with collecting, reconciling, verifying and publishing anthropogenic methane emissions data at a global level • The EU's Copernicus programme for earth observation is contributing to improved indirect air surveillance and the monitoring of methane emissions
Potential ways the industry can contribute to the reduction of methane emissions	• New technologies as innovation on technologies and methodologies (such as drones, satellites, etc.)
Limiting the climate impacts of the EU's gas supply	• EU policy makers and regulators focus on the desired outcome, by taking a flexible and dynamic approach to capitalize on the best available solutions and data
Can the current EU regulatory framework deliver	• Continuing learning and innovation

Material	Key regulatory aspects covered
decarbonization of gas?	
Methane Emissions in the Gas Sector	• Regulation can be conducive to methane emissions abatement through a dynamic regulation

EU strategy to reduce methane emissions envisages that the Commission will support the establishment of an independent international methane emissions observatory, tasked with collecting, reconciling, verifying and publishing anthropogenic methane emissions data at a global level. For the purpose of data verification and reconciliation of energy related methane emissions, company reporting needs to be complemented with data from national emission inventories, scientific research, as well as satellite observations and other remote sensing technologies verified by ground-level observations. The observatory would also be tasked with testing new monitoring and reporting technologies and assessing how these technologies could be used within existing methodologies, as well as assessing the level of improvement these technologies provide to the quality of data submitted by companies. Additionally, the EU's Copernicus programme for earth observation is contributing to improved indirect air surveillance and the monitoring of methane emissions. In particular, Copernicus can contribute to an EU-coordinated capability for detecting and monitoring global super emitters, principally via its Copernicus Atmosphere Monitoring Service (CAMS). Improved top-down data from satellites will help to target bottom-up leak detection on the ground as well as aerial monitoring. There have been significant technological advances made in these areas in recent years with improved accuracy and cost-effectiveness. For example, the use of drones makes it possible to survey large amounts of infrastructure and facilitates more widespread use of aerial monitoring as well as increased frequency, which is key to addressing intermittent leaks. Sophisticated analytical programs allow for the reconciliation of data at different levels and can guide abatement efforts. The Commission intends to support the sharing of information and technology across stakeholders to enhance access and catalyze abatement efforts.

Potential ways the industry can contribute to the reduction of methane emissions emphasizes the importance of new technologies as innovation on technologies and methodologies (such as drones, satellites, etc.) is key to further detect and reduce methane emissions.

According to *Limiting the climate impacts of the EU's gas supply* EU market should capitalize on science and technology to help us improve the measurement and monitoring of methane emissions. As technology and science evolves, it is important that EU policy makers and regulators focus on the desired outcome — lower methane and carbon dioxide emissions — whilst taking a flexible and dynamic approach to capitalise on the best available solutions and data. Rather than aiming to set the perfect regulation now, it may be desirable to start with pilot projects and regulatory sandboxes to test proposed measures, before enshrining them into law.

Can the current EU regulatory framework deliver decarbonization of gas identifies five themes which have an impact on gas infrastructure needs and policy including:

- The importance of continued learning and innovation in less mature technologies.
- The importance of a level playing field for gases both with other energy carriers and between gases because of the variety of sector coupling and low carbon gases technologies.
- The flow of new gases in existing gas infrastructure in the future.
- The importance of coordination in system planning and operation because of the increased interlinkages between energy carriers and between transmission and distribution systems.
- Different countries or regions may adopt different technological approaches.

Methane Emissions in the Gas Sector envisages that regulation can be conducive to methane emissions abatement through a dynamic regulation, where technology tools enable operators and regulators to use them within their legal domain.

5 Methane emissions abatement regulatory gap analysis

5.1 Gap analysis

Development of methane-specific regulations in Europe will require the European Commission to make some challenging choices: to find the right balance between the stringency of the MRV framework and the cost to the regulated entities, and to create a framework that embraces technological development and is rigid at the same time. In this direction, EU policy makers and regulators should focus on the desired outcome, by taking a flexible and dynamic approach to capitalize on the best available solutions and data.

Table 14 summarizes they key findings arisen from the review and meta-analysis of the material related to the methane emissions abatement. The current state and the desired future state, including options to be considered, result from the whole range of papers reviewed and the Consultant's meta-analysis. The following gap analysis does not intend to proritze possible actions, but to list them, so that could be addressed by the energy market players. Focus areas and the whole content of the following table is not a matter of importance ranking, but a matter of depicting the future of methane emissions abatement on the energy sector.

Table 14: Gap analysis

Focus Areas	Current State	Desired Future State (including options to be considered)	Gap identification and possible actions
Acknowledgement of infrastructure adaptation costs	• Identification and quantification of methane emissions in the different segments of the natural gas value chain • Verification and validation of the methane emissions • Inadequate technology specific regulations	• Gas infrastructure remains a significant component of the EU energy mix in the long-term • Increase transparency and comparability • Improve accuracy of national inventory reports • Harmonization of quantification and reporting methodologies	• Recognition by NRAs of LDAR and methane reduction investments as allowed costs for regulated entities • Industry to be engaged early and often in any new policy development
Time horizon of the regulatory period	• International initiatives such as the Global Methane Alliance refers to 2025 and 2030	• Legislative proposal on compulsory measurement, reporting and verification • Mandatory methane performance standard	• Phasing out of fossil fuels • Fixed, year-on-year and average emissions target setting
Evaluation of infrastructure investments	• Uncoordinated infrastructure planning between methane	• Methane emissions management and natural gas role in future energy mix	• Methane reduction investments will be promoted as allowed

Focus Areas	Current State	Desired Future State (including options to be considered)	Gap identification and possible actions
	emissions abatement and natural gas/electricity sectors		costs for regulated entities
Benefits expected from the adaptations needed to enable handling of CH4 emissions abatement	• Lack of awareness and knowledge	• Regulatory framework to address the benefits, apart from the risks	• Reducing venting and flaring • Reducing leaks in fossil gas transmission • Venting and routine flaring
Market, economic and financial terms and conditions to be accounted by regulators regarding CH4 emissions abatement	• Collaboration initiatives • Lack of awareness and knowledge	• Single European market • Sustainable and transparent market	• International pillar with the EU leading international efforts through bilateral and multilateral cooperation • Standard-setter in global gas markets • Company organization and culture innovation • Adequate funding to continue long-term background ozone and methane observations
New technologies, products and measured with a focus on those who address cross-border barriers for methane emissions abatement handling	• Lack of awareness and knowledge	• Collecting, reconciling, verifying and publishing anthropogenic methane emissions data at a global level	• Flexible and dynamic approach to capitalize on the best available solutions and data • Continuing learning and innovation

5.2 Key findings and recommendations

Methane emissions occasioned by the EU gas sector operations account for a 0.6 % of the total EU GHG emissions. Methane emissions management and abatement is a top priority for the European natural gas value chain. Preventing and mitigating methane emissions is considered as an opportunity to actively contribute to short-term mitigation of climate change, to accelerate environmental commitments and further enhancement of the environmental value of natural gas.

The Commission will deliver legislative proposals in 2021 on:

- Compulsory measurement, reporting, and verification (MRV) for all energy related methane emissions, building on the Oil and Gas Methane Partnership (OGMP 2.0) methodology.

- Obligation to improve leak detection and repair (LDAR) of leaks on all fossil gas infrastructure, as well as any other infrastructure that produces, transports or uses fossil gas, including as a feedstock.

The Commission will work to extend the OGMP framework to more companies in the gas and oil upstream, midstream and downstream as well as to the coal sector and closed as well as abandoned sites.

Harmonisation of quantification and reporting methodologies (specific for the gas sector, covering all the different types of methane emissions and the entire gas value chain) is very important. The development of a common, robust measurement methodology and life-cycle based reporting of net methane emissions are necessary.

Quantification of methane emission is a complex task. Complementary approaches to quantify methane emissions through a combination of measurement, calculations and modelling to fit each situation have been developed. Two quantification approaches "bottom-up" and "top-down" are available and currently in use, showing significant gaps in macro figures. The gas value chain stakeholders shall contribute to the identification of reliable methodologies to quantify emissions for each part of the value chain. Any future EU or national policy aimed at reducing methane emissions should be based upon source level quantification, transparent reporting and the stimulation of feasible reduction measures.

Policies should be economically and administratively efficient – balancing regulation with market-based mechanisms. Cost-effectiveness tests should be applied to all proposed measures, ensuring that regulations have a net benefit. It is necessary to ensure consistency and avoid overlapping legislation. There are already regulations in place that affect methane emissions, such as the Fuel Quality Directive, the Efforts Sharing Regulation, and the national legislation in some Member States. Policies should incentivise the early and continuous actions, while taking into account learning from previous efforts of the gas industry, in terms of innovation stimulation and continuous improvement.

The European gas value chain should support development of efficient policy and regulatory frameworks that incentivise early action, drive performance improvements, facilitate proper enforcement, and stimulate innovation and the implementation of new technologies/practices, such as digitalisation.

It is necessary to improve the accuracy of the national inventory reports. Collaboration between national authorities and the gas industry should be enhanced to improve the quality of the data.

A balanced and holistic approach, addressing all contributing sources of methane emissions across the economy, should be taken into consideration.