Fugitive emissions: a blind spot in the fight against climate change

The category of fugitive emissions covers a vast number of poorly controlled emissions: accidental, diffuse or unproductive. Fugitive emissions represent a significant proportion of anthropogenic greenhouse gas emissions and their assessment, let alone reduction, is still in its infancy. Often overlooked by climate policies and institutional mechanisms, actions in this area rely primarily on the emitters themselves, pushed by civil society and local stakeholders.

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1 • FUGITIVE EMISSIONS: DEFINITION AND EVOLUTION

The nature of fugitive emissions makes them difficult to assess but their level is significant - around 5% of global emissions - and has probably increased in recent years.

• DEFINITION(S) • The IPCC defines fugitive emissions as "emissions [of greenhouse gases] that are not produced intentionally by a stack or vent" and stipulates that they may "include leaks from industrial plants and pipelines" (IPCC, 2006). A previous definition provides more detail on potential sources of fugitive emissions: "they may be caused by the production, processing, transmission, storage and use of fuels and include combustion emissions only if they do not meet production needs (e.g. natural gas flaring at gas and oil production facilities) "(IPCC, 1996).
This definition may vary from one sector to another. In the fossil fuel sector, fugitive emissions are sometimes broadly defined as any emissions unrelated to the end use of the fuel. In air pollution, a fugitive emission can be defined as the "release of pollutants into the free atmosphere after they have escaped an attempt to capture them with a hood, seal or any other means for ensuring the capture and retention of these pollutants". They therefore contrast with channelled emissions (CITEPA, 1999).

Accordingly, there is no stable and universal definition of fugitive emissions. In practice, they generally include accidental emissions (pipeline breakage, coal seam fire, etc.), leaks and diffuse escapes (defective valves or seals, migration of gas to the surface near wells or mines, emissions from abandoned wells, etc.) and unintentional but non-productive discharges (mine ventilation, flaring, degassing, etc.). Many phenomena are therefore involved in a category that is primarily negative: fugitive emissions are ultimately emissions related to human activities that do not fit into any other category.

• AVAILABLE DATA ON FUGITIVE EMISSIONS • Their very nature makes fugitive emissions difficult to quantify. There is no comprehensive global data, but it is possible to assess their significance and evolution by combining national inventories and secondary data.

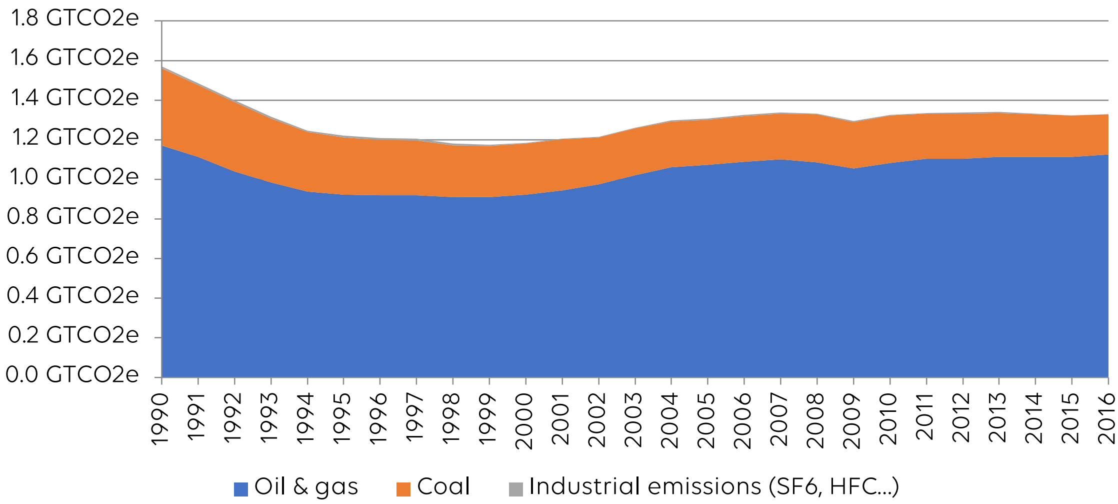

FIGURE 1. FUGITIVE EMISSIONS (ANNEX I COUNTRIES)

Under the United Nations Framework Convention on Climate Change, industrialised countries ("Annex I countries") regularly report fugitive emissions. These inventories show stable emissions since the mid-2000s after a decline in the early 1990s and a rebound around 2000. **In 2016, fugitive emissions reported by industrialised countries were 1.33 billion tonnes CO_2 equivalent compared to 1.57 in 1990, about 85% of which were from the hydrocarbons sector, 15% from coal and a fraction from industry (UNFCCC GHG data).**

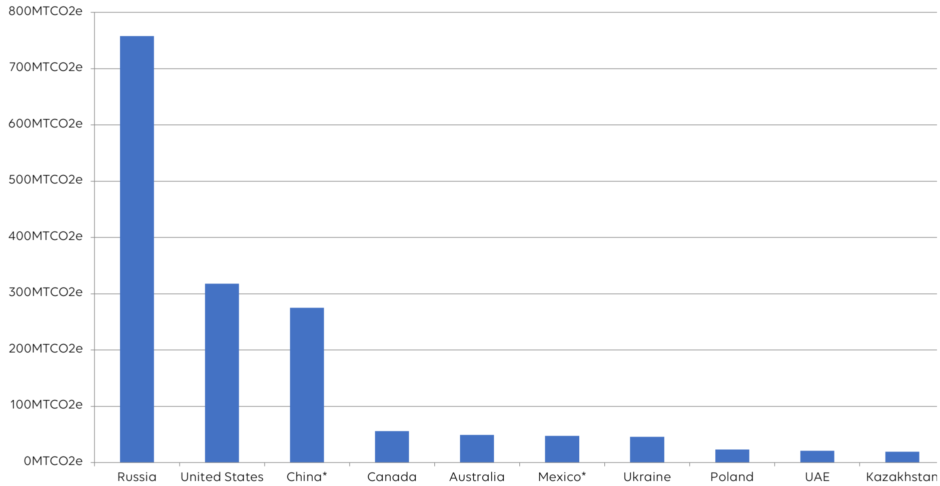

FIGURE 2. FUGITIVE EMISSIONS FOR SELECTED COUNTRIES UNFCCC GHG DATA EXCEPT *ENERDATA)

Outside Annex I countries, fugitive emission data are generally partial and dated: 276MTCO_2e for China (2005, CH4 only), 58MTCO_2e for Africa (2000, CH4 only), 47MTCO_2e for Mexico (2006, CH4 only), 21MTCO_2e for the UAE, etc. (Enerdata)

These data, although incomplete and partly obsolete, show that fugitive emissions account for a significant share of global greenhouse gas emissions: at least 2GTCO_2e i.e. 5% of the total. It also shows a correlation between countries with high emissions and those with a large oil, gas or coal industry.

While fugitive emissions can occur in any activities handling greenhouse gases - refrigeration (HFCs, CFCs), electricity (SF6), health (N2O), etc. - they occur mainly during the extraction, transport, storage and processing of fossil fuels and largely consist of CH4 (methane or "natural gas").

• A PRESUMPTION OF INCREASE • The orders of magnitude mentioned above must however be taken with caution. In fact, since the mid-2000s, there has been an unexplained increase in the concentration of methane in the atmosphere. This could indicate that fugitive emissions of this gas have been underestimated: the simultaneous increase of the ethane concentration seems to indicate that the oil and gas industry is responsible but the isotopic signature of the methane points to a natural origin (rice fields, swamps, livestock, degradation of natural or agricultural plant waste, etc.). Recent work has suggested a solution to this paradox and tends to confirm the responsibility of hydrocarbon production, which would be responsible for 50 to 75% of the observed increase (Worden, 2017).

Although this hypothesis remains controversial, it is corroborated by measurements carried out near the hydrocarbon production sites. These have found unusually high levels of methane (Zavala-Araiza, 2015): fugitive emissions reported by the US oil and gas sector could be under-estimated by 60% (Alvarez, 2018).

2 • IMPROVING MEASUREMENT AND REPORTING

The evaluation of fugitive emissions is an issue for the climate but also a political and economic one.

This is particularly the case for the gas industry. At equivalent energy, gas combustion produces about half as much carbon dioxide as coal and 30% less than petroleum products. However, at equivalent amounts, methane contributes much more to global warming than carbon dioxide, so this advantage can be rapidly offset by higher fugitive emissions. In the United States, for example, the shift from coal to gas in electricity production represents a gain for the climate only if the upstream leakage rate of plants is less than 3%. The conversion of liquid fuel to gas for commercial vehicles (trucks, buses, etc.) represents a gain if the leakage rate is less than 1% (WRI, 2013). Some studies suggest that fugitive emissions may exceed 4% (Pétron, 2014) or even 7.9% for unconventional gas

(Howarth, 2011). **These assessments cast doubt on the climate advantage attributed to gas compared to other fossil fuels, and therefore the investments made in this energy.**

• ISSUES AND SOURCES OF UNCERTAINTY • In addition to the lack of a clear definition, the evaluation of these emissions raises several practical and methodological problems. The first of them is detection. The emissions may actually be unintentional (leaks and losses from the gas network for example) or they may occur a long time after the end of an activity (emissions related to abandoned wells and mines, for example). Furthermore, the main gas involved is methane which, in its natural state, is invisible and odourless.

Independent producers in the United States

Since fugitive emissions are often diffuse, the collection of information is also problematic. This is particularly the case when the emitting activities are fragmented with many small players.

This is the situation in the oil and gas sector in the United States. Due to an original mining right that allows landowners to exploit the geological resources found on their land without authorisation or concession, oil and gas production in the United States is dominated by small and medium-sized enterprises. Accordingly, the United States has 9,000 independent producers (i.e. producing less than 5 million dollars of hydrocarbons a year or refining fewer than 75,000 barrels a day). These companies, with an average of 12 employees, drill 95% of wells and produce 54% of US oil and 85% of the gas. This situation makes the estimation of fugitive emissions more complex and limits the means that companies can assign to measuring and reducing them.

Source : Independant petroléum association of America

TEXT BOX 1

A second problem is related to the conversion of these emissions into carbon equivalent. Fugitive emissions are largely composed of methane, a gas whose lifetime in the atmosphere and ability to intercept infrared radiation differs from that of carbon dioxide. To express the climate impact of these emissions in a single unit, their 100-year global warming potential (GWP) is calculated, i.e. the additional energy that they will send back to the Earth's surface in a century compared to that resent by a tonne of carbon dioxide. This equivalence makes it possible to estimate how many tonnes of CO_2 are "worth" one tonne of CH4. However, this figure has been revised steadily since the 1990s: The IPCC's second report puts it at 21, i.e. one tonne of methane would have the same effect on the climate as 21 tonnes of CO_2 - a figure that is still often referred to, while the fourth IPCC report puts it at 25 and the fifth at 28 (Greenhouse gas protocol, 2016). **All other things being equal, these revaluations mechanically increase the role of fugitive emissions.**

• ACADEMIC, ASSOCIATIVE AND INDUSTRIAL INITIATIVES • Significant work is still needed to arrive at a reliable evaluation of fugitive emissions both at the macro level and at the level of the facilities responsible for the emissions. Researchers, non-governmental organisations and manufacturers are mobilising to reduce these uncertainties and the resulting climate and economic risks.

Studies Initiated by the Environmental Defense Fund

The American NGO, the Environmental Defense Fund, has initiated a large-scale research programme to assess and locate fugitive emissions in the US gas supply chain. This programme, covering 16 independent projects, involved 140 researchers and experts from 40 universities or research centres (NOAA Earth System Research Laboratory, Stanford, Harvard, University of Texas ...) and 50 companies.

It led to more than thirty scientific publications between 2013 and 2018. A summary of this work was published in Science (Alvarez, 2018). It evaluates leaks during the extraction, transmission, storage and processing of gas to be 2.3% of US production, or 60% more than the inventory produced by the EPA, the federal environmental protection agency, based on the declarations of the companies concerned. It also shows large disparities between different sites and suggests that faster detection of leaks would reduce them significantly and cheaply, with existing technologies.

Source : www.edf.org/climate/methane-studies

TEXT BOX 2

Research and development projects are also under way to bring solutions for faster detection of diffuse emissions to the market. This is the case, for example, of the GaSes optical imaging project, developed by the Spanish company SENSIA and supported by the European Union as part of the H2020 programme.

3 • MAJOR SOURCES OF FUGITIVE EMISSIONS, SOLUTIONS AND INITIATIVES

Even if the data are incomplete, it is possible to identify some activities that contribute significantly to fugitive emissions: gas flaring, the hydrocarbon logistics chain and the coal supply chain.

• FLARING OF NATURAL GAS • Gas flaring involves burning gas without using the heat produced. This operation makes it easy to get rid of combustible gases from oil extraction or refining but releases carbon dioxide. By convention, flaring-related emissions are considered fugitive emissions. Last year, 140.57 billion cubic metres of gas were flared, equivalent to 3% of worldwide natural gas production. **This practice decreased in 2017 for the first time since 2010: gas flaring volume dropped by around 5% despite an increase in world oil production of 0.5% (World Bank, 2018)**. Flaring, however, remains responsible for the emission of 300 million tonnes of CO_2 per year.

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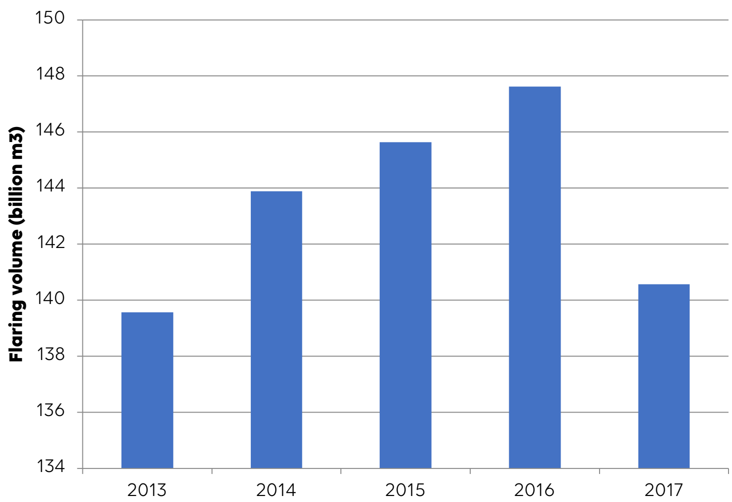

FIGURE 3. ANNUAL VOLUME OF GAS FLARED IN THE WORLD (WORLD BANK)

Source : Banque Mondiale

Origin of Flaring and Solutions

In general, oil deposits also contain methane. This "associated gas" must be separated from liquid hydrocarbons before they are processed. This gas has long been considered an embarrassing by-product of oil production that was rejected or burned. It was only in the second half of the 20th century that large-scale use of natural gas began, but even today it is sometimes cheaper to burn gas than to send it to a buyer, especially when the production site is distant from the consumption areas.

The range of solutions available for gas carriage has expanded. In addition to the construction of a gas pipeline, it is possible to compress the gas to reduce its volume, to liquefy it or to solidify it to make it easier to transport. Formerly marginal, this process has largely developed over the past 10 years, especially under the impulse of American companies - Chevron, Cheniere, Dominion, etc. - seeking new export markets. However, it requires particularly expensive infrastructure that takes a long time to implement.

There are other solutions for avoiding flaring even when gas cannot be transported cheaply, if at all. Note the following, in particular:

- The reinjection of gas in wells - this option can be used to increase the pressure in the tank and make it easier to recover the oil but also to conserve the gas so that it can be extracted again later, if required. Established in Kazakhstan in 2000, reinjection has prevented the discharge of 49 million tonnes of carbon dioxide and in Iran 31 million cubic metres per day are reinjected into tanks. This solution, however, is profitable only if the amount of gas involved is low.
- Generating electricity by burning the gas in a turbine rather than a flare.
- The production of methanol (which is used to produce other petrochemicals such as ethylene or propylene) or ammonia. This method is widespread in Persian Gulf countries.

Source : Soltanieh, 2016

TEXT BOX 3

Despite this progress, flaring remains common, especially in countries that do not have a market or infrastructure for the sale of gas. Its use is therefore often linked to the development and stability of the region: in Yemen, for example, the volume of gas flared per barrel of oil produced has increased four-fold between 2013 and 2017, while in Syria it has increased ten-fold (World Bank).

To limit this practice, the World Bank has launched a "Zero routine flaring" initiative that is mobilising oil tankers and governments to eliminate flaring in the normal operation of facilities by 2030.

Reduction of flaring at ENI

Some companies have committed to achieving this result more quickly: e.g. ENI. In 2007, the Italian company committed to gradually reducing flaring with a view to eliminating it completely in 2025. Two billion dollars were invested in this scheme, which has already reduced the volume of flaring gas by 75%. Additionally, since 2010, new projects developed by Eni no longer use flaring under normal operating conditions.

ENI has achieved this firstly by recovering the associated gas by coordination with the governments of the countries involved. This recovery in electricity generation or in local gas distribution is also used to improve the access of local populations to a modern energy. If recovery is not possible, Eni re-injects the gas into its wells.

The M'Boundi project (Republic of the Congo) is an example of this process: in March 2014, Eni completed the installation of two compression plants to enable the majority of the associated gas to be transported to a 300MW power plant belonging to CEC (Congo Electric Power Plant), with the surplus gas reinjected into wells. This project required an investment of 300 million dollars and is recovering 3 million cubic metres of gas per day.

Source : ENI

TEXT BOX 4

Flaring also has consequences for the local environment (air pollution, noise, etc.), which is why communities are mobilising to end the practice, often with the support of NGOs. In 2015, for example, Nigerian representatives of the Egi communities participated in Total's general assembly to demand the cessation of flaring in the Niger Delta and to testify to the environmental and social problems caused by the exploitation of hydrocarbons. They were supported by the NGO Friends of the Earth (Novethic, 2015). In 2017, Total Exploration and Production Nigeria signed 2 agreements with the Egi community to improve the living conditions of those living near its facilities.

• UPSTREAM GAS AND OIL• In addition to flaring, the hydrocarbon sector is responsible for fugitive emissions of methane at all stages of its activity:

• Wells: methane is normally piped and recovered through the well casing but some can escape into the atmosphere through the soil in the area around the boreholes (Kang, 2014). These diffuse discharges can last a decade after the end of operations (Boothroyd, 2016),

• During gas transportation and storage: defective sealing of valves and fittings, breaks and leaks, intentional or uncontrolled degassing, etc.

• During the processing of petroleum products: a refinery has tens of thousands of valves that can leak small amounts of greenhouse gases or other pollutants.

The Aliso Canyon accident in 2015-2016

The Aliso Canyon gas storage facility, near to Porter Ranch, is operated by SoCalGas, the leading natural gas distributor in Southern California. It has 114 wells with capacity for 2.4 billion cubic metres of gas, equivalent to 15 million barrels of oil. This storage facility is the second largest in the United States and supplies gas to 11 million homes and 16 thermal power stations in the Los Angeles area.

On 23 October, 2015, site employees found a massive leak in the tank: every day about 1,000 tonnes of gas were escaping into the atmosphere. After many unsuccessful attempts, the leak was finally found and sealed on 13 February 2016.

During these four months, 97,100 tonnes of methane and 7,300 tonnes of ethane were discharged - the equivalent of the greenhouse gas emissions of 200,000 Americans for one year. The disaster resulted in the evacuation of 2,000 households located near the site. The estimated cost was $665 million.

This accident drew attention to the vulnerability of US gas infrastructures to methane leaks. Most fugitive methane emissions are, however, much less spectacular - and therefore much more difficult to identify and remedy.

Source : Conley et Al, 2016

TEXT BOX 5

The solutions available for reducing these fugitive emissions depend on their source but in all cases require the mobilisation of companies involved in the hydrocarbon logistics chain. Apart from the major leaks and those that represent a risk to staff, it is not always economically profitable to reduce fugitive emissions: indeed, to detect leaks, to determine their source and correct them requires investments which may be much higher than the cost of the lost gas.

Local regulation and the actions of communities and NGOs can play an important role in encouraging businesses to respond to low-volume leaks. For example, BP has installed a leak detection and repair system on more than 80,000 valves at its refinery in Whiting, Indiana, but it needed the company to be bound by an agreement with the American justice system at the end of a procedure initiated by 3 American states (Indiana vs. BP, 2001). More recently, on 23 March, 2017, California adopted a new regulation on methane emissions in the hydrocarbon sector, to come into effect between 2018 and 2020, expected to reduce the state's emissions by 1.4 CO_2mteq per year, in particular by establishing quarterly monitoring of fugitive emissions and by imposing repair timescales when leaks occur.

The challenge of gas distribution networks

As operators of gas distribution networks enjoy a natural monopoly, they do not always have an economic incentive to reduce losses. In the absence of competition, tariffs are generally set by a regulator, often on the "Cost +" model: the remuneration received by the operator is based on the operating cost of the activity, valued based on previous years, plus a margin. In this system, gas lost during transmission and distribution is absorbed in the historical operating costs. As a result, the operator does not suffer losses from fugitive emissions and there is no incentive to invest to reduce them. Local authorities often play a role in the management of the distribution network: they can own it (as in France), set rates (this is generally the case at state level in the United States), be on boards of directors, etc. They can use this role to encourage network operators to combat leaks, thereby helping to reduce their fugitive emissions even when the gas industry is not directly present on their territory.

Source : Hausman, 2016

TEXT BOX 6

Cooperation between companies, researchers and public bodies at sub-national level is particularly necessary in the United States, where the election of Donald Trump in 2016 led to federal regulation being undermined and the commitments of the previous administration being abandoned. There are initiatives in this direction (Konschnik, 2018).

At world level, the objective of the Oil and Gas Methane Partnership, under the auspices of the Climate and Clean Air Coalition, is to encourage oil tankers to take voluntary action. Ten of the largest oil companies on the planet, including Royal Dutch Shell, Total and BP, as well as Mexico's PEMEX and Thailand's PPT, have ratified its guiding principles for reducing methane emissions in the gas industry.

• THE COAL SECTOR • After hydrocarbons, the next sector causing fugitive emissions is coal: like oil reservoirs, coal seams generally contain methane that can escape into the atmosphere when the resource is exploited.

Coal-related fugitive emissions mainly occur:

• During coal mining: the fracturing of the ore releases trapped methane. In an open cast mine, the gas occurs directly in the atmosphere. When the mine is underground, the methane spreads in the tunnels before being evacuated by the ventilation system. The concentration of methane in the ventilated air outside mines is usually a few tenths of a percent, while the risk of explosion ("firedamp") starts from a few percent.

• During the transportation and storage of coal: the gas still present in the ore is released into the atmosphere

• Following decommissioning: methane can continue to escape through cracks and wells created during operation. In the United States, for example, there are several thousand abandoned mines, including 400 identified as discharging significant quantities of methane (EPA, 2017).

According to the available inventories, most emissions occur during ore extraction: ventilated methane alone accounts for half of the sector's fugitive emissions (EPA).

The gas associated with coal can be recovered and used as natural gas for electricity generation, vehicle fuel or in petrochemical processes. It can also be used in mining: to dry ores, heat tunnels, etc. The reduction of fugitive emissions in the coal sector can thus be a profitable operation: in Europe, coal degassing would yield €1.8 - €2.2 per tonne of CO_2 equivalent avoided (Ecofys, 2009). However, these emissions are often neglected: in the ETS framework, the European carbon market, for example, they are not included in calculations of the carbon footprint of coal producers.

The Global Methane Initiative, a public-private partnership launched in 2004 to reduce methane emissions, identified nearly 200 projects in the coal sector in 2016 (Global Methane, 2016). Among the most recent are the installation of a 1MW gas turbine (with the option to extend to 6MW) in the Fuhong underground mine in China or gas recovery and use for the production of steam, heat and electricity at the Severnaya mine in Russia.

Degasification of the Khe Cham Coal Mine (Vietnam)

Located in the northeastern province of Quang Ninh, the Khe Cham coal mine is operated by a subsidiary of the public conglomerate Vinacomin (Vietnam National Coal and Mineral Industries Group) and produces 1.5 million tonnes of coal per year.

The Khe Cham coalfield is one of the richest in methane in the country. These fugitive emissions pose safety problems: in 2009, a firedamp fire killed 11 miners.

In 2012, a drainage system was put in place, which reduced the methane concentration in the mine atmosphere by 0.2 to 0.6 points. This meant that the mine was no longer forced to suspend operations due to the abnormal presence of methane (compared to an average of 20 hours per month of interruption before its installation). Ventilation costs have also been reduced by a third and output efficiency has improved. Finally, the collected methane can be used to supply a gas turbine and partly cover the electricity needs of the mine.

FIGURE 4. STATION DE DRAINAGE DE MÉTHANE À KHE CHAM

Source : Global Methane

TEXT BOX 7

As emissions continue beyond end of operations, site remediation and the attention of local authorities can also help to reduce emissions.

CONCLUSION

Despite a significant contribution, fugitive emissions are one of the blind spots in combating climate change. Much work remains to be done for better evaluation and reduction of fugitive emissions. The available information suggests that the extraction and, to a lesser extent the processing and transportation, of fossil fuels is the main source of fugitive emissions. Responsibility for their reduction therefore rests first and foremost in the oil, gas and coal companies, assisted - sometimes spurred - by other actors: researchers, local authorities and local communities, NGOs.

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