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King Abdullah Petroleum Studies and Research Center

THE WORLD BANK

جامعة الملك عبدالله للعلوم والتقنية
King Abdullah University of Science and Technology

How Can Governments, Oil and Gas Enterprises, and Research Institutions Collaborate to End Routine Gas Flaring?

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About KAPSARC

KAPSARC is an advisory think tank within global energy economics and sustainability providing advisory services to entities and authorities in the Saudi energy sector to advance Saudi Arabia's energy sector and inform global policies through evidence-based advice and applied research.

This publication is also available in Arabic.

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Key Points

Natural gas is a feedstock for the petrochemical industry and a fuel of choice in the power sector to help transition toward clean, sustainable, and affordable energy. As vital as gas is for electricity generation, the petrochemical industry, and the transportation sector, many oil operators flare or vent associated gas as a by-product of oil extraction at the wellhead or gathering stations.

According to the World Bank, the amount of natural gas flared by the oil and gas industry globally reached 142 billion cubic meters in 2020, or more than 310 million tonnes of carbon dioxide (CO2) equivalent. The amount of energy lost due to flaring this gas is equivalent to more than 770 billion kilowatthours (kWh): enough energy to power all the sub-Saharan African nations, where 1.1 billion people live. That is the equivalent of over $12 billion worth of gas sales.

Many countries and oil and gas operators have managed to curb gas flaring across their oil and gas value chains, while others are still facing challenges. These challenges include infrastructure constraints, market barriers, a lack of know-how and financial incentives to capture and process gas, poor regulatory frameworks, or binding contractual provisions.

During the virtual workshop, “How Can Governments, Oil and Gas Enterprises, and Research Institutions Collaborate to End Routine Gas Flaring?”, participants exchanged knowledge and experiences regarding the best practices and technology enablers that can detect gas flaring volumes and methane emissions, and the progress made thus far to eliminate them. They also proposed fit-for-purpose policies and regulations to optimize the capture and productive use of flared gas in the context of the circular carbon economy.[1]

Key takeaways and points addressed in the webinar were as follows:

> Greenhouse gas emissions from the oil and gas industry, whether caused by gas flaring, venting, or leaking, are significant and, if not addressed, they will hinder efforts to meet the climate goals of the Paris Agreement. Reducing routine gas flaring in the oil and gas industry is regarded as low-hanging fruit.

> Strategic partnerships between governments and the private sector remain the main catalyst for stopping routine gas flaring, and it is envisaged that these partnerships will play an important role in advancing the circular carbon economy.

> Technological solutions exist to tackle routine gas flaring across the oil and gas value chain. However, they incur additional costs for operators and lessen their profitability, especially if the gas they do not flare is not marketable. Mid-stream networks and functioning gas markets are crucial for justifying additional investments from operators to harness gas.

> The lessons learned from Saudi Arabia’s experience can be scaled up, especially when ownership of the hydrocarbon assets belongs to the state, such as in Iraq. Governments in such a position can exercise pressure on operators to collaborate on flaring mitigation, while providing financial incentives to capture, process, compress, and transport gas to demand centers.

[1] The circular carbon economy is an integrated, holistic framework for managing and reducing emissions through four main strategies: reduce, reuse, recycle, and remove. CCE was developed during Saudi Arabia’s G20 Presidency and endorsed by G20 leaders and energy ministers in 2020.

Background to the Webinar

On November 30, 2021, the King Abdullah Petroleum Studies and Research Center (KAPSARC) hosted a webinar titled "How Can Governments, Oil and Gas Enterprises, and Research Institutions Collaborate to End Routine Gas Flaring?" in collaboration with the World Bank Group and the King Abdullah University of Science and Technology (KAUST).

The webinar was attended by a global delegation of regulators, policymakers, industry professionals, and academics from a wide range of research institutions, the financial sector, the oil and gas industry, and energy consulting firms to shed light on global gas flaring and venting.

The webinar comprised two panel sessions. The first panel highlighted the status of routine flaring in the oil and gas industry, its magnitude and environmental impact, and the efforts made thus far to track the progress in reducing routine gas flaring and venting. The panel addressed the importance of reducing greenhouse gas (GHG) emissions from oil and gas operations, and how these reductions help governments and oil producers to meet their international climate change commitments (e.g., nationally determined contributions [NDCs] for governments, or net-zero or low-carbon emission targets for major oil and gas producers).

The second panel emphasized the role of technologies in detecting, measuring, and monitoring gas flaring and methane leaks. It drew on lessons learned from countries and oil producers that are on track to mitigate their gas flaring and discussed the market mechanisms and financial instruments that governments, institutions, and oil and gas developers can capitalize on to curb fugitive emissions, mitigate gas flaring, and monetize gas.

Overview of Global Routine Gas Flaring

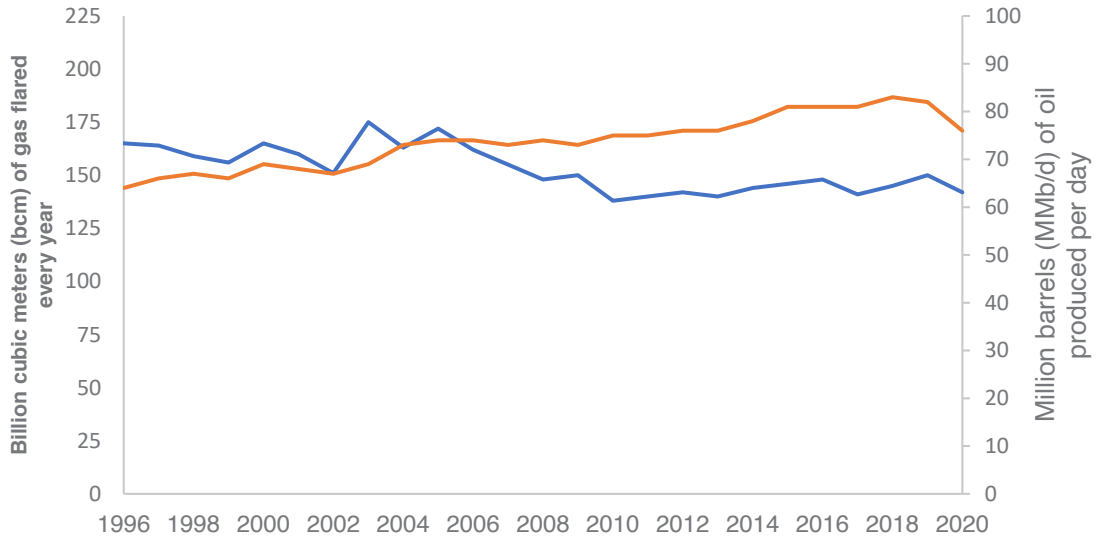
In 2019, global GHG emissions were estimated at 51 gigatonnes of CO2 equivalent (GtCO2e), of which carbon emissions contributed 37 GtCO2e. The combustion and flaring of oil and gas made up just over half of the global CO2 emissions from fossil fuels.

Gas flaring is the burning of natural gas associated with oil and gas exploration, drilling, and development. Routine gas flaring, also known as upstream flaring, occurs at the wellhead during drilling operations and regular production. It is not to be confused with safety flaring, maintenance flaring, or other flaring practices characterized by shorter durations or smaller volumes of gas disposal. There are many ongoing initiatives to tackle non-routine gas flaring, most of which are for safety reasons.

The webinar focused on routine gas flaring, which has been portrayed as low-hanging fruit in reducing the oil and gas sector's emissions. Many countries and oil and gas operators have managed to curb gas flaring across their oil and gas value chains, while others are still facing challenges. These challenges include infrastructure constraints, market barriers, a lack of know-how and financial incentives to capture and process gas, poor regulatory frameworks and binding contractual provisions. Significant reductions in flaring operations occurred between 2004 and 2010. Currently, gas flaring at upstream oil and gas production sites and liquified natural gas (LNG) liquefication plants decreased by 14% in 2020 compared with 1996 levels (Figure 1).

During the United Nations Framework Convention on Climate Change (UNFCCC) 21st Conference of the Parties (COP 21), the NDCs proposed by many countries prioritized "efficient associated gas utilization." This text was included in the NDCs of Algeria, Bahrain, China, Ecuador, Egypt, Gabon, Iran, Iraq, Nigeria, Oman, and Saudi Arabia. At COP 26, 10 countries underscored the importance of flaring mitigation in their NDCs.

Figure 1. Global Gas Flaring and Oil Production.



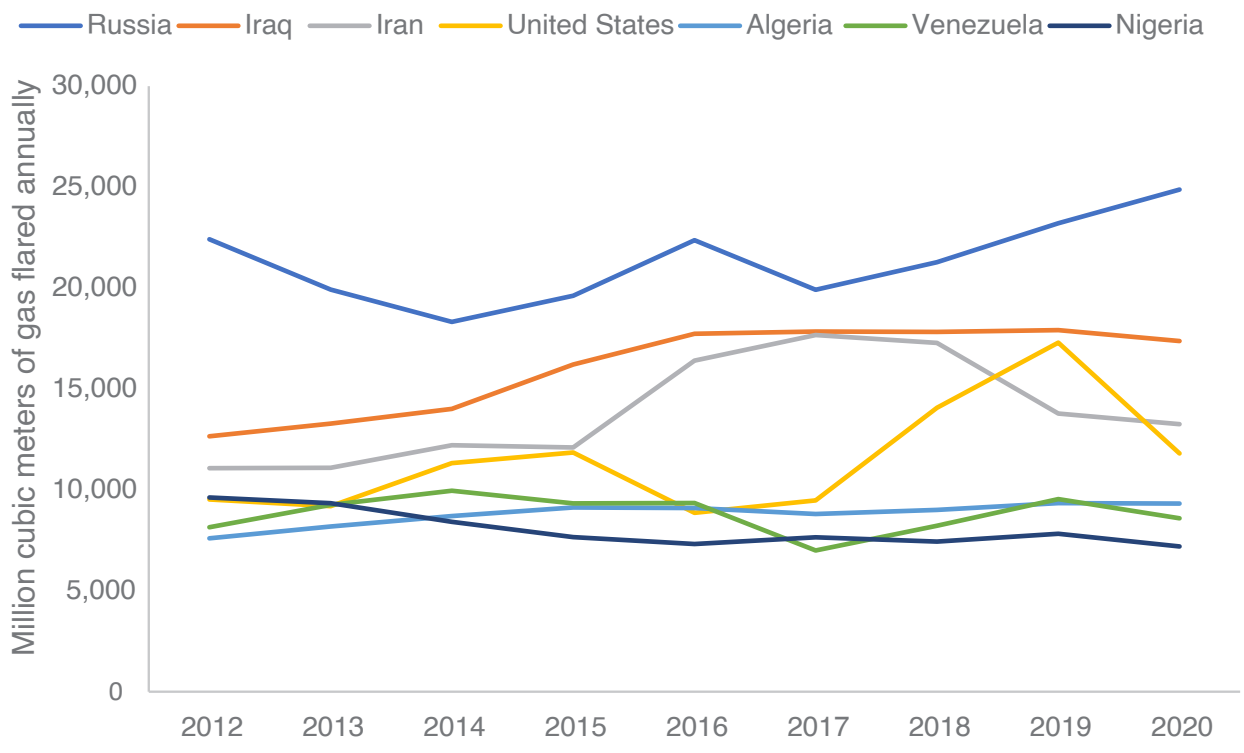
Source: National Oceanic and Atmospheric Administration, Colorado School of Mines, Global Gas Flaring Reduction Partnership, The World Bank, U.S. Energy Information Administration.

Gas Flaring Indicators

Russia, Iraq, Iran, the United States, Algeria, Venezuela and Nigeria have remained the top-seven gas flaring countries for nine years running. These seven countries produce 40% of the world's oil each year but account for roughly two-thirds (65%) of global gas flaring (The World Bank 2021a).

Gas flaring cannot be addressed without also addressing oil production. Historically, upstream gas flaring has been correlated with oil production (Figure 1). For this purpose, two indices have been developed to guide policymakers and stakeholders on how to adopt technologies, and fit-for-purpose policies and regulations, to mitigate gas flaring in upstream oil and gas. These two indicators are as follows:

Figure 2. Annual flaring volumes by the seven-largest gas flaring nations since 2012.

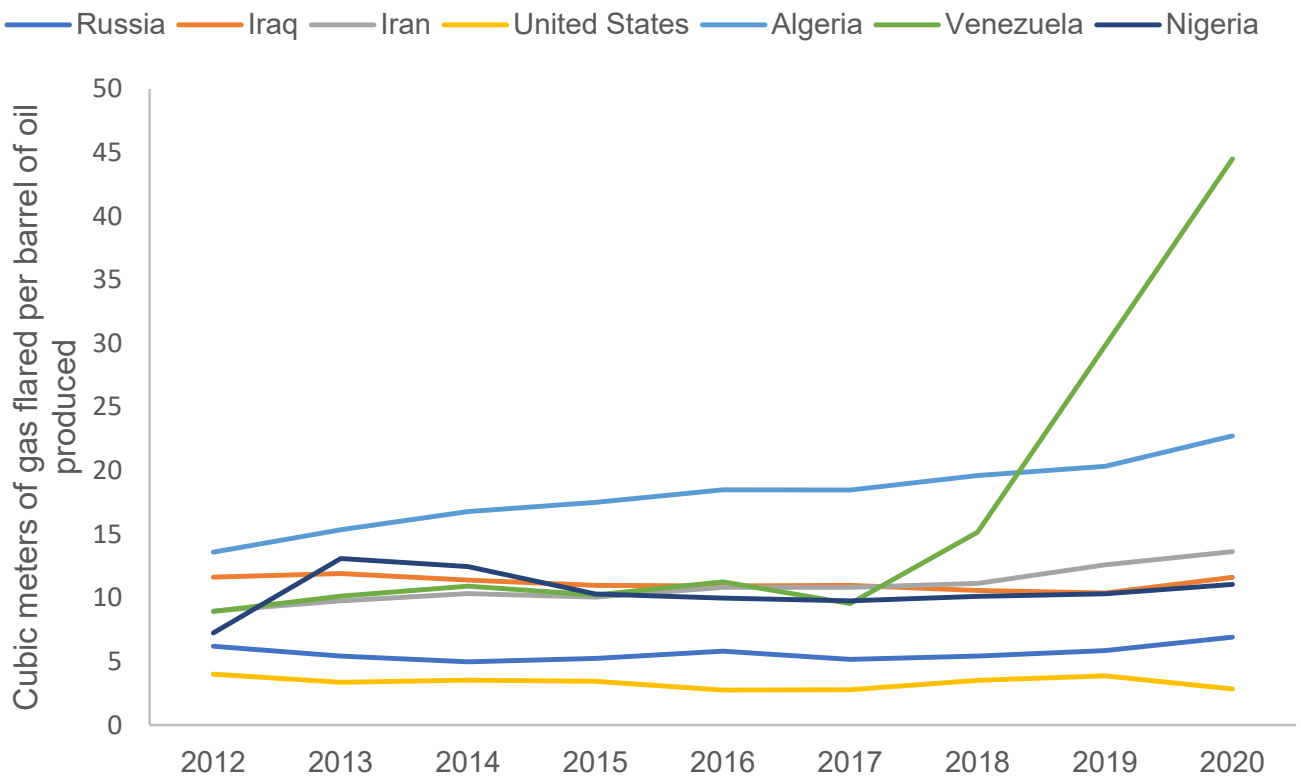


Sources: Global Gas Flaring Reduction Partnership, The World Bank.

Upstream Flaring Intensity Index

Upstream flaring intensity is the ratio of gas flaring to oil production. The top-seven flaring nations have maintained relatively stable intensity levels despite fluctuations in their oil output. However, the flaring intensities of both Algeria and Venezuela have been rising. For Venezuela, in particular, economic sanctions, political unrest, and aging oil and gas infrastructure has resulted in flaring volumes rising steeply despite dwindling oil production, as shown in Figure 3.

Figure 3. Annual flaring intensity by the seven-largest gas flaring nations since 2012.

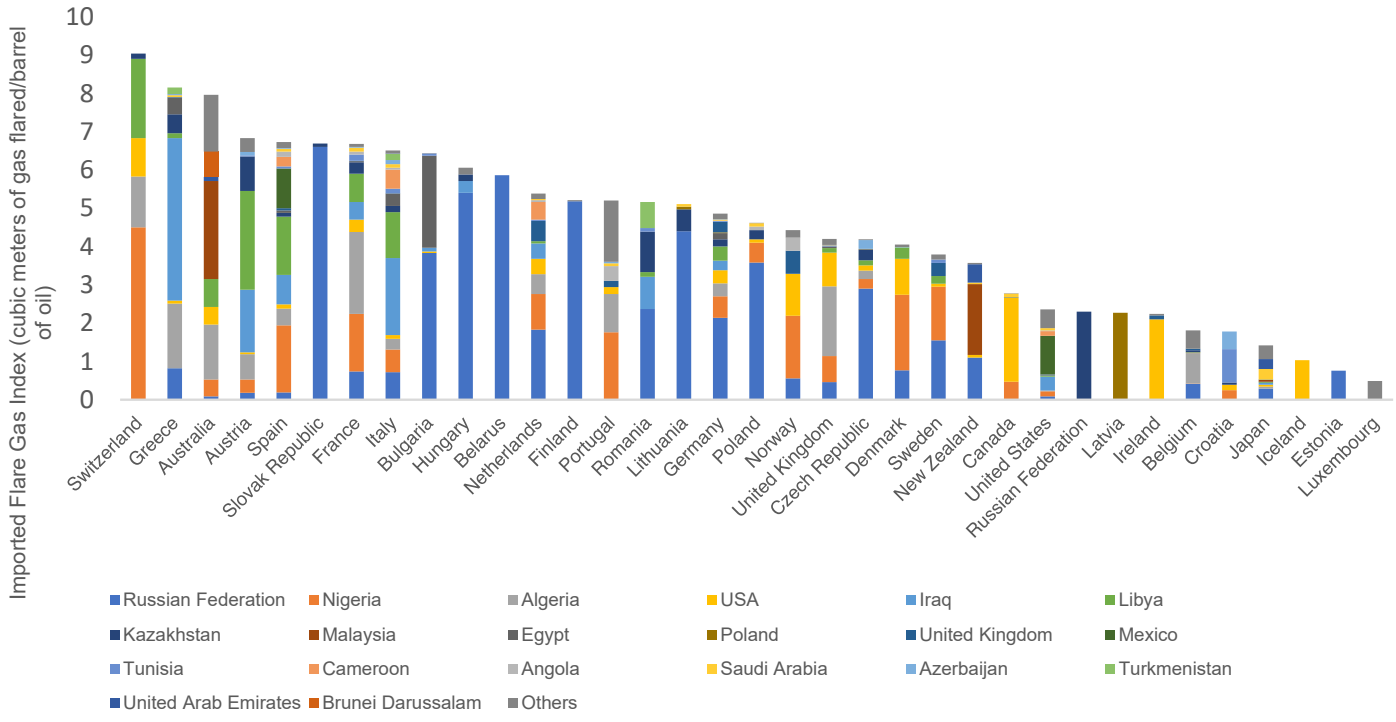


Sources: Global Gas Flaring Reduction Partnership, The World Bank.

Imported Flare Gas Index

The Imported Flare Gas (IFG) Index is a relatively new index. It identifies how countries that import crude oil are also importing embedded emissions from gas flaring. The IFG Index is a consumer-oriented indicator that helps importing countries recognize their responsibility and role in decarbonizing energy systems globally. The Index can also help oil-importing countries assess where the flaring hotspots are in their fossil fuel supply chain, engage in dialogues with countries from which they buy oil, and implement flaring reduction initiatives. It can also help provide indirect pressure to oil-importing countries to take further measures and significantly improve the carbon emissions-intensity of the oil they consume (The World Bank 2021c).

Figure 4. Imported Flare Gas Index for Annex I Nations in 2020.



Sources: Global Gas Flaring Reduction Partnership, The World Bank.

Global Initiatives and Partnerships

The following two initiatives and partnerships concerning gas flaring and venting were presented during the webinar:

Zero Routine Gas Flaring by 2030

In April 2015, The World Bank introduced the Zero Routine Flaring (ZRF) by 2030 initiative to promote sustainable and environmentally responsible production processes. The initiative is now endorsed by 34 governments/countries, 49 oil and gas companies, and 15 development institutions. The government of Saudi Arabia, its national oil company Saudi Aramco, and the Islamic Development Bank headquartered in Saudi Arabia are amongst the first endorsers of ZRF.

The initiative, albeit non-binding, mandates that both governments and oil companies make new field developments with ZRF and make efforts to end legacy flaring in existing oilfields by 2030. Governments set legal, regulatory, investment and operating conditions for oil and gas development, so their roles in flaring abatement and meeting net-zero routine flaring targets are essential. Financial institutions can facilitate cooperation and use green investment instruments to finance decarbonization projects across the oil and gas value chain, enabling many countries to achieve their emissions targets. In countries that are politically stressed, such as Venezuela, these institutions can mobilize funds to monetize flared gas for economic development.

Notwithstanding the above, major oil producing countries such as Algeria, Libya, Syria, and Iran have not yet endorsed ZRF by 2030. Major consuming countries, such as India and China, whose combined oil consumption represented 22% of total global oil consumption in 2020, according to the BP Statistical Review, have also not endorsed the initiative. ZRF is gaining wide acceptance by major oil producers to address their industries' impact on climate change, endorsed by 49 major international and national oil companies, hybrid enterprises, and independents. They provided nearly 45% of the world's crude oil production in 2020.

Oil and Gas Climate Initiative

The Oil and Gas Climate Initiative (OGCI) is a consortium of 12 major international and state-owned oil and gas companies, including Saudi Aramco, BP, Chevron, the China National Petroleum Corporation (CNPC), Eni, Equinor, ExxonMobil, Occidental, Petrobras, Repsol, Shell and Total Energies. It was established in 2014 and has a mandate to work together to accelerate the reduction of GHG emissions in support of the Paris Agreement and its goals.

OGCI members focus on areas where they can leverage their competitive technological advantage, such as carbon capture, utilization, and storage (CCUS), to help reduce global emissions. They set examples for other producers, and finance large-scale projects to decarbonize the oil and gas industry. OGCI members have collectively set short-term targets to reduce upstream carbon intensity to 17 kilograms (kg)CO2e/barrels of oil equivalent by 2025 and bring routine flaring to zero by 2030.

The OGCI, World Bank and Colorado School of Mines have partnered to develop the Global Gas Flaring Explorer. This web-based flaring tool kit aims to guide users on how to increase awareness of gas flaring and improve the data accuracy of flared volumes.[2]

[2] The Global Gas Flaring Explorer will make use of the Visible Infrared Imaging Radiometer Suite's (VIIRS) nightfire data collected by the Suomi National Polar-Orbiting Partnership (Suomi NPP) spacecraft. Nightfire data is also used by SkyTruth (https://skytruth.org/flaring/) and flare-intl (https://flareintel.com/) to provide both free and commercial global monitoring tools for flared gas.

Reducing Flared Volumes in Practice

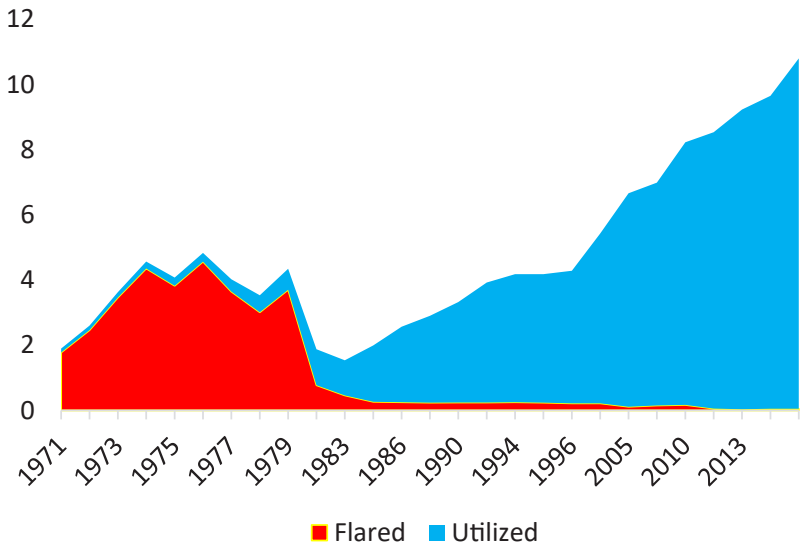
Many countries and oil operators have managed to mitigate gas flaring and venting in their exploration and production (E&P) operations. Others are still struggling to reduce routine flaring in their operations. Several case studies were discussed during the webinar, including conventional oil production in Iraq and Saudi Arabia and unconventional shale oil production in the United States (U.S.).

Saudi Arabia

As of 2020, Saudi Arabia had the third-lowest gas flaring intensity of all G20 countries, and it is poised to mitigate routine gas flaring by 2030. The Kingdom's gas flaring mitigation has not been a smooth transition. Before the 1970s, Aramco used to flare gas in its upstream operations because there was no local market to sell gas through, and exporting the gas would have required substantial infrastructure investment that would have negatively impacted the company's revenues. Later, gas came to be increasingly regarded as an important part of a wider attempt to diversify the Saudi economy away from its narrow dependence on crude oil.

The Saudi government gave Aramco a contract to establish the $12 billion Master Gas System (MGS) to capture, process and utilize gas as fuel and feedstock for petrochemical plants. By the fall of 1982, the key components of the MGS – gas gathering and processing facilities and pipelines – were fully operational. The MGS saved 4.2 billion standard cubic feet of gas from being flared, which has prevented roughly 80 million tonnes of CO2 from being emitted into the atmosphere annually (Figure 5) (Alsuwailem 2020).

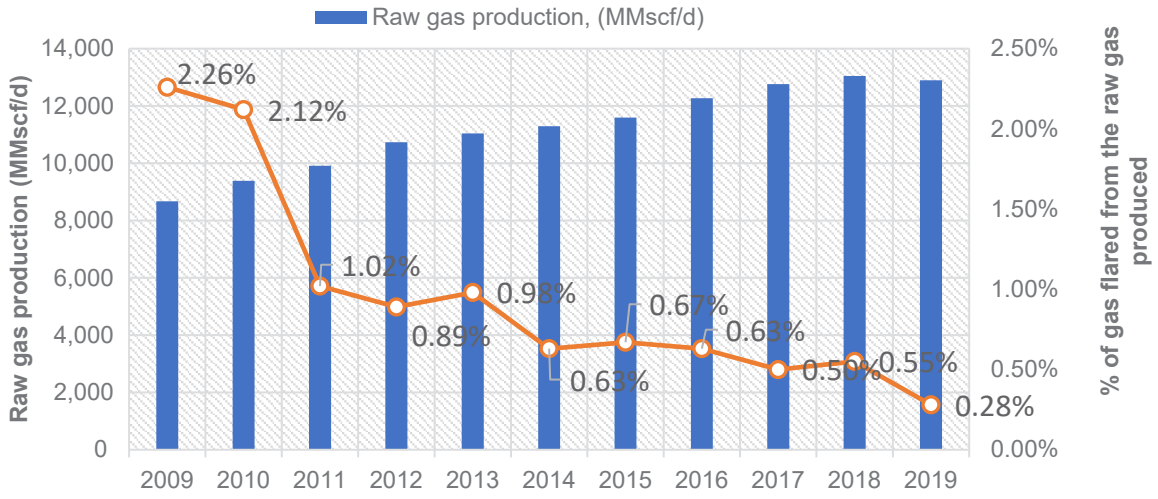
Figure 5. Natural gas utilization and flaring in Saudi Arabia.



Sources: KAPSARC analysis based on BP and Saudi Aramco data.

Over the past two decades, Saudi Aramco has been implementing company-wide programs to further mitigate routine gas flaring across its oil and gas value chain. This has included revisions to its standards, and the use of best-in-class technologies in well clean-up operations before placing them on stream. The company deployed flare gas recovery systems in its gas oil separator plants to reduce gas flaring, including high-pressure air assist flare tips and other technologies, especially in offshore oil and gas fields. Because of these efforts, gas flaring declined significantly from 2.3% of total raw gas in 2009 to less than 1% in 2019 (Figure 6).

Figure 6. Saudi Aramco's efforts to reduce gas flaring in its E&P sector.



Note: MMscf/d = million standard cubic feet per day

Sources: KAPSARC estimates based on OPEC, Organization of Arab Petroleum Exporting Countries, and Saudi Aramco data.

Saudi Arabia's gas flaring mitigation process is a successful case study of how governments and oil operators can collaborate to monetize gas when it is not viewed as a valuable commodity. The lessons learned from this process can be scaled up, especially when ownership of the hydrocarbon assets belongs to the state, such as in Iraq. Governments in such a position can exercise pressure on operators to collaborate on flaring mitigation, while providing financial incentives to capture, process, compress, and transport gas to demand centers.

Iraq

Iraq has the second-largest gas flaring volumes after Russia, flaring around 50% of its gross gas output of 3.3 billion standard cubic feet per day (scf/d). Gas flaring has increased by around 1 billion scf/d over the past decade, driven by oil production increases in southern Iraq and the slow pace of new gas capture projects. In 2021, emissions from flaring in Iraq amounted to approximately 38 million tonnes of CO2eq. While Iraq is second to Russia in total flared volumes, Iraq scores significantly higher for flaring intensity. Based on current production levels, Iraq's upstream flaring intensity amounts to approximately 26 kg CO2 per barrel of oil equivalent – almost three times higher than Russia's.

Of the gas captured in Iraq, dry gas volumes are sent to the national grid and rich gas volumes are sent to fractionation units to extract liquified petroleum gas and other products. There have been many infrastructural challenges in capturing flared gas over the past decade. These include a lack of midstream pipelines, compression capacity requirements at different hubs and the mismatch between upstream operator plans and coordinating master gas planning. Formula pricing for dry gas also needs to change. The failure to capture flared volumes has hindered the development of Iraq's petrochemical sector – a missed opportunity as Iraq's associated gas is ethane-rich, and multiple low-cost technologies currently exist for deep ethane recovery.

While Iraq has had a missed decade, reducing gas flaring is currently a major government priority. This priority is not only driven by global climate concerns but also the massive gas-to-power opportunity that exists in the country. In 2020, for example, Iraq needed around 1.4 billion scf/d gas to plug its gas deficit to meet its average power demand and almost 3.8 billion scf/d to meet its peak summer seasonal electricity demand. Iraq's gas flaring has meant that it has burned liquids for power, both crude and high sulfur fuel oil.

Burning liquids is costly and impacts the efficiency rates in power generation. The opportunity cost of liquid burning is also huge, given the export value of Iraqi crude oil. Addressing the flaring crisis would also reduce Iraq's reliance on costly Iranian gas imports. At present, the Basrah Gas Company (BGC) – a joint venture between the South Gas Company (51%), Shell (44%) and Mitsubishi (5%) – currently collects around 1 billion scf/d from the fields of Rumaila, Zubair and West-Qurna 1. More projects are in the pipeline, including the expansion of BGC operations and the 600 million scf/d Ratawi gas hub, part of the TotalEnergies-led Gas Growth Integrated Project. If all of Iraq's planned gas processing projects are completed, it will raise the country's total gas processing capacity by 1.5 billion scf/d to 2.8 billion scf/d. But even with that big capacity increase, Iraq will still miss its target of capturing all associated gas and ending flaring at its oil fields by 2025.

U.S.

Gas flaring emerged as a major environmental issue in the U.S. during the rise of unconventional tight oil production. One challenge of flaring from tight oil production in the U.S. was the rapid growth of new wellheads in geological formations such as the Bakken and a shortage of gas pipeline gathering systems. In addition, regulations adopted by states like North Dakota allowed for tight oil producers to flare during the first 90 days after the completion of new wells, when most of the associated gas is produced.

Tight oil plays are characterized by short production cycles, with most of the oil produced within the first 24 months. Many producers were focused on fast turnovers and quick returns on investment. As a result, in 2013, natural gas worth around $100 million was being flared per month from Bakken tight oil plays. However, landowners and investors started to require tight oil producers to find new ways to monetize this resource by deploying more flexible solutions. This included the use of compressed natural gas trucks to ship gas out of the Bakken, localized gas to power, and natural gas liquid recovery to address the absence of gas pipeline networks.

Tight oil producers also explored the use of modular gas processing, such as gas to liquid and miniature liquefied natural gas plants that could be easily installed and transported between wells once the production and flaring started. In this case, the innovation and stricter capital discipline required by investors and landowners enabled states like North Dakota to reduce their flaring volumes as gas production continued to rise and overcome regulatory shortfalls.

Methane Emissions: The Elephant in the Room

Methane leakages occur during drilling and transporting gas via pipelines. In the U.S., for instance, there are 3.2 million abandoned wells, thousands of offshore installations, and tens of thousands of kilometers of pipelines that are suspected to be leaking gas. To avoid those leakages, especially at the wellheads and installation, the associated gas must be flared safely, instead of venting it freely, because of its hazardous nature.

Satellite images and novel drone-based sensors, coupled with modeling and statistical analysis, are helping to detect these leaks, but it remains difficult to quantify their volumes. There are larger uncertainties around methane emissions data than for CO2 emissions, as the latter typically rely on direct measurements. These measurements are still insufficient to provide high-quality and high-resolution data for oil and gas emissions globally. Current top-down approaches indicate that there were roughly 80 million tonnes of global annual methane emissions from the oil and gas industry in 2019, equivalent to nearly 2.4 GtCO2eq, with global warming potential of 100 years, or approximately one-quarter of global methane emissions, according to Rystad.

Methane leakage is 30 times worse for the climate than gas flaring. Flaring is a much better way to dispose of methane than venting. The figure below illustrates the damage that can be caused by unlit flares (Kleinberg 2020). Methane emissions from the Permian flares exceed the Environmental Protection Agency's (EPA's) estimates, according to a study published by the Environmental Defense Fund. According to the EPA, all flares were operating at 98% efficiency. In reality, not all flares have been operating efficiently and, based on satellite images and measurements, many were malfunctioning or simply unlit. Thus, methane releases into the atmosphere are four times higher than what the EPA has reported. In November 2021, the EPA stated that unlit or inefficient flares are not permitted in its new proposed rule: Flares or other devices must achieve at least a 95% reduction in methane emissions. The EPA's webinar presenter stated that while such regulations are important, it is still very difficult to monitor and verify compliance.

Market Mechanisms to Mitigate Flaring and Methane Leakages

Policy and regulations are crucial instruments to advance the industry's goal of zero routine flaring. They are important tools in addressing environmental concerns and encourage the industry to avoid wasteful emissions. However, as regulations face implementation complications, parallel market instruments can help the industry advance its environmental objective. Achieving zero routine flaring entails additional investment and operating costs that need to be incorporated into the value chain of fuels.

One solution is to issue performance certificates capable of communicating and marketing environmental resource optimization to final consumers. Such certificates could help differentiate fuels based on their emissions impact. They could help raise capital to lower emissions from upstream exploration and production. For example, the Xpansiv commodity exchange and S&P Platts recently released the Methane Performance Certificate (MPC), representing avoided methane emissions during the production of natural gas below a threshold of 0.1%. Issuing such certificates relies on third-party standards and protocols to certify metered data. In the MPC, these are Digital Natural Gas (DNG) units registered with Xpansiv.

Performance certification could also be extended to gas flaring operations to support efforts to reduce routine flaring. These tradeable certificates could also be aligned with the objectives of the World Bank's IFG Index, providing oil exporters and importers with a market instrument to coordinate efforts to reduce gas flaring as embedded emissions in international trade. The certificates would prove that an importer purchased energy from suppliers who have committed to or achieved zero routine flaring targets. The goal would be to support investment in the infrastructure needed to avoid unnecessary flaring by enabling cross-border cooperation on related NDCs.

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About the Workshop

KAPSARC held a virtual workshop on November 30, 2021, in partnership with The World Bank Group and King Abdullah University of Science and Technology (KAUST). The workshop participants discussed the following topics to highlight the importance of gas flaring and venting mitigation to provide affordable, sustainable energy access and address climate change:

- Global view of gas flaring and venting.
- The role of technologies in detecting, measuring, and monitoring gas flaring and methane leaks.
- Policy levers and lessons learnt from international experience.

The workshop gathered over 100 attendees from various fields, including policy, research, investment, and the oil and gas industry.

List of participants

Abdulmuhsen Alkhalaf, Executive Director, The World Bank Group

Adam Sieminski, Senior Advisor to the Board of Trustees, KAPSARC

Ahmed Mehdi, Visiting Research Fellow, Oxford Institute for Energy Studies and Chief Analyst, Renaissance Energy

Majed AlSharif, Advisor, The World Bank Group

Amal Al-Mutlak, Advisor, The World Bank Group

Bertrand Rioux, Research Fellow, KAPSARC

Fahad Almalki, Workshop Coordinator, KAPSARC

Frank Felder, Director of Energy Transitions and Electric Power, KAPSARC

Julien Perez, Vice President Strategy & Policy at the Oil and Gas Climate Initiative

Majed Alsuwailem, Research Fellow I, KAPSARC

Magnus Lohne, Head of Sustainability, Rystad Energy

Mark Jonathan Davis, CEO of Capterio

Naif Alhawwas, Advisor, Saudi Ministry of Economy and Planning

Robert Kleinberg, Adjunct Senior Research Scholar, the Center on Global Energy Policy

Tadesusz Patzek, Director of Ali I. Al-Naimi Petroleum Engineering Research Center, KAUST

Zubin Bamji, Program Manager, The World Bank Group

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About the Team

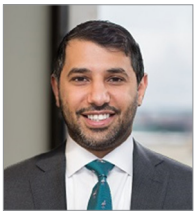
Fahad Alturki

Dr. Fahad Alturki is vice president of knowledge and analysis at King Abdullah Petroleum Studies and Research Center (KAPSARC). In this role, he oversees KAPSARC's research programs and priorities, ensuring that these are strategically focused on impacts within the Kingdom of Saudi Arabia. Dr. Fahad interacts with key stakeholder groups within the Kingdom and internationally in the private, academic, and government sectors. Moreover, he is responsible for setting the overall directions and parameters for KAPSARC's collaboration with its partners and affiliates.

Prior to joining KAPSARC, Dr. Fahad was the chief economist and head of research at Jadwa Investment Company in Riyadh, where he managed the economic research department and published regular reports on issues related to the Saudi and global economies and the world oil market. He was also the chairperson of the Public Funds Board, a board member of the Jadwa REIT Al Haramain Fund and Jadwa REIT Saudi Fund, and a member of Jadwa's executive management committee.

Dr. Fahad has a proven track record in economics, with more than 20 years of experience in the field. Before joining Jadwa, Dr. Fahad was the chief economist at Barclays, Saudi Arabia. Prior to his time at Barclays, Dr. Fahad was an economic specialist at the Saudi Arabian Monetary Authority, where he worked for 11 years in the Economic Research and Statistics Department. Dr. Fahad has also worked as an economist at the Middle East and Central Asia Department of the International Monetary Fund.

Dr. Fahad holds a B.A. in Business Administration from King Saud University in Saudi Arabia and master's and Ph.D. degrees in economics from the University of Oregon (Eugene, United States).



Abdulmohsen Alkhalaf

Abdulmuhsen S. Alkhalaf is executive director at The World Bank Group (WBG), representing the Kingdom of Saudi Arabia since 1 November 2020. Prior to that, Mr. Alkhalaf served as alternate executive director from 2018 to 2020, and as advisor to the Saudi executive director from 2014 to 2018.

Mr. Alkhalaf is currently the chair of the Audit Committee of the WBG Executive Board, which oversees WBG finances, accounting, risk management, internal controls, and institutional integrity. He is also participating in other WBG Executive Board's standing committees.

During the Saudi G20 Presidency in 2020, Mr. Alkhalaf served as the chief policy officer of the Finance Track program. In this capacity, he led the Finance Track agenda and work program, overseeing relevant economic and financial workstreams, including the G20 Framework Working Group, the G20 International Financial Architecture Working Group, the G20 Infrastructure Working Group, the G20 Global Partnership for Financial Inclusion, the G20 International Taxation Agenda and the G20 Financial Regulation Agenda. As chief policy officer of the Finance Track Program, he organized and coordinated agenda and policy discussions for the G20 finance minister and central bank governor meetings, as well as for the G20 Leaders' Summit.

Prior to joining the WBG Board, he worked as an economist at the Ministry of Finance of Saudi Arabia, where he worked on several economic and financial policy issues and a variety of topics on the G20 agenda, including representing Saudi Arabia in the G20 Development Working Group. He started his career in the banking sector in the credit-risk-rating field.

Tadeusz Patzek

Tad Patzek is a professor and petroleum industry analyst at King Abdullah University of Science and Technology (KAUST) in Thuwal, Saudi Arabia.

Until December 2014, he was the Lois K. and Richard D. Folger Leadership Professor and chairman of the Department of Petroleum and Geosystems Engineering at the University of Texas at Austin. He also held the Cockrell Family Regents Chair. Between 1990 and 2008, Patzek was a professor of geoengineering at the University of California, Berkeley. Patzek is also a presidential full professor in Poland.

Patzek briefed Congress on the BP Deepwater Horizon well disaster in the Gulf, and was a frequent guest on NPR, ABC, BBC, CNN, and CBS. In January 2011, Patzek became a member of the Ocean Energy Safety Advisory Committee for the United States Department of Interior's Bureau of Safety and Environmental Enforcement. He co-wrote a popular book with historian Joseph Tainter, *Drilling Down: The Gulf Debacle and our Energy Dilemma.*

Since 2003, Patzek has engaged in the study of sustainability and industrial agricultural and agrofuel systems, all viewed through the lens of ecology and thermodynamics. In 2007, Patzek participated in the OECD ministerial meetings in Paris on the new biofuel mandates established in the U.S.

One of the focal points of Patzek's research has been an effort to obtain realistic assessments of oil, gas, and coal production. This work includes new forms of decline curve analysis, making predictions for the next several decades of production from gas shales.

Majed Al-Suwailem

Majed is a research fellow at KAPSARC with a focus on energy security, oil trade, and market structure. He has more than 15 years of experience in the oil and gas industry in the fields of simulation and modeling, asset management, oil field development, disruptive technologies, and business planning, gained at Chevron and Saudi Aramco.

Majed holds a B.S. degree in petroleum engineering from the University of Tulsa in the U.S., along with two master of science (M.S.) degrees in petroleum engineering, and reservoir geosciences and engineering, respectively, from Texas A&M University and the Institut Francais du Petrole (IFP School). He recently earned his M.S. degree in public economics and policy from Purdue University.

Bertrand Rioux

Bertrand is a research fellow focusing on the impact of market regulation and liberalization in energy markets. An experienced energy systems model developer (linear optimization and mixed complementary problems), he is working on developing the KAPSARC Energy Model (KEM) as a decision support tool for analyzing price regulation in energy economies. Bertrand has contributed to the development of KEM Saudi Arabia and is the lead developer of KEM China, studying the impact of government regulation in the coal, power and natural gas markets. He was previously employed as a research assistant at the Canadian Space Agency.

Frank Felder

Frank is an engineer, energy policy analyst, and program director for the Energy Transitions and Electric Power program at KAPSARC. Prior to joining KAPSARC, Frank was a research professor at the School of Planning and Public Policy at Rutgers University, director of the Rutgers Energy Institute, and director of the Center for Energy, Economics and Environmental Policy. In those roles, he conducted original and applied research in the areas of electric power system modeling, clean energy policies, and climate change for academic foundations, government agencies, and energy utilities. He has also worked as an economic consultant and nuclear engineer.

Ahmed Mehdi

Ahmed Mehdi is a visiting research fellow at the Oxford Institute for Energy Studies (OIES), where his work focuses on oil market fundamentals, Middle East upstream crude and products, and Iraq's energy sector. Alongside his role at OIES, Ahmed is chief analyst at Renaissance Energy Advisors, a specialist energy consulting firm which advises some of the world's leading international oil companies and trading houses. He is also a distinguished associate at Facts Global Energy (FGE) and principal at Benchmark Mineral Intelligence, the world's leading pricing agency dedicated to battery metals. Ahmed previously acted as an advisor to BHP Petroleum and has worked in the deals advisory team for PricewaterhouseCoopers (PwC) in London. Ahmed was educated at the University of Oxford and University College London.

About the Project

The rapid increase in natural gas demand for power generation and industrial development during the past decades has put pressure on Saudi Arabia's natural gas supply. While developments are underway to ramp up the country's natural gas production and harness associated gas production, supplementing domestic supply with liquified natural gas imports is an option for the Kingdom. This project looks at the challenges and opportunities for developing Saudi Arabia's natural gas production further.

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