U.S. Energy Information Administration

OCD Exhibit 21

NATURAL GAS

OVERVIEW DATA ANALYSIS & PROJECTIONS GLOSSARY › FAQS ›

Natural Gas Gross Withdrawals and Production

(Volumes in Million Cubic Feet)

Area: U.S. **Period-Unit:** Annual-Million Cubic Feet

Show Data By: Data Series / Area	Graph Clear	2014	2015	2016	2017	2018	2019	View History
Gross Withdrawals		31,405,381	32,914,647	32,591,578	33,292,113	37,129,374	40,704,488	1936-2019
From Gas Wells		10,123,418	9,371,281	7,287,858	6,161,420	6,350,001		1967-2018
From Oil Wells		5,999,955	6,537,627	6,385,120	6,217,438	6,275,713		1967-2018
From Shale Gas Wells		13,974,936	15,819,319	17,847,539	19,927,602	23,550,471		2007-2018
From Coalbed Wells		1,307,072	1,186,420	1,071,062	985,653	953,189		2002-2018
Repressuring		3,291,091	3,412,269	3,548,106	NA	3,584,274		1936-2018
Vented and Flared		293,916	289,545	230,410	NA	468,347		1936-2018
Nonhydrocarbon Gases Removed		322,620	440,789	413,013	264,582	253,459		1973-2018
Marketed Production		27,497,754	28,772,044	28,400,049	29,203,550	32,823,295	36,197,056	1900-2019
NGPL Production, Gaseous Equivalent		1,608,148	1,706,584	1,807,934	1,897,242	2,234,593	2,539,995	1930-2019
Dry Production		25,889,605	27,065,460	26,592,115	27,306,308	30,588,702	33,657,061	1930-2019

Click on the source key icon to learn how to download series into Excel, or to embed a chart or map on your website.

- = No Data Reported; **--** = Not Applicable; **NA** = Not Available; **W** = Withheld to avoid disclosure of individual company data.

Notes: Beginning with 2006, "Other States" volumes for the production series include the following states/areas: Alabama, Arizona, Florida, Idaho, Illinois, Indiana, Kentucky, Maryland, Michigan, Mississippi, Missouri, Nebraska, Nevada, New York, Oregon, South Dakota, Tennessee, and Virginia. Federal Offshore Pacific is included in California through 2017, and in "Other States" starting in 2018. Production series data for 2018 forward are estimates. Final 2018 state-level production series data will not be available until the 2018 Natural Gas Annual is published (scheduled for the third quarter of 2019). Gross withdrawal volumes in Florida fluctuate from year to year because nonhydrocarbon gases are occasionally included in gross withdrawals. See Definitions, Sources, and Notes link above for more information on this table.

Release Date: 5/29/2020
Next Release Date: 6/30/2020

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Natural Gas Gross Withdrawals and Production

(Volumes in Million Cubic Feet)

Area: New Mexico **Period-Unit:** Annual-Million Cubic Feet

Show Data By: Data Series / Area	Graph Clear	2014	2015	2016	2017	2018	2019	View History
Gross Withdrawals		1,266,379	1,296,793	1,282,666	1,323,019	1,527,319	1,863,942	1967-2019
From Gas Wells		532,600	499,504	342,339	316,914	300,863		1967-2018
From Oil Wells		204,342	251,149	254,940	224,149	211,281		1967-2018
From Shale Gas Wells		218,023	264,606	431,302	546,632	780,201		2007-2018
From Coalbed Wells		311,414	281,535	254,085	235,324	234,974		2002-2018
Repressuring		17,599	26,382	26,829	5,738	4,852		1967-2018
Vented and Flared		19,119	24,850	25,680	17,494	37,220		1967-2018
Nonhydrocarbon Gases Removed		142	416	510	55	105		1980-2018
Marketed Production		1,229,519	1,245,145	1,229,647	1,299,732	1,485,142	1,812,498	1967-2019
NGPL Production, Gaseous Equivalent		88,894	93,652	89,821	96,526	125,141		1967-2018
Dry Production		1,140,626	1,151,493	1,139,826	1,203,206	1,360,001		1982-2018

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Natural Gas Gross Withdrawals and Production

(Volumes in Million Cubic Feet)

Area: Texas **Period-Unit:** Annual-Million Cubic Feet

Show Data By: Data Series / Area	Graph Clear	2014	2015	2016	2017	2018	2019	View History
Gross Withdrawals		8,659,188	8,799,465	8,156,296	8,079,974	8,915,266	10,222,840	1967-2019
From Gas Wells		2,672,326	2,018,855	897,854	878,525	739,326		1967-2018
From Oil Wells		1,558,002	1,803,086	1,680,873	1,569,154	1,537,090		1967-2018
From Shale Gas Wells		4,428,859	4,977,524	5,577,570	5,632,295	6,638,851		2007-2018
From Coalbed Wells		0	0	0	0	0		2002-2018
Repressuring		440,153	533,047	592,484	NA	620,164		1967-2018
Vented and Flared		90,125	113,786	87,527	NA	238,054		1967-2018
Nonhydrocarbon Gases Removed		143,891	262,174	250,813	208,850	209,947		1980-2018
Marketed Production		7,985,019	7,890,459	7,225,472	7,189,566	7,847,102	8,998,144	1967-2019
NGPL Production, Gaseous Equivalent		806,794	810,121	819,021	840,601	1,011,753		1967-2018
Dry Production		7,178,225	7,080,338	6,406,450	6,348,965	6,835,349		1982-2018

Click on the source key icon to learn how to download series into Excel, or to embed a chart or map on your website.

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Release Date: 5/29/2020
Next Release Date: 6/30/2020

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NATURAL GAS

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Natural Gas Gross Withdrawals and Production

(Volumes in Million Cubic Feet)

Area: Colorado **Period-Unit:** Annual-Million Cubic Feet

Show Data By: Data Series / Area	Graph Clear	2014	2015	2016	2017	2018	2019	View History
Gross Withdrawals		1,643,487	1,688,733	1,688,375	1,710,643	1,836,422	1,992,623	1967-2019
From Gas Wells		728,978	1,009,817	447,854	437,482	342,854		1967-2018
From Oil Wells		178,657	236,015	204,177	225,740	329,962		1967-2018
From Shale Gas Wells		315,469	49,771	665,351	698,568	818,013		2007-2018
From Coalbed Wells		420,383	393,130	370,994	348,852	345,593		2002-2018
Repressuring		NA	0	NA	0	0		1967-2018
Vented and Flared		NA	0	2,620	4,279	5,097		1967-2018
Nonhydrocarbon Gases Removed		0	0	0	0	0		1980-2018
Marketed Production		1,643,487	1,688,733	1,685,755	1,706,364	1,831,325	1,987,043	1967-2019
NGPL Production, Gaseous Equivalent		85,198	104,633	115,353	127,456	143,285		1967-2018
Dry Production		1,558,289	1,584,100	1,570,403	1,578,908	1,688,040		1982-2018

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U.S. Energy Information Administration

NATURAL GAS

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Natural Gas Gross Withdrawals and Production

(Volumes in Million Cubic Feet)

Area: California Onshore **Period-Unit:** Annual-Million Cubic Feet

Show Data By: Data Series / Area	Graph Clear	2013	2014	2015	2016	2017	2018	View History
Gross Withdrawals		219,386	218,668	216,772	196,041	203,979	198,051	1992-2018
From Gas Wells		73,493	53,520	36,061	28,169	40,916	44,137	1992-2018
From Oil Wells		51,625	57,572	55,889	49,373	51,401	47,458	1992-2018
From Shale Gas Wells			107,513	107,964		111,662	106,456	2012-2018
Repressuring		NA	NA	NA	NA	NA	NA	1992-2018
Vented and Flared		NA	NA	NA	NA	NA	NA	1992-2018
Nonhydrocarbon Gases Removed		NA	NA	NA	NA	NA	NA	1992-2018
Marketed Production		219,386	218,668	216,772	196,041	203,979	198,051	1992-2018
Dry Production			205,320	205,173	185,490	194,557	188,682	2012-2018

Click on the source key icon to learn how to download series into Excel, or to embed a chart or map on your website.

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Release Date: 5/29/2020
Next Release Date: 6/30/2020

U.S. Energy Information Administration

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NATURAL GAS

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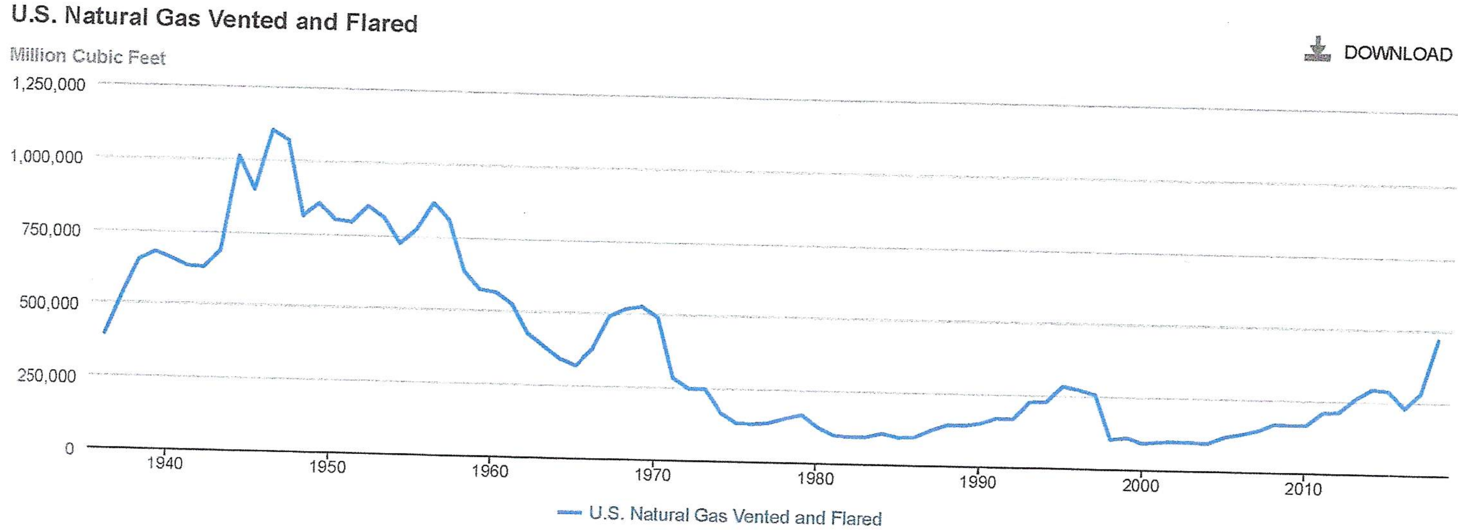
Referring Pages:

- Natural Gas Vented and Flared
- U.S. Natural Gas Gross Withdrawals and Production
- Natural Gas Vented and Flared (Summary)

View History: Monthly Annual

Download Data (XLS File)

U.S. Natural Gas Vented and Flared



Source: U.S. Energy Information Administration

This series is available through the EIA open data API and can be downloaded to Excel or embedded as an interactive chart or map on your website.

U.S. Natural Gas Vented and Flared (Million Cubic Feet)

Decade	Year-0	Year-1	Year-2	Year-3	Year-4	Year-5	Year-6	Year-7	Year-8	Year-9
1930's							392,528	526,159	649,106	677,311
1940's	655,967	630,212	626,782	684,115	1,010,285	896,208	1,102,033	1,067,938	810,178	853,884
1950's	801,044	793,186	848,608	810,276	723,567	773,639	864,334	809,148	633,412	571,048
1960's	562,877	523,533	425,629	383,408	341,853	319,143	375,695	489,877	516,508	525,750
1970's	489,460	284,561	248,119	248,292	169,381	133,913	131,930	136,807	153,350	167,019
1980's	125,451	98,017	93,365	94,962	107,913	94,778	97,633	123,707	142,525	141,642
1990's	150,415	169,909	167,519	226,743	228,336	283,739	272,117	256,351	103,019	110,285
2000's	91,232	96,913	99,178	98,113	96,408	119,097	129,469	143,457	166,909	165,360
2010's	165,928	209,439	212,848	260,394	293,916	289,545	230,410	281,947	468,347	

- = No Data Reported; -- = Not Applicable; NA = Not Available; W = Withheld to avoid disclosure of individual company data.

Release Date: 2/28/2020
Next Release Date: 3/31/2020

Referring Pages:

- Natural Gas Vented and Flared
- U.S. Natural Gas Gross Withdrawals and Production
- Natural Gas Vented and Flared (Summary)

U.S. Energy Information Administration

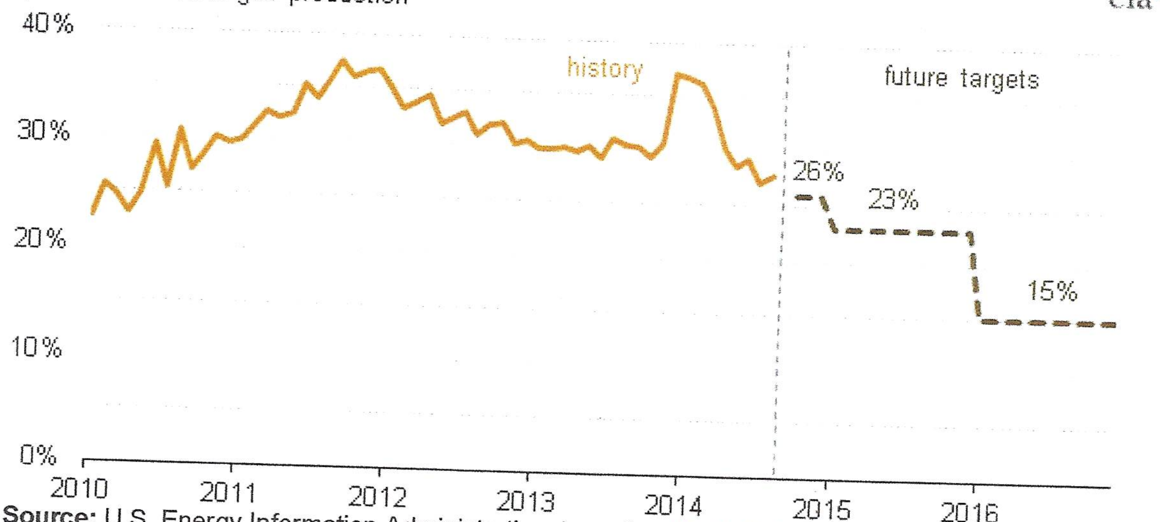
OCD Exhibit 23

Today in Energy

October 20, 2014

North Dakota aims to reduce natural gas flaring

Natural gas flared in North Dakota (2010-16)
percent of natural gas production



Source: U.S. Energy Information Administration, based on North Dakota Industrial Commission

About one-third of the natural gas North Dakota has produced in recent years has been flared rather than sold to customers or consumed on-site. The rapid growth in North Dakota oil production, which rose from more than 230,000 barrels per day (bbl/d) in January 2010 to more than 1,130,000 bbl/d in August 2014, has led to increased volumes of associated gas, or natural gas that comes from oil reservoirs. These increased volumes require additional infrastructure to gather, process, and transport gas volumes instead of flaring them. These additions can take time to build, and well operators are often reluctant to delay production. In an effort to reduce the amount of natural gas flared, North Dakota's Industrial Commission (NDIC) established targets that decrease the amount of flared gas over the next several years.

The first target of 26% flared is set for fourth-quarter 2014, with continued decreases in flaring reaching 10% by 2020. North Dakota recently reported that it was close to achieving the 26% reduction target for natural gas flaring, as the percentage in August was 28% flared, or 375 million cubic feet per day (MMcf/d) out of a total production of 1,340 MMcf/d. The rest of the produced natural gas was either sold or used at the production site.

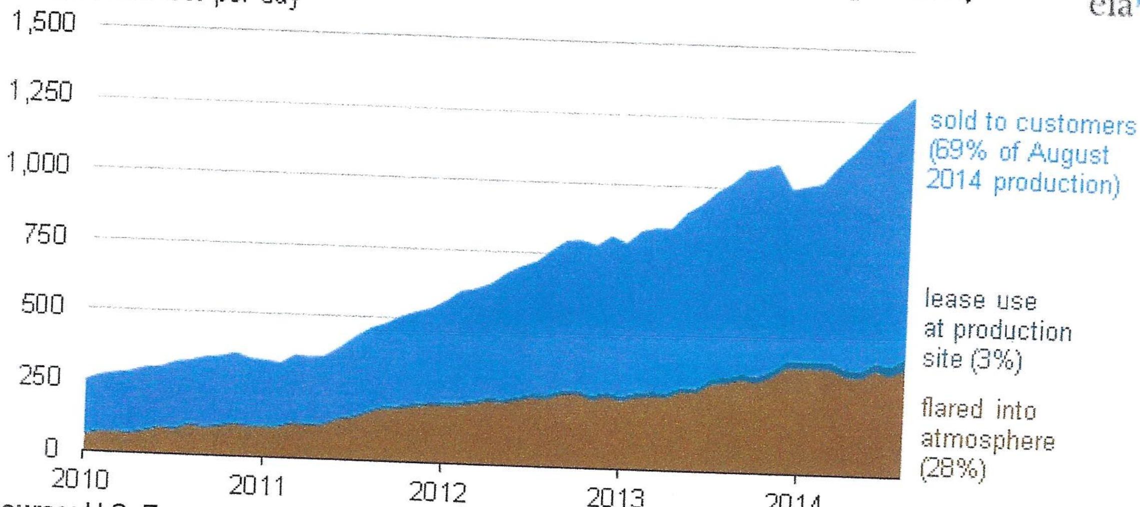
Natural gas is flared, or burned directly to the atmosphere, rather than being vented without combustion because methane, the primary constituent of natural gas, has much higher global warming potential than carbon dioxide, the main component of combusted gas. By law, North Dakota prohibits natural gas venting.

The NDIC seeks to reduce the volume of flared gas, even if it means cutting back production at its largest oil production areas (the Bakken and Three Forks formations). The NDIC's order issued on July 1 said it will "consider amending...field rules to restrict oil production and/or impose such provisions as deemed appropriate to reduce the amount of flared gas." Recognizing the difficult economics of dealing with rapidly declining production from newly drilled wells, the NDIC's order allows for exemptions on a case-by-case basis.

The North Dakota Pipeline Authority estimates that more than one-third of the flared gas results from a lack of gathering pipelines. Infrastructure buildouts can cause delays in realizing the value of crude oil and other liquids that motivate drilling in North Dakota, and are uneconomic when natural gas volumes there are too low. The largest challenge, according to the NDIC, is securing landowner permission for connection activities, which can delay projects half a year or longer. Other obstacles include zoning and permitting delays, harsh weather, and labor shortages. The remaining flared gas results from challenges to existing infrastructure, including the need for additional gathering-line pressure to offset higher pressure from newly drilled wells, additional gathering-pipeline capacity at high-pressure wells, and additional clearing of existing lines to remove natural gas liquid volumes.

Increased capacity to process and transport natural gas also contributes to higher volumes of natural gas that are sold rather than flared. By the end of the year, expected completions of natural gas processing plant projects would increase North Dakota's natural gas processing capacity to 1,454 MMcf/d, or 440 MMcf/d more than last year. ONEOK, Inc. plans to add another 400 MMcf/d of natural gas processing capacity by the end of 2016. Capacity to move this additional gas on pipelines would also increase as a result of the Northern Border Pipeline Company's 55-mile Bakken Header pipeline (400 MMcf/d as early as 2016) and WBI Energy's 375-mile Dakota Pipeline (between 400 and 500 MMcf/d by the end of 2017).

Disposition of North Dakota natural gas production (Jan 2010 - August 2014)
million cubic feet per day



Source: U.S. Energy Information Administration, based on North Dakota Industrial Commission
Principal contributors: Philip Budzik, Michael Ford

U.S. Energy Information Administration

OCD Exhibit 24

Natural Gas

Natural Gas Weekly Update

for week ending February 12, 2020 | **Release date:** February 13, 2020 | **Next release:** February 20, 2020 |

In the News:

North Dakota provides regulatory guidance to reduce natural gas flaring

Natural gas production in North Dakota reached 3.1 billion cubic feet per day (Bcf/d) in November 2019, a more than ten-fold increase compared with January 2010 levels. In the first 11 months of 2019, North Dakota flared about 20% of its natural gas production, or 0.56 Bcf/d, which is 40% higher than in 2018. Increases in natural gas production are primarily related to associated gas produced from oil wells in the Bakken formation. Flaring refers to combusting natural gas in the atmosphere instead of capturing and processing natural gas in a processing plant.

North Dakota implemented natural gas capture goals in 2014 to limit the amount of natural gas flared into the atmosphere. Natural gas processing capacity has increased alongside crude oil production but has lagged behind the growth in associated natural gas production. The state natural gas capture target—currently at 88% and set to increase to 91% in November 2020—has not been met in every month since March 2018. In the most recent data month, November 2019, only 83% of natural gas produced in North Dakota was captured.

Insufficient natural gas processing capacity has placed constraints on crude oil production, and oil producers are looking for ways to comply with natural gas capture targets. According to the North Dakota Pipeline Authority, natural gas processing plant capacity additions in 2019 increased total capacity by 0.71 Bcf/d to reach 3.1 Bcf/d. They expect an additional 0.9 Bcf/d of natural gas processing to enter service during 2020 and 2021. These additions will support crude oil production growth, but the new capacity may fill up faster than anticipated.

On November 15, 2019, the North Dakota Industrial Commission (NDIC), the regulatory entity that oversees the state's flaring reduction rules, held a hearing to consider both how to raise natural gas capture levels using alternative natural gas capture strategies and how to provide regulatory clarity in natural gas gathering agreements. According to the North Dakota Pipeline Authority, about three-fourths of flaring is associated with oil wells connected to natural gas gathering pipelines.

As a result of the hearing, the NDIC issued an order to encourage *firm service* contractual agreements along natural gas gathering pipelines. In North Dakota, most contractual agreements between natural gas producers and purchasers are for *interruptible service*, which means a producer may be denied the ability to transport natural gas in a gathering system. *Firm service* contracts provide a greater level of certainty to producers because service along the gathering line is guaranteed and may reduce the amount of well shut-ins and flared natural gas.

A low natural gas price environment relative to crude oil poses a challenge to the buildout of natural gas gathering pipelines and natural gas processing facilities. However, according to NDIC, firm service contracts may encourage a faster buildout of gathering line infrastructure because investments with guaranteed commitments provide economic certainty for project developers.

Overview:

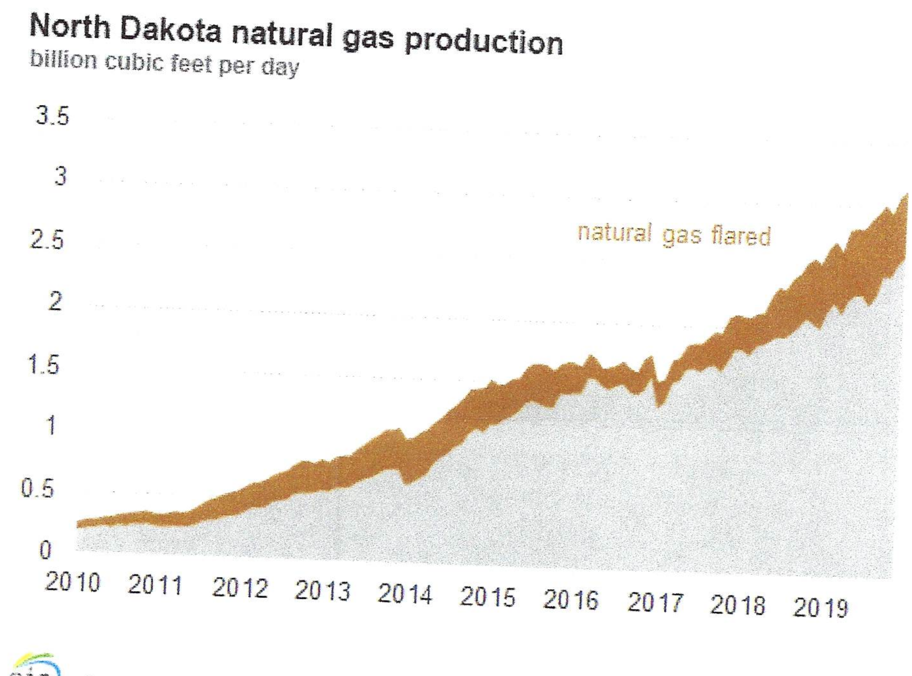
(For the week ending Wednesday, February 12, 2019)

- Natural gas spot prices rose at most locations this report week (Wednesday, February 5 to Wednesday, February 12). The Henry Hub spot price rose from $1.85 per million British thermal units (MMBtu) last Wednesday to $1.87/MMBtu yesterday.

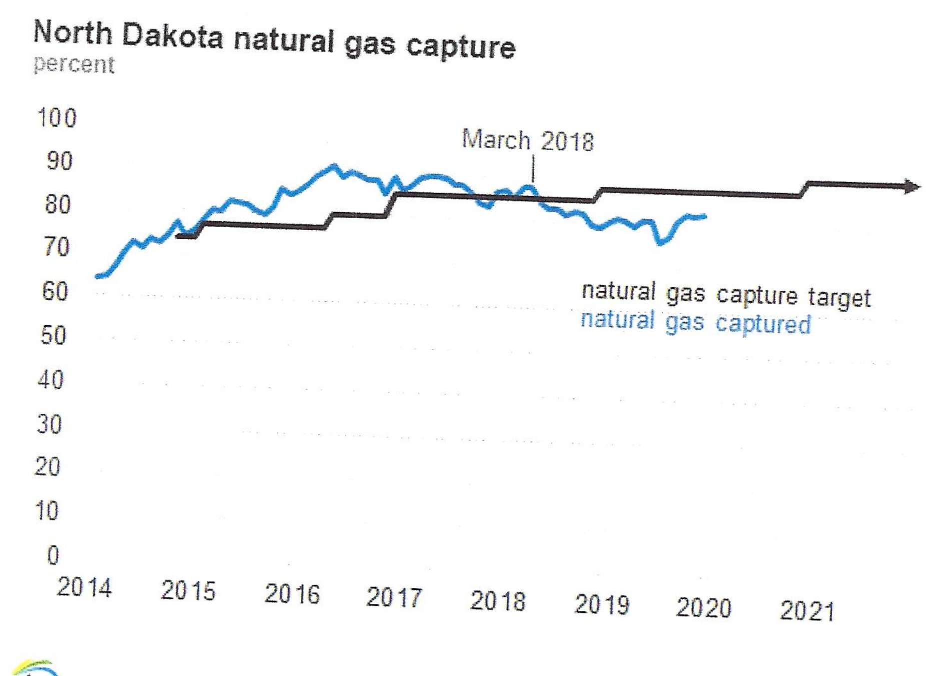
According to a Bloomberg survey of natural gas analysts, estimates of the weekly net change to working natural gas stocks ranged from a net withdrawal of 102 Bcf to 116 Bcf, with a median estimate of 110 Bcf.

The average rate of withdrawal from storage is 13% lower than the five-year average so far in the withdrawal season (November through March). If the rate of withdrawal from storage matched the five-year average of 11 Bcf/d for the remainder of the withdrawal season, the total inventory would be 1,912 Bcf on March 31, which is 215 Bcf higher than the five-year average of 1,697 Bcf for that time of year.

More storage data and analysis can be found on the *Natural Gas Storage Dashboard* and the *Weekly Natural Gas Storage Report*.



Source: North Dakota Industrial Commission (January 2010–November 2019)



Source: North Dakota Industrial Commission (January 2014–November 2019)

OCD Exhibit 25

Methane Emissions from Oil and Gas

Not on track

Tracking report — June 2020

Authors and contributors

Contents

Cite Share

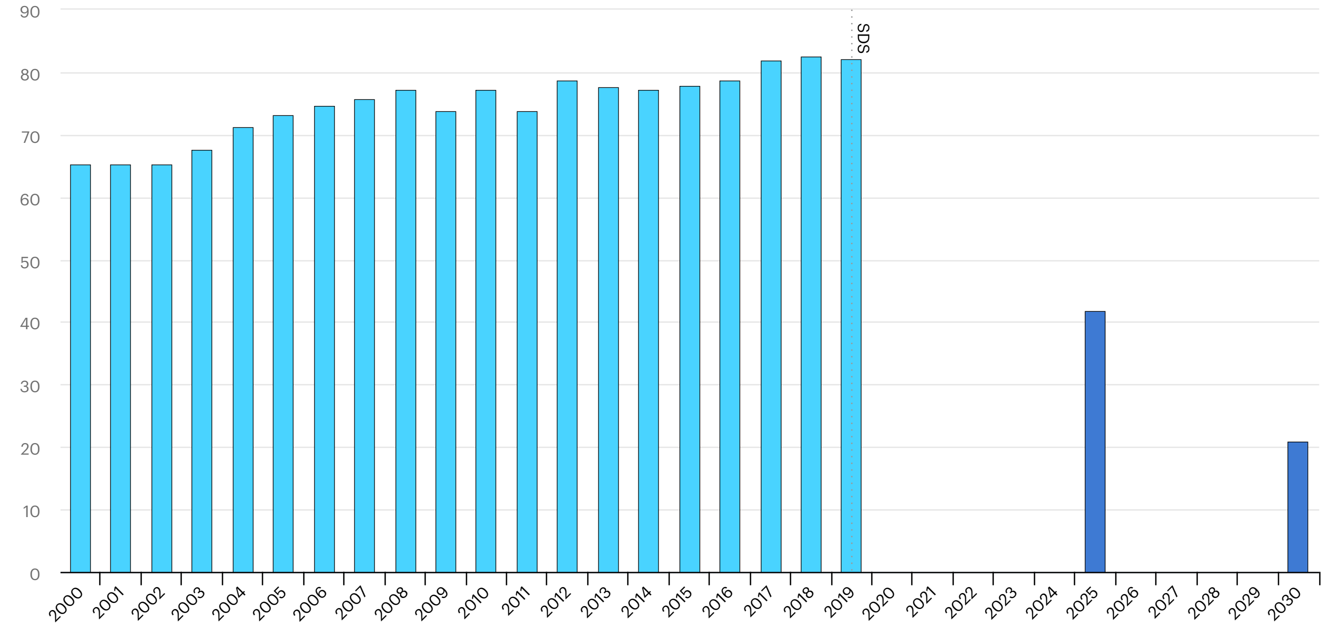
In this report

Methane emissions are the second-largest cause of global warming today. Methane emissions come from a range of anthropogenic and natural sources; within the energy sector, from oil, natural gas, coal and bioenergy. The IEA estimates that the oil and gas sector emitted 82 Mt (around 2.5 GtCO2-eq) in 2019. While methane tends to receive less attention than CO2, reducing methane emissions will be critical to avoid the worst effects of climate change. Emissions remain high despite initial industry-led initiatives, government policies and regulations, as implementing abatement options quickly and at scale remains a challenge. Policies will be critical to achieve the 75% emissions reduction by 2030 demonstrated in the SDS, but further innovation and support are needed to better understand emissions levels, make leak detection and repair more consistent, and reduce the overall cost of emissions mitigation programmes.

Oil and gas sector methane emissions 2000-2030 in the Sustainable Development Scenario

Open

MtCH4



Despite some efforts from industry and policy-makers to reduce methane emissions from oil and gas operations, an immediate and significant change in ambition is needed to achieve SDS reductions. Although prospects for methane emissions abatement are rising as new aerial and satellite measurements guarantee greater transparency in the oil and gas sector, there is a risk that the drop in oil and gas prices consequent to the 2020 Covid-19 crisis could reduce companies' abilities and willingness to prioritise environmental performance.

The IEA tracks oil and gas methane and provides detailed country-by-country estimates of emissions, abatement technologies, costs and regulation in its Methane Tracker.

Tracking progress

The concentration of methane in the atmosphere is currently around 2.5 times pre-industrial levels and is increasing steadily. This rise has important implications for climate change. Although methane has a much shorter atmospheric lifetime than CO_2 – around 12 years, compared with centuries for CO_2 – it absorbs much more energy while in the atmosphere.

Estimates of methane emissions are subject to a high degree of uncertainty, but the most recent comprehensive estimate suggests that annual global methane emissions are around 570 Mt. This includes emissions from natural sources (40%) and those originating from human activity, also known as anthropogenic emissions, comprise the remaining 60%. [1]

The largest source of anthropogenic methane emissions is agriculture, responsible for one-quarter of the total, followed closely by the energy sector, which includes emissions from coal, oil, natural gas and biofuel combustion.

It is necessary to tackle all sources of methane emissions arising from human activity, but there are important reasons to focus on the oil and gas sector:

- Although coal and bioenergy combustion also release substantial methane emissions, oil and gas operations are likely the largest source in the energy sector.
- Analysis shows clear scope to reduce oil- and gas-related methane emissions cost-effectively. Unlike CO_2, methane – the main component of natural gas – has commercial value, so that any methane captured can often be monetised, and this is typically ier in oil and gas than elsewhere in the energy sector. This means that emissions reductions could result in economic savings or be realised at low cost.

The Covid-19 pandemic could affect oil and gas methane emissions in different ways. Lower oil and gas production could result in a concurrent reduction in leaks, but a decline in revenues from oil and gas operations, as well as low natural gas prices, could also cause companies to pay less attention to the monitoring and maintenance activities needed to tackle methane emissions.

Evaluating emissions trends: Tracking and measurement

Several emerging technologies and approaches to methane detection and measurement are set to provide timely and actionable information on leaks and generally enlarge the amount of data available on oil and gas methane emissions.

Early analytical results suggest satellites are a promising method to conduct global scans to detect and estimate emissions levels from large point sources, and could increasingly be used to provide actionable real-time information to operators. There are also more granular aerial surveillance programmes are being conducted using lower altitude unmanned aerial vehicles including cube sats, planes, helicopters and drones combined with infrared and thermal imaging techniques.

A number of operator-led aerial surveillance programmes are being conducted by companies including ExxonMobil, Royal Dutch Shell, Chevron, Conoco Phillips and BP. Increased stationary surveillance, complemented with routine aerial monitoring, can provide early and widespread detection for methane leaks across operator type 1 and 2 emission sources.

These top-down approaches are also raising awareness of the magnitude of methane emissions. A recent study on the Permian basin based on an assessment from satellite data indicated methane emissions double those detected through bottom-up evaluations.

Researchers are hopeful that greater precision will be obtained with the use of the latest instruments and accompanying methodologies, such as the Environmental Defense Fund's MethaneSat scheduled for launch in 2022. The IEA is monitoring emerging measurement strategies closely and working to integrate results from credible sources into the latest Methane Tracker updates.

Nevertheless, more progress is needed before satellites can generate a comprehensive and reliable global depiction of methane emissions from all oil and gas activities. Challenges persist, such as time delays in converting atmospheric measurements into useful intelligence about surface-level activities, the inability to properly attribute detected emissions to the source, and the difficulty detecting emissions in certain areas (i.e. existing satellites are generally unable to detect emissions over snowy, marshy or offshore areas).

Technology performance

Since methane is a valuable product, and in many cases can be sold if it is captured, it is estimated that around 45% of the 82 Mt of methane emitted today could be avoided with measures that would have no net cost.

A wide variety of generally well-known and well-understood technologies and measures are available to reduce methane emissions from oil and gas operations.

Devices such as vapour recovery units can be installed, while existing devices can be replaced with lower-emitting alternatives such as instrument air systems, no-bleed control and pump systems and electric motors. Leaks from compressors in upstream and midstream assets are a significant source of methane emissions. Emissions can be reduced by improving reliability (uptime), consistent maintenance programs to replace seals, the use of centrifugal compression with dry seals or transitioning to low-emission compression.

One of the most cost-effective mitigation options is leak detection and repair, which is critical to detect and reduce fugitive (or accidental) methane leaks. This is a very dynamic area for technology innovation, and the cost of some of the novel detection methods (including the aerial monitoring and imaging technologies described above) is coming down, however, interpreting extensive datasets for wide spans of onshore developments can be challenging.

Despite these advances, methane emissions from oil and gas operations appear to remain stubbornly high and trends are diverging strongly from the Sustainable Development Scenario (SDS) needs. In the SDS, all technology options are quickly deployed across the entire oil and gas value chains – even if they cannot immediately be paid for through sales of the captured methane – leading to a 75% fall in emissions by 2030.

Industry-led initiatives and policy actions supported by financial investment

Multiple international oil companies (IOCs) have set targets to restrict emissions, or the emissions intensity of production, and many voluntary, industry-led efforts attempt to reduce methane emissions from oil and gas operations:

- The Methane Guiding Principles (MGP) established in 2017 is a multi-stakeholder collaborative platform incorporating more than 20 institutions from industry, intergovernmental organisations (including the IEA), academia and civil society. The principles aim to advance understanding and best practices to reduce methane emissions, and to develop and implement methane policies and regulations.
- The Oil and Gas Climate Initiative (OGCI) aims to improve methane data collection and to develop and deploy cost-effective methane management technologies; it is made up of 13 major international oil and gas companies. In 2018, OGCI members announced the target of reducing the collective average methane intensity of their aggregated upstream gas and oil operations to below 0.25% by 2025 (from 0.32% in 2017), with the objective of ultimately achieving a level of 0.2%.
- The Oil & Gas Methane Partnership (an initiative of the Climate and Clean Air Coalition) provides protocols for companies to survey and address emissions and a platform for them to demonstrate results. It consists of ten representatives from oil and gas companies, governments, the UN Environment Programme, the World Bank and the Environmental Defence Fund.
- The Environmental Partnership (TEP) is an industry-led voluntary program in the United States that consists of taking action, learning about best practices and technology, and fostering collaboration to reduce emissions. The scope consist of specific actions on leak detection and repair programmes, high bleed pneumatic controllers, and manual liquid unloadings.

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. Policies and regulations are therefore essential to align emissions more with the SDS.

Emissions reduction policies are not as ubiquitous as they should be, but some progress has been made:

- Canada has introduced regulations to cut methane emissions 40-45% by 2025 from the 2012 baseline. The provinces of Alberta, British Columbia and Saskatchewan have additional regulatory measures in place to address venting and flaring from upstream oil and gas operations.
- The European Commission is preparing a first-ever strategic plan to reduce methane emissions in the energy sector, with a particular focus on improving measurement, reporting and verification.
- Facilitated by the UN Environment Programme, Nigeria and Côte d'Ivoire announced in January that they would join the Global Methane Alliance. They have committed to increase efforts to reduce methane emissions from oil and gas operations within their borders.

Recommended actions

Quantitative targets set by IOCs to restrict emissions are a welcome first step to help bring this subsector closer to alignment with the SDS.

For companies already claiming low emissions, seeking to continuously reduce emissions is as valuable as quantitative limits; third-party verification and transparency on data and methods are also essential for credible reporting.

However, large volumes of methane are emitted from assets not operated by IOCs. A critical near-term step will be for IOCs to apply their leakage criteria to oil and gas produced from equity assets (joint ventures and non-operated assets).

Along with these voluntary efforts, policies and regulations will be central to methane emissions reductions, and commitments to reduce methane emissions could be an important addition to Paris Agreement NDCs.

Although improving data-gathering and reporting is a key first step, having a lack of detailed information on emissions levels should not preclude the introduction of emissions abatement goals. Policies should concurrently seek to encourage operators to take advantage of abatement opportunities.

Some of the key considerations and principles that could inform methane emissions reduction strategies are set out below. They are likely to be most successful if carried out in stages to help maximise effectiveness and efficiency while shifting emissions trends.

Emphasise data-gathering: Current emission levels are highly uncertain. Raising clarity through direct and consistent measurement is critical to improve understanding of the situation, make it possible to measure progress against goals, and develop and refine objectives and targets. There are large data gaps that need to be filled for numerous major gas-producing and -consuming regions, including Russia and the Middle East.

Set an overall emissions reduction goal: These can be expressed in both broad, qualitative terms and as specific, quantitative and time-bound targets.

Foster innovation and technology deployment: Technological innovations to detect emissions and deliver reliable measurements at low cost is a key technology priority that should be a focus of both public support (at a pre-commercial phase) and private initiatives. Methane management should also be embedded in the oil and gas industry's ongoing digitalisation efforts.

Maximise transparency: Measurement and analysis protocols (including existing datasets) could be shared within the oil and gas industry and among regulators to help ensure consistent quantification and abatement and to spur implementation.

Ensure widespread engagement during the design of regulations: This is important to build support and commitment from as broad a stakeholder group as possible, both in the understanding of emissions and proven abatement options and in the approaches to measurement, reporting and compliance.

Incentivise collaboration: Industry partnerships between national and international oil companies can provide a powerful impetus for the adoption of best practices in regions where policy and regulatory frameworks are less developed. Oilfield service companies, technology firms and auditing firms can also be involved.

Establish adequate enforcement: Devising an effective system entails deciding how oversight and regulation should be carried out, determining an institution responsible for regulation and enforcement, providing leadership and resources for that institution, and establishing meaningful disincentives that support behavioural change, such as penalties for non-compliance.

Incorporate flexibility into measurement and abatement policies: This might be done through various means, including allowing for adjustments to overall goals over time if interim milestones are either exceeded or not met.

Focus on outcomes: In deciding on specific practices, standards, technologies, certification systems and quantitative limits to be introduced, it is important to bear in mind the overarching emissions reduction goal and to focus on the outcomes to be achieved.

Encourage new corporate thinking on methane emissions reductions: While some companies view minimising methane emissions as a central pillar of their operations, others appear to attach much less importance to it.

Explore lower-cost capital investment options for methane reduction technologies: The investment community can stimulate the methane-reduction transition by helping technology companies innovate and deploy new technologies at scale.

Resources

The new methane tracker offers the most comprehensive global overview of methane emissions, covering 8 industry subsectors across more than 70 countries.

IEA Methane Tracker

This IEA commentary describes some of the key insights from the updated methane tracker.

Global methane emissions from oil and gas

This IEA commentary addresses some of the key findings on the environmental case for gas from the World Energy Outlook 2017

Commentary: The environmental case for natural gas

This excerpt from the World Energy Outlook 2017 explores the contours of the new, emerging natural gas order in detail. It examines the opportunities and risks for gas in the transition to a cleaner energy system as well as how the rise of shale gas and LNG are changing the global gas market.

WEO 2017 Special Report: Outlook for Natural Gas

The Methane Guiding Principles were established to address the priority areas for action highlighted in the World Energy Outlook 2017.

Guiding Principles on Reducing Methane Emissions across the Natural Gas Value Chain

OGCI Climate Investments has financed a number of start-up companies aiming to develop low-cost LDAR technologies.

OGCI Climate Investments

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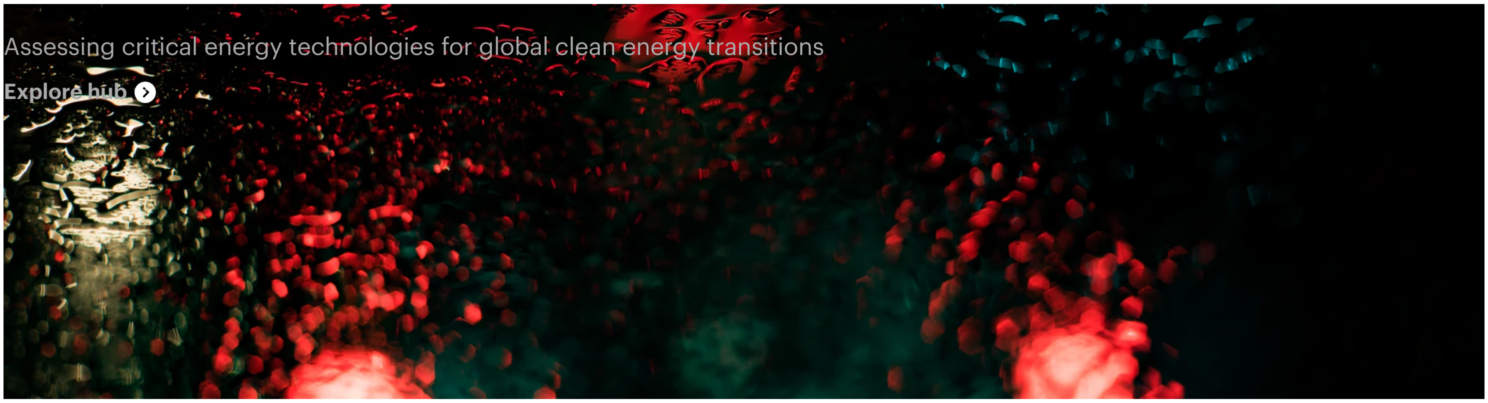
1. Saunois et al. (2016), "The global methane budget 2000-2012", Earth System Science Data, No. 8, pp. 697-751.
2. Hmiel et al. (2020), Preindustrial $14CH_4$ indicates greater anthropogenic fossil CH_4 emissions, Nature, No. 578, pp. 409-412.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Methane Tracker

Report — July 2019

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In this report

Oil and gas producers that can demonstrate that they are taking strong action to reduce methane emissions can credibly argue that their resources should be preferred over higher-emission options. It is crucial for the oil and gas industry to be proactive in limiting, in all ways possible, the environmental impact of oil and gas supply, and for policy makers to recognise this is a pivotal element of global energy transitions.

Overview

Oil and natural gas will be part of the energy system for decades to come – even under ambitious efforts to reduce greenhouse gas emissions in line with the Paris Agreement. As part of today's energy transitions, it is therefore vital to reduce the immediate environmental impacts associated with producing and consuming these fuels. Reducing methane emissions is a powerful and cost-effective way to act, providing an essential complement to action on reducing CO_2.

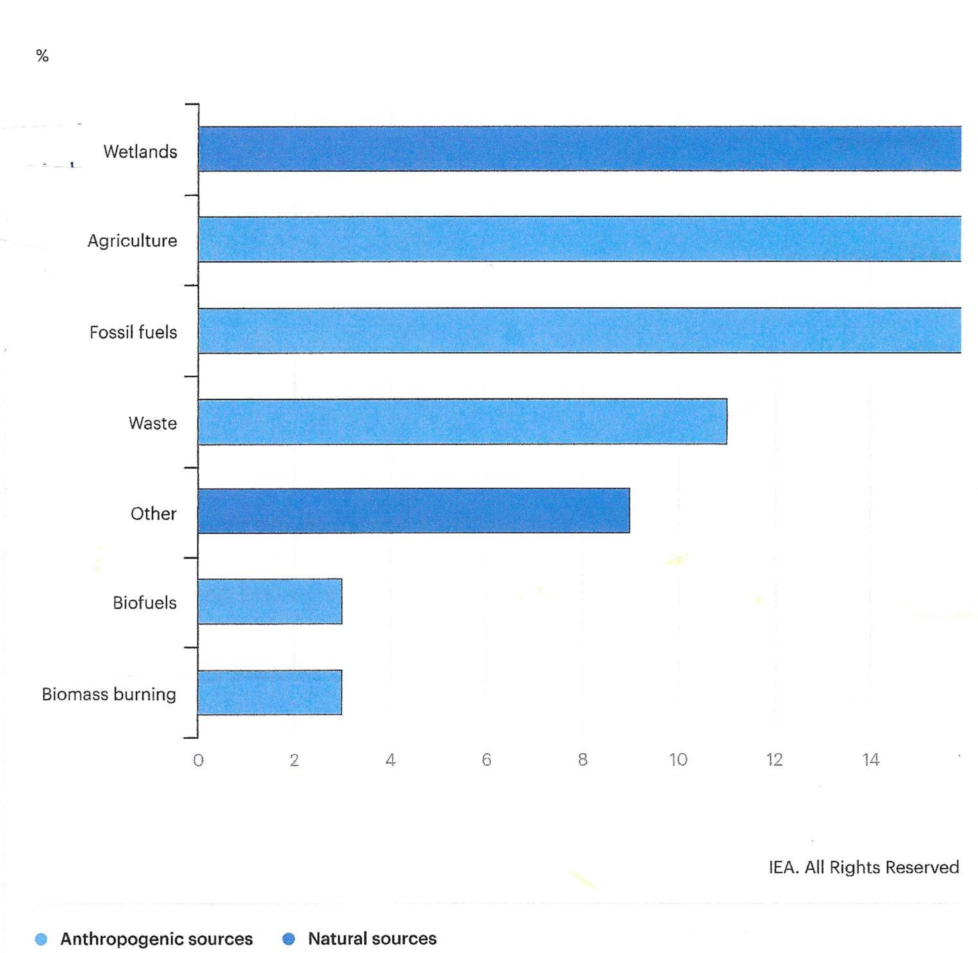
Methane and climate change

The concentration of methane in the atmosphere is currently around two-and-half times greater than pre-industrial levels and is increasing steadily. This rise has important implications for climate change.

Estimates of methane emissions are subject to a high degree of uncertainty, but the most recent comprehensive estimate suggests that annual global methane emissions are around 570 million tonnes (Mt). This includes emissions from natural sources (around 40% of emissions), and those originating from human activity (the remaining 60% - known as anthropogenic emissions).

The largest source of anthropogenic methane emissions is agriculture, responsible for around a quarter of the total, closely followed by the energy sector, which includes emissions from coal, oil, natural gas and biofuels.

Sources of methane emissions



Methane has important implications for climate change, particularly in the near term.

Two key characteristics determine the impact of different greenhouse gases on the climate: the length of time they remain in the atmosphere and their ability to absorb energy. Methane has a much shorter atmospheric lifetime than CO_2 (around 12 years compared with centuries for CO_2) but it is a much more potent greenhouse gas, absorbing much more energy while it exists in the atmosphere.

There are various ways to combine these factors to estimate the effect on global warming; the most common is the global warming potential (GWP). This can be used to express a tonne of a greenhouse-gas emitted in CO_2 equivalent terms, in order to provide a single measure of total greenhouse-gas emissions (in CO_2-eq).

The Intergovernmental Panel on Climate Change (IPCC) has indicated a GWP for methane between 84-87 when considering its impact over a 20-year timeframe (GWP_{20}) and between 28-36 when considering its impact over a 100-year timeframe (GWP_{100}). This means that one tonne of methane can considered to be equivalent to 28 to 36 tonnes of CO_2 if looking at its impact over 100 years.

In addition to its climate impacts, methane also affects air quality because it is an ingredient in the formation of ground level (tropospheric) ozone, a dangerous air pollutant.

Why focus on methane emissions from oil and gas?

It is important to tackle all sources of methane emissions arising from human activity, but there are reasons to focus on emissions from oil and gas operations.

First, although emissions also come from coal and bioenergy, oil and gas operations are likely the largest source of emissions from the energy sector.

Second, our analysis shows clear scope to reduce them cost-effectively. Unlike CO_2, methane – the main component of natural gas – has commercial value: the additional methane captured can often be monetised directly, and this is typically easier in the oil and gas sectors than elsewhere in the energy sector. This means that emissions reductions could result in economic savings or be carried out at low cost.

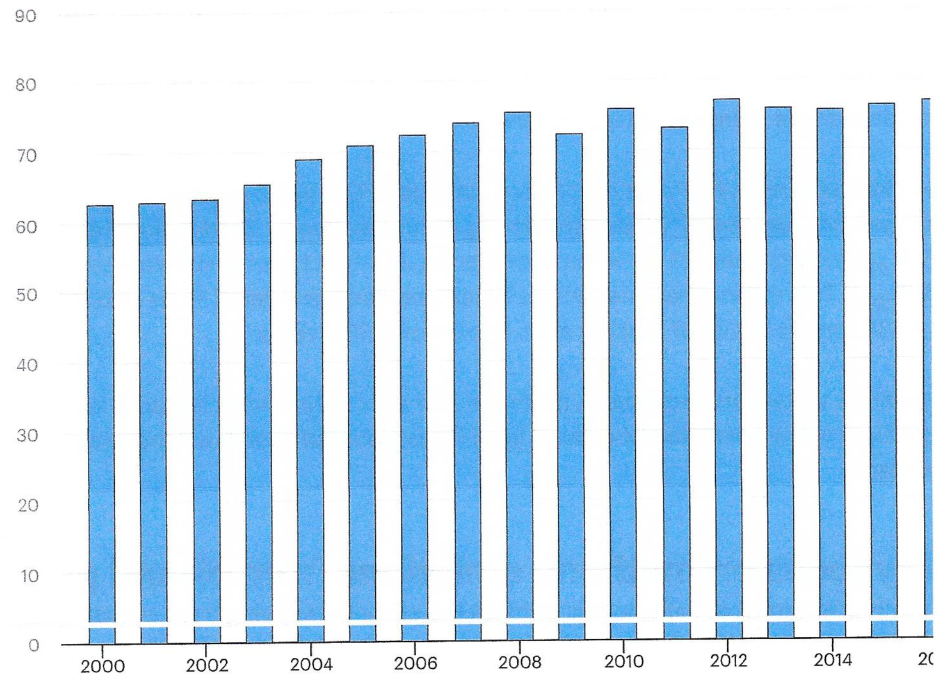
Our scenario projections also suggest that oil and, particularly, natural gas will play important roles in the energy system for decades to come, even under strong decarbonisation scenarios such as the IEA's Sustainable Development Scenario.

Gas can play an important supporting role in energy transitions by replacing more polluting fuels; it may also deliver services that are difficult to provide cost-effectively with low-carbon alternatives, such as peak winter heating, seasonal storage, or high temperature heat for industry. However, fulfilling this role requires that adverse social and environmental impacts are minimised: immediate and major reductions in methane emissions are central to this.

Global methane emissions from oil and gas operations in the Sustainable Development Scenario, 2000-2030

Open

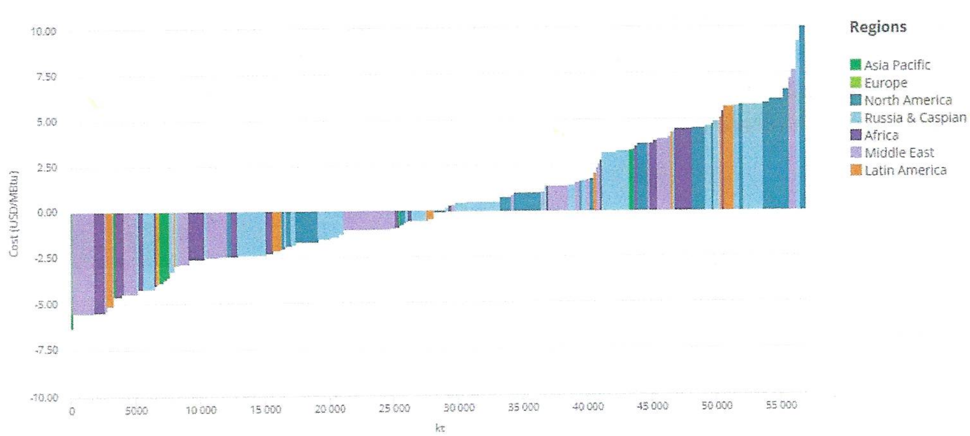
Mt



A compelling case for action

The World Energy Outlook 2017 produced detailed new estimates for methane emissions from oil and gas operations, which form the basis for the detailed data available in this methane tracker. We also developed first-of-a-kind global marginal methane abatement cost curves. These curves describe the reduction potentials as well as the costs and revenues of measures to mitigate methane emissions globally.

Marginal abatement cost curve for oil- and gas-related methane emissions globally



Using this analysis, we estimate that it is technically possible to avoid around three quarters of today's methane emissions from global oil and gas operations. Even more significantly, around 40-50% of current methane emissions could be avoided at no net cost.

If a high share of current emissions can be mitigated using measures that will pay for themselves from the methane recovered, why have these not already been widely adopted?

Possible reasons include:

- a lack of awareness about emission levels or the cost-effectiveness of abatement
- competition for capital within companies with a variety of investment opportunities
- insufficiently quick payback periods to clear the threshold for investment
- the possibility of split incentives (where the owner of the equipment does not directly benefit from reducing leaks or the owner of the gas doesn't see its full value).

The benefit to overcoming these hurdles would be enormous. Implementing only the abatement measures that have positive net present values in the WEO's New Policies Scenario would reduce the temperature rise in 2100 by 0.07 °C compared with a trajectory that has no explicit reductions.

This may not sound like much, but it is immense in climate terms. To yield the same reduction in the temperature rise by reducing CO_2 emissions would require emitting 160 billion fewer tonnes of CO_2 over the rest of the century. This is broadly equivalent to the CO_2 emissions that would be saved by immediately shutting down 60% of the world's coal-fired power plants that are in operation today and replacing them with zero-emissions generation.

Action is also essential in the Sustainable Development Scenario. We incorporate even more stringent reductions in oil and gas methane emissions in this scenario, as failing to do so would require even faster reductions in CO_2. Alongside the rapid declines in CO_2 emissions in the Sustainable Development Scenario, and therefore reductions in fossil-fuel consumption, it remains critical to tackle methane emissions as well.

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Methane from oil & gas

Overview

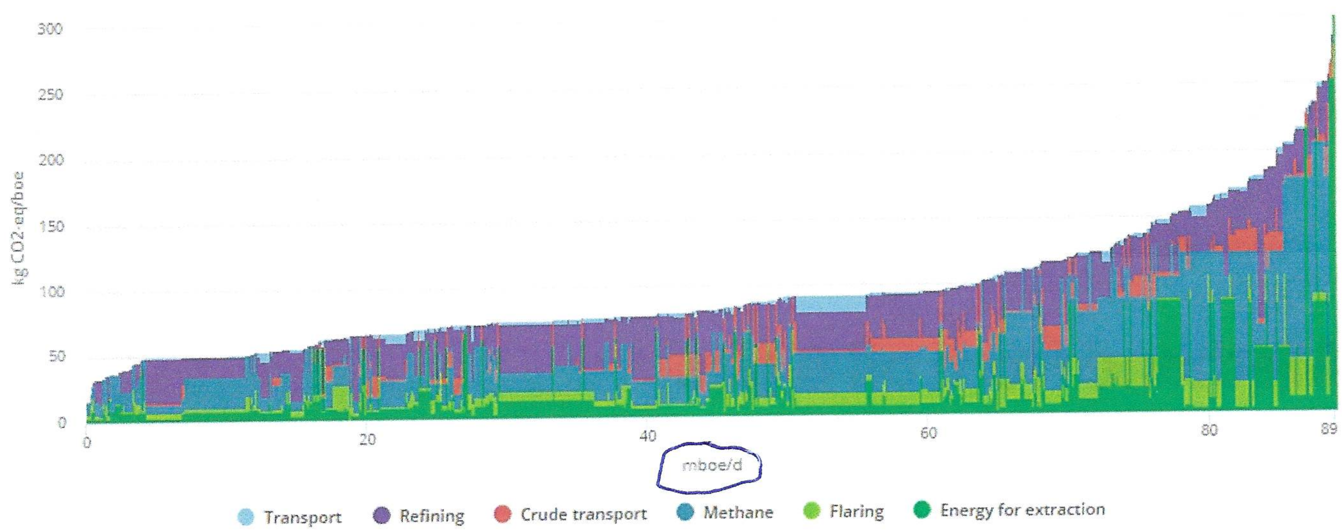
There is very little dispute about the emissions associated with combustion of fossil fuels and the differences between them: CO_2 emissions per unit of energy produced from gas are around 40% lower than coal and around 20% lower than oil. However, there is much less consensus over the indirect emissions on the path from oil or gas production to final consumer, in particular the level of methane emissions that can occur – whether by accident or by design – along the way.

Total indirect greenhouse gas (GHG) emissions from oil and gas operations today are around 5 200 million tonnes (Mt) of carbon-dioxide equivalent (CO2-eq), 15% of total energy sector GHG emissions. Methane, a much more powerful (though shorter-lived) GHG than CO_2, is the largest single component of these indirect emissions.

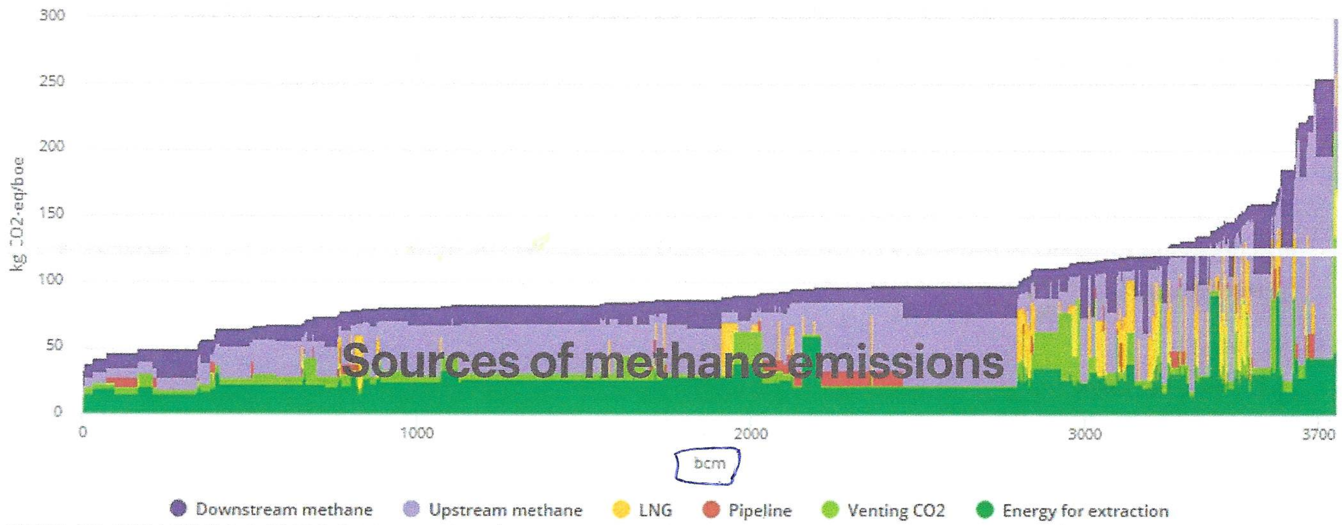
The World Energy Outlook 2018 includes detailed analysis of the indirect emissions associated with producing, processing and transporting the oil and natural gas consumed today.

This analysis highlighted the very broad range in the indirect emissions intensity of different sources of oil and gas. The most-emitting sources of oil and gas produce more than four times the indirect emissions than the least-emitting sources. Indirect emissions from oil are between 10% and 30% of its full lifecycle emissions intensity, while for natural gas they are between 15% and 40%.

Indirect emissions intensity of global oil production, 2017



Indirect emissions intensity of global gas production, 2017



split in roughly equal parts between the two.

These emissions came from a wide variety of sources along the oil and gas value chains, from conventional and unconventional production, from the collection and processing of gas, as well as from its transmission and distribution to end-use consumers. Some emissions are accidental, for example because of a faulty seal or leaking valve, while others are deliberate, often carried out for safety reasons or due to the design of the facility or equipment.

Lifecycle greenhouse-gas emissions: how do gas and coal compare?

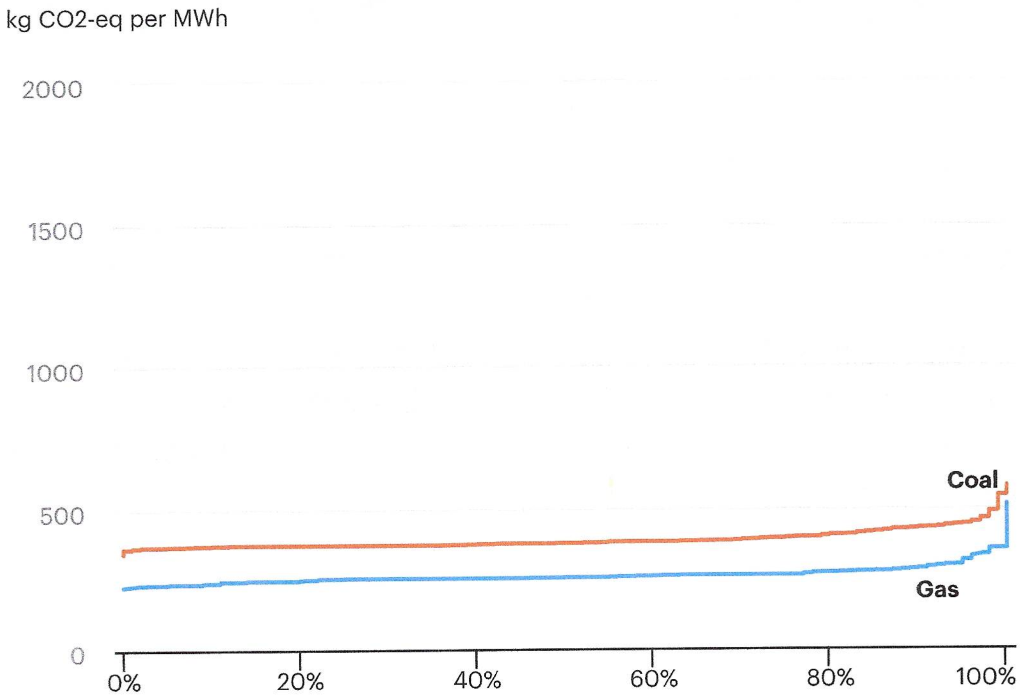
The CO_2 emissions from the combustion of natural gas are certainly lower than those from coal. But are they also lower when assessing full lifecycle greenhouse-gas emissions, after taking account of methane emissions released during the supply of the respective fuels?

Most of the gas and coal produced today is used for power generation and as a source of heat for industry and buildings.

Our detailed estimates, taking into account both CO_2 and methane, show a wide variation across different sources of coal and gas. Nonetheless, an estimated 98% of gas consumed today has a lower lifecycle emissions intensity than coal when used for power or heat (this comparison excludes any coal use for which gas could not be a reasonable substitute, such as coking coal used in steel production).

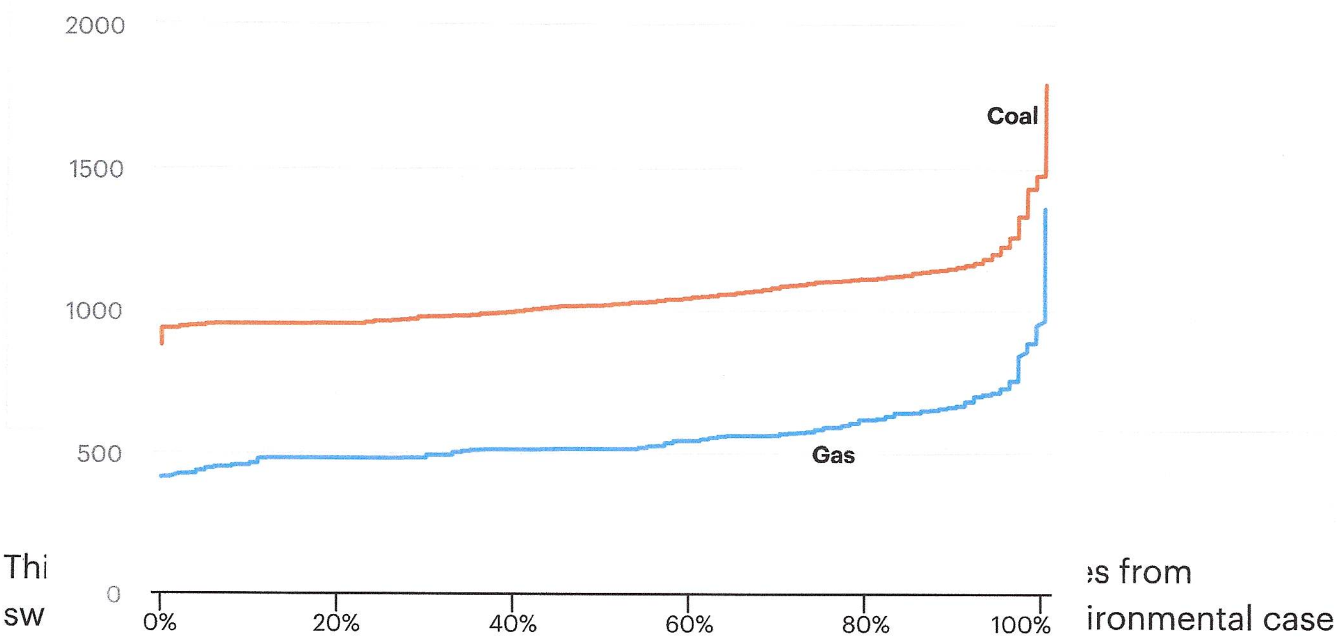
This analysis shows that, on average, coal-to-gas switching reduces emissions by 50% when producing electricity and by 33% when providing heat.

Full lifecycle emissions intensity of global coal and gas supply for heat generation, 2018 **Open**



Full lifecycle emissions intensity of global coal and gas supply for power generation, 2018 **Open**

kg CO2-eq per MWh



Thi ꞏꞏꞏ es from sw ꞏꞏꞏ ironmental case for ꞏꞏꞏ e most carbon-intensive fuel, but in ensuring that its emissions intensity is as low as practicable.

The longer-term comparison between the fuels also depends on the extent to which emissions are mitigated by large-scale deployment of carbon capture, utilisation and storage technologies.

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Methane Tracker

Report — July 2019

Methane abatement

Detecting and measuring methane emissions in a comprehensive and cost-effective manner remains a fundamental challenge because of the high cost of detection systems.

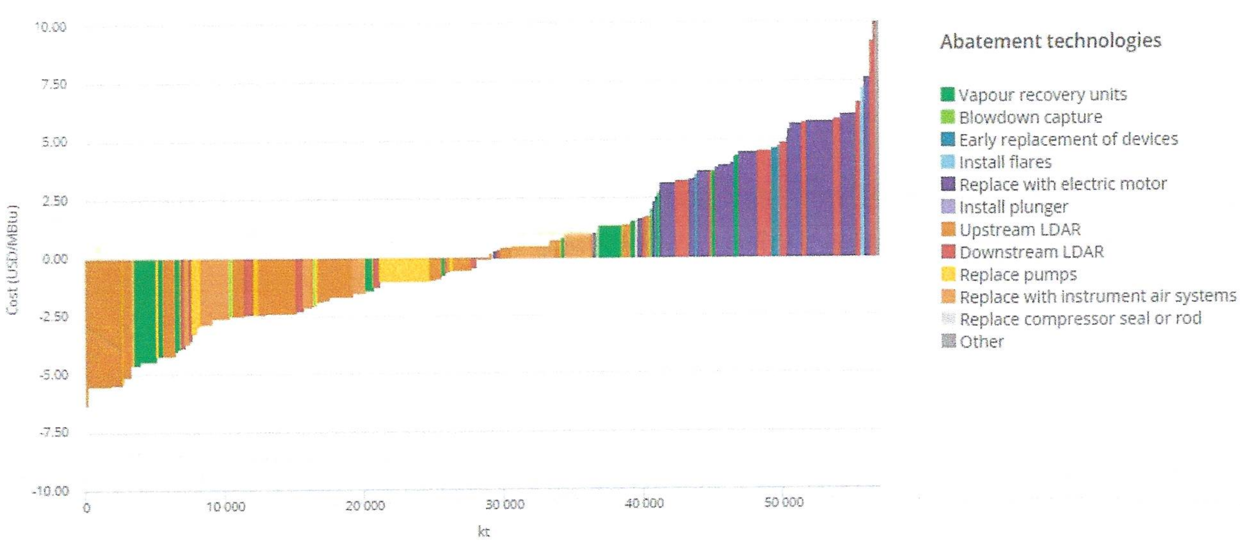
Technologies that can prevent vented and fugitive emissions, by contrast, are reasonably well-known. The challenge is to incentivise the deployment of these abatement technologies via voluntary or regulatory means. In many cases, investment in abatement technologies is economic, as the gas saved quickly pays for the installation of better equipment or the implementation of new operating procedures.

Abatement technologies and costs

If all options were to be deployed across the oil and gas value chains, we estimate that around 75% of these emissions could be avoided. Importantly, since methane is a valuable product and in many cases can be sold if it is captured, we also estimate that around 45% of these emissions could be avoided with measures that would have no net cost (at 2017 natural gas prices).

There is a large degree of variation between countries given different gas prices and capital and labour costs, but the global averages for the key options in the marginal abatement cost curve are shown.

Marginal abatement cost curve for oil- and gas-related methane emissions by mitigation measure, 2018



Explore the interactive version

View abatement curves by country

There are multiple efforts underway to restrict methane emissions or the emissions intensity of oil and gas production. There are also a number of voluntary, industry-led efforts to reduce methane emissions from oil and gas operations:

- 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 methane emissions reduction and to develop and implement methane policy and regulation.
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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 are also therefore essential to bring emissions into line with the trajectory in the Sustainable Development Scenario. The methane tracker provides essential information to help governments and other stakeholders design effective strategies.

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Country and regional estimates

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Methane Tracker 2020

Reducing the environmental impact of oil and gas supply is a pivotal element of global energy transitions

Fuel report — March 2020

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In this report

This 2020 update to the IEA's methane tracker includes detailed estimates for 2019 that incorporate new data for oil and gas supply as well as the latest evidence from the scientific literature and measurement campaigns.

Oil and gas producers that can demonstrate that they are taking strong action to reduce methane emissions can credibly argue that their resources should be preferred over higher-emission options. It is crucial for the oil and gas industry to be proactive in limiting, in all ways possible, the environmental impact of oil and gas supply, and for policy makers to recognise this is a pivotal element of global energy transitions.

Read a discussion of our latest findings on methane emissions

Global methane emissions from oil and gas

Overview

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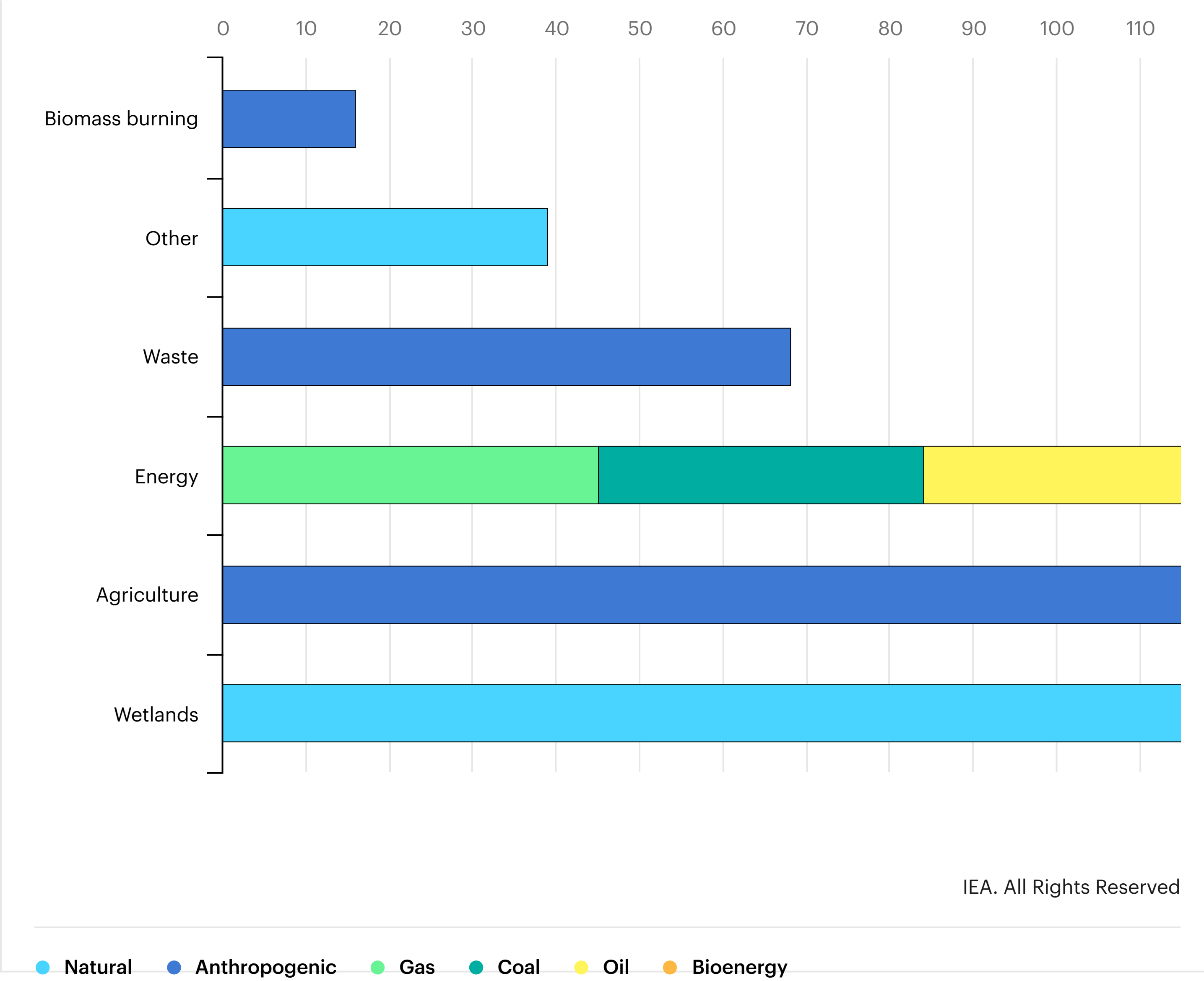
Sources of methane emissions **Open**

MT of methane



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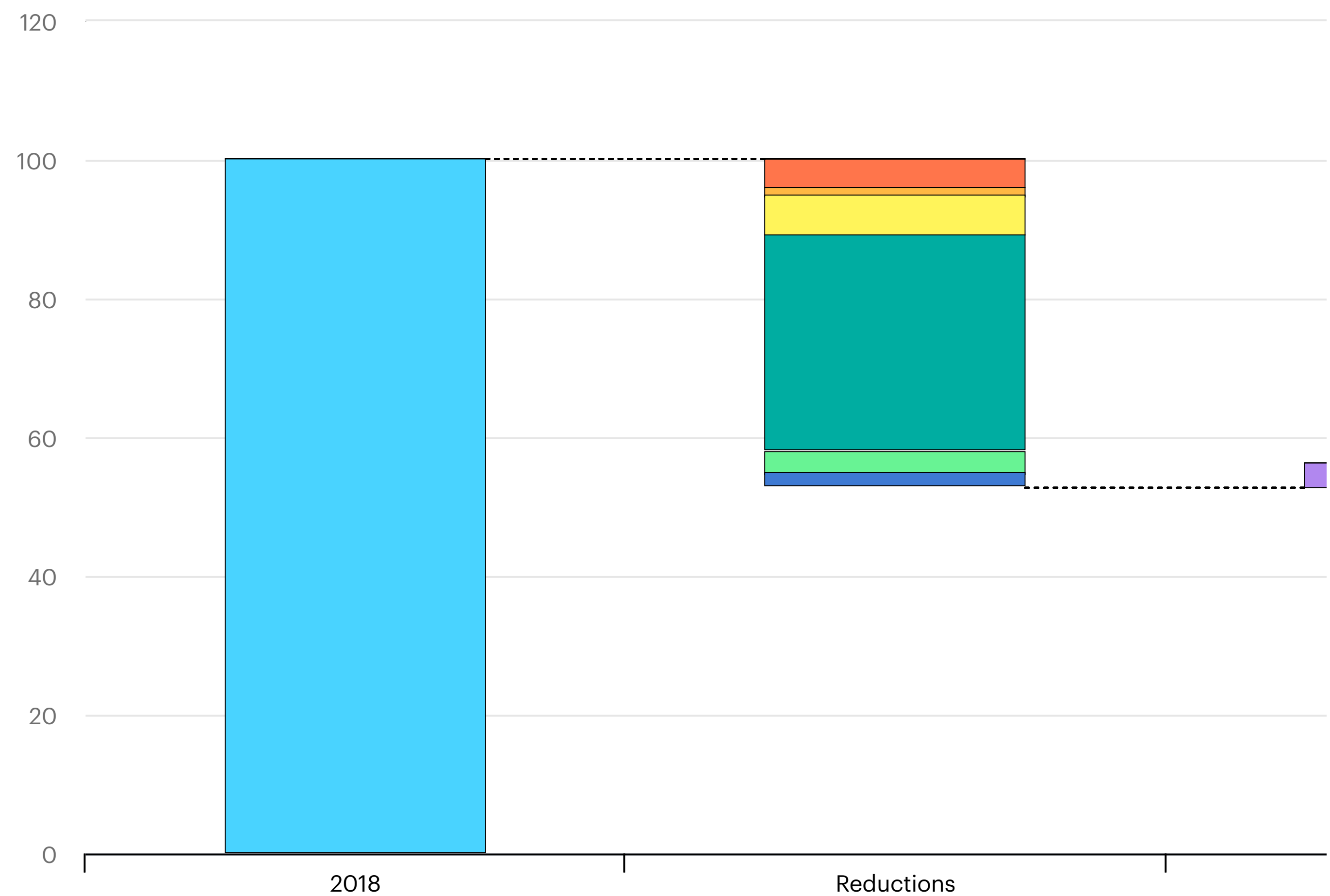
Gas can play an important supporting role in energy transitions by replacing more polluting fuels; it may also deliver services that are difficult to provide cost-effectively with low-carbon alternatives, such as peak winter heating, seasonal storage, or high temperature heat for industry. However, fulfilling this role requires that adverse social and environmental impacts are minimised: immediate and major reductions in methane emissions are central to this.

Changes in the average global emissions intensity of oil and natural gas operations in the Sustainable Development Scenario, 2018-2030 **Open**

%

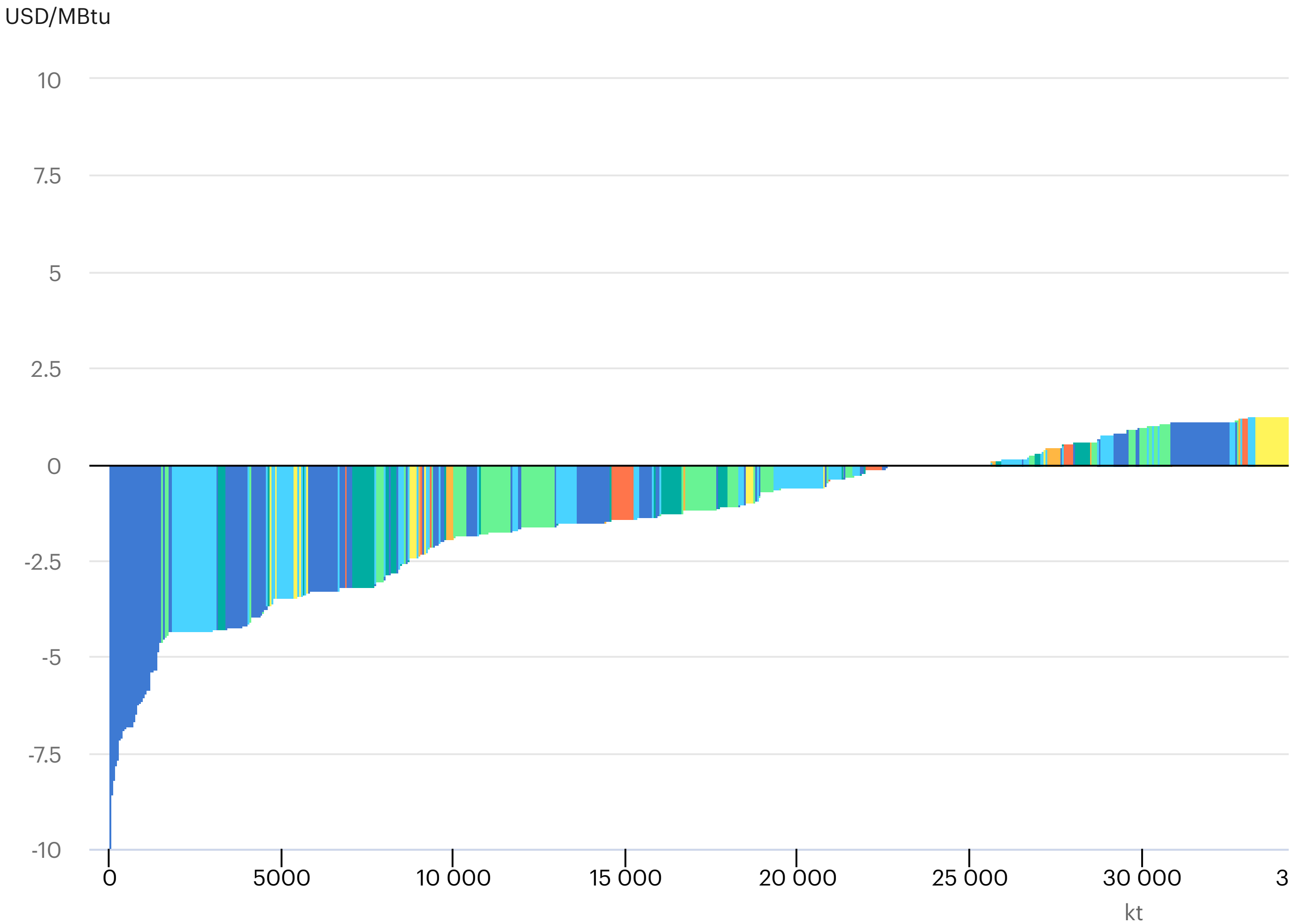


A compelling case for action

The World Energy Outlook has produced detailed estimates for methane emissions from oil and gas operations, which form the basis for the detailed data available in this methane tracker. We also developed first-of-a-kind global marginal methane abatement cost curves. These curves describe the reduction potentials as well as the costs and revenues of measures to mitigate methane emissions globally.

Marginal abatement cost curve for oil- and gas-related methane emissions globally

Open



Africa Asia Pacific Europe Latin America Middle East North America Russia & Caspian

We estimate that it is technically possible to avoid around three quarters of today's methane emissions from global oil and gas operations. Even more significantly, around 40% of current methane emissions could be avoided at no net cost.

If a high share of current emissions can be mitigated using measures that will pay for themselves from the methane recovered, why have these not already been widely adopted?

There are three primary categories of obstacles that serve to limit the uptake of mitigation measures:

- a lack of complete **information** regarding the problem, including a lack awareness about emission levels or the cost-effectiveness of abatement
- inadequate **infrastructure** or underdeveloped/saturated local markets that make it difficult to match abated gas to a productive use
- misaligned **investment** incentives, arising from competition for capital within companies with a variety of investment opportunities, insufficiently quick payback periods, or the possibility of split incentives (where the owner of the equipment does not directly benefit from reducing leaks or the owner of the gas doesn't see its full value).

The benefit to overcoming these hurdles would be enormous. Implementing only the abatement measures that have positive net present values in the WEO's Stated Policies Scenario would reduce the temperature rise in 2100 by 0.07 °C compared with a trajectory that has no explicit reductions.

This may not sound like much, but it is immense in climate terms. To yield the same reduction in the temperature rise by reducing CO_2 emissions would require emitting 160 billion fewer tonnes of CO_2 over the rest of the century. This is broadly equivalent to the CO_2 emissions that would be saved by immediately shutting down 60% of the world's coal-fired power plants that are in operation today and replacing them with zero-emissions generation.

Action is also essential in the Sustainable Development Scenario. We incorporate even more stringent reductions in oil and gas methane emissions in this scenario, as failing to do so would require even faster reductions in CO_2. Alongside the rapid declines in CO_2 emissions in the Sustainable Development Scenario, and therefore reductions in fossil-fuel consumption, it remains critical to tackle methane emissions as well.

Industry and other stakeholder recognise that policy and regulation can play a key role in addressing barriers to action and can align incentives to encourage companies to act. Different regulatory approaches could be used to structure a regulatory regime, and each jurisidiction will need to make adaptations to address their particular circumstances. We are working with governments and industry to provide tools to bolster actions in this area.

Analysis

All analysis

Article

Global methane emissions from oil and gas

Insights from the updated IEA Methane Tracker

31 March 2020

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Flaring Emissions

Not on track

Tracking report — June 2020

Authors and contributors

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In this report

Around 145 bcm of natural gas were flared in 2018, a slight increase from levels in previous years and broadly equal to gas demand across the continent of Africa. This resulted in emissions of roughly 275 MtCO2, as well as some methane emissions (from uncombusted portions of flares) and other GHGs such as black carbon and nitrogen oxide. Russia, Iraq, Iran, Algeria and the United States were responsible for more than half of global flaring. Several field trials have demonstrated viable technologies to reduce flaring, but at root the issue of flaring is also a question of business models. If there is inadequate provision for productive use of the gas at the project planning stage, including the necessary gas infrastructure, then finding a technology fix later on is much more difficult. There is an increasing number of voluntary government and industry commitments to eliminate flaring by 2030. The SDS relies on a rapid reduction in flaring, with government policies and industry commitment all but eliminating it by 2025.

Flaring by region in the Sustainable Development Scenario, 1985-2030

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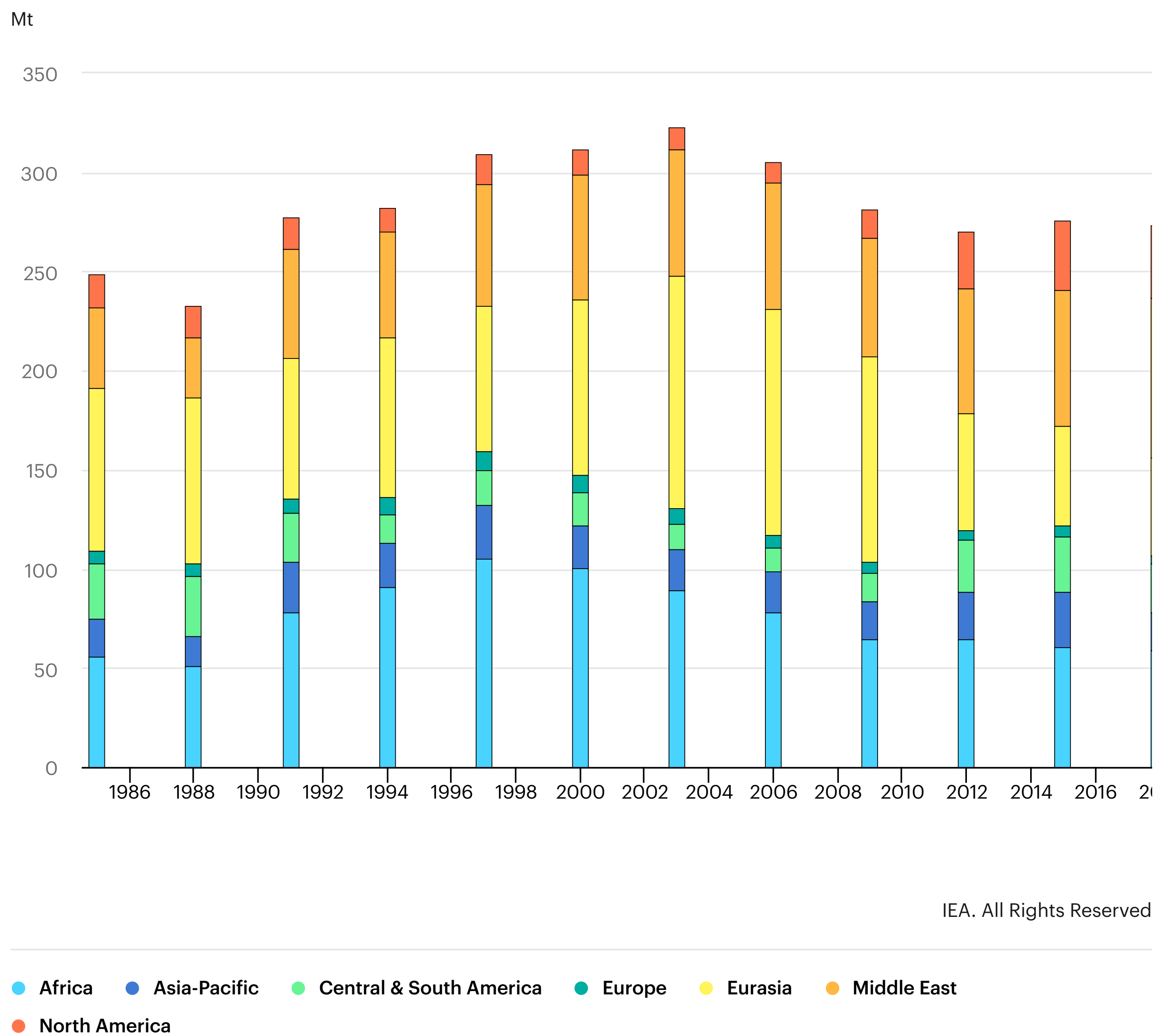

Tracking progress

Natural gas is often produced as a by-product (i.e. associated gas) during oil extraction. If the oil project has been planned in a way that does not incorporate access to a gas market or other productive uses, then there are only a few options left for the gas: an operator must choose whether to use it onsite for its own operations, reinject it into the ground, flare it or vent it to the atmosphere (this is even worse from an environmental perspective than flaring, see section on methane abatement).

Most flaring that takes place today is known as routine flaring and occurs during normal oil production operations.

Some gas is also flared as a safety measure (e.g. if gas pressure has built up due to a change in operating conditions), and there can also be other non-routine incidences of flaring but these are typically intermittent and of short duration.

Flaring reduction initiatives typically target routine flaring, which falls rapidly to zero in the Sustainable Development Scenario (SDS).

In theory, more than 99% of the natural gas is combusted when flaring is done in optimal conditions. In real-world conditions, however, flaring can be significantly less efficient due to sub-optimal combustion dynamics (e.g. variable heat content, flame instability). As a result, substantial volumes of methane can be released along with black carbon and nitrous oxide – all potent GHGs.

The Environmental Defense Fund (EDF) recently released a study from the Permian tight-oil basin noting 11% of flares were unlit or working sub-optimally resulting in more than 3.5 times more methane released than officially reported. There are technologies to increase flaring efficiency but they are currently expensive and therefore not widely deployed.

Reducing routine flaring means productive uses for the associated gas must be found, or it has to be reinjected into the reservoir. The optimal solution is to ensure a connection to the main gas grid, but there can be ways to use the gas productively even in the absence of such a connection.

For example, onshore operators in the United States have field-trialled a variety of flaring reduction technologies. Additionally, a study released by the Climate and Clean Air Coalition reported positive net present values and payback times of less than two years in six of eight flaring reduction projects in Columbia from 2017 to 2019.

Measuring and reporting flaring volumes

Few countries systematically measure, record and release flaring data publicly. The lack of monitoring equipment and limited oversight make it difficult to precisely quantify the amount of flaring around the world. Based on satellite measurements, the Global Gas Flaring Reduction

(GGFR) Partnership publishes flaring estimates for approximately 85 countries on an annual basis.

GGFR data suggests that over 145 bcm of gas were flared globally in 2018, with five countries (Russia, Iraq, Iran, the United States and Algeria) responsible for more than 50%. In total, flaring resulted in around 275 $MtCO_2$ of emissions, of which 3 Mt was methane. Considerations for further sub-optimal flaring could indicate an even greater level of emissions.

Flaring from conventional oil operations is the main source of flaring worldwide, including the top three countries by volume. However, flaring from unconventional oil production, notably tight oil in the United States, has also risen sharply in recent years.

Flaring in tight oil basins has some distinctive characteristics. In many cases, a key reason for routine flaring is the lack of proximity to a commercial market or a lack of infrastructure. This is true in some tight oil basins as well, e.g. the Bakken, where production has run ahead of the capacity of midstream gas players to commission natural gas processing capacity and pipelines.

However, another issue – especially in the Permian basin – has been a temporal mismatch, e.g. when a gathering system has several new wells that have a high rate of production, or wells where the gas to oil ratio increases over time. Minimising flaring in these cases requires some tailored solutions in terms of production management and planning. A recent assessment of the Permian tight-oil basin indicates a fourfold increase in flaring since 2012, with annual flaring estimated at 6 bcm.

In the SDS, the volume of gas flared drops dramatically in the upcoming decade. Flaring is soon eliminated in all but the most extreme cases, with less than 13 bcm flared from 2025 onwards – less than 10% of the current global level.

Existing and emerging technologies

It will be important to minimise the flow of new projects that might require flaring; this is a question of regulation and careful project selection and design.

For existing sources of flaring, in the majority of cases the optimal solution to flaring is to extend the natural gas grid. But even in the absence of connection to the gas network (sometimes not a practical option for remote oilfields), there are alternatives that can offer productive uses for the natural gas:

- **Portable CNG or mini-LNG facilities** to treat gas onsite. CNG compresses gas at the wellhead for it to be trucked short distances for in-field fuel use or to nearby gas processing facilities. In 2015, the US EPA estimated that up to 89% of flared gas in the Bakken field could be eliminated with this technology. Similarly, several mini-LNG technologies have been trialled or are in deployment..

- **Small-scale gas-to-methanol or gas-to-liquids conversion plants.** The US DOE is exploring a number of possible options, for example multifunctional catalysts to develop products from associated gas streams, with a focus on modular conversion equipment.
- **Onsite direct electrical power generation.** Gas that would otherwise be flared is captured and turned into electrical power that can be used onsite or could be sold back into an electrical grid.

There are also opportunities to improve the efficiency of existing flare technologies.

Flare reduction initiatives

It can be challenging for individual and small-scale operators to deploy flaring reduction options if they cannot benefit from economies of scale. In some regions, the ownership of fuel streams may also differ, creating legal or royalty issues related to the conversion and sale of associated gas. This emphasises the importance of voluntary initiatives and regulations to encourage operators to work together to reduce flaring.

Various energy companies, governments and institutions have endorsed the Zero Routine Flaring by 2030 initiative launched by the World Bank and the United Nations in 2015.

For new fields, this initiative encourages operators to develop plans to use or conserve all the field's associated gas without routine flaring. For existing fields, operators are asked to eliminate routine flaring when it is economically viable as soon as possible, and no later than 2030.

So far, 38 oil companies, 32 governments and 15 development institutions have endorsed the initiative. In February 2020, Occidental Petroleum Company became the first American company to endorse Zero Routine Flaring by 2030.

Recommended actions

Although the overall percentage of fossil fuel use may decrease over time in the SDS, it is still necessary for governments, the oil and gas industry and financial institutions to work together to support the development and deployment of existing and emerging flaring reduction technologies.

Government policies and regulations

Revise oil and gas legislation so that policies on the treatment of associated gas are clear and unambiguous, and so that fiscal terms encourage or require the use of associated gas. Policies should clarify responsibilities and ownership of associated gas and ensure that new oil developments are approved only if they include the utilisation of associated gas.

Develop national frameworks to provide a legal, regulatory, investment and operating environment that can help develop infrastructure to deliver captured gas to markets, including local provision of electricity supply from associated gas.

Set an overall goal: this could include a flaring cap, wherein if flaring rises above a minimal level this triggers targeted restraints on oil output.

Establish adequate enforcement: in many cases, policies restricting flaring exist but are not sufficiently enforced.

Maximise transparency by making flaring figures (and the method for calculating them) public.

Selected examples of implemented policies

Norway was one of the first countries to introduce regulations (in 1993) requiring operators to meter flared gas and taxing flaring-related CO_2 emissions. A reduction of more than 60% has been achieved from pre-1990 levels.

In Canada, Alberta's Energy and Utilities Board regulates flaring and venting with Directive 060: Upstream Petroleum Industry Flaring, Incinerating and Venting. Requirements cover limits for non-routine flaring, incinerating and venting; permits for temporary flaring/incineration; leak detection and quantification, and fugitive gas management; notification; and reporting and recordkeeping.

The amount of gas flared fell by more than 70% from 1996 to 2004. British Columbia and Saskatchewan also have regulatory measures in place to address flaring in upstream oil and gas operations. During the Covid-19 downturn, the Government of Canada has designated CAD 750 million to financially assist operators in the form of repayable loans for emissions reduction projects.

In 2016 Nigeria announced its intention to ensure that new field development plans include a gas utilisation scheme prohibiting routine flaring by 2020. Nigeria successfully reduced flaring by 70% between 2000 and 2019, but significant flaring is still occurring at many sites across the country. Nigeria's Department of Petroleum Resources (DPR) therefore initiated a bidders' conference to tackle existing gas flaring at 45 sites.

Oil and gas technological and operational practices

Ensure the timely development of gas infrastructure, including gas processing or pipeline capacity for existing and new oilfields, to ensure that associated gas can be brought to the market.

Include gas utilisation technologies and flaring reduction technologies in the design of new oil developments: flaring can much be more easily avoided (and at a lower cost) if it is addressed during development planning. This requires collaboration and alignment all along the value chains for the hydrocarbons being produced.

Increase the direct measurement of flared gas, as it is generally just estimated using a gas balance exercise.

Financial institutions

Investigate opportunities to support and fund companies and field trials seeking to implement gas utilisation and flaring reduction technologies and their deployment.

Resources

Leading initiatives

The Global Gas Flaring Reduction Partnership (GGFR) is a public-private initiative made up of national and international oil companies, national and regional governments, and international institutions. The GGFR aims to increase the use of natural gas associated with oil production by helping to remove technical and regulatory barriers to flaring reduction, conducting research, disseminating best practices and developing country-specific gas flaring reduction programmes.

Global Gas Flaring Reduction Partnership

The **Oil and Gas Climate Initiative (OGCI)** consists of 13 major international oil and gas companies that seek to identify and support measures that can help achieve zero routine flaring by 2030.

Oil and Gas Climate Initiative

The **Climate and Clean Air Coalition (CCAC)** is a global voluntary partnership of over 120 governments, intergovernmental organisations, businesses and institutions committed to improving air quality and protecting the climate through actions to reduce the emission of short-lived climate pollutants. The CCAC works to bring stakeholders together to address climate policies and practices, and it “helps partners and stakeholders create policies and practices that will deliver substantial reductions in short-lived climate pollutant emissions, starting now”.

Climate and Clean Air Coalition

Additional resources

The IEA’s WEO 2019 contains a dedicated discussion on associated gas flaring and venting.

World Energy Outlook 2019

World Energy Outlook 2017 • WEO 2017 has a special section dedicated to innovation and the environmental performance of oil and gas, and explores ways to reduce the emissions intensity of oil and gas operations. • https://www.iea.org/reports/world-energy-outlook-2017

World Energy Outlook 2017

Over the last decade, the EDF has completed over 16 studies to examine methane leaks across the oil and gas supply chain. Their studies on methane leaks and flaring have contributed significantly to the growing body of knowledge pinpointing and quantifying leak sources.

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OCD Exhibit 29

METHANE
GUIDING
PRINCIPLES

Policy Framework for reducing Oil and Gas Methane Emissions

1. INTRODUCTION

Providing access to energy, while addressing global climate change, is one of the greatest challenges of the 21st century. Natural gas plays a major role in meeting global energy demand today. Since natural gas consists mainly of methane, a potent greenhouse gas, its part in the transition to a low-carbon future will be influenced by the extent to which the oil and gas industry reduces its methane emissions.

In November 2017, eight oil and gas companies signed up to Guiding Principles for reducing methane emissions along the natural gas value chain, from production to the final consumer. The principles were developed collaboratively by a coalition of industry, international institutions, non-governmental organisations and academics. The Principles are complementary to and mutually reinforcing of other initiatives, including the Oil and Gas Climate Initiative and the Climate and Clean Air Coalition's Oil and Gas Methane Partnership.

Methane reducing measures are already adopted by many companies on a voluntary basis. Policy and regulatory frameworks can ensure assertive and proportional effort across the full value chain. The Methane Guiding Principles advocate for sound methane policies and regulations that incentivise early action, drive performance improvements, facilitate proper enforcement, and support flexibility and innovation.

This document sets out the key elements that would form an effective policy framework focused on ensuring ambitious methane reduction outcomes are met. It is intended to provide a common basis upon which industry can engage constructively with international institutions, governments, and NGOs in the development and implementation of effective methane abatement policies. The framework is intended to provide a foundation upon which jurisdiction-specific regulatory recommendations could be based.

2. POLICY OBJECTIVES

Policies pertaining to methane emissions can help achieve important global objectives with respect to the role of natural gas in the future global energy mix:

- **Climate Goals:**
  Help governments address oil and gas methane emission reductions as part of holistic efforts to meet their respective climate goals under the Paris Agreement;
- **Stakeholder Confidence:**
  Establish public and investor confidence that natural gas can play a constructive role in a shift to a lower carbon future;
- **Foreseeability:**
  Provide long-term certainty for industry planning and investment;
- **Energy for Development:**
  Advance the UN Sustainable Development Goals 7 and 8, which pertain to the provision of "affordable, reliable, sustainable and modern energy for all," while also promoting "inclusive and sustainable economic growth, employment and decent work for all," respectively.

3. POLICY OBJECTIVES

In developing policy frameworks for effectively meeting methane emissions outcomes, we encourage governments to observe the following principles: a) incentivise early action for reducing methane emissions; b) drive performance improvements; c) facilitate proper enforcement; and d) support flexibility and innovation. More specifically, policies should be designed to achieve the following:

- **Oil and Gas Application**

  Within the oil and gas sector, methane emission reduction measures should be applied to both oil and gas operations, recognising that operational and economic conditions may necessitate different approaches to each. Similarly, measures should be applied across various segments of the oil and gas value chain, while recognizing that physical, market, or operational differences may necessitate different policy approaches.

  While this document speaks to the oil and gas industry and value chain, governments should recognise and address other methane sources as well.

- **Ambitious Emission Reduction Outcomes**

  Policies should be informed by best available data and control techniques and be designed to achieve verifiable emission reductions and incentivize early action, consistent with ambitious national or sub-national outcomes and timelines.

- **Apply to New and Existing Facilities**

  Emission reduction measures should cover both new and existing facilities, recognising that operational and economic conditions may necessitate different approaches to each. For new facilities, policies should encourage the application of high standards of modern design and technology that minimise methane emissions. For existing facilities, policies should encourage implementation of proven strategies to reduce emissions.

- **Cost-effective and Flexible**

  Policies should consider the overall cost to industry and society, as well as societal and climate benefits of reducing emissions. Policies offering appropriate flexibility are likely to be most economically efficient and effective in achieving emission reductions.

- **Stimulate Innovation**

  Policies should encourage and support innovation, development and implementation of new technologies and practices that prevent, monitor and mitigate emissions with expected equal or greater verifiable reductions than existing commercially competitive technologies. Policies should include a pathway to facilitate the introduction of new technologies and practices.

- **Establish Transparency**

  Reporting requirements should be designed to support transparency and effective regulatory oversight, avoid unnecessary administrative burden, and encourage consistent reporting throughout the value chain.

- **Continuous Improvement**

  Policy frameworks should learn from, and where practicable improve upon, existing methane policies and should include provisions to drive more ambition over time as technologies and practices improve and new methane emission reduction strategies become available.

Regulations can create benefits and costs beyond the main topic the regulation is seeking to address. For example, flexible rules can result in unintended environmental, socio-economic, or economic effects that are not the subject of a given regulation. Policymakers should take these potential issues into account when crafting rules and strive to fully address potential for disproportionate impacts to nearby communities.

OCD Exhibit 30

METHANE
GUIDING
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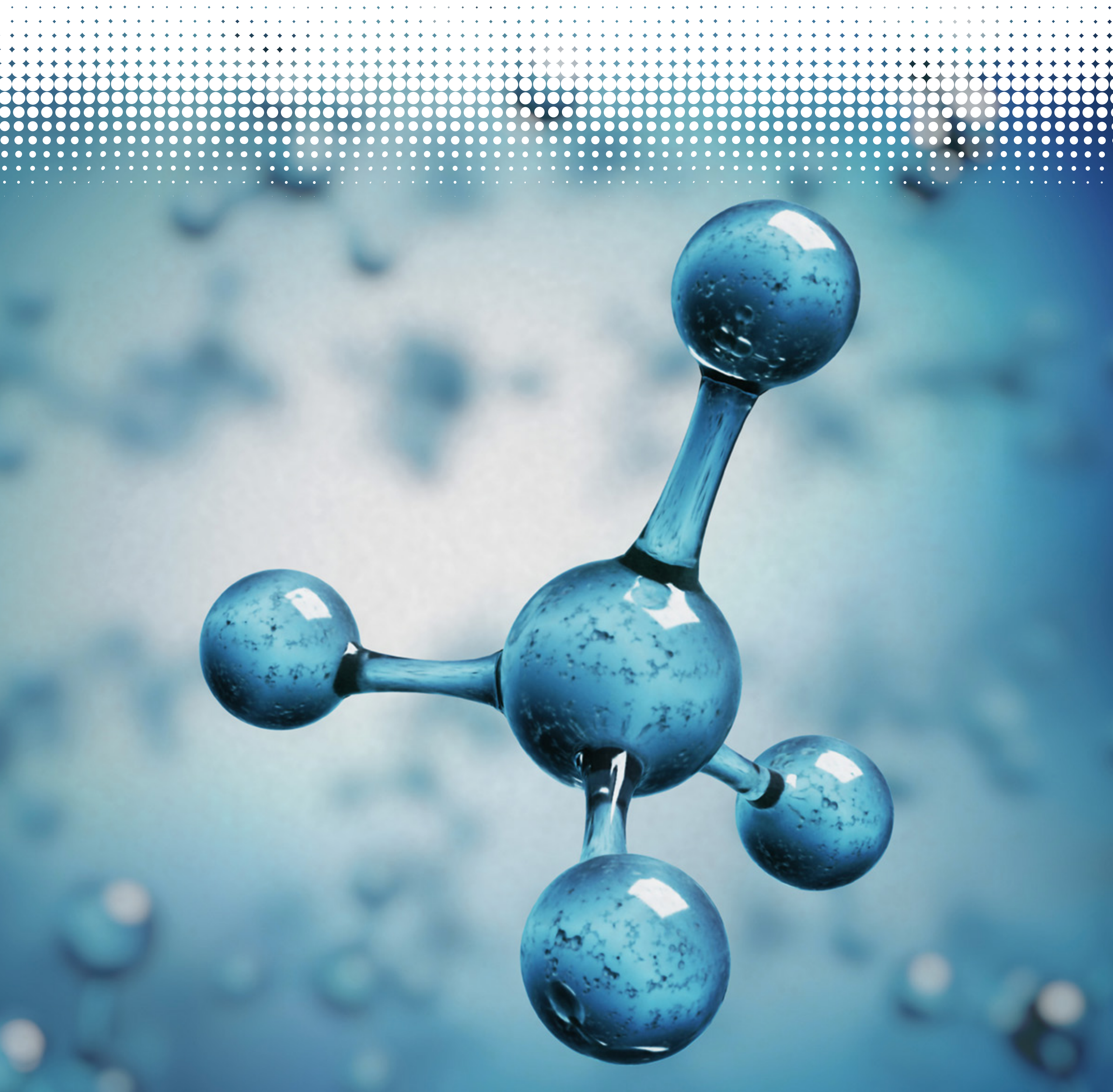
Synopses

Reducing Methane Emissions: Best Practice Guide

September 2020



Disclaimer

This document has been developed by the Methane Guiding Principles partnership. Each Synopsis provides a summary of current known mitigations, costs, and available technologies as at the date of publication, but these may change or improve over time. The information included is accurate to the best of the authors' knowledge, but does not necessarily reflect the views or positions of all Signatories to or Supporting Organisations of the Methane Guiding Principles partnership, and readers will need to make their own evaluation of the information provided. No warranty is given to readers concerning the completeness or accuracy of the information included in each Synopsis by SLR International Corporation and its contractors, the Methane Guiding Principles partnership or its Signatories or Supporting Organisations.
Each Synopsis describes actions that an organisation can take to help manage methane emissions.
Any actions or recommendations are not mandatory; they are simply one effective way to help manage methane emissions. Other approaches might be as effective, or more effective in a particular situation.
What readers choose to do will often depend on the circumstances, the specific risks under management and the applicable legal regime.

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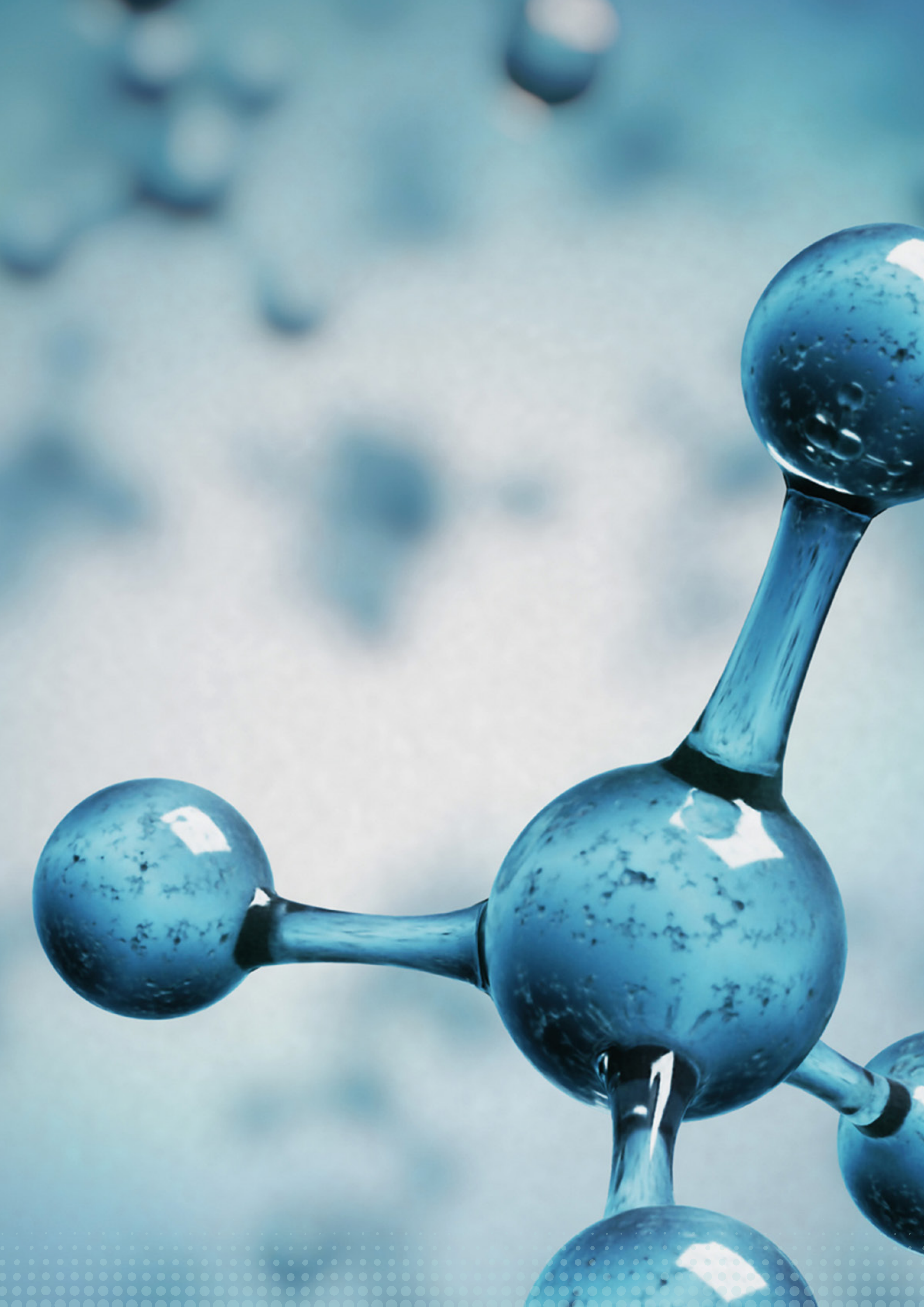


Introduction

Providing access to energy, while addressing global climate change, is one of the greatest challenges of the 21st century. Natural gas plays a major role in meeting global energy demand today. Since natural gas consists mainly of methane, a potent greenhouse gas, its part in the transition to a low-carbon future will be influenced by the extent to which the oil and gas industry reduces its methane emissions.

A concerted industry response is needed to raise ambition and improve performance in methane emissions management along oil and gas supply chains, from production to the final customer. To support this effort, the Methane Guiding Principles (MGP) partnership, a coalition of industry, international institutions, non-governmental organisations and academics, has developed a series of Best Practices, which focus on the following:

1. Systematically minimise methane emissions through Engineering, Design and Construction
2. Reducing methane emissions from flaring
3. Reducing methane emissions that result from energy use
4. Reducing methane emissions from equipment leaks
5. Reducing methane emissions from venting
6. Reducing methane emissions from natural gas driven pneumatic equipment
7. Reducing methane emissions related to operational repairs
8. Systematically improving methane management through continual improvement
9. Reducing methane emissions through identification, detection, measurement and quantification
10. Reducing methane emissions in transmission, storage, LNG terminals and distribution

Each Best Practice is accompanied by a detailed guide and a summary overview, or synopsis, to support the uptake and implementation of the Best Practices.

This brochure contains the synopsis for each Best Practice. Full versions of the guides and other tools are available for download on **www.methaneguidingprinciples.org**

Reducing Methane Emissions: Best Practices

Strengthening the environmental credibility of gas

Engineering Design and Construction

Systematically minimise methane emissions

- Engineer and design equipment to reduce emissions including:
- Minimising potential fugitive and venting sources;
- Optimising combustion and operational efficiency; and
- Equipment selection and consideration of future upgrades.

Flaring

Reduce methane emissions from flaring

Eliminate or reduce flaring wherever feasible.

Where flaring is necessary, maximise its combustion efficiency.

Check your flare systems are operating according to design.

Energy Use

Reduce methane emissions that result from energy use

Use smart metering and controls to reduce end-user energy use and emissions (e.g. gas turbines and boilers).

Maintain gas fired equipment to operate according to design

When replacing equipment, update with the latest proven energy efficient models.

Consider upgrading to continuous or predictive emissions monitoring.

Equipment Leaks

Reduce methane emissions from fugitives and wells

Systematically perform fugitive inspections and prioritise repairs

Build your fugitive inspection and repair capability and skills, including operator discipline.

Consider new technology e.g. detection, quantification, condition monitoring and predictive maintenance.

Consider modern, high integrity materials and jointing technology when constructing downstream distribution networks.

Venting

Reduce methane emissions from process and cold venting

If methane needs to be released – prioritise recycling or flaring over venting.

Avoid or reduce venting from tanks, compressor seals and other potential emission sources (e.g. vapour recovery).

Conduct regular monitoring of vented emission sources (e.g. compressor seals and tanks).

Minimise emissions during well completion and maintenance activities (e.g. green completions).

Pneumatic Devices	**Reduce methane emissions from natural gas driven pneumatic devices** Replace natural gas driven pneumatic devices with compressed air, electric or mechanical equipment where practical (e.g. power availability). Confirm that your pneumatic device is operating per design and repair or replace malfunctioning equipment. Phase out use of high-bleed pneumatic control devices where practical. Conduct preventative maintenance on pneumatic devices.
Operational Repairs	**Reduce methane emissions related to equipment repairs** Make reducing emissions a key aim of your repair planning. Plan and make repairs promptly and safely. Verify repairs are successful through follow-up leak monitoring surveys When depressurising equipment minimise venting by recycling or flaring where feasible.
Continual Improvement	**Systematically improve methane management** Optimise emissions monitoring frequency in operations and maintenance programs. Incorporate emission reduction considerations into overall business and operating strategies. Share learnings within your company and across the natural gas industry Phase-in use of the latest proven lower emission technology and approaches where practical. Regularly review the scope, quality and frequency of emissions reporting.
Identification, Detection, Measurement and Quantification	**Reduce methane emissions through identification, detection, measurement and quantification** Identify known sources and potential sources of emissions in an inventory. Survey known and potential sources to detect actual emissions. Quantify methane emissions directly by measuring emission rates, or indirectly using a combination of measurements, calculations and modelling. Use information from quantification to create or update inventories. Periodically update and improve IDM&Q programs.
Transmission, Storage, LNG Terminals and Distribution	**Reduce methane emissions in transmissions, storage, LNG terminals and distribution** Mitigation measures may be unique to transmission, storage, LNG terminals and distribution, or may have different technical or economic characteristics than measures in other parts of the natural gas supply chain. Keep an accurate inventory of emissions from all sources. Prevent emissions whenever possible and reduce emissions that cannot be prevented. Identify and repair equipment that is not working properly. Track emissions and mitigation activities.

Synopsis

Reducing Methane Emissions: Engineering Design and Construction

Checklist

Methods of reducing methane emissions from engineering design and construction

- Use electric, mechanical, or instrument air powered equipment used where possible. Including pneumatic controllers, pumps and engines.
- Centralized and consolidated facilities where possible.
- Use pipelines for liquid and gas takeaway.
- Recover natural gas for beneficial use where possible.
- Flare or combust natural gas when recovery is not possible.
- Consider the use of alternative low emission alternative equipment/process.
- Consider the use of alternative low maintenance alternative equipment/ process.

Engineering design can be used to reduce methane emissions prior to the start of operations for new facilities or modifications to existing facilities. The design phase is where there is the most opportunity to identify reduction opportunities. It is also typically less expensive to implement reduction strategies in the design phase than have to modify the facility after operations have begun. The engineer should consider the following hierarchy of strategies to reduce methane emissions:

1. Eliminate sources of methane,
2. Reduce the amount of methane emitted and fuel used if the source cannot be eliminated,
3. Control remaining sources of methane.

Most engineering solutions will be specific to a company's operations and each facility and will evolve as technology does. Any design must prioritize integrity, safety, fire protection, and regulatory requirement over methane reductions. Effective general design strategies to reduce methane emissions throughout the natural gas supply chain for both operations and maintenance activities are discussed in detail below.

1. Prioritize use of electric, mechanical and compressed air equipment
2. Centralize and consolidate facilities
3. Use pipelines for liquid and gas takeaway
4. Prioritize recovery of methane for beneficial use
5. Consider alternative low emission and low maintenance equipment

Design and Construction Strategies

Prioritize use of electric, mechanical and compressed air equipment

In some types of operations, pneumatic devices represent a significant source of emissions from the oil and industry. Using electric, mechanical or compressed devices can eliminate pneumatic device emissions completely. This also includes the use of electric compressors and pumps which reduces the amount of fuel used and for compressors can improve reliability.

Centralize and Consolidate Facilities

Centralization and consolidation of facilities allows for the use of more efficient equipment and processes. It also can make equipment more economically viable than at numerous smaller facilities. For example, an oil stabilizer can take production from surrounding facilities and eliminate venting from storage tanks but smaller stabilizers are not available or would not be economical at smaller facilities.

Use Pipelines for Oil and Natural Gas Transportation from Facilities

Use of pipelines ensures natural gas is sold and reduces or eliminates flaring or venting of natural gas. Liquid pipelines can eliminate atmospheric storage tanks, and truck loading sources.

Prioritize Recovery of Methane for Beneficial Use

Natural gas recovery should be prioritized over flaring or venting. The natural gas can be sold or used as fuel on site. Vapor recovery units can be installed to boost the pressure of low pressure gas to be sold. Gas can also be directed to a low pressure fuel system. The recovery of natural gas should be designed for where possible.

Consider Alternative Low Emission Equipment

Some processes or equipment can be eliminated or replaced with a low emission alternative system. These alternative low emission systems should be considered as long as they can meet the requirements of the project. For example methanol injection or desiccant dehydrators are some low emission alternatives to traditional glycol dehydrators.

Examples of actual design and engineering technologies and techniques that use these strategies include:

1. Locating facilities near current pipelines and power lines or brining pipeline and grid power to a facility
2. Using modular design on upstream facilities and removing equipment as production declines
3. Using welds instead of threaded connections and flanges
4. Locating fire gates and isolation valves as close to equipment as possible
5. Recovery of secondary and tertiary separator gas from condensate and crude oil
6. Elimination of storage tanks by using LACTs, pumping liquids around facility or storage in pressurized tanks
7. Proper design of storage tank control systems
8. Use of electrically driven compressors
9. Use of pig ramps and jumper lines to reduce the amount of methane released during pigging operations
10. Use of methanol for hydrate prevention instead of glycol dehydrators
11. Use of flash tanks on amine systems
12. Controlling amine acid gas streams with regenerative or recuperative thermal oxidizers

Synopsis

Reducing Methane Emissions: Flaring

Checklist

Methods of reducing methane emissions from flaring

- Keep an accurate inventory of flaring activity.
- Prevent flaring by designing systems that do not produce waste gases.
- Recover waste gases as products to be sold.
- Inject waste gases into oil or gas reservoirs.
- Find alternative uses for flared gases, such as generating electricity.
- Improve the efficiency of combustion when gases have to be flared.
- Track progress in reducing flaring and venting.

Flares burn flammable gases that would otherwise be released into the atmosphere. Flaring in upstream oil and gas operations may be needed for safety reasons, because of a lack of capacity to use produced gases, or as a part of routine emission controls. Approximately 145 billion cubic meters of gas per year are flared in oil and gas operations around the world, accounting for 2% of global methane emissions from oil and gas production.

Flaring can be reduced in three ways. Ideally, waste gas production is prevented. If this is not feasible then waste gas recovery for sale can generate revenue. Otherwise, storing (re-injecting) gases in oil and gas reservoirs is also an alternative. If the waste gas cannot be recovered to be sold as a natural gas or natural-gas liquid product, or cannot be stored, it may be able to be used for generating electricity. If flaring cannot feasibly be prevented, improving the efficiency of flares can reduce emissions of methane.

Methane emissions from flaring can be reduced in the following ways.

- Preventing flaring by designing systems that do not produce waste gases (for example, by introducing high- and low-pressure separators at well sites)
- Recovering waste gases from tanks and from well-testing and completion, and returning the gases to on-site product streams
- Recovering waste gases that are currently flared and transporting them to nearby gas-processing facilities, where they are recovered as natural gas and natural-gas liquid products
- Storing gases that might otherwise be flared by injecting them into oil and gas reservoirs (which may also increase oil and gas production)
- Finding alternative uses for the gas, often to generate electricity
- Improving the efficiency of flaring

Methods for reducing emissions from flaring have many elements in common with best practice for reducing emissions from venting of gases, and best practice for engineering design, which are summarized in other best-practice guides. Tracking your progress in reducing emissions from flaring should be coordinated with the tracking of your progress in reducing venting, as some reductions in venting lead to increased flaring.

Methods of reducing methane emissions

Prevent flaring through the design of systems

Wells that produce condensate or crude oil send hydrocarbon liquid from a pressurized separator to a non-pressurized condensate tank. Methane will 'flash' from the liquid in the tank and may be flared. Flaring of this 'flash gas' can be significantly reduced by installing both high- and low-pressure separators on well sites.

Recover waste gases using vapor-recovery units

Vapor-recovery units can capture flash gas from tanks and compress it into the gas line so it can be sold rather than being released into the atmosphere or flared.

Recover waste gases from well-testing and completion

After a new well is drilled, it is brought into production through in a completion process that can result in venting or flaring of the completion flowback gas. Separators have been used during completion to capture the gas, and while some of the gas may be flared, some of the gas may be recoverable for sale.

Recover waste gases at well sites and transport by truck to gas processing facilities

Waste gas, which might otherwise be flared, can be treated to remove water, sulfur and carbon dioxide, then compressed on-site to produce compressed natural gas (CNG) and a natural gas liquids (NGL) product. To meet pipeline and other product requirements, the CNG and LNG must typically be further treated. This can be done by transporting the products by truck to a gas processing facility.

Inject waste gases in oil and gas reservoirs

Gas that might otherwise be flared can, in some cases, be injected back into the reservoirs it was produced from, or other reservoirs. As well as storing the gas for future use, this also may help increase oil production.

Convert waste gas to electrical power

Gas turbines and 'reciprocating engines' can convert gases that would otherwise be flared into electricity. The electricity can be used on-site to power equipment (including controllers, pumps and compressors) or sold to the grid.

Improve the efficiency of flaring

If flaring cannot feasibly be avoided, methane emissions can be reduced by improving the efficiency of the combustion in the flare. Since the design of a flare depends on the volume of and variations in gas flow, methods for improving combustion differ between low-volume and high-volume flares. Some measures involve making changes to flaring equipment, while other measures involve changing practices.

Synopsis

Reducing Methane Emissions: Energy Use

Checklist

Methods of reducing methane emissions from energy use

- Keep an accurate inventory of where natural gas is used as fuel.
- Use electrical power or pneumatic power using compressed air or nitrogen.
- Improve the energy efficiency of gathering operations and other equipment.
- If natural gas needs to be used, improve the efficiency of fuel combustion.
- Track your progress in reducing fuel use.

Natural gas, which consists mainly of methane, is used as a fuel throughout oil and gas operations, for compression, generating electricity, heating, dehydration and removing acid gas. Equipment that uses natural gas as a fuel is generally designed to have at least 98% combustion efficiency (that is, at least 98% of the gas will be burned), so some methane is released as unburned gas. This is known as methane slip. Even though methane slip is generally a small percentage of the fuel used, in operations that use a significant amount of energy, methane slip can be a major source of emissions.

Using natural gas as a fuel also results in emissions associated with the engine burning the gas, such as emissions from cylinders or rod packing. Reducing the amount of natural gas used as fuel at oil and gas operations helps reduce methane emissions, and may cut energy costs.

Methane emissions from energy use (using natural gas as a fuel) can be reduced by doing the following.

- Using electricity or other types of power instead of natural gas
- Making processes more efficient, which reduces the amount of energy used
- When natural gas must be used as a fuel, improving the efficiency of the combustion engines

Reductions in fuel costs mean that the cost of options may be recovered in a few months to a year.

Methods of reducing methane emissions

Install electrical compressors

Compressors fired by natural gas, which are used in gas gathering and transmission, can be replaced with electrically driven compressors (if an electricity supply is available). This eliminates methane slip on the site. However, it may not reduce the total methane slip across the whole supply chain if the electricity is generated using natural gas as a fuel. Even if natural gas is used to generate the electricity used to power compressors, overall emissions for all operations may still be reduced. Using electrical compressors also eliminates emissions from engine components.

Replace natural gas used in compressor starter motors with electrical starters or pneumatic starters using air or nitrogen

In the natural-gas industry, combustion engines are often started using gas-expansion turbine motors. The starter motors use high-pressure natural gas, which is stored in a tank. To start the compressor, the gas is expanded through the starter turbine then vented.

Each start-up uses approximately 1.4 cubic meters of gas for every 100 horsepower of motor size. Methane emissions can be eliminated by using compressed air or nitrogen instead of natural gas. If electricity is available, the gas-expansion turbine motor can be replaced by an electrical motor.

Make more efficient use of energy in gathering lines

Gathering systems deliver gas from networks of wells to processing plants. The volume of gas processed and the capacity of the network changes because of changes in production, liquid and hydrate building up in the gathering lines, changes in the composition of the gas and changes in atmospheric and weather conditions. Extra compression and energy use may be needed at times for the network to function and to prevent flaring of gas. The capacity of a gathering system can be increased, and energy use reduced, through frequent clearing of lines (pigging) and minimizing the build-up of liquid and hydrate through line heating or chemical injection, although some of these operations may lead to venting. Increasing the capacity of a gathering system may also prevent flaring (see the best-practice guide on flaring).

Replace compressor-cylinder unloaders

A cylinder unloader is used to adjust the output of a reciprocating engine, by adjusting the volume of the cylinder. Cylinder unloaders release methane through leaking o-rings, covers and pressure packing. Unloaders that need frequent maintenance can also lead to emissions and shutdowns. Replacing unloaders can reduce methane emissions and may also reduce maintenance and unscheduled shutdowns.

Install automated air-to-fuel ratio controls

Engines in natural-gas supply chains are run under a variety of loads and air-to-fuel ratios. Low air-to-fuel mixtures (rich burn) are used when a greater horsepower is needed. High air-to-fuel mixtures (lean burn) are used when lower horsepower and greater fuel-efficiency are the goals. Rich burn results in more unburned fuel (mainly methane) and fewer emissions of nitrogen oxides (NOx). Lean burn produces lower methane, but more emissions of NOx. Installing automated air-to-fuel ratio control systems allows the performance of engines to be maximized by adjusting air manifold pressure and temperature, and improving the delivery of fuel to the combustion chambers. These controls might also allow captured hydrocarbon emissions to be used as fuel. Overall assessments of emissions should consider emissions of methane, carbon dioxide, unburned hydrocarbons and NOx.

Synopsis
Reducing Methane Emissions: Equipment Leaks

Checklist
Methods of reducing methane emissions from leaks in equipment

- Keep an accurate inventory of emissions from equipment leaks.
- Conduct a periodic leak detection and repair program.
- Consider using alternative monitoring programs.
- Replace or eliminate components that persistently leak.

Unintentional leaks from pressurized equipment used in oil and gas operations can lead to gas being released to the atmosphere. Methane emissions from leaks in equipment are mostly caused by imperfections or ordinary wear in sealed joints such as flange gaskets, screwed connections, valve-stem packing, seats on pressure relief valves, or poorly seated open-ended valves. They sometimes (though rarely) come from the wall of a vessel or pipeline.

Methane emissions from leaks in equipment can be reduced by the following steps.

- Keep an accurate inventory of emissions from leaking equipment by using a screening or measurement approach.
- Conduct periodic leak detection and repair surveys (LDAR) on all facilities above ground, and on underground pipelines, to identify and then repair leaks.
- Use focused programs such as 'predictive maintenance and condition monitoring', 'directed inspection and maintenance' (DI&M), or an 'alternative monitoring program'.
- Replace or eliminate components that are chronic leakers.

These leak-reduction methods involve detecting and repairing leaks or, in the case of focused programs, concentrating on certain equipment or components that can produce large leaks, or by repairing only leaks that can be corrected cost-effectively. Operational repairs of leaks are also covered in a separate guide on that subject.

To be fully effective, all methods for detecting and repairing leaks should be built into a company's management systems.

Methods of reducing methane emissions

Leak detection and repair (LDAR) programs

Leak detection and repair surveys should be performed at intervals to identify and repair leaks. Leak detection and repair programs may be voluntary or, in some areas, required by regulation. The frequency of surveys varies (generally from once a month to once a year).

Subsets of detection and repair programs are ‘smart LDAR’ programs or directed inspection and maintenance (DI&M) programs, which survey only some equipment and components known to have the most leaks, or which survey all equipment and components but only repair leaks when it is cost-effective.

Alternative programs

Equipment leaks may be reduced by ‘alternative programs’ or ‘equivalent LDAR programs’ that are alternates to the single method periodic surveys. Examples are varied, but include:

- more frequent remote screening combined with less frequent ground-based leak-detection surveys; or
- continuous monitoring programs.

These alternative programs are often based on newer technologies, and are still being developed and tested. Their equivalency to existing programs is not completely defined, but alternative programs may offer a more cost-effective solution than traditional LDAR.

Replacing or eliminating components that persistently leak

For components that regularly leak, instead of carrying out repeated repairs, you can replace the component with a superior one or completely eliminate the component.

Other methods of minimizing emissions during the repair of leaks are described in the operational repairs guide. Any method of leak detection and repair that you choose should be built into your management and record-keeping systems. The continual improvement guide deals with this integration.

Synopsis

Reducing Methane Emissions: Venting

Checklist

Methods of reducing methane emissions from venting

- Keep an accurate inventory of venting activity.
- Alter physical systems and operating practices to reduce venting.
- Recapture gas where possible.
- If methane needs to be released, flare it rather than venting it.
- Track your progress in reducing venting.

Venting simply means releasing gas arising from a process or activity straight into the atmosphere. There are a large number of sources of venting in the oil and gas industry, but this document deals with these main equipment sources – storage tanks, compressors (seals and starter motors), and glycol dehydrators. The main venting activities this synopsis deals with are removing liquids from gas wells, and well completions.

Methane emissions from the main sources of venting can be reduced by doing the following:

- Keeping an inventory of emissions from venting.
- Avoiding or reducing venting from the following.
  - Hydrocarbon liquid storage tanks
  - Compressor seals and starter motors
  - Glycol dehydrators
  - Removing liquids from gas wells
  - Well-completion operations
  - Oil well casinghead venting
- If methane needs to be released, using vapor recovery or flaring rather than venting.

The methods for reducing emissions from venting have a lot in common with best practice for reducing emissions from flaring, and through engineering design, which are summarized in separate documents.

Methods of reducing methane emissions

Reduce venting from storage tanks

Storage tanks, especially in production, can vent significant volumes of gas. Strategies to reduce emissions depend on the venting causes for your location. Strategies include:

- installing vapor-recovery systems;
- getting rid of tanks at production sites;
- adding automatic gauging and vapor-balance systems to tanks;
- adding tank-pressure monitors; and
- including tanks in a routine leak detection and repair program.

If venting cannot be reduced, flaring the gas released from tanks can reduce methane emissions.

Reduce venting from compressor seals

Emissions from reciprocating compressor rod packing can be reduced by including packing vents to a routing leak detection and repair program, or by replacing rod packing as part of a routine replacement program.

Venting from centrifugal compressors that have wet seals can be reduced by adding the vents in a leak detection and repair program, or converting the seals to dry systems, which release less gas.

Where venting cannot be reduced, flaring the released gas can reduce methane emissions.

Reduce venting from compressor starter motors

Compressor starter motors that are powered by natural gas can be converted to be powered by electricity or compressed air. If this is not possible, directing the released gases to a vapor-recovery system or flare can reduce methane emissions.

Reduce venting from glycol dehydrators

Glycol dehydrators can be replaced with alternative technologies (such as desiccant systems) that have lower emissions, or emissions can be reduced by electrifying the lean glycol pump, and by installing a flash tank so gas can be recovered and reused.

Reduce venting arising from well completions

Venting from the process of completing and flowback from wells can be reduced by using 'green' completion technologies, such as large temporary pressurized flowback equipment.

Reduce venting arising from removing liquid from gas wells

Venting from the process of removing liquid from gas wells (also called "gas well unloading") can be reduced by altering the manual process to minimize the duration of venting, physically altering the well and downhole equipment to remove the need for processes that vent or, in some cases, adding automated liquid-removal systems.

Reduce venting arising from oil well casinghead venting

Venting at an oil wellhead from the annular casinghead space can be reduced by using vapor recovery systems or by flaring.

Synopsis

Reducing Methane Emissions: Pneumatic Devices

Checklist

Methods of reducing methane emissions from pneumatic devices:

- Keep an accurate inventory of pneumatic controllers and pumps powered by natural gas.
- Replace pneumatic devices with electrical or mechanical devices where practical.
- If pneumatic devices are used, eliminate emissions by using compressed air rather than natural gas to power them.
- If using devices powered by natural gas is the best option, replace high-bleed controllers with alternatives with lower emissions.
- Include pneumatic devices in an inspection and maintenance program and report emissions from these devices in an annual inventory.

Pneumatic devices are powered by gas pressure. They are mainly used where electrical power is not available. The two main types of pneumatic device used in the oil and gas industry are:

- pneumatic controllers, which control conditions such as levels, temperatures and pressure; and
- pneumatic pumps, which inject chemicals into wells and pipelines or circulate dehydrator fluids.

Millions of pneumatic devices, mostly pneumatic controllers, are used in the oil and gas industry. These devices, when powered using natural gas, can be one of the largest sources of methane emissions in petroleum and natural gas supply chains.

The methane released from pneumatic devices comes from the natural gas that is vented while powering the device, so preventing or reducing emissions can also often have economic benefits. The International Energy Agency (IEA) has estimated that methane emissions could be reduced by more than 11000 kilotons (kt) globally from pneumatic devices – more than 7000 kt from pneumatic controllers and more than 4000 kt from pneumatic pumps – by using best practices for reducing methane emissions. This represents about 15% of the total global emissions of methane from oil and gas operations.

Methods of reducing methane emissions from pneumatic devices range from preventing emissions, to reducing emissions, to repairing those devices with emissions that are higher than expected.

Methane emissions from pneumatic devices can be reduced by:

- replacing pneumatic devices with electrical pumps or controllers;
- replacing pneumatic devices with mechanical controllers;
- using compressed air rather than natural gas to power pneumatic devices;
- replacing 'high-bleed' pneumatic devices with intermittent or 'low-bleed' devices; and
- inspecting devices and repairing those that release emissions that are higher than expected.

Methods of reducing methane emissions

Replace pneumatic devices with electrical pumps or controllers

At remote locations where electricity is not readily available, circulation pumps in glycol dehydration units, and chemical injection pumps used to inject chemicals into wells and flow lines, are often powered by pressurized natural gas. Chemical injection pumps run at relatively low volumes (releasing roughly 10 cubic meters of natural gas a day for methanol injection pumps at well sites), while circulation pumps in glycol dehydration units may release hundreds of cubic meters of natural gas a day.

These pumps can be replaced by solar-powered electric pumps and standard electric pumps. Similarly, pneumatic controllers can be replaced by electrical devices where electricity is available.

Replace pneumatic devices with mechanical controllers

Pneumatic devices used to control pressure levels can be replaced with mechanical controllers. At low-pressure, low-volume wells, mechanical dump valves (rather than pneumatic dump valves) have been installed on vertical separators. Mechanical controllers have also been used at midstream dehydration facilities.

In separators operating at high pressure and high volumes, the dump valve needs to be continuously throttled, so fluids can constantly flow out of the vessel. As pressure and production decline, the need for pneumatic throttle control may be able to be replaced by separators with mechanical dumps.

Use compressed air rather than natural gas from the well to power pneumatic devices

Using compressed air rather than pressurized natural gas eliminates the methane in vented gas. Due to the cost of compressed-air systems, at present they are mainly used at locations, which use relatively high rates of gases to drive pneumatic devices.

Replace high-bleed (high-emitting) pneumatic devices with intermittent or low-bleed devices

High-bleed pneumatic controllers have vent rates that are typically more than 1 standard cubic meter per hour (scm/h). At these rates, natural gas with a value of more than US$1000 a year is lost from each high-bleed device. If the operating conditions do not need high-bleed devices, low-bleed or intermittent controllers, with average vent rates of between 0.03 and 0.4scm/h, can significantly reduce methane emissions and the loss of natural gas.

Inspect devices and repair those that release emissions that are higher than expected

Several studies have found that a small fraction of pneumatic controllers tend to be responsible for the majority of methane emissions associated with pneumatic controllers. Although not all high emitting controllers are faulty, emission patterns indicate that some high emitting controllers are not operating as designed. Inspection and maintenance programs for pneumatic devices have been effective in reducing the number of high emitting pneumatic devices not operating as designed. New inspection and maintenance programs could be introduced specifically for these devices, or the devices could be added to an existing inspection and maintenance program, such as a program for detecting and repairing leaks.

Synopsis
Reducing Methane Emissions: Operational Repairs

Checklist

Methods of reducing methane emissions through operational repairs

For equipment leaks:
✔ Perform periodic leak-detection surveys.
✔ Repair leaks as soon as practical.
✔ Check that repairs have been successful.
✔ Keep track of repairs that have not been carried out.
✔ Keep and analyze records of leaks and repairs.
For routine maintenance and repairs:
✔ Use pumpdowns for pipelines and large vessels.
✔ Minimize the volume that has to be depressurized.
✔ Use vapor-recovery units when pigging.
✔ Avoid emissions by, for example, using hot taps to make connections to pipelines, carrying out non-intrusive inspections, and coordinating repairs and maintenance.
✔ If venting is necessary, flare the vented gases.

Operational repairs are vital for reducing methane emissions, by both repairing leaking equipment and minimizing emissions that arise during routine maintenance and repairs. This guide covers repairs to leaks discovered during inspections carried out as part of a leak detection and repair program, as well as releases that may occur because of other maintenance and repairs.

Methane emissions from equipment leaks can be reduced by the following measures:

- Keeping an accurate inventory of emissions from equipment leaks (including the duration of the leaks), and carrying out inspections as part of a leak detection and repair program (leak detection is also covered in the separate Equipment Leaks best practice guide).
- Emissions from leaks can be further reduced by:
  - making repairs as soon as reasonably practical and keeping track of any repairs that have to be delayed;
  - carrying out checks to make sure repairs have been successful;
  - keeping accurate records of leaks and repairs; and
  - routinely analyzing records of leaks and repairs.

Methane emissions from routine maintenance and repairs can be reduced by the following measures:

- Planning steps to reduce venting when large vessels and pipelines need to be depressurized;
- If venting cannot be avoided, flaring the released gases.

Methods of reducing methane emissions from equipment leaks

Carrying out a leak detection and repair program

With a leak detection and repair program in place, regular inspections are carried out to find leaks and carry out repairs.

Repairing leaks as soon as reasonably practical

Making repairs as soon as reasonably practical is important in order to minimize emissions.

Carrying out checks to make sure repairs have been successful

A leak is considered to have been repaired only after follow-up checks show that the equipment is no longer leaking.

Keeping track of outstanding repairs

Leaks not yet repaired should be placed on a 'delay of repair' list. This list should show the location of the leak, the date it was discovered, an estimated date for the repair, and an explanation of why the repair was delayed.

Keeping accurate records of leaks and repairs

Each facility should maintain a record of all leaks that are discovered, the date of each repair and an explanation of the repair method, and confirmation that the repair has been successful (when this has been confirmed). The record must be detailed enough to allow future analysis of whether the same component is leaking again.

Analyzing records of leaks and repairs and taking action where necessary

Regularly analyzing information, at approximately the same frequency as your inspections to detect leaks, can identify components or types of component that persistently leak. These components should be targeted for correction or preventative maintenance.

Methods of reducing methane emissions from routine maintenance and repairs

Minimizing the volume that has to be depressurized

To reduce the internal volume of a pipeline or vessel that needs to be depressurized by releasing gas, use temporary line stops to isolate the section where repairs are needed.

Reducing emissions from pigging a pipeline by using a vapor-recovery unit to capture the released gases.

Gas is vented when a pig is launched and received. Gas is also released from storage tanks receiving the liquid and debris removed by pigging. These emissions can be reduced by using a vapor-recovery unit or flaring the gases that are released.

Avoiding emissions

In some cases, emissions can be avoided completely by:

- using hot taps to make new connections to pipelines;
- carrying out non-intrusive inspections (for example, by using pigs with sensors); and
- reducing the number of blowdowns by coordinating repairs and maintenance events into a single downtime.

Flaring vented gases, if venting cannot be avoided

If venting cannot be avoided, flaring the gas will reduce the emissions impact of a venting event.

Synopsis
Reducing Methane Emissions: Continual Improvement

Checklist
Achieving continual improvement in methane management

- Commit to a program of methane management.
- Improve methane reduction capabilities for preventing, identifying and repairing leaks, and using effective engineering and design.
- Set strong methane-reduction targets.
- Report methane-reduction efforts and results.
- Integrate methane management into the company culture.

Continual improvement of methane management efforts will eventually result in 'methane excellence', i.e., low methane emissions from oil and gas operations. Methane excellence can enable the oil and gas industry to become one of the main players in reducing methane emissions and providing low-carbon energy worldwide.

The most important factor in achieving methane excellence is commitment throughout the company, from senior management to front-line employees.

With that commitment, continual improvement of methane management is accomplished by doing the following;

- Systematically improving methane management by having a formal or informal management system such as the Plan Do Check Act cycle
- Improving methane-reduction by improving the processes of preventing, identifying and repairing leaks
- Learning from existing practices and maximizing methane reduction through project engineering and design
- Setting strong methane-reduction intensity targets for operated assets
- Reporting an overall group level methane number (Mte) and a methane intensity (%)
- Reporting methane as both carbon dioxide equivalents and methane
- Building methane-reduction efforts into company culture

Systematically improving methane management

Transforming a company from one that does the minimum required by law to one that achieves methane excellence is a complex journey that involves technical, organizational and leadership skills. Such an undertaking requires a systematic approach. Continual improvement in methane management requires a management system like the plan-do-check-act cycle to be applied to the elements of reducing methane emissions.

Improving methane monitoring and reduction capabilities

The starting point for improving methane management capabilities is an accurate inventory of the sources of methane and the amounts they emit. This helps to identify the sources that should be prioritized for reduction activities. From there, projects such as increasing leak detection practices and improving the process of repairing and preventing leaks can be launched. As methane reduction technologies develop and operations grow and change, a systematic continual improvement process will make sure that best practices continue to be applied.

Setting strong methane-reduction targets

Continual improvement in methane management is driven by methane reduction targets. Methane reduction targets should be ambitious but also achievable. Current best practice for setting strong methane reduction targets includes setting intensity targets for operated assets. Future recommended best practice includes setting targets for both natural-gas and oil production; addressing emissions from both operated and non-operated assets; including both an absolute and an intensity target for methane; performing rigorous emissions measurements and analysis to inform targets and validate reduction levels.

Transparent reporting

Transparent reporting of methane emissions and reduction targets, as well as the information these are based on, is critical to building internal and external stakeholders' confidence in a company's efforts to reduce methane emissions. Globally, investors are starting to ask more questions about a company's management of climate change issues. Current best practice demonstrating transparent reporting includes reporting an overall group level methane number (Mte) and a methane intensity number (%) and reporting methane emissions in carbon dioxide equivalents (CO_2e) and methane (CH_4). Future recommended best practice includes reporting of asset level methane emissions, moving towards regional emission factors and the use of direct methane detection and measurement technologies and third party validation of methane performance reporting.

Building methane management into company culture

An oil and gas company can promote a culture that supports methane excellence by continually improving awareness of methane management strategies across the business until methane management is embedded in the company's culture. Specific best practices for integrating methane management into company culture include.

- Integrating methane reduction into existing business and operational procedures
- Establishing new learning opportunities relating to reducing emissions for both technical and non-technical staff
- Promoting methane excellence and innovation by encouraging team communications, setting team goals and boundaries, then tracking and rewarding positive results.

Synopsis
Reducing Methane Emissions: Identification, Detection, Measurement and Quantification

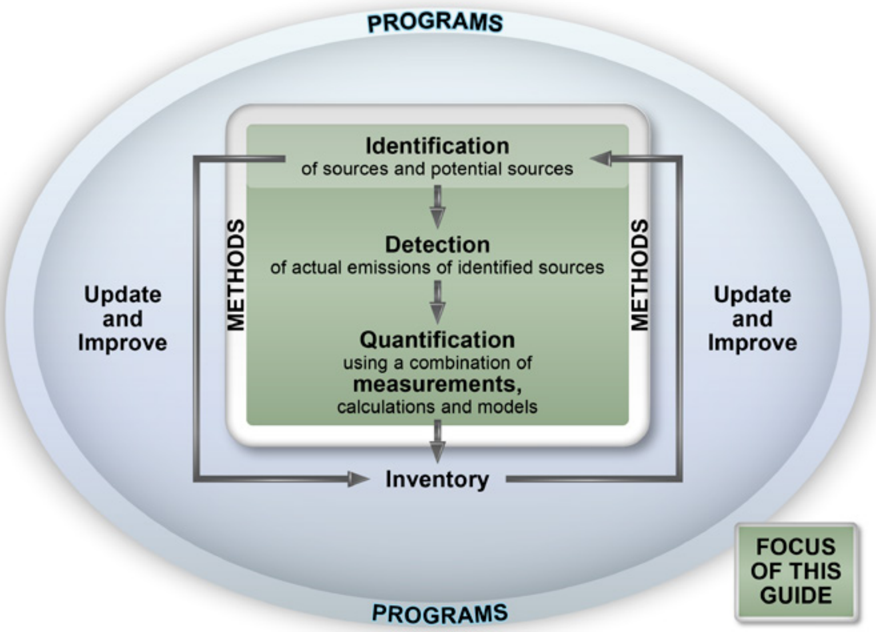
Checklist

Methods of reducing methane emissions through identification, detection, measurement and quantification

- Identify known sources of emissions and survey for emissions
- Quantify sources of emissions directly by taking measurements or indirectly using a combination of measurements, calculations and models
- Create, update and periodically improve inventories of emissions

A key step in reducing methane emissions is to identify and detect sources of the emissions. Emissions that have been identified and detected are measured, quantified and recorded in inventories. These inventories serve as a starting point for prioritizing mitigation activities (measures to reduce methane emissions). Because of the wide range of sources of methane emissions in natural gas value chains, methods for identifying, detecting, measuring and quantifying emissions are varied.

Methods include approaches that have been available for decades and approaches that are just emerging. The best practice to follow will depend on the characteristics of a facility and the cost-effectiveness of the methods. Best practice will also depend on the need for inventories, which may include introducing voluntary programs, developing detailed corporate inventories, or keeping to regulations that require particular methods to be used.



Identification and detection

Some sources of methane emissions are a known part of the design of natural gas systems. In these cases, analyses of a system's design are used to identify emission sources. Other methane emissions are unintentional. Detection surveys need to be carried out to identify unintended sources and to confirm known sources. Detection methods may use passive or active sampling. They may detect at a fixed point or over an open path, and may involve imaging. The methods use a range of sensing technologies. Some methods apply to all sectors of the natural gas value chain. Others have more specialized uses. Because of the wide range of methods and uses, best practice for identifying, detecting, measuring and quantifying emissions will depend on the characteristics of a facility and the cost-effectiveness of the methods.

Measurement and quantification

Once emissions are identified and detected, a wide variety of methods can be used to quantify them. Methods often involve measuring methane concentrations in flows of gases or ambient air, but could also include a wide variety of other measurements (ranging from gas pressures to wind speeds). Emission rates can be quantified directly by carrying out measurements or indirectly through a combination of measurements, calculations and models.

Methods applied at a variety of scales

Emissions are identified, detected, measured and quantified using devices that are handheld, fixed at a location or fitted on vehicles, drones or aircraft, or by satellite. Large-scale emission estimates aggregated over many individual sources, are generally referred to as top-down assessments. Estimates of emissions from individual sources, which are then added together to produce estimates for a site or area, are generally referred to as bottom-up assessments. Bottom-up assessments provide detailed information about emissions from equipment and operations, but may miss some unexpected, unintended or uncharacteristic emission sources. Top-down assessments generally lack detail about individual sources but can provide comprehensive information about emissions at a site or in a region. Depending on the scale of the measurement, top-down measurements may include contributions from sources that are not a part of the natural gas value chain, and this needs to be accounted for when interpreting findings and reconciling top-down assessments with bottom-up estimates. Co-ordinated use of measurements at varying scales may provide more reliable quantification.

Programs to develop, update and improve inventories

Several methods are generally used in programs to identify, detect, measure and quantify emissions. The resulting information is recorded in emission inventories, which are regularly updated and improved. The continual improvement of inventories may include new methods of detecting and measuring emissions, new information on average emission rates from equipment, new emission models, or other innovations. Comparisons between top-down assessments and bottom-up assessments can guide continual improvement.

Synopsis

Reducing Methane Emissions: Transmission, Storage, LNG Terminals and Distribution

Checklist

Methods of reducing methane emissions in transmission, storage, LNG terminals and distribution

- Keep an accurate inventory of emissions from all sources
- Prevent emissions whenever possible
- Reduce emissions that cannot be prevented
- Identify and repair equipment that is not working properly
- Track emissions and mitigation activities

Methane emissions in the natural gas supply chain arise from venting, fugitive emissions and incomplete combustion (methane slip). Best practice for reducing or eliminating emissions from these sources has been described in guides developed by the signatories to the Methane Guiding Principles (MGP). However, the technical and economic characteristics of the best practice may vary depending on the characteristics of the part of the supply chain the best practice is applied in.

This synopsis describes ‘mitigation measures’ to reduce methane emissions in transmission, storage, LNG terminals and distribution. These measures may require different practices to other parts of the supply chain. For example, leaks from buried pipelines can be more difficult to identify and quantify than leaks from sources above the ground, and the cost of repairs will be higher.

Mitigation measures

Mitigation measures include approaches used across the full natural gas supply chain and methods that are specific to transmission, storage, LNG terminals and distribution. Sources which mitigation measures are applied to include the following.

- **Compressors** (convert wet seals to dry seals, address rod-packing seals, reduce emissions from gas starts)
- **Pneumatics** (convert to be powered by electricity or compressed air, replace high-bleed devices)
- **Dehydrators** (switch to low-emission or no-emission dehydration, optimize glycol dehydrators, and route flash gas to flare or use as fuel)
- **LNG truck loading** (dry connects, use nitrogen to purge lines, vapor balancing)
- **Pipeline maintenance** (pump down, recompress and reroute, use hot taps, flare residual gas, use in-line inspection technologies)
- **Pipeline commissioning** (vacuum instead of purge)
- **Third-party damage** (damage-prevention programs, install excess-flow valves in lines)
- **Storage systems** (monitoring, well-integrity monitoring and reviews)
- **Boil-off gas in LNG terminals**
- **Equipment leaks** (implement leak detection and repair programs, replace equipment prone to leaks)
- **Energy use** (reduce methane from incomplete combustion of fuel by having automated air/

fuel ratio controls, minimizing the number of start-ups and increasing combustion efficiency of equipment)

- **Flares** (minimize flaring, improve efficiency, avoid pilot failure)

Continual improvement in reducing emissions should be achieved across all parts of the supply chain.

Case studies with features unique to this sector

Pipeline draw-down and pump-down

Operators can lower gas pressure in sections of pipeline that need maintenance work by blocking it off and allowing customers to withdraw gas, before venting. Operators can also reduce venting using a mobile compressor that removes gas from the pipeline section to be vented and recompresses it into a nearby section.

Recovering blowdown gas with permanent compressors

Install electrically driven compressors in compressor stations to reroute and not vent blowdown gas, with temporary tank storage.

Flare residual blowdown gas

If gas cannot be moved into another pressurized system, or there is residual gas left after a recompression operation, flaring reduces the methane in the vented gas.

Hot tapping for pipeline connections

Hot tapping makes a new connection to a pipeline while the pipeline remains in service. This avoids the need to depressurize and vent the pipeline to make the connection.

Monitoring underground storage

Implement well-integrity management systems.

Replace dehydrators in storage systems with lower-emission alternatives

Vapor-compression refrigeration and Joule-Thompson expansion can be used to condense water in gas streams, reducing emissions compared to glycol dehydrators.

Minimizing emissions through the design of LNG terminals and LNG truck- loading systems

A variety of mitigation practices reduce venting and fugitive emissions in LNG terminal operations.

Commissioning with vacuum pumps

Constructing and commissioning a new section of distribution network gives rise to methane emissions during the purging process and pressurization of the new section. Emissions can be avoided by using a vacuum pump to remove the air in the new section.

Avoid emissions caused by third-party damage

Civil work around gas networks can cause damage to service lines, resulting in emissions. Work with third parties to prevent damage events.

Install excess-flow valves in service lines

When damage arises in service lines or inside customer premises, gas is released into the atmosphere. The resulting flow of gas can be detected and stopped with an automated cut-off valve.

Further information

MGP Website:
www.methaneguidingprinciples.org

OGCI:
https://oilandgasclimateinitiative.com

CCAC OGMP:
https://www.ccacoalition.org/en/activity/ccac-oil-gas-methane-partnership

IEA Methane Tracker:
https://www.iea.org/weo/methane

Natural Gas STAR Program:
https://www.epa.gov/natural-gas-star-program

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