Global Gas Flaring Tracker Report

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GFMR
Global Flaring and Methane Reduction Partnership

THE WORLD BANK
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Photo: Leonid Ikan

Foreword

The World Bank's Global Gas Flaring Tracker Report provides the only independent indicator of gas flaring worldwide. Each year, the trends revealed serve as a guide to governments, oil and gas companies, civil society, and international organizations, helping to enhance understanding of the global state of gas flaring.

After a welcome reduction in 2022, global gas flare volumes rose by 7 percent to an estimated 148 billion cubic meters in 2023, taking the world back to levels last seen in 2019. With only six years left to achieve Zero Routine Flaring by 2030, the world needs to rapidly accelerate efforts to reduce gas flaring.

This year's Tracker Report comes as a global sense of urgency is taking hold. At the end of last year, the 2023 United Nations Climate Change Conference (COP28) again underscored the importance of transitioning away from unabated oil and gas. At the same time, oil and gas will continue to play a material role in the global energy system until at least 2050. This places the burden of responsibility on operators to ensure that oil and gas are produced as cleanly as possible during the energy transition.

It is clear that routine gas flaring also continues to represent a lost opportunity to provide communities around the world with much-needed energy security and a cleaner source of power. This business-as-usual practice of pursuing oil production with little consideration for the potential use of associated gas is not just polluting, it is immensely wasteful.

To support countries with the least resources and capacity to address greenhouse gas emissions from the oil and gas sector, the World Bank has launched the Global Flaring and Methane Reduction (GFMR) Partnership. GFMR builds on the legacy of the Global Gas Flaring Reduction Partnership and broadens the scope to include providing support for gas flaring and methane emissions reduction along the entire oil and gas value chain.

We urge all oil and gas producers to carefully assess how they produce oil and gas and identify and seize opportunities for effective and long-term flaring reduction. It is our hope that governments and operators around the world use the data and the insights in this report to not just take stock of how much gas is being flared, but also use it as the basis for implementing meaningful regulations and investments to significantly and sustainably drive down global gas flaring.

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Acknowledgments

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Preparation of the report was made possible thanks to long-standing collaboration with the team led by Christopher Elvidge of the Earth Observation Group, part of the Payne Institute for Public Policy at the Colorado School of Mines, with the support of his colleagues, Mikhail Zhizhin and Tamara Sparks.

The report's technical analysis uses satellite detections of methane data provided by Carbon Mapper, Kayrros SAS, and the United Nations Environment Program (UNEP) International Methane Emissions Observatory (IMEO) Methane Alert and Response System (MARS); as well as oil and gas production data from the U.S. Energy Information Administration.

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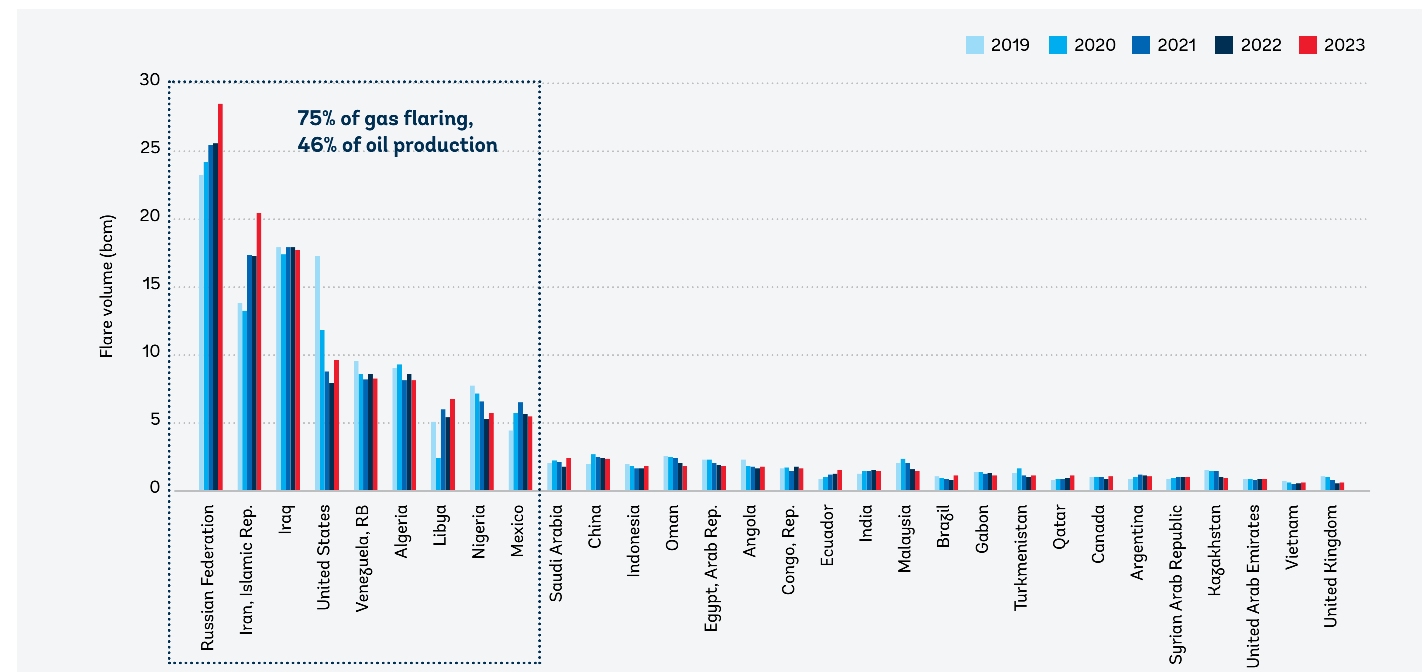
Abbreviations

bbl	barrels (of oil produced)
bcm	billion cubic meters (of gas flared)
CBAM	Carbon Border Adjustment Mechanism
COP28	28th Conference of Parties of the United Nations Framework Convention on Climate Change
EIA	Energy Information Administration
GFMR	Global Flaring and Methane Reduction
GHG	greenhouse gas
IFG Index	Imported Flare Gas Index
IMEO	International Methane Emissions Observatory
m^3/bbl	cubic meter (of gas flared) per barrel (of oil produced)
MARS	Methane Alert and Response System
MMbbl/d	million barrels of oil per day
$MMtCO_2e$	million tonnes of carbon dioxide equivalent
NOAA	National Oceanic and Atmospheric Administration
VIIRS	Visible Infrared Imaging Radiometer Suite of detectors

Key findings

- **In 2023, global gas flaring at upstream oil and gas facilities increased by 9 billion cubic meters (bcm) from 139 bcm in 2022 to 148 bcm in 2023, a 7 percent increase.** At the same time, oil production rose by just 1 percent, leading to a 5 percent increase in global average flaring intensity, the amount of gas flared per barrel of oil produced. At the current price of gas, the potential market value of the overall amount of gas flared in 2023 could have been between $9 Billion and $48 Billion[1]. Eliminating gas flaring would avert at least 381 million tonnes of carbon dioxide equivalent emissions being released into the atmosphere each year.
- **This increase indicates a reversal of the reduction in gas flaring observed between 2021 and 2022, resulting in the highest volume recorded in the last five years and an increase in flaring intensity.** This suggests that the global efforts to reduce gas flaring have not been sustainable and urgent action is required if the world is to achieve Zero Routine Flaring by 2030.
- **Substantial reductions in gas flaring and flaring intensity are achievable through effective partnerships and the creation of solutions to monetize associated gas.** Last year's report shared the considerable success in countries like the United States and Angola, and this year we acknowledge sustained improvements in both Algeria and Venezuela. However, the increases in gas flaring in 2023 have far outweighed these improvements.
- **The Russian Federation, the Islamic Republic of Iran, Iraq, the United States, República Bolivariana de Venezuela, Algeria, Libya, Nigeria, and Mexico remain the top nine flaring countries in 2023.** Together, these nine countries are responsible for 75 percent of global gas flaring, but just 46 percent of global oil production (figure 1).

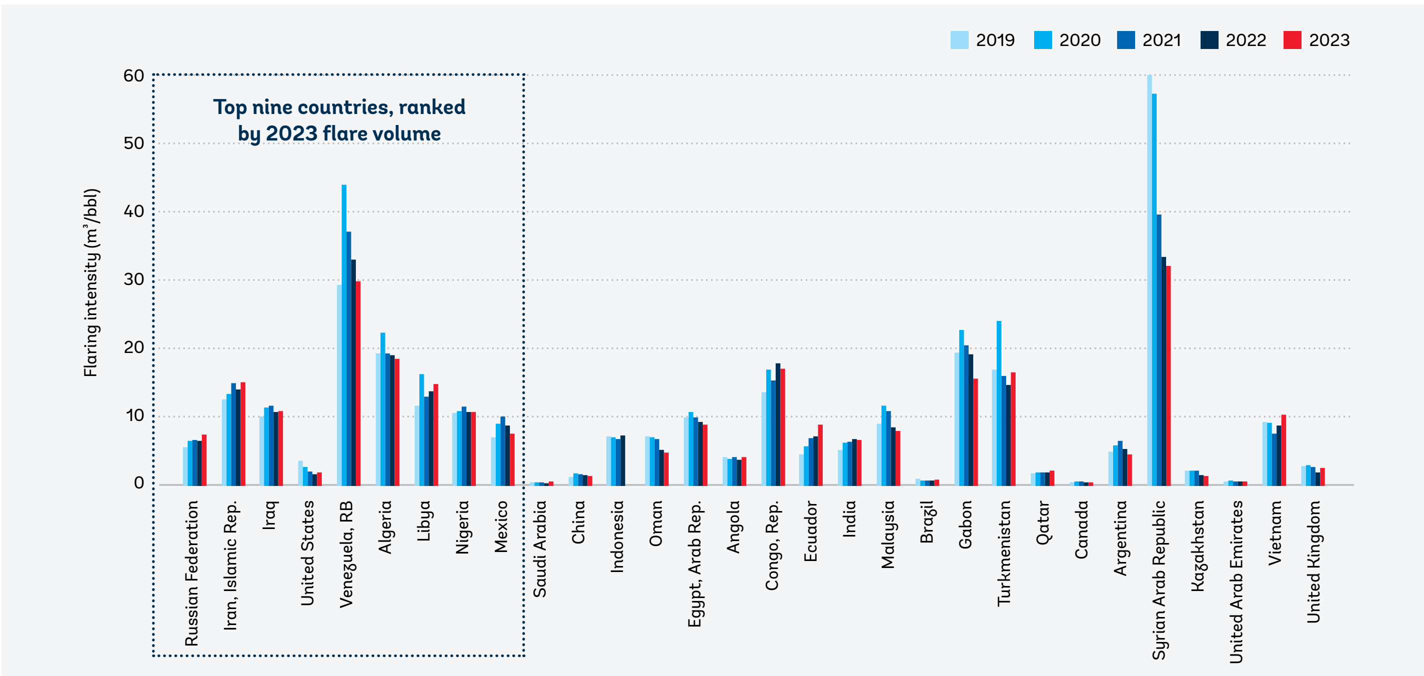
Figure 1. Flare volumes in the top 30 flaring countries, in order of 2023 flare volume with the top 9 flaring countries indicated, 2019–23



Source: Payne Institute and Colorado School of Mines, National Oceanic and Atmospheric Administration (NOAA), World Bank.
Note: bcm = billion cubic meters.

1 Assumes gas flared has a higher heating value of 1,020 British thermal units per standard cubic foot (BTU/scf), that 1 cubic meter equals 35.315 standard cubic feet and that recovered gas would achieve a price range based on a Henry Hub natural gas spot price of $1.65 per million BTU and European Union natural gas import price of $9.085 per million BTU (both correct as of April 2024).

Figure 2. Flaring intensity in the top 30 flaring countries from 2019 to 2023 in order of 2023 flare volume, with the top 9 flaring countries indicated



Source: Payne Institute and Colorado School of Mines, NOAA, US Energy Information Administration (EIA), and World Bank.
Note: m^3/bbl = cubic meters per barrel.

- **The largest increases in flaring in 2023 occurred in four of the top nine flaring countries—the Islamic Republic of Iran, Russia, the United States, and Libya—which together accounted for 9 bcm of additional gas flaring.** In addition to increases in flare volume, these countries also experienced an increase in flaring intensity.
- **In Russia—which remains the top flaring country in the world—flaring increased by 11 percent. In the United States, the Islamic Republic of Iran, and Libya, flaring increased by 21, 19, and 25 percent, respectively.** These countries have very different flaring intensities (figure 2), reflecting the inherent differences in the gas-to-oil ratios of the basins and the different levels of gas utilization they have achieved. However, as Russia and the United States represent a large share of the global oil production, the fluctuation in their gas flaring intensities has a notable impact on the global totals.
  - In the Islamic Republic of Iran and Libya, the increase in flaring was directly related to increased oil production coupled with a lack of investment in and prioritization of associated gas recovery and utilization. This led to a combined increase in routine gas flaring in these two countries by 4.6 bcm, putting an additional strain on achieving the Zero Routine Flaring globally by 2030. Flaring intensity increased in both countries by 8 percent.
  - In Russia, flaring rose across all oil-producing regions, despite falling oil production, which led to a 13 percent increase in flaring intensity. This is likely the result of a deterioration of oil and gas infrastructure due to a limited availability of equipment and the continuation of oil production without corresponding investments in the infrastructure to recover and utilize the associated gas.
  - In the United States, the flaring volumes and intensity increases occurred predominately in the shale-producing regions of the Permian and Eagle Ford. In the Permian, the increases were a result of the pressures put on the energy systems by unusually hot weather and ongoing maintenance of, and reliability issues with, midstream infrastructure. This led to an increase in overall flaring intensity in the United States of 11 percent, although the United States remains one of the countries with the lowest flaring intensities in the world. The flaring increase experienced in 2023 points to the importance of integrated management of oil and associated gas production. During periods when the operational capacity of gas collection and transportation infrastructure is reduced, non-routine flaring can quickly accumulate.
- **Promising reductions in gas flaring were achieved in Algeria and República Bolivariana de Venezuela.** In Algeria, flaring reduced by 5 percent and flaring intensity decreased by 3 percent. In República Bolivariana de Venezuela, flaring reduced by 4 percent and flaring intensity decreased by 10 percent. These reductions reflect efforts by the national oil companies to implement associated gas recovery projects, although República Bolivariana de Venezuela remains among the handful of countries with the highest flaring intensity globally.
- **Using the conventional approach to estimate greenhouse gas (GHG) emissions, the 148 bcm of gas flared in 2023 resulted in 381 million tonnes of carbon dioxide equivalent ($MMtCO_2e$) emissions, including 45 $MMtCO_2e$ in the form of unburned methane.** However, as flares may be operating inefficiently or may be unlit and venting, their "effective" destruction efficiency may be lower compared to the conventional estimates, leading to much higher methane emissions. If the "effective" destruction efficiency of flares is as much as 4 percent lower (94 percent), the methane emissions from gas flaring would be triple the conventional estimates.
- **The imported flare gas index—the weighted average of flaring intensity of oil imports from various origins in a given country—indicates that some European countries continue to be exposed to a high gas flaring intensity through their crude oil imports.** This index can also be used to inform governments and operators in oil and gas exporting countries of the possible implications of emerging carbon border adjustment policies and emissions transparency initiatives, such as the recent EU Methane Regulation and the EU's Carbon Border Adjustment Mechanism (CBAM).
- **The World Bank has developed a novel approach to detecting unlit flaring and attributing methane emissions to such events, illustrated by a case study in this report.** With further refinement, this approach could be used to assess the prevalence of unlit flaring globally and provide early warning to operators of potential unlit flaring events.

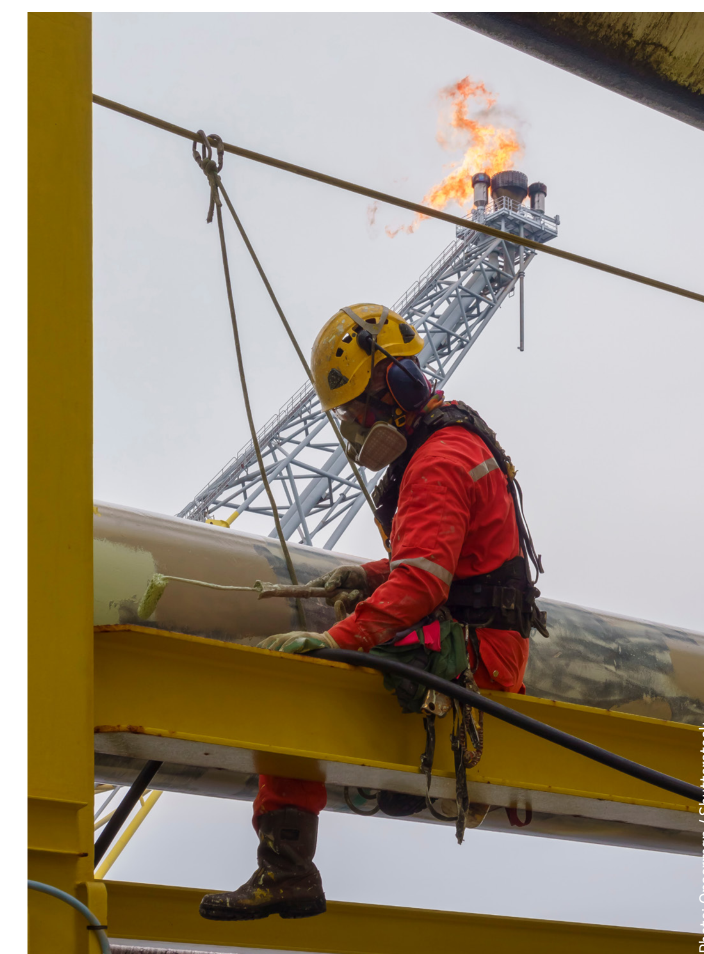


Photo: Opsorman / Shutterstock

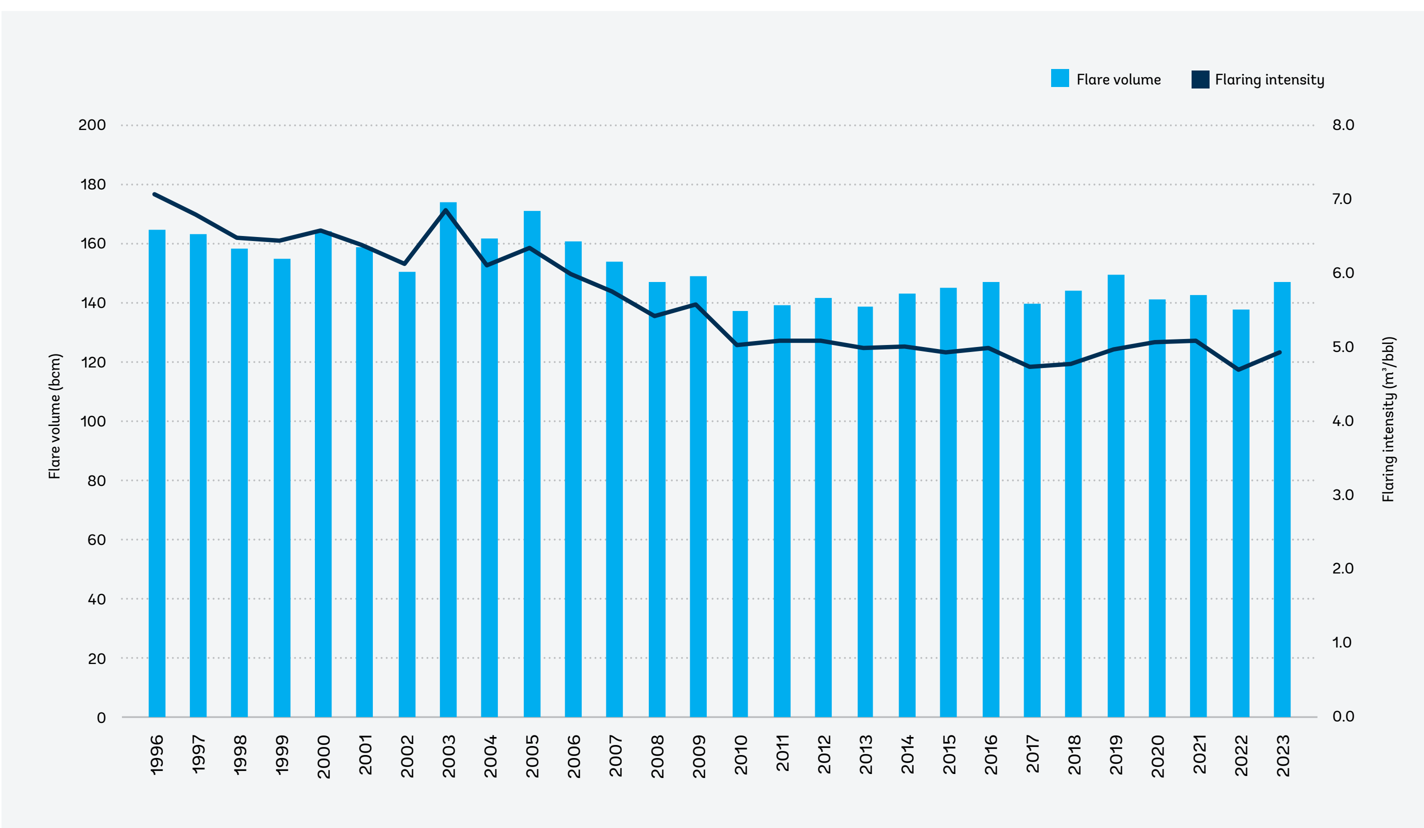
Global Perspective

Flare gas volume estimates explained.
The World Bank, together with the Colorado School of Mines, estimates flare gas volumes from individual oil and gas facilities around the world based on the satellite-mounted Visible Infrared Imaging Radiometer Suite of detectors (VIIRS) Nightfire data. Over the years, the organizations have collaborated to develop advanced algorithms to distinguish flaring from other hot sources, and to estimate flare volumes, considering atmospheric conditions such as cloud cover. Further information on the methodology can be found in Appendix A.

Satellite-based estimates show that gas flaring at upstream oil and gas facilities[2] increased from 139 billion cubic meters (bcm) in 2022 to 148 bcm in 2023 (figure 3), an increase of 9 bcm (7 percent). This more than reversed the reduction in gas flaring observed between 2021 and 2022, resulting in the highest volume recorded in the last five years.

At the same time, global oil production increased by just 1 percent from 80.4 million barrels of oil per day (MMbbl/d) in 2022 to 81.6 MMbbl/d in 2023 (figure 4). As a result, global flaring intensity (i.e., the amount of gas flared per barrel of oil produced), increased by 5 percent from 4.7 cubic meters per barrel (m^3/bbl) in 2022 to 5.0 m^3/bbl in 2023.

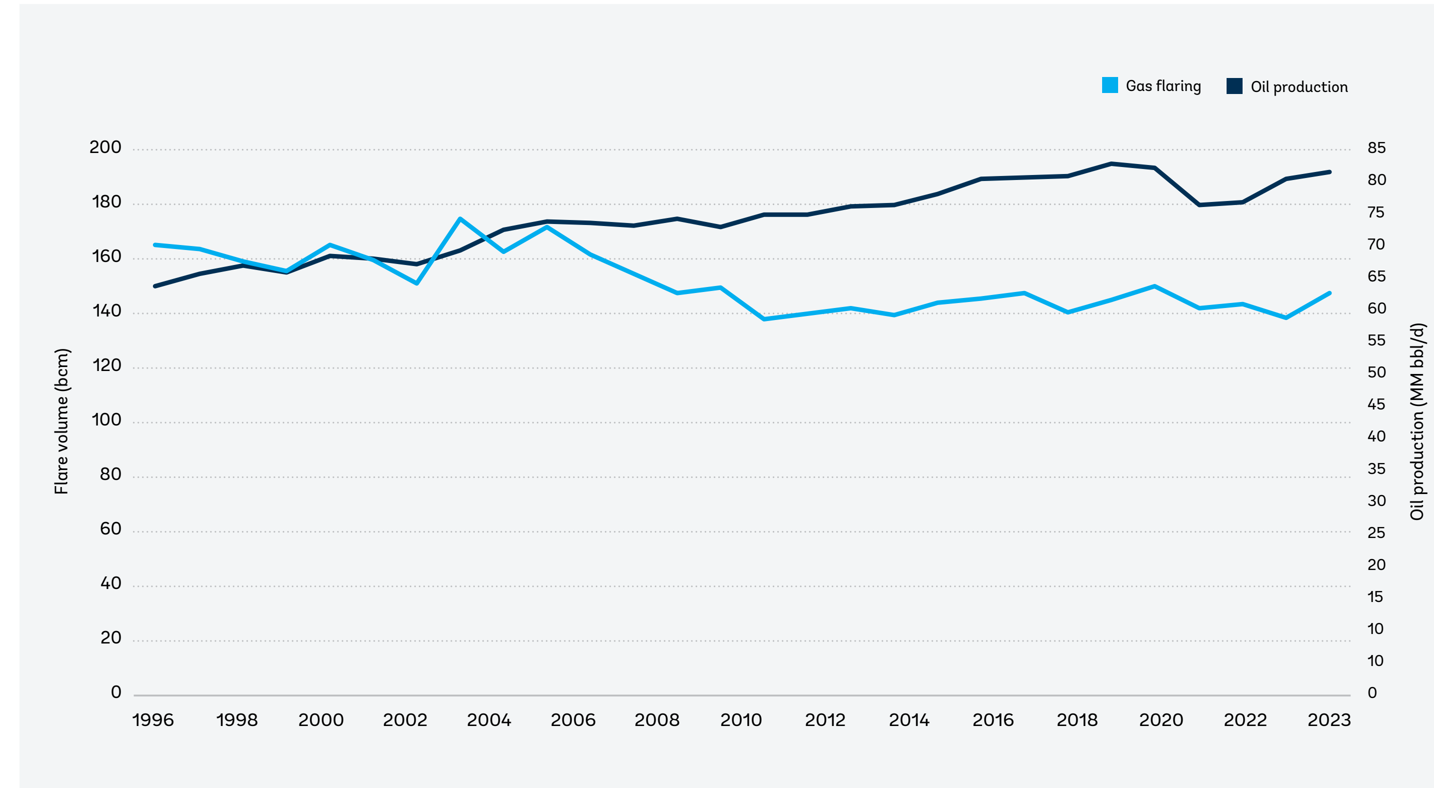
Figure 3. Global gas flaring at upstream oil and gas facilities, and flaring intensity, 1996–2023



Source: Payne Institute and Colorado School of Mines, NOAA, EIA, and World Bank
Note: bcm = billion cubic meters; MMbbl/d = million barrels of oil per day.

2 Upstream oil and gas facilities include oil and gas production facilities, and facilities that produce liquefied natural gas.

Figure 4. Global gas flaring and oil production, 1996–2023



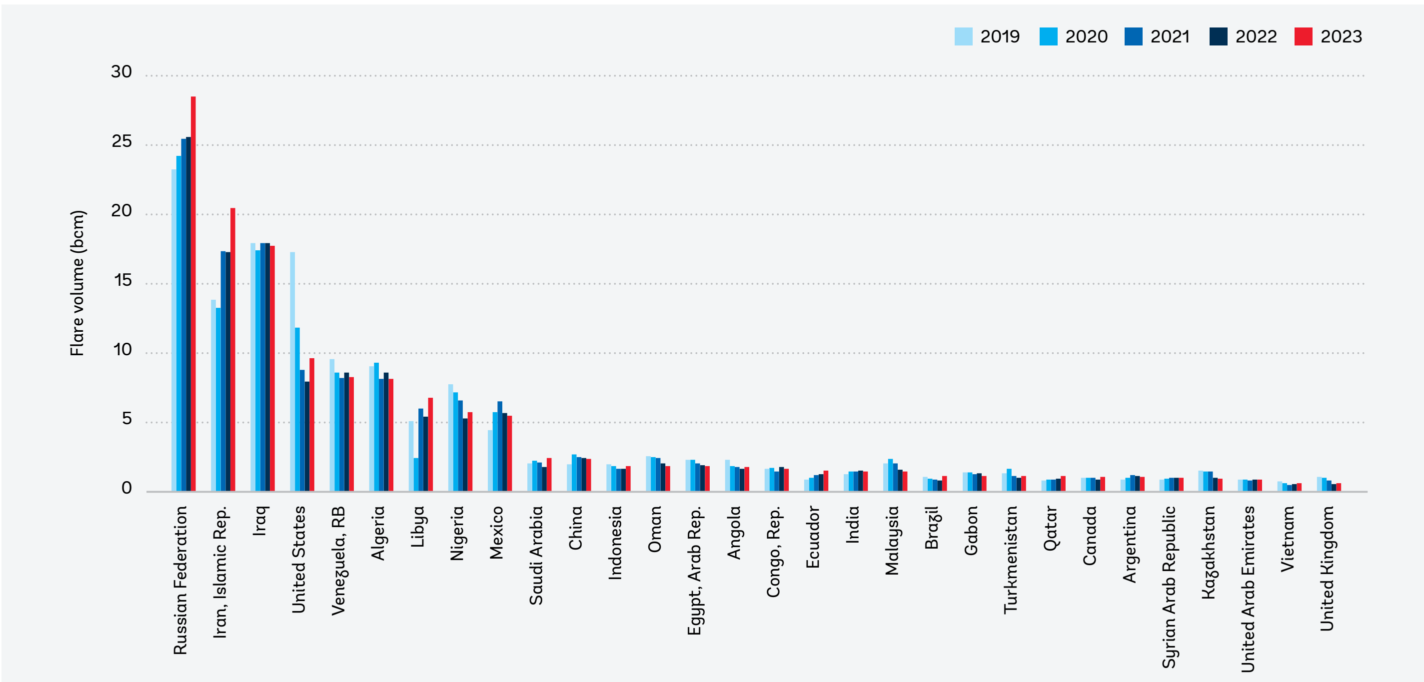
Source: Payne Institute and Colorado School of Mines, NOAA, EIA, and World Bank

For over a decade, gas flaring around the world has been dominated by nine countries: Russia, the Islamic Republic of Iran, Iraq, the United States, República Bolivariana de Venezuela, Algeria, Libya, Nigeria, and Mexico. In 2023, these top nine flaring countries were responsible for 75 percent of global gas flare volumes, while they accounted for just 46 percent of oil production (figure 5). Over 60 countries comprise the remaining 25 percent of global gas flare volumes.

Flaring intensity continues to be highest in countries affected by fragility, conflict, and violence such as the Syrian Arab Republic and República Bolivariana de Venezuela, although both have shown a steady improvement in flaring intensity over the past few years. Flaring intensity is also high in some other oil-producing countries, such as Gabon, Turkmenistan, and the Republic of Congo, which suggests there may be opportunities to implement measures to recover and utilize associated gas in these countries.

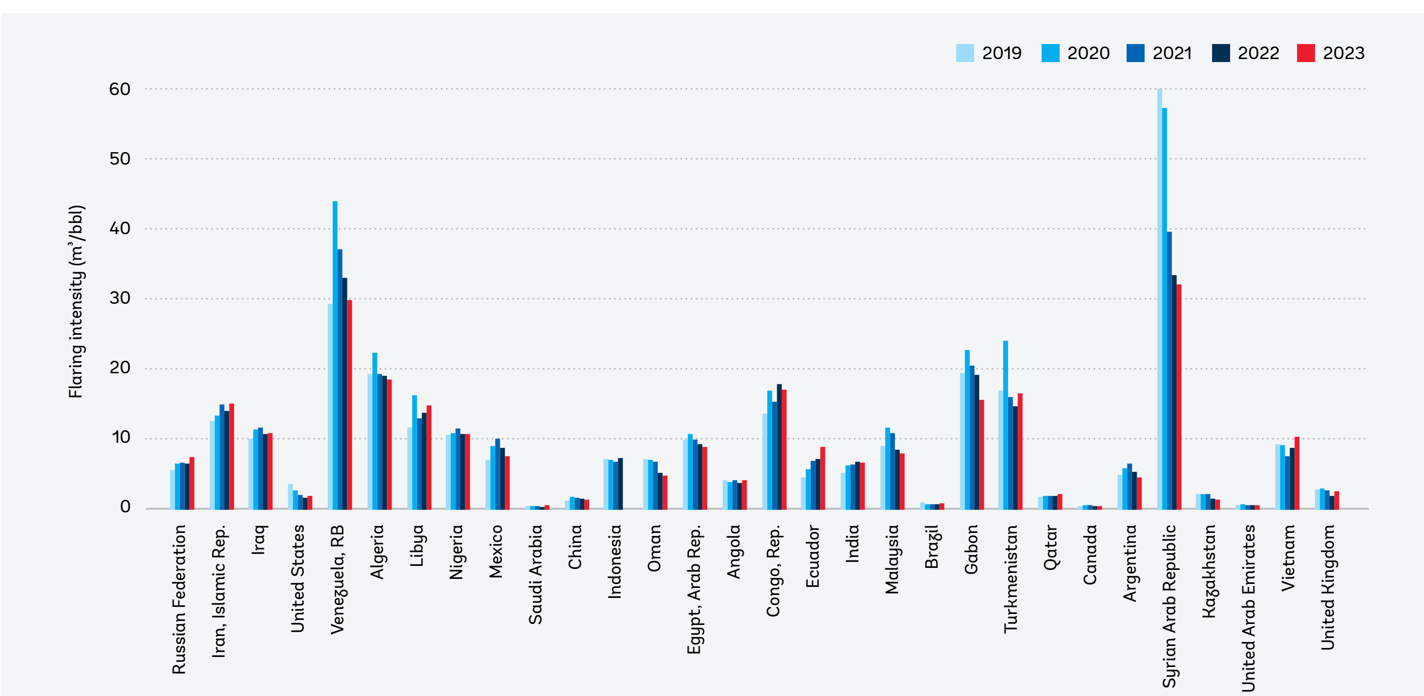
Among the top nine flaring countries, flaring intensity has increased in Russia, the Islamic Republic of Iran, Iraq, the United States, and Libya; has remained largely the same in Nigeria; and has decreased in República Bolivariana de Venezuela, Algeria, and Mexico (figure 6).

Figure 5. Flare volumes in the top 30 flaring countries (in order of 2023 flare volume)



Source: Payne Institute and Colorado School of Mines, NOAA, and World Bank

Figure 6. Flaring intensity in the top 30 flaring countries (in order of 2023 flare volume), 2019–23



Source: Payne Institute and Colorado School of Mines, NOAA, EIA, and World Bank

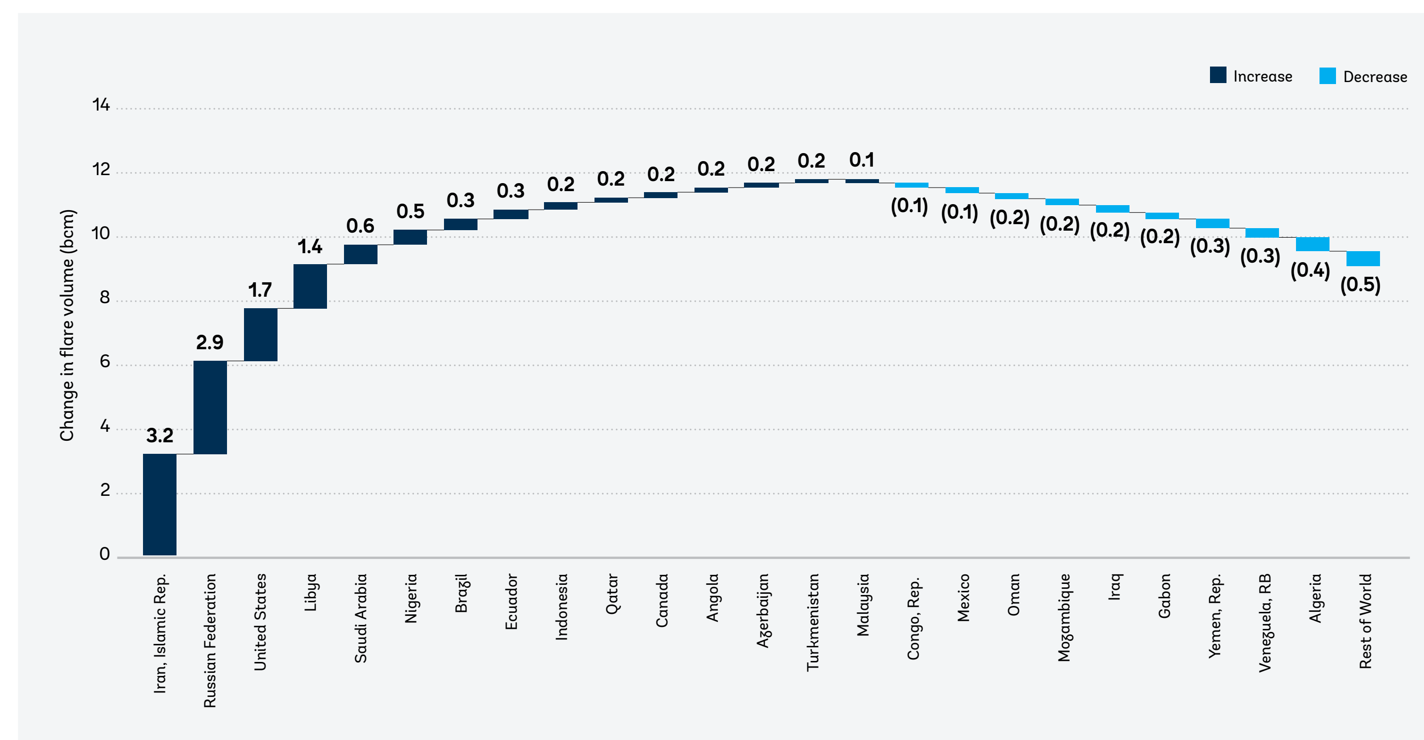
Flaring intensity explained.

Most of the gas flared globally is produced in association with crude oil (associated gas). Flaring intensity is the volume of gas flared, in cubic meters, per barrel of oil produced. It is typically calculated at a country level and, over time, serves as an indication of how well that country is doing to recover and utilize associated gas. If flaring intensity is declining (improving), it suggests a country is implementing measures to avoid gas flaring or effectively utilize the recovered gas. If it is increasing, it suggests the country has opportunities to recover and utilize more of its associated gas.

The gas-to-oil ratio of reservoirs varies significantly across basins and regions and, as a result, it is not meaningful to directly compare the flaring intensity of one country with another. However, flaring intensity can be a useful indicator of improving or deteriorating performance within a particular country or region.

Between 2022 and 2023, the largest increase in flaring occurred in four countries (in order of the flare volume increase): the Islamic Republic of Iran, Russia, the United States, and Libya (figure 7). Together, these countries accounted for a 9 bcm increase in flare volumes. The increase in these four countries is larger than the total flare volume in Algeria, the sixth-highest flaring country last year, and led to an additional 23 million tonnes of carbon dioxide equivalent (MMtCO_2e) of GHG emissions, equivalent to putting 5 million new cars on the road.

Figure 7. Change in flare volume across countries where it was significant, and rest of world, 2022–23



Source: Payne Institute and Colorado School of Mines, NOAA, and World Bank

Spotlight Countries

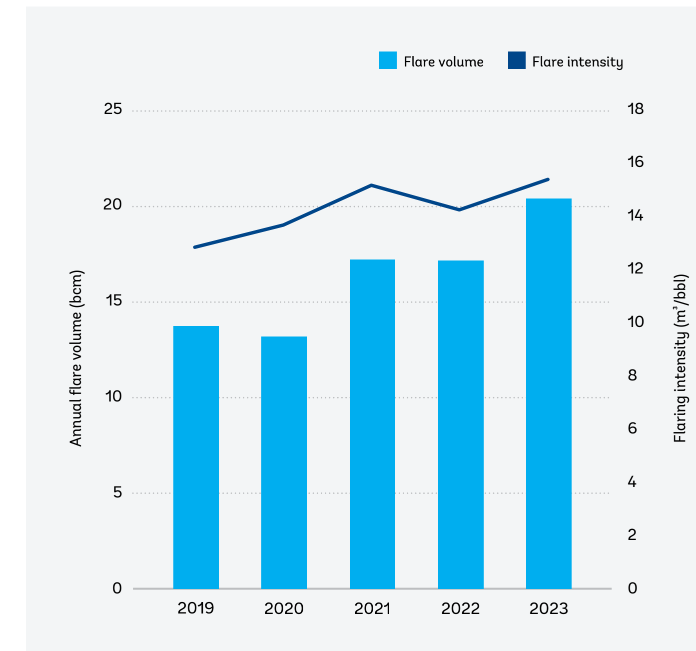
The Islamic Republic of Iran and Libya

In 2023, the largest increase in the volume of gas flared was observed in the Islamic Republic of Iran (figure 8), where flaring increased by 3.2 bcm (19 percent), while oil production increased by 10 percent. This resulted in an 8 percent increase in flaring intensity from 14.3 m³/bbl in 2022 to 15.4 m³/bbl in 2023, the highest number recorded for the Islamic Republic of Iran since satellite-based estimates of flaring began in 2012.

In Libya, gas flaring increased by 1.4 bcm (25 percent) in 2023, while oil production increased by 16 percent, resulting in an 8 percent increase in flaring intensity from 14.0 m³/bbl in 2022 to 15.2 m³/bbl.

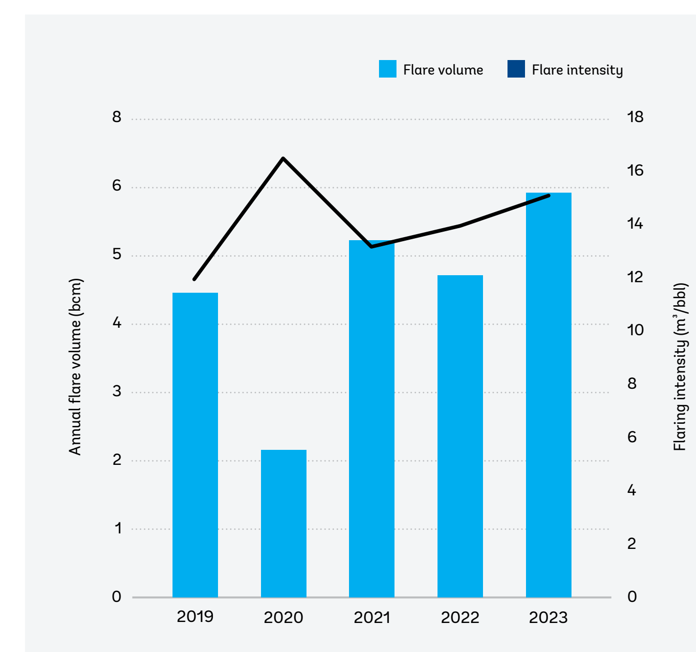
When associated gas is flared due to insufficient infrastructure to recover and utilize the gas, or an insufficient investment to maintain such infrastructure, it is routine gas flaring. In both countries, the flaring increases are associated with an increase in oil production. The increased flaring intensity suggests that there has been a lack of corresponding investment in gas infrastructure and utilization.

Figure 8. Flare volume and flaring intensity in the Islamic Republic of Iran, 2019–23



Source: Payne Institute and Colorado School of Mines, NOAA, EIA, World Bank

Figure 9. Flare volume and flaring intensity in Libya, 2019–23



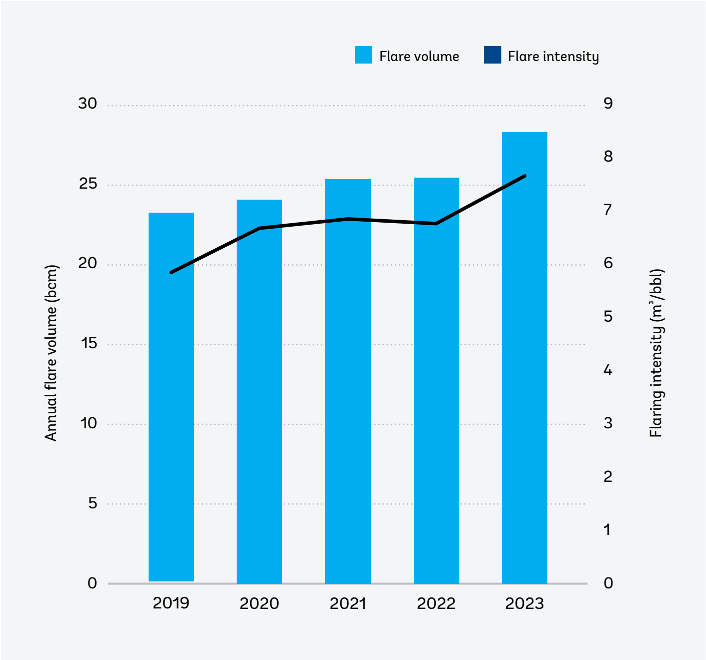
Source: Payne Institute and Colorado School of Mines, NOAA, EIA, World Bank

Russia

In Russia, flaring increased by 2.9 bcm (11 percent) during 2023 despite a decrease in oil production of 2 percent (figure 10). This resulted in a 13 percent increase in flaring intensity from 6.8 m^3/bbl in 2022 to 7.7 m^3/bbl in 2023, the highest number recorded since the World Bank began systematically tracking satellite-based estimates of flaring in 2012.

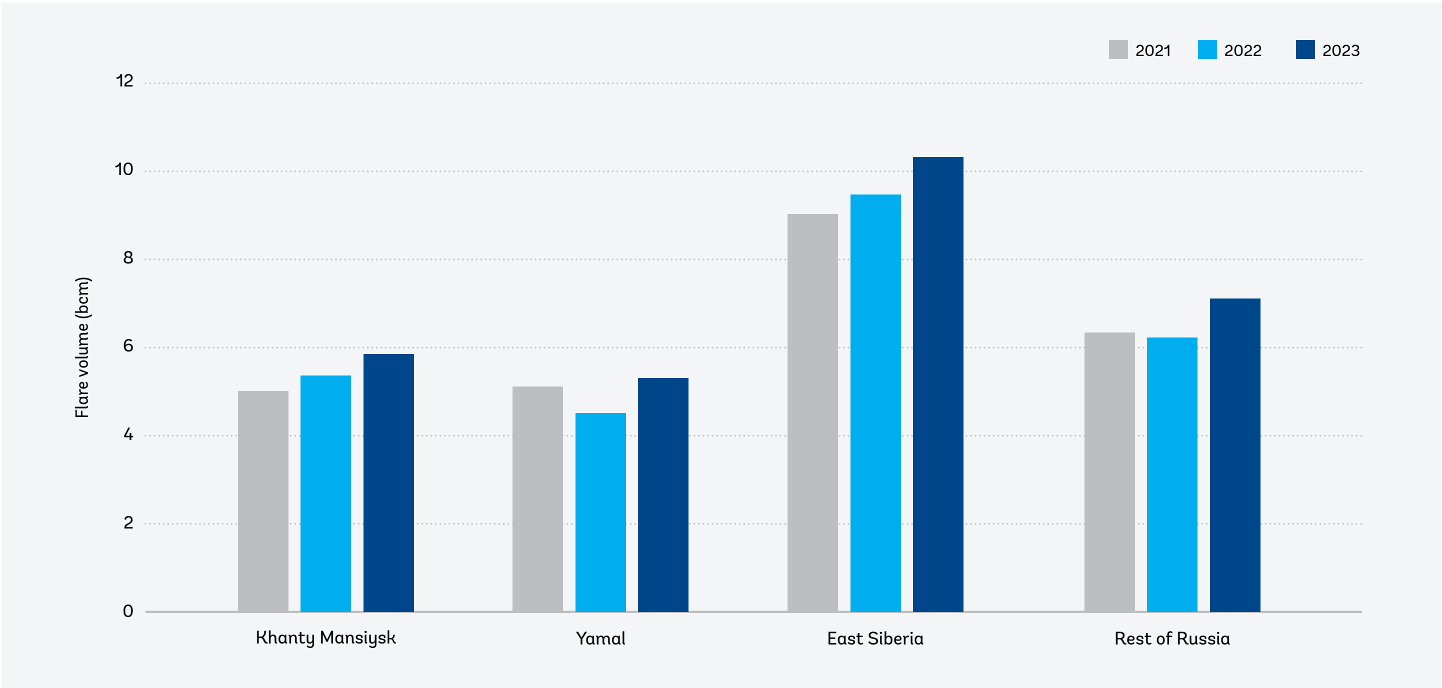
The increase in flaring occurred across each of the main oil-producing regions in Russia (figure 11). This suggests the issues that led to flaring were systemwide rather than isolated in nature. The increase is likely to have resulted from a prioritization of oil production without corresponding investments in the infrastructure to recover and utilize the associated gas. It is also likely that there has been a deterioration in the condition of oil and gas facilities caused by the limited availability of equipment, which is in part a consequence of supply chain disruptions due to the ongoing invasion of Ukraine.

Figure 10. Flare volume and flaring intensity in the Russian Federation, 2019–23



Source: Payne Institute and Colorado School of Mines, NOAA, EIA, World Bank

Figure 11. Flare volumes by region in the Russian Federation, 2021–23



Source: Payne Institute and Colorado School of Mines, NOAA, World Bank

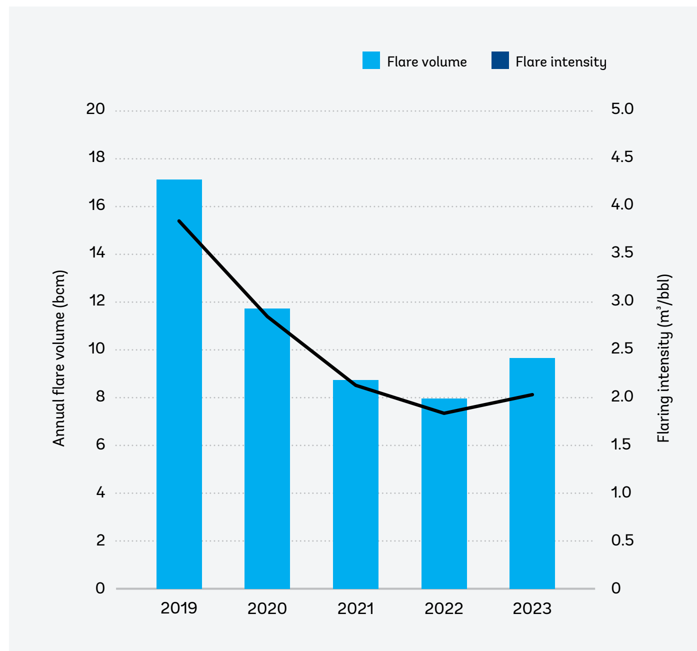
United States

In 2023, the United States experienced a 1.7 bcm (21 percent) increase in gas flaring (figure 12). Oil production increased by 9 percent, which resulted in an 11 percent increase in flaring intensity from 1.8 m³/bbl in 2022 to 2.0 m³/bbl in 2023. Notwithstanding this increase, the United States has one of the lowest flaring intensities in the world.

In the United States, 90 percent of all flaring occurs on state-regulated lands. Facilities located on federal land are responsible for the remaining 10 percent of gas flare volumes and are regulated at the federal level. During 2023, flaring on federal land decreased by 12 percent, while it increased by 26 percent on state-regulated lands.

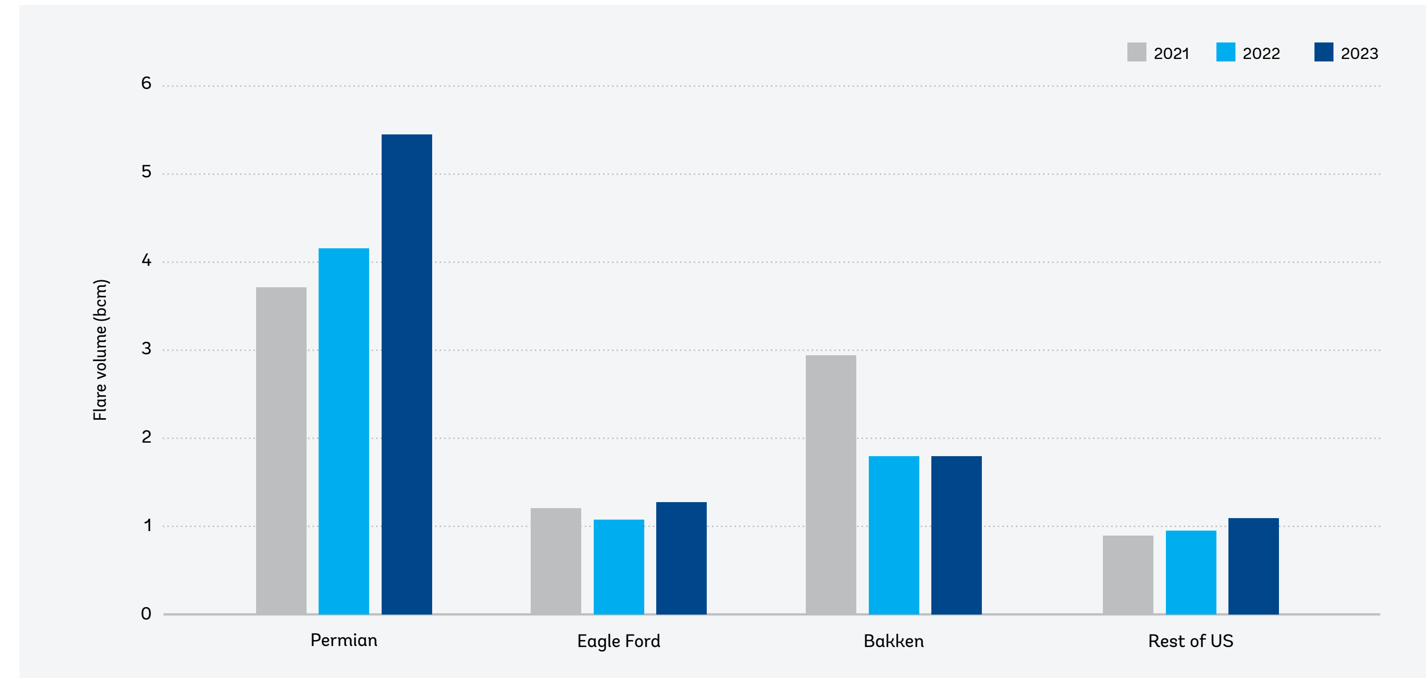
A breakdown of flaring data across major oil-producing basins in the United States shows that the increase in flare volumes and flaring intensity experienced in 2023 occurred predominantly in the shale-producing regions of the Permian and Eagle Ford (figures 13 and 14). The Permian basin (figure 15) stretches from southeast New Mexico into Texas and the Eagle Ford stretches along southern Texas.

Figure 12. Flare volume and flaring intensity in the United States, 2019–23



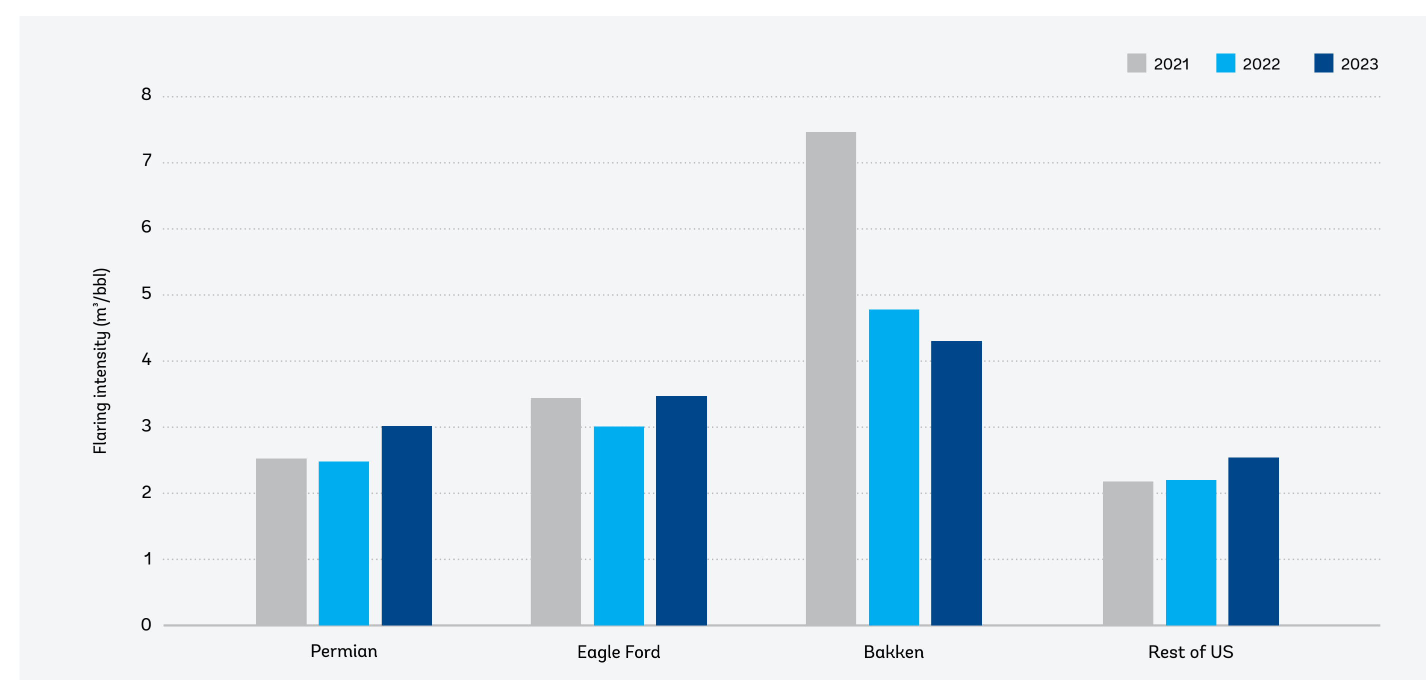
Source: Payne Institute and Colorado School of Mines, EIA, NOAA, and World Bank

Figure 13. Flare volumes in the Permian, Eagle Ford, and Bakken regions, and the rest of the United States



Source: Payne Institute and Colorado School of Mines, NOAA, and World Bank

Figure 14. Flaring intensity in the Permian, Eagle Ford, and Bakken regions, and the rest of the United States

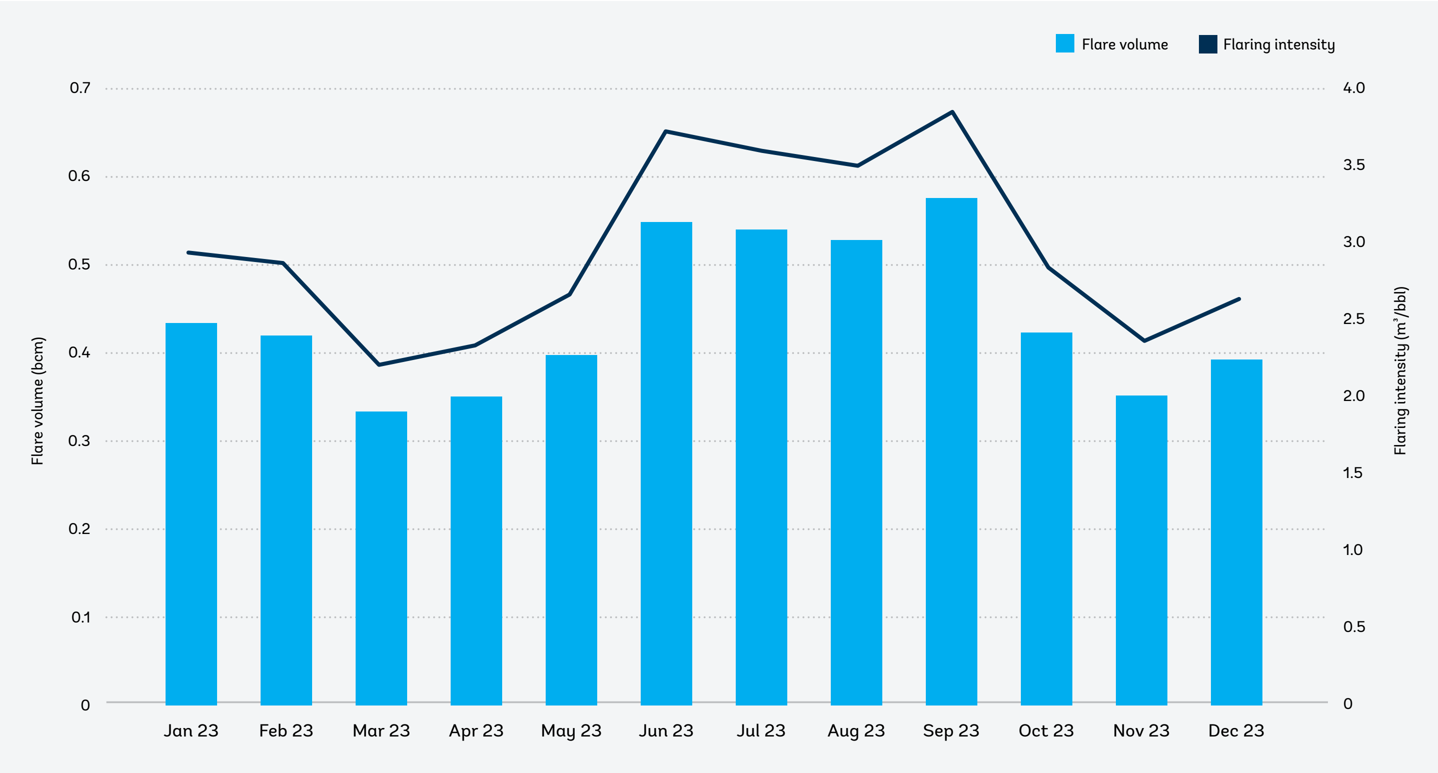


Source: Payne Institute and Colorado School of Mines, EIA, NOAA, and World Bank

In the Permian, both flare volume and flaring intensity increased during the summer between June and September. The summer of 2023 was the second hottest on record for Texas.[3] Prolonged high temperatures resulted in significant pressure on the electrical grid, which led to curtailing of power supply to electrically-driven gas compressor facilities and rendered parts of the gas takeaway infrastructure inoperable. While some safety flaring to depressurize facilities is often necessary in these situations, operators who elected to maintain oil production would have increased flaring at their production sites. In addition, for some operators in the region, ongoing maintenance and operational issues with part of the midstream network further reduced gas takeaway capacity, which led to additional increases in flaring for operators who maintained oil production during this period. This experience may also suggest the need for operators worldwide to consider the ability of oil and gas infrastructure to withstand the emerging impact of climate change hazards in their planning and design solutions.

The data on the Permian region suggests that during periods of gas takeaway constraint, due to unexpected incidents or routine maintenance, gas flaring volumes can accumulate rapidly. This underlines the importance of following industry best practices and managing oil (and associated gas) production within the handling capacity of existing gas infrastructure. In 2023 and 2024, new federal rules were finalized that enhance requirements to end routine gas flaring as well as reduce methane venting and leaks, including Environmental Protection Agency requirements on new and existing oil and gas facilities nationwide and Department of Interior requirements for oil and gas operations on federal and Tribal lands. The rules also encourage states to further limiting methane emissions from existing sources.

Figure 15. Monthly flare volumes and flaring intensity in the US Permian region, 2023



Source: Payne Institute and Colorado School of Mines, NOAA, EIA, and World Bank

3 National Oceanic and Atmospheric Administration, National Weather Service website, accessed on May 17, 2024. https://www.weather.gov/lub/events-2023-2023summer-heat

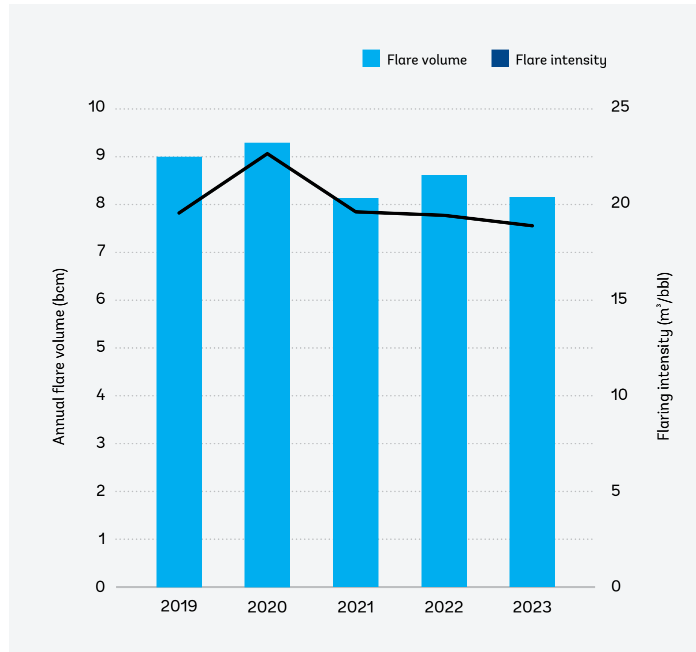
Photo: Photo smile / Shutterstock

Algeria

The largest reduction in flaring in 2023 was observed in Algeria, where flare volumes decreased by 0.4 bcm (5 percent). Although oil production also decreased by 2 percent, there was an overall 3 percent reduction in flaring intensity in Algeria (figure 16), continuing the improvement in flaring intensity achieved over the last three years.

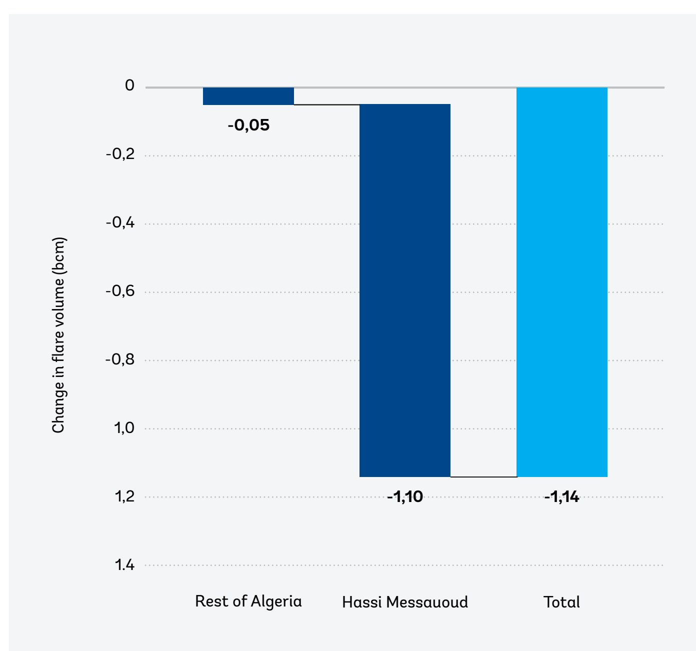
Since 2020, Sonatrach, Algeria's national oil company, has implemented several flare gas recovery projects in Hassi Messaoud (figure 17), the largest oil field in Algeria. In 2023, the company committed to projects in other fields, including at the Tiguentourine, Ohanet, and Tin-Fouye-Tabankort regions, which are anticipated to lead to further reductions in flare volumes in Algeria.

Figure 16. Flare volume and flaring intensity in Algeria, 2019–23



Source: Payne Institute and Colorado School of Mines, NOAA, EIA, World Bank

Figure 17. Change in flare volume split between Hassi Messaoud and the rest of Algeria, 2020–23



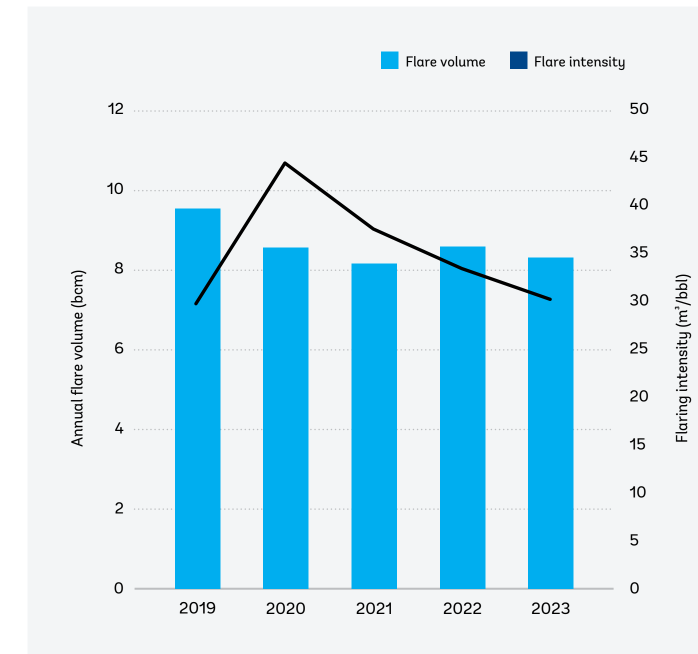
Source: Payne Institute and Colorado School of Mines, NOAA, World Bank

República Bolivariana de Venezuela

During 2023, gas flaring volumes in República Bolivariana de Venezuela decreased by 0.3 bcm (4 percent) while oil production increased by 7 percent, leading to a 10 percent reduction in flaring intensity, the third consecutive year of flaring intensity reduction (figure 18). Typically, a rise in oil production would result in an increase in gas flaring if measures were not implemented to recover and utilize associated gas. The continued fall in flaring intensity in República Bolivariana de Venezuela suggests an ongoing effort to manage associated gas. Notwithstanding these positive developments, República Bolivariana de Venezuela continues to be one of the top nine flaring countries and has one of the highest flaring intensities in the world.

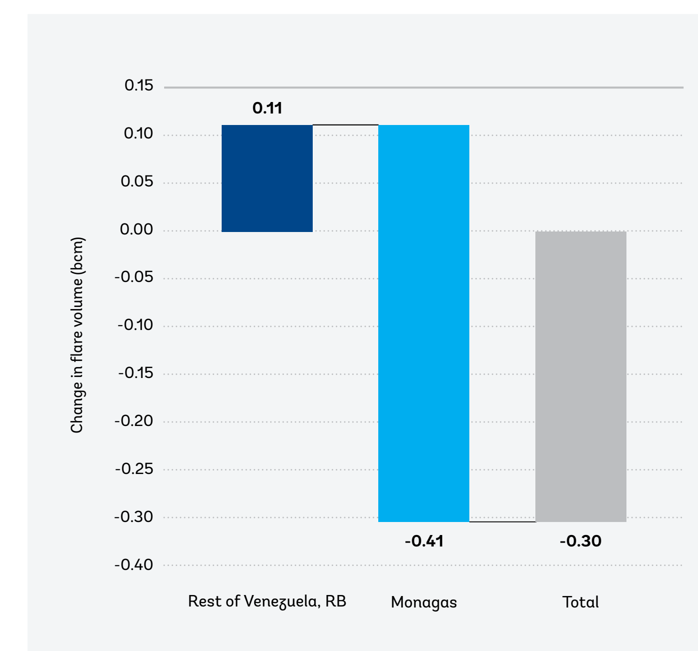
The reductions in flare gas volumes in 2023 occurred almost exclusively at oil fields in the north of Monagas State (figure 19). Petróleos de Venezuela S.A (PDVSA), the national oil company of República Bolivariana de Venezuela, reports implementing large-scale projects to manage associated gas in the region.

Figure 18. Flare volume and flaring intensity in República Bolivariana de Venezuela, 2019–23



Source: Payne Institute and Colorado School of Mines, NOAA, EIA, World Bank

Figure 19. Change in flare volume, split between Monagas State and the rest of República Bolivariana de Venezuela, 2022–23



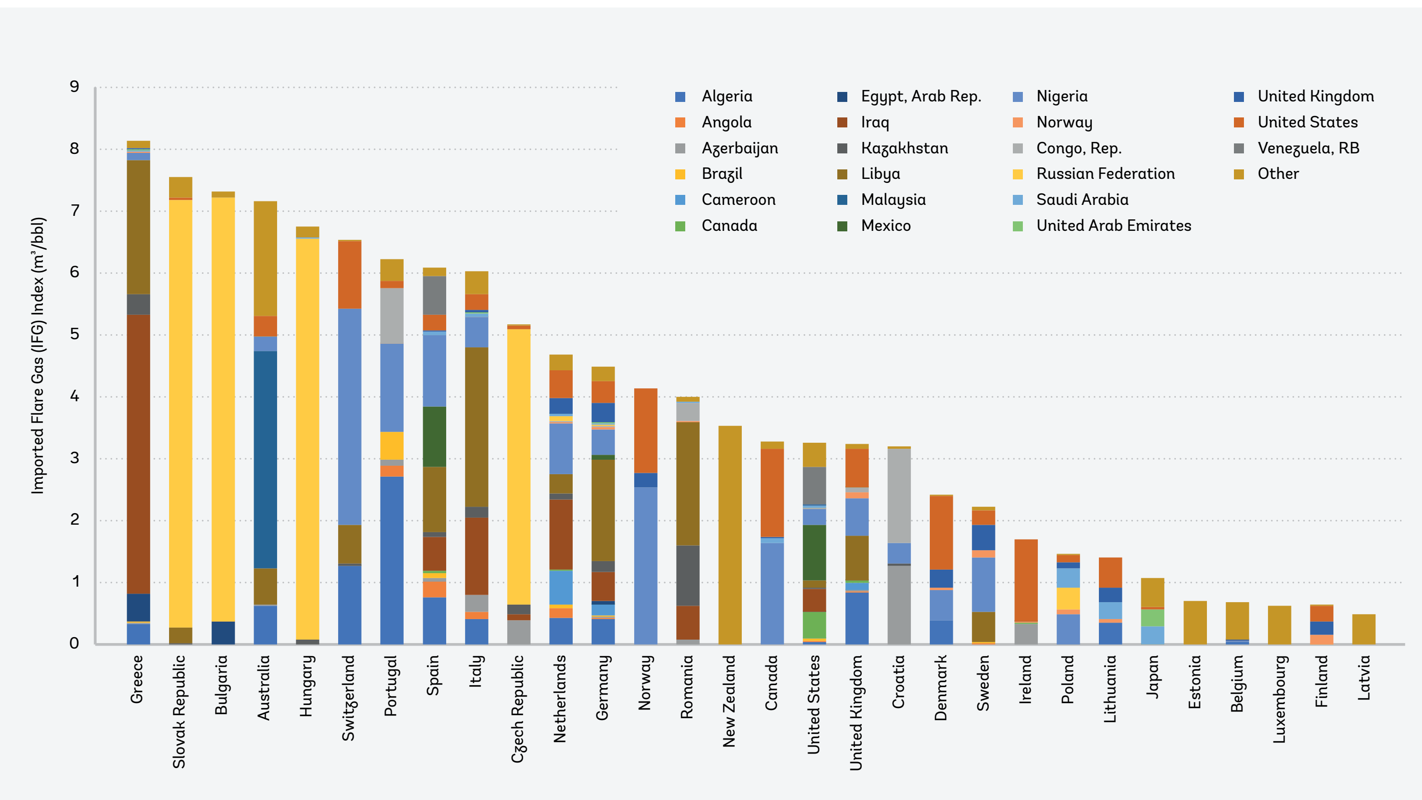
Source: Payne Institute and Colorado School of Mines, NOAA, World Bank

Imported Flare Gas Index

In addition to flare volume and flaring intensity, the World Bank has developed a third metric, the Imported Flare Gas (IFG) Index of crude-importing countries, which is the weighted average flaring intensity of oil imports based on the country of origin. The IFG Index is based on the premise that if a country is importing crude oil, it also shares responsibility for the flaring intensity of those imported barrels.

The IFG Index aims to help governments and companies in importing countries gauge the potential additional costs of their hydrocarbon imports, which will change the ranking of the effective prices paid for crude oil, refined products, and natural gas imported compared to that without the carbon adjustment. The same information also informs governments and operators in oil and gas exporting countries about the possible implications of the emerging carbon border adjustment policies and emission transparency initiatives, such as the recent EU Methane Regulation[4] and the EU's Carbon Border Adjustment Mechanism (CBAM)[5], which is expected to start covering oil and gas imports in 2030.

Figure 20. Imported Flare Gas Index of UNFCCC Annex 1 countries with a breakdown of countries of origin

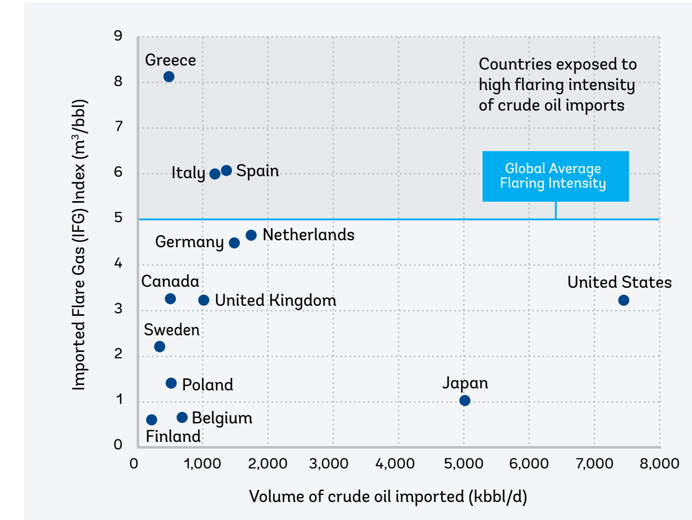


Source: Payne Institute and Colorado School of Mines, NOAA, World Bank, COMTRADE, and EIA.
Note: IFG = Imported Flare Gas; UNFCCC = United Nations Framework Convention on Climate Change.

Analysis of the 2023 data indicates that countries such as Greece, Italy, and Spain are "exposed" to high levels of gas flaring associated with the production of large volumes of crude oil they import from countries with a high flaring intensity, such as Iraq, Mexico, Nigeria, and Libya (figures 20 and 21). Under the new EU Methane Regulation and the proposals to include oil and gas imports under CBAM, the carbon intensity of crude oil and gas exports to Europe will face greater scrutiny. GHG-emissions–intensive production, such as crude oil production associated with high flaring intensity, may face limits to their associated carbon dioxide and methane emissions and, under CBAM, will be impacted by the carbon price paid on the emissions embedded in the oil and gas produced.

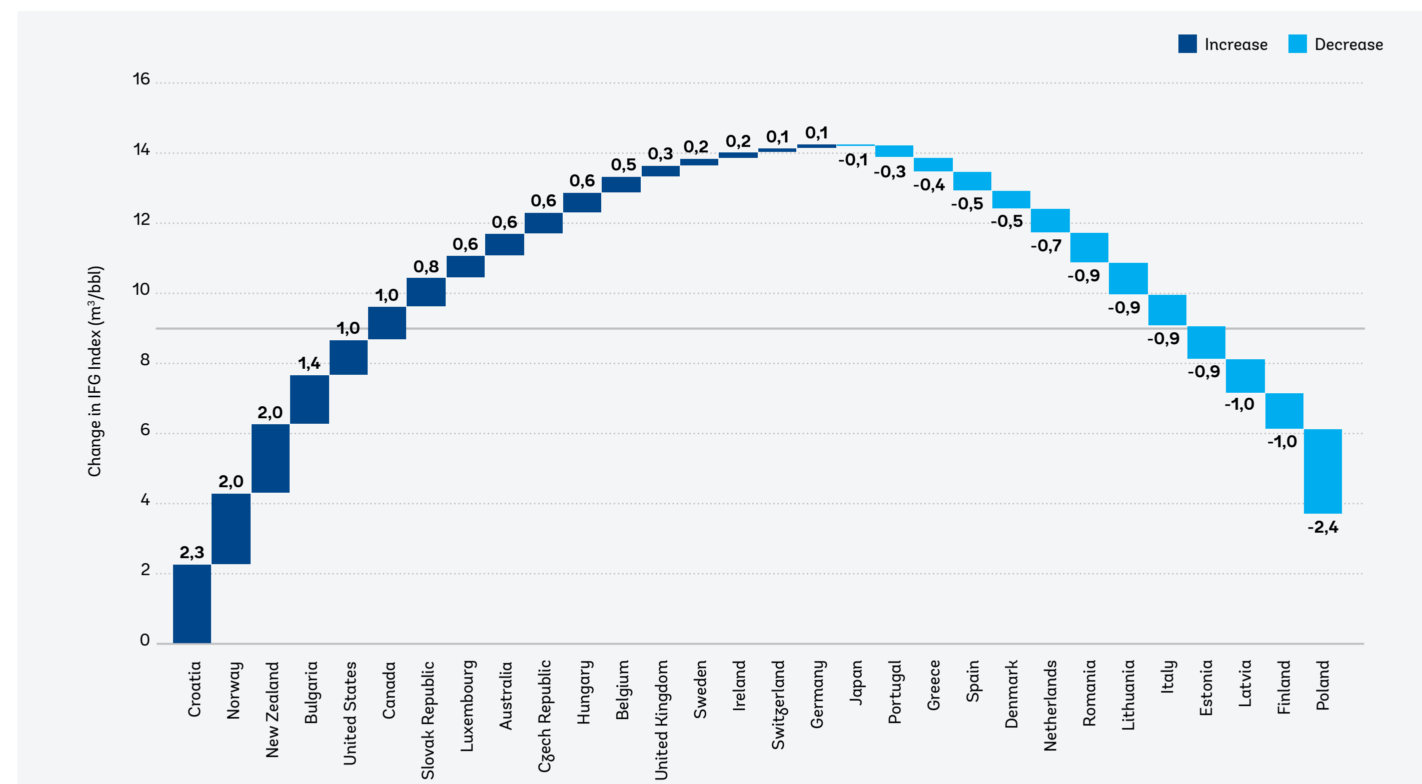
At the level of individual countries, geopolitical and commercial movements in global oil markets have led to a redistribution of imported flaring associated with crude oil from certain countries to others (figure 22).

Figure 21. Imported Flare Gas versus volume of crude oil imports in countries importing more than 250 kbbl/d



Source: Payne Institute and Colorado School of Mines, NOAA,World Bank, COMTRADE, EIA.
Note: The global flaring intensity indicated is 5m³/bbl. kbbl/d = kilobarrels per day

Figure 22. Change in Imported Flare Gas Index of UNFCCC Annex 1 countries, 2022–23



Source: Payne Institute and Colorado School of Mines, NOAA, World Bank, COMTRADE, EIA.

4 A new European Union (EU) Regulation to reduce energy sector methane emissions in Europe and in the global supply chains aims to contribute to delivering the European Green Deal and reducing European net GHG emissions by at least 55 percent by 2030. The regulation will require the oil and gas industry to properly measure, monitor, report, and verify their methane emissions according to the highest monitoring standards and take action to reduce them; European Commission, "Commission Welcomes Deal on First-Ever EU Law to Curb Methane Emissions in the EU and Globally," accessed May 17, 2024, https://ec.europa.eu/commission/presscorner/detail/en/IP_23_5776, accessed on May 17, 2024.

5 "The EU's Carbon Border Adjustment Mechanism (CBAM) is the EU's tool to put a fair price on the carbon emitted during the production of carbon intensive goods that are entering the EU, and to encourage cleaner industrial production in non-EU countries," : https://taxation-customs.ec.europa.eu/carbon-border-adjustment-mechanism_en

Unburned Potential: Methane Emissions from Gas Flaring

Conventional estimates of methane emissions from gas flaring, such as those used in this report, are based on the following two key assumptions:

1. Flares operate with a "methane destruction efficiency" of 98 percent, which means that 98 percent of the methane in the flare gas stream is combusted and converted to carbon dioxide and water, and 2 percent of the methane is directly released into the atmosphere unburned.
2. Flares are lit and operating properly all of the time.

However, several recent publications challenge these conventional assumptions and indicate that gas flaring may be responsible for a significantly larger amount of methane emissions than previously thought. These findings have attracted the attention of the international community and highlight the need for further research into the issue of methane emissions from flaring.

Flares are designed to safely dispose of large volumes of gas quickly; with few exceptions,[9] they should always be lit and well maintained. However, in practice, a flare could become temporarily unlit, for example, due to strong winds, a pilot flame malfunction, or low-quality gas "snuffing" the flare. In such cases, it is a good practice for the operators to swiftly ensure the flare is reignited. At unmanned facilities, unlit flaring may continue for a period of time until resources are deployed to reignite the flare.

The persistent, direct release of methane emissions into the atmosphere due to unlit flaring is an irresponsible practice. Therefore, it is important to ensure that operators adopt appropriate detection and data transmission tools that help raise awareness of any unlit flares and enable the operator to promptly reignite them.

This section describes the initial efforts by GFMR to develop a more robust approach to establishing the prevalence of unlit flaring globally and correctly attributing methane emissions to unlit flaring events, and presents a case study utilizing this approach.

Uncertainty regarding emissions from flaring explained.
A study[6] on the shale basins of the United States found that many of the flares sampled had methane destruction efficiencies lower than 98 percent (meaning more methane was being released) and reported many flares to be unlit and therefore directly venting methane to the atmosphere. Yet there are several reasons why flares in these unconventional basins may not be representative of flares globally. Further research is needed to examine both flare destruction efficiency and the prevalence of unlit flaring at conventional oil and gas facilities.
In addition, several scientific papers have sought to attribute methane plumes to unlit flaring events.[7,8] An internal review by the World Bank has found that, in many cases, unlit flaring was not the source of these emissions. These findings support the need for further research and have been shared with the groups involved in the studies.

6 Genevieve Plant, Eric Kort, Adam Brandt, Yuanlei Chen, Graham Fordice, Alan Negron, Stefan Schwietzke, Mackenzie Smith, and Daniel Zavala-Araiza, "Inefficient and Unlit Natural Gas Flares Both Emit Large Quantities of Methane," Science 377, no. 6614 (2022): 1566–71.

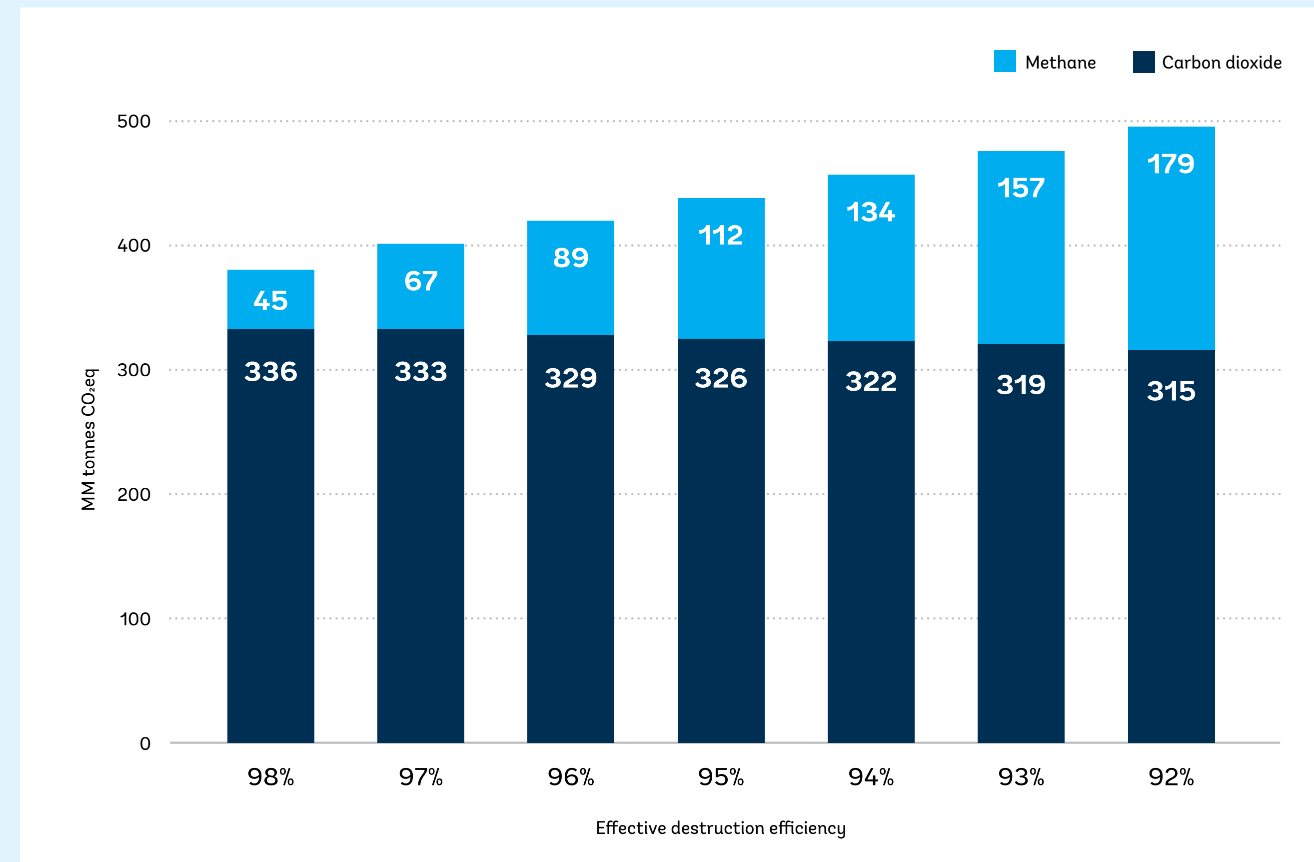
7 Itziar Irakulis-Loitxate, Luis Guanter, Joannes D. Maasakkers, Daniel Zavala-Araiza, and Ilse Aben, "Satellites Detect Abatable Super-Emissions in One of the World's Largest Methane Hotspot Regions," Environmental Science and Technology 56, no. 4 (2022): 2143–52.

8 Stijn Naus, Joannes D. Maasakkers, Ritesh Gautam, Mark Omara, Roelof Stikker, Allard Veenstra, Brian Nathan, Itziar Irakulis-Loitxate, Luis Guanter, Sudhanshu Pandey, Marianne Girard, Alba Lorente, Tobias Borsdorff, and Ilse Aben, "Assessing the Relative Importance of Satellite-Detected Methane Superemitters in Quantifying Total Emissions for Oil and Gas Production Areas in Algeria," Environmental Science and Technology 57, no. 48 (2023): 19545–56.

9 Facilities that have adopted closed or zero flare technology operate with no flare under normal operating conditions, with the flare system closed. The flare is only ignited, via a highly reliable ignition system, during process upset conditions to safely dispose of gas. This technology is common in the Norwegian offshore environment but is currently very rare in other locations.

Flare methane destruction efficiency explained.
Using the conventional assumption of 98 percent and assuming that flares are lit at all times, the volume of gas flared globally during 2023 resulted in 381 $MMtCO_2e$, comprising 336 MMt in the form of carbon dioxide and 45 $MMtCO_2e$ due to unburned methane.[10,11]
Accounting for flares that may be operating inefficiently and flares that may be unlit and venting, if the effective destruction efficiency is just 1 percent lower (97 percent rather than 98 percent), the resulting methane emissions would increase by 50 percent. For example, if the effective destruction efficiency is 4 percent lower (94 percent), the methane emissions from gas flaring would be triple conventional estimates. This highlights the importance of additional work to better understand flare emissions.

Figure 23. Greenhouse gas emissions arising from the 148 bcm of gas flared in 2023, comparing the 98 percent conventional assumption with a range of effective destruction efficiency scenarios



Source: Payne Institute and Colorado School of Mines, NOAA, and World Bank.

10 Assumes a flare gas methane content of 80 percent and a methane global warming potential of 28 over a 100-year period, consistent with the Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report (AR5).

11 Using the 20-year global warming potential value of 84 (AR5), methane emissions from flaring increase to 134 $MMtCO_2e$.

Case Study - Using Satellite Data to Detect Unlit Flares

The World Bank has developed an approach using satellite detections of both flaring and methane emissions to identify instances of unlit flares. This approach is demonstrated in the following example of an unlit flare at a facility close to an unnamed gas field in Central Asia (figure 24).

Satellite imagery of the facility shows a visible, lit flare at this facility in an image captured in July 2017. In a subsequent image captured in November 2021, there is no flame visible at the flare stack (figure 25).

The satellite-mounted Visible Infrared Imaging Radiometer Suite (VIIRS) Nightfire time series shows a lit flare at this facility from June 2016 until a sudden stop in February 2021 (with a short break during late 2016). VIIRS observations have been cross-referenced against heat detections by the Sentinel 2 and Landsat 8/9 satellites, which also support a cessation of flaring in February 2021 (figure 26).

To investigate if the flare became unlit at this time, the World Bank collated methane emissions data from Kayrros SAS, a commercial provider of high-resolution satellite data, from a publicly available database developed by Carbon Mapper[12], and obtained data from the International Methane Emissions Observatory (IMEO) Methane Alert and Response System (MARS).[13] The methane emissions data show numerous detections near the flare stack (figure 25). Combining flaring and methane detections in the vicinity of the flare stack clearly shows the cessation of flaring followed by numerous methane detections, providing strong evidence that the flare was unlit and venting methane at this facility (figures 27 and 28).

Figure 24. High-resolution satellite image of an unnamed facility in Central Asia showing a lit flare stack

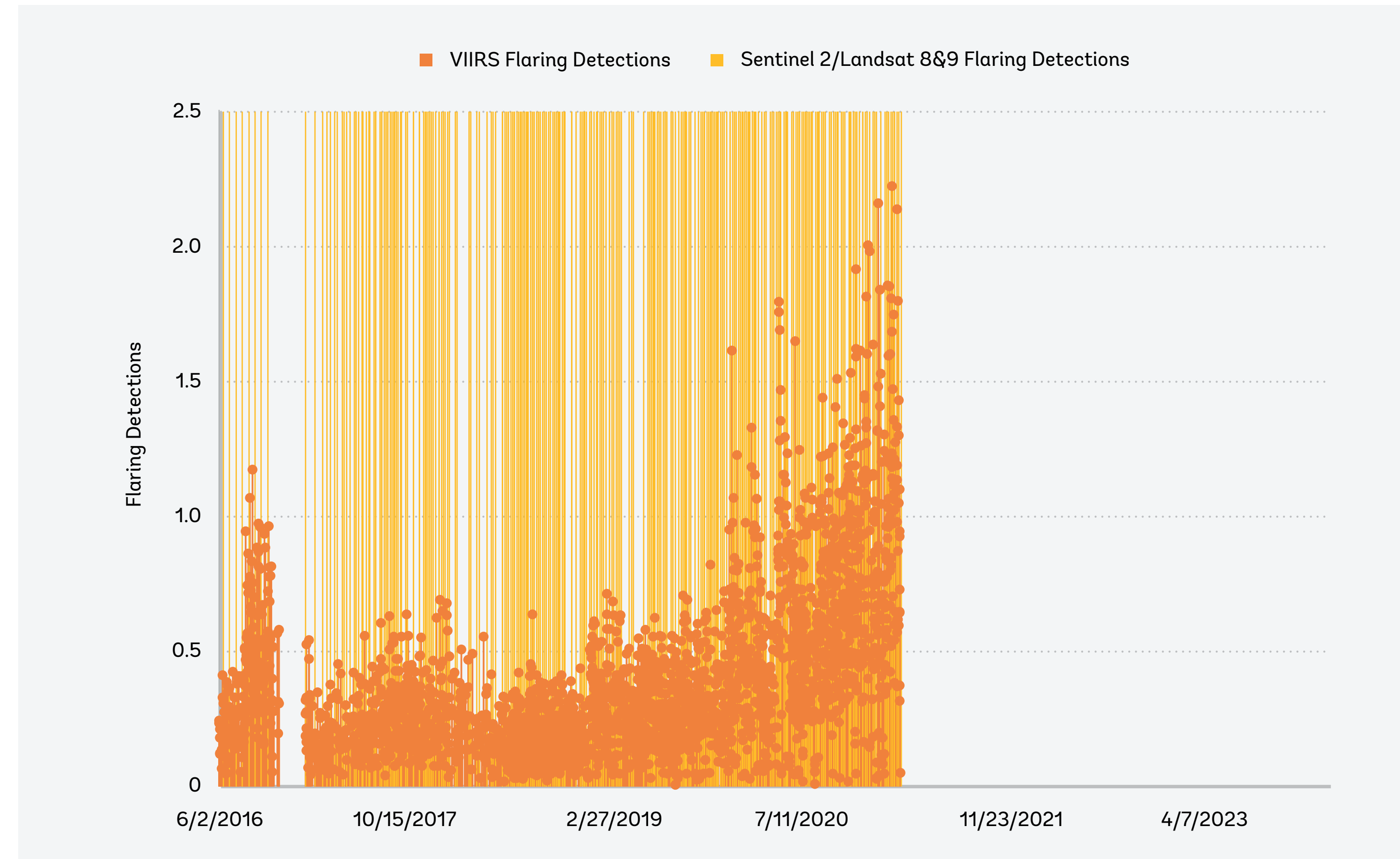
Source: Esri.
Note: The image is dated July 28, 2017 and shows a lit flare stack to the east of the facility.

Figure 25. Methane detections at the facility, with a cluster around the location of the flare stack

Source: Esri, CSM, Kayrros SAS, IMEO, Carbon Mapper, and World Bank.
Note: The image is dated November 17, 2021 and shows no flame visible from the flare stack. Dark blue dots represent Kayrros detections, light blue dots represent IMEO MARS detections, and green dots represent Carbon Mapper detections. The red pin marks the center of VIIRS detections of flaring.

12 Data provided by Carbon mapper available at https://carbonmapper.org/data/
13 IMEO MARS is a part of the United Nations Environment Programme.

Figure 26. Time series of VIIRS flaring detections at the facility, cross-referenced with Sentinel 2 and Landsat 8/9 detections of flaring



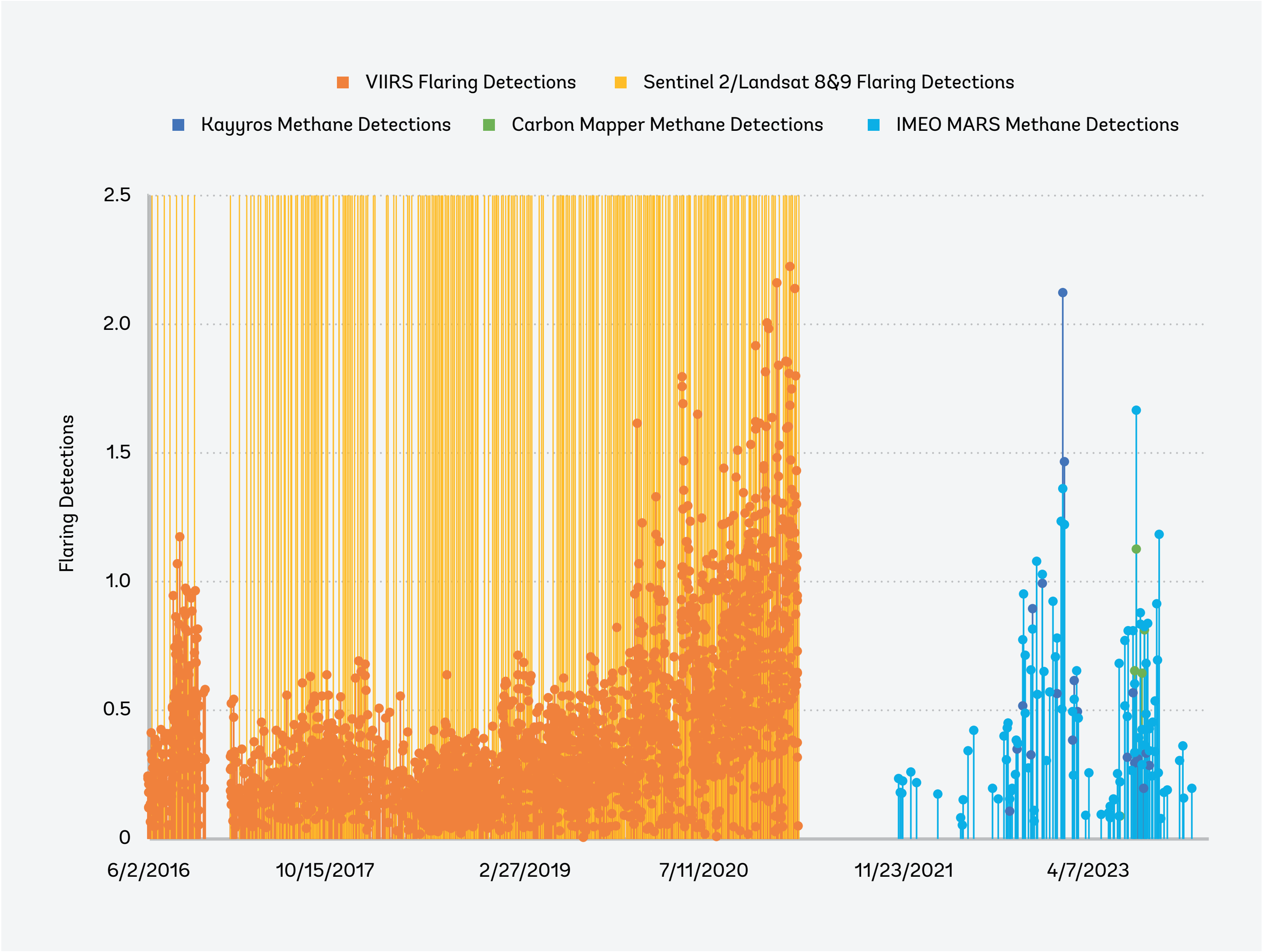
Source: Payne Institute and Colorado School of Mines, NOAA, Kayrros SAS, International Methane Emissions Observatory (IMEO), Carbon Mapper, and World Bank.
Note: VIIRS = Visible Infrared Imaging Radiometer Suite of detectors.

This approach leverages the extensive database of VIIRS nightly flare detections that has been built up by the Colorado School of Mines since 2012, with the support of the World Bank's GFMR. This dataset is the only high-frequency database available that allows researchers to infer periods of "no detection" of a flare, which could indicate that the flare has become unlit. Following additional testing and further refinement, this approach could be rolled out to find evidence of other instances of unlit flaring around the world, thereby increasing global understanding of the prevalence of unlit flaring and the associated methane emissions. It could also be used to develop an alert system to provide warning to operators of possible unlit flaring events and encourage rapid action to reignite flares.

Figure 27. One of many methane plumes originating from the flare stack, detected by Sentinel 2 on November 25, 2022

Source: Kayrros SAS analysis, contains modified Copernicus data, courtesy of ESA (2024).

Figure 28. Time series of VIIRS flaring detections at the facility cross-referenced with Sentinel 2 and Landsat 8/9 detections of flaring and satellite detections of methane



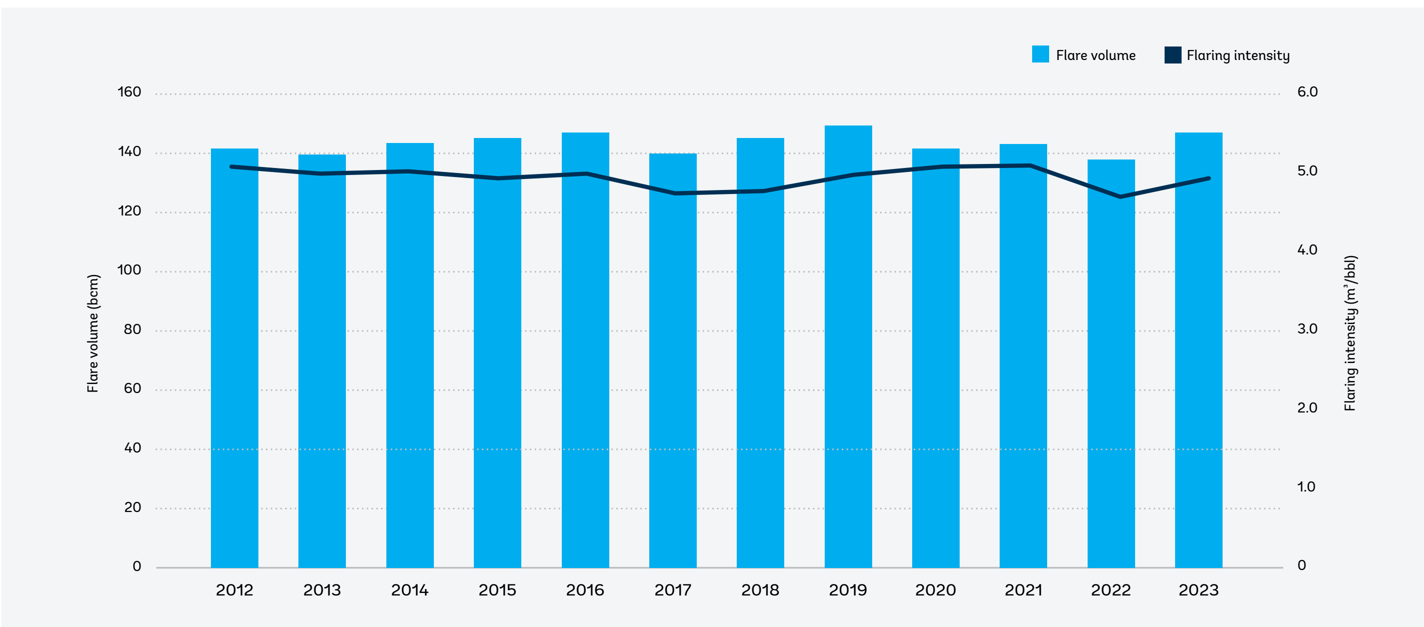
Source: Payne Institute and Colorado School of Mines, NOAA, Kayrros SAS, IMEO, Carbon Mapper, and World Bank.

Photo: Ed Kashi

Concluding Remarks

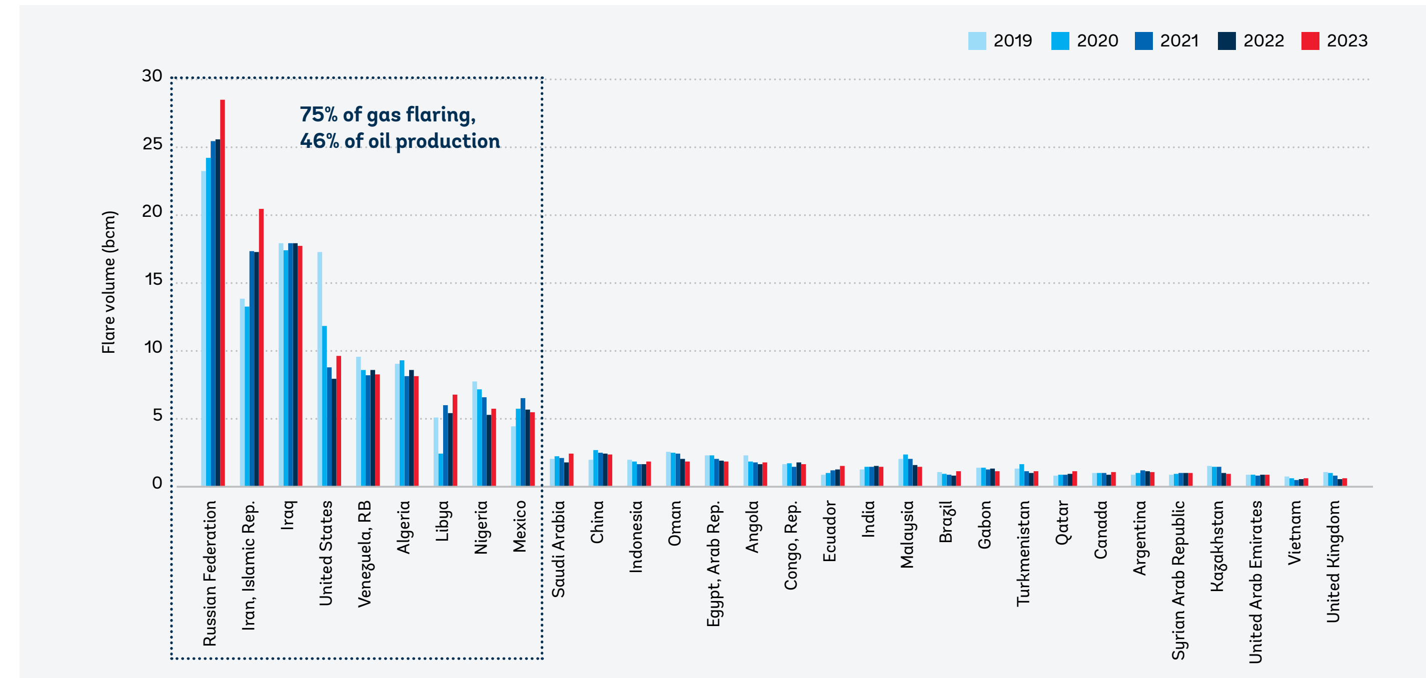
The increase in flaring in 2023 more than reverses the reduction in gas flaring observed between 2021 and 2022, resulting in the highest volume recorded in the past five years and an increase in global average flaring intensity (figure 29). This indicates that the efforts made to date have not been sufficient or sustainable enough to address gas flaring.

Figure 29. Global gas flaring at upstream oil and gas facilities, and flaring intensity, 2012–23



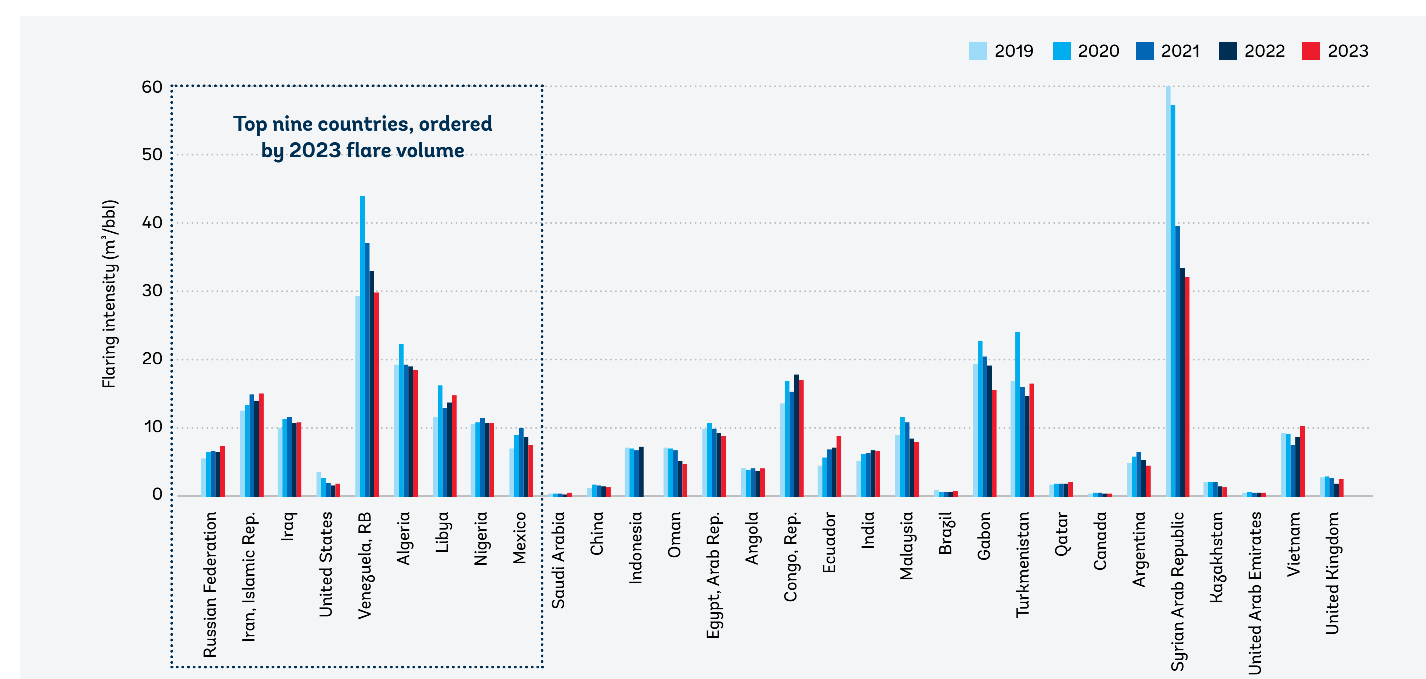
Source: Payne Institute and Colorado School of Mines, NOAA, EIA, and World Bank

Figure 30. Flare volumes in the top 30 flaring countries, in order of 2023 flare volume with the top 9 flaring countries indicated, 2019–23



Source: Payne Institute and Colorado School of Mines, NOAA, and World Bank

Figure 31. Flaring intensity in the top 30 flaring countries from 2019 to 2023, with the top 9 flaring countries indicated



Source: Payne Institute and Colorado School of Mines, NOAA, EIA, and World Bank

Global gas flaring continues to be dominated by nine oil-producing countries. While the flaring intensities of each vary due to the different gas-to-oil ratios of the basins and the different efficiencies they have been achieved through gas utilization, oil production in some of these countries is so large that any fluctuation in their flaring intensities has an impact on global gas flaring totals.

There is an urgent need to mobilize and renew political will and leadership, coupled with industry investments and improved practices across the world, to take critical action on several fronts:

1. Rapidly accelerate flaring reduction progress in the top nine flaring countries: Russia, the Islamic Republic of Iran, Iraq, the United States, República Bolivariana de Venezuela, Algeria, Libya, Nigeria, and Mexico.
2. Urgently put in place and kick-start investment plans to accelerate the flaring reduction, recognizing that ending routine gas flaring and reducing nonroutine flare volumes to as low as possible are essential to reducing global GHG emissions from the oil and gas industry. There investments can also significantly contribute to urgently needed near-term methane emission reductions from flares.
3. Ensure that investment in associated gas recovery and utilization projects are prioritized when planning, designing, and operating oil and gas infrastructure to keep Zero Routine Flaring by 2030 within reach.
4. While gas flaring persists, minimize methane emissions by ensuring flares are lit and operating effectively.
5. In countries with a weaker regulatory environment or where gas value chains are underdeveloped, ensure that oil and gas operators have access to the financing and technical support needed to reduce gas flaring.
6. Promote the best practices of managing oil (and associated gas) production within the handling capacity of existing gas infrastructure in particular, during periods where this infrastructure has reduced capacity, to avoid rapid accumulation of nonroutine gas flaring.
7. Design oil and gas infrastructure and emission reduction projects to better withstand the physical impacts of climate change hazards.
8. Leverage existing collaboration between public and private sectors to enable the widespread adoption and implementation of effective regulations.

Photo: Essam al-Sudani / Shutterstock

The World Bank's role in gas flaring reduction

The World Bank's GFMR Partnership works closely with governments and oil companies to help assess technologies, develop policies and regulations, and build capacity to end routine flaring by 2030. We are also continuing to secure commitments for the Zero Routine Flaring by 2030 initiative, building upon the 92 government and oil company endorsers that, together, account for close to 60 percent of global flaring. Ending routine gas flaring is critical if governments and companies are to deliver their products in the cleanest manner possible, meet net-zero targets, and maintain their license to operate, especially in developing countries where millions lack access to energy. To do this, we must test and scale innovative approaches, while considering new solutions that treat associated gas as an asset, not a waste product. Such approaches must also be tailored to the unique circumstances and context of a particular country, or even a specific oil production site. We need to work collaboratively with governments and oil companies to develop holistic policies, considering a range of incentives and penalties, to finally put an end to this practice.

Appendix A: Methodology

The Global Gas Flaring Tracker Report is produced on an annual basis by the World Bank's Global Flaring and Methane Reduction (GFMR) Partnership, comprising governments, oil companies, and international institutions working to end routine gas flaring at oil production sites around the world. GFMR, in partnership with the US National Oceanic and Atmospheric Administration (NOAA) and the Payne Institute for Public Policy at the Colorado School of Mines, has developed global gas flaring estimates based upon observations from a satellite launched at the end of 2011. The advanced sensors of this satellite detect the heat emitted by gas flares as infrared emissions at global upstream oil and gas facilities.

The Colorado School of Mines and GFMR quantify these infrared emissions and calibrate them using country-level data collected by a third-party data supplier, Cedigaz, to produce robust estimates of global gas flaring volumes. The satellite data for estimating flare gas volumes are collected by NOAA's satellite-mounted Visual and Infrared Radiometer Suite of detectors (VIIRS).

VIIRS has a multispectral set of infrared detectors which:

- At nighttime respond only to heat emissions and hence are not affected by moonlight, or other light sources;
- Respond to wavelengths where emissions from flares are at a maximum; and
- Have excellent spatial resolution.

The ability of VIIRS to detect and discriminate hot sources, such as gas flares, enables flares to be detected automatically with minimal manual intervention. Emissions from nonflare hot sources (e.g., biomass burning) can be removed from the data by selecting only emissions with temperatures above 1,100°C; other hot sources burn at lower temperatures. Indeed, flares burn hotter than any other terrestrial hot sources, including volcanos. Since the first year of operation in 2012, VIIRS has automatically detected ~10,000 flares annually around the globe.

References:
Elvidge, C.D.; Zhizhin, M.; Hsu, F.-C.; Baugh, K.E. VIIRS Nightfire: Satellite Pyrometry at Night. Remote Sens. 2013, 5, 4423-4449. https://doi.org/10.3390/rs5094423
Elvidge, C.D.; Zhizhin, M.; Baugh, K.; Hsu, F.-C.; Ghosh, T. Methods for Global Survey of Natural Gas Flaring from Visible Infrared Imaging Radiometer Suite Data. Energies 2016, 9, 14. https://doi.org/10.3390/en9010014

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