Commentary

Saudi Arabia’s Gas Flaring Mitigation Experience

September 2020
Majed Al-Suwailem
Gas is envisaged as the fuel of choice in the power sector and is the ideal fuel to help transition toward clean, sustainable, and affordable energy access. As vital as gas is for electricity generation, the petrochemical industry, the transportation sector, and heating, many oil operators either flare or vent associated gas, a by-product of oil extraction, at the wellhead or gathering stations. This releases greenhouse gases (GHGs) into the atmosphere and is done for various reasons, including infrastructure constraints, a lack of financial incentives to capture and process gas, poor regulatory frameworks, or binding contractual rights.

The World Bank estimated the amount of flared natural gas in the oil and gas industry reached 5.1 trillion cubic feet (tcf) in 2018 (World Bank 2018). The amount of energy lost due to flaring or venting this gas is equivalent to more than 770 billion kilowatthours (kWh), and it releases more than 310 million tonnes of carbon equivalent. Due to these troubling statistics, many countries and oil operators have managed to mitigate gas flaring and venting across their oil and gas value chains.

One such example is the Kingdom of Saudi Arabia. The Kingdom’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. Before 1975, the Saudi oil and gas industry flared or vented over 4 billion standard cubic feet (scf) of associated gas, a by-product of oil extraction. This would have continued had it not been for the construction of Saudi Arabia’s Master Gas System (MGS), a network of gas-gathering facilities and pipelines to capture, process, and utilize gas as fuel and feedstock for the yet-to-be-established gas-based petrochemical industries in Jubail and Yanbu (Al-Ghamdi 2018).

With rising domestic gas demand in Saudi Arabia, particularly in the past two decades, Saudi Aramco sought solutions for meeting this demand. It succeeded in lowering gas flaring in its exploration and production activities by upgrading its facilities and using fit-for-purpose technologies to minimize flaring and prevent venting. Flaring at wellheads has been gradually phased out, and routine gas flaring at processing facilities was reduced to 80.9 tcf in 2018. This gave the Kingdom the fourth-lowest gas flaring intensity of all G20 countries, and it produces more gas than the three countries with lower gas flaring intensities.

Gas flaring mitigation has evolved rather than being a smooth transition. This commentary discusses Saudi Arabia’s progress in gas flaring, the measures the government has taken thus far, and how operators have adapted to them. It also identifies many lessons learned and technological solutions that could be scaled on national or corporate levels to reduce gas flaring, especially in cases where the state owns hydrocarbon assets and leases them to other operators. This commentary is part of a series of studies that examines Saudi Arabia’s gas demand, domestic gas supply, and trade in the global context.
Figure 1. Flaring intensities of G20 countries.

<table>
<thead>
<tr>
<th>Country</th>
<th>Cubic feet of gas flared per barrel of oil produced</th>
</tr>
</thead>
<tbody>
<tr>
<td>Australia</td>
<td>250.00</td>
</tr>
<tr>
<td>Indonesia</td>
<td>150.00</td>
</tr>
<tr>
<td>Mexico</td>
<td>100.00</td>
</tr>
<tr>
<td>Russia</td>
<td>200.00</td>
</tr>
<tr>
<td>India</td>
<td>200.00</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>100.00</td>
</tr>
<tr>
<td>Argentina</td>
<td>50.00</td>
</tr>
<tr>
<td>United States</td>
<td>25.00</td>
</tr>
<tr>
<td>China</td>
<td>25.00</td>
</tr>
<tr>
<td>Brazil</td>
<td>10.00</td>
</tr>
<tr>
<td>Canada</td>
<td>10.00</td>
</tr>
<tr>
<td>South Africa</td>
<td>5.00</td>
</tr>
<tr>
<td>Saudi Arabia</td>
<td>5.00</td>
</tr>
<tr>
<td>Turkey</td>
<td>5.00</td>
</tr>
<tr>
<td>France</td>
<td>5.00</td>
</tr>
<tr>
<td>Italy</td>
<td>5.00</td>
</tr>
</tbody>
</table>

Source: World Bank

*No flaring data figures were given for South Africa, Germany, and Japan
*South Korea does not produce crude oil domestically

History of gas flaring in the Kingdom

In the early 1900s, oil operators did not see gas as a viable commodity, and hence it was common practice in many global oil operations to flare and vent the gas produced at oil wells. Standard Oil of California, which was granted a concession by the Saudi government to explore and produce hydrocarbons in the Kingdom, flared gas at wellheads. The company carried out flaring for years, even after selling stakes in its Saudi business to other major United States (U.S.) oil companies. The business was subsequently renamed the Arabian American Oil Company, or Aramco.

Following the discovery of Ghawar, Saudi Arabia's largest oilfield, in 1948, which became operational in 1951, oil production in the country increased and more associated gas was produced and flared. As with Standard Oil, Aramco had no interest in capturing gas produced from its oil operations. There was no local or regional market for it, and exporting the gas would have required substantial infrastructure investments, which would have negatively impacted revenues. This coincided with periods of low crude oil prices that made gas projects uneconomic.
A few disagreements between the Saudi government and Aramco over contractual provisions and preemptive rights to the available associated gas beyond oil field operations persisted for a long time. A residual aversion to gas flaring had persisted among those concerned with oil and gas activities. In 1960, Abdullah Turaiki, Saudi Arabia’s first Minister of Petroleum and Mineral Resources, advocated ceasing flaring associated gas and utilizing it as feedstock for the Kingdom’s yet-to-be-established petrochemical industry (McMurray 2011).

The Saudi Ministry of Oil and Mineral Resources exercised its control by demanding the company reinject the gas produced from its operations into the oil reservoirs to provide reservoir pressure support. This led to building the Abqaiq and Ain Dar gas recycling plants, which became operational in 1955 and 1959, respectively. They could accommodate 200 million cubic feet (mcf) of associated gas per plant (McMurray 2011) and were suspended when the MGS was constructed in the mid-1970s.

Aramco attempted to monetize the associated gas in the mid-1970s by either selling liquefied petroleum gas (LPG) to local and international markets, particularly in Japan (IEA 2010), or using it to generate electricity to support its operations and residential zones (Haghihara 2013). These initiatives helped to reduce gas flaring (Figure 2) when it ranged between 85% to 95% in the 1970s. However, the initiatives were still deemed insufficient by the government.

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. In the early 1970s, the Saudi Ministry of Petroleum and Minerals contracted the Texas Eastern Corporation to conduct a technical and economic feasibility study. It evaluated the benefits of establishing a massive refining and petrochemical industry in the city of Jubail on the Arabian Gulf and Yanbu on the red sea, with gas as an important feedstock. The study required major capital expenditures on mid-stream oil operations. Aramco, on the other hand, proposed exploiting associated gas to generate electricity (Taher 2011).

Since the price of oil did not exceed $3 per barrel before the 1970s, the Saudi government opted to go for the first option. Aramco, however, only foresaw an opportunity in this development if the government contributed major capital to the mid-stream, resulting in a win-win for both the stakeholders and the operator, which turned out to be the case.

**Master Gas System**

The government gave Saudi Aramco a contract to establish the $12 billion Master Gas System (MGS) to capture, process, and utilize gas as fuel and feedstock for the petrochemical plants. Most of this project was paid for by the government.

By the fall of 1982, the key components of the MGS – gas gathering and processing facilities and pipelines – were fully operational (Robins 2002). The MGS saved 4.2 billion scf of gas from being flared, which prevented
80 million tonnes of carbon dioxide (CO$_2$) from being emitted into the atmosphere annually (Figures 2 and 3) (Al-Ghamdi 2018).

**Figures 2 and 3.** Gas utilization in Saudi Arabia.

---

Sources: KAPSARC analysis based on BP and Saudi Aramco data.
Over time, the MGS has been expanded as more oil and non-associated gas fields have been placed on-stream, and as demand has risen for dry gas in the power sector. As of 2018, the MGS gathered almost 3.5 tcf per year and is one of the world's largest single hydrocarbon networks. It includes 4,000 kilometers of pipelines, 50 gas oil separation plants, seven gas plants, and two natural gas liquid (NGL) units.

**Figure 4.** Master Gas System as of 2015.


**Growing domestic gas demand**

According to OPEC's 2019 Statistical Bulletin, Saudi Arabia is the world's ninth-largest producer of gas, with marketable gas production of 11.5 billion cubic feet per day. Continued investment in gas has resulted in steadily rising output over the years, with a sizable ramp-up in production over the past 10 years to meet increasing demand from the power and petrochemical sectors.

Over the past two decades, the Kingdom has witnessed the creation of several petrochemical companies. The Saudi Arabian Basic Industries Corporation (SABIC) is the leading petrochemical player, with Sipchem also a leading manufacturer. Saudi Aramco went into joint venture projects with U.S. firm Dow Chemical, creating the Sadara Chemical Company. It represented Aramco's first major step toward becoming a globally integrated energy and chemicals company. This move was followed by Aramco’s recent acquisition of the Saudi Public Investment Fund’s (PIF’s) 70% stake in SABIC.
To gain a better understanding of the Kingdom’s decision to harness associated gas, one should explore the infrastructural developments of the Jubail and Yanbu industrial cities, as well as consider that the Saudi population has grown from 25.8 million to 33.7 million in only a decade. This growth coincided with periods of high oil prices, especially between 2008 and 2018, making crude oil and other products too expensive to burn. As such, the use of gas as a fuel has been gaining momentum gradually, primarily to meet domestic demand and displace existing oil-based power generation from the energy mix (Figure 5).

**Figure 5.** Annual fuel consumption of power in Saudi Arabia by type.

Had it not been for the Kingdom’s decision to collaborate with Aramco to harness associated gas, the country would not have a flourishing petrochemical industry. Furthermore, the contribution of gas to overall power generation would have been insignificant, and more liquid fuels would have been used to generate electricity. This would have incurred additional costs and reduced oil exports, not to mention that the country would have been among the top three gas flarers globally.

To get a better perspective, let us take Iraq as an analog. It is the second-largest gas flarer after Russia. In its oil industry, 65% of the gas produced is flared, most of which is associated gas. The remainder is used for electricity generation, in Iraq’s marginal petrochemical industry, or recycled into oil reservoirs as a means of pressure support or to enhance oil recovery. The lack of midstream infrastructure to capture, process, and transport gas into power plants and the absence of a
large-scale petrochemical industry augmented the issue even further (Al Suwailem, Al Muhanna, and Shabaneh 2020).

There are no incentives for international oil companies in Iraq to capture this gas since oil is profitable, and the service contracts signed with these companies are non-binding. The Iraqi power sector suffers from aging infrastructure and fuel shortages, which causes frequent blackouts, especially during the summer when demand for electricity for cooling is at its peak (Al Suwailem, Al Muhanna, and Shabaneh 2020).

Without the measures taken by the Saudi government and the joint investment between the government and Aramco in building the MGS, the Kingdom might have had to produce an additional 18 billion scf per day in 2018 to meet domestic gas demand, while burning 65% of the total gas produced. This assumes all other factors held constant.

**Figure 6.** Hypothetical (flaring 65% of total gas) vs. actual gas production.

In reality, the Kingdom cannot produce more gas, as doing so would require producing more oil to liberate the associated gas. This conflicts with Saudi Arabia’s strategy, in collaboration with its partners inside and outside OPEC, to stabilize oil markets.

Hence, to meet growing demand, Aramco has placed a lot of emphasis on two frontiers: aggressively curbing gas flaring in its midstream and oilfield operations and developing more non-associated gas fields, including unconventional ones such as the Jafura field.
Environmental regulations and economic co-benefits

There are currently no specific regulations for eliminating gas flaring and venting in exploration and production. Regulations and standards to monitor and impose a limit on gas vapors do exist, but they are more focused on the downstream (refining and oil storage) aspect of the oil and gas industry. For instance, General Authority of Meteorology and Environment Protection (GAMEP) standards mandate that oil storage vessels with capacities of more than 1,000 barrels must be equipped with vapor emission control devices (GAMEP 2001).

Air quality improvement is a key initiative of GAMEP, with network source emission measuring devices and ambient air quality stations currently linked to the national air quality control center (Goswami 2019). Even though this initiative is non-binding, Saudi Aramco and its subsidiary, the Aramco Gulf Operations Company, have taken air quality improvement measures seriously in the partitioned zone between Saudi Arabia and Kuwait as part of their health, safety, and environment guidelines and best practices.

Government intervention is not always needed to limit oil companies’ gas emissions as long as the company demonstrates environmental stewardship, as in the case of Saudi Aramco. Oil companies can take the lead in this respect, while serving the national strategic objectives of their host countries.

Saudi Arabia’s Nationally Determined Contributions (NDCs), submitted to the United Nations Framework Convention on Climate Change (UNFCCC) in November 2015, highlight the actions taken by Saudi Aramco. Three out of its five contributions were gas-related initiatives, with one clearly highlighting Saudi Arabia’s proactiveness in recovering methane and minimizing flaring and fugitive emissions (UNFCCC 2015).

Corporate gas flaring mitigation initiatives

Over the past two decades, Saudi Aramco has been implementing corporate-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 innovative technologies in well clean-up operations before placing them on-stream, as well as the deployment of flare gas recovery systems in its gas oil separator plants (GOSPs) and crude and gas processing complexes (Al-Ghamdi 2018).

Technical petroleum engineering papers from Saudi Aramco suggest that flaring at wellheads has been gradually eliminated in its upstream operations by ensuring that oil wells do not go online until gas takeaway is in place. Though difficult to achieve, Aramco deployed best-in-class technologies and practices to minimize associated gas flaring, with the first application of these and large-scale deployment at the Manifa offshore development.

The Manifa bay is a habitat of seagrass and coral reefs: sources of food for aquatic ecosystems. It is also home to a vibrant array of creatures, from shrimp and crabs to endangered species such as turtles. Fishery is also active in this area, yet conventional oil development (e.g., flare residues) and subsequent operations make it susceptible to accidental oil spills, thus threatening the delicate marine ecosystem (Saudi Aramco n.d.).
Sour gas containing hydrogen sulfide ($H_2S$) represented another challenge. Manifa’s heavy crude has low, but alarming concentrations of sulfur in its oil and gas streams. The separation of $H_2S$ deposits from mainstream oil and gas was crucial during the well clean-up process, not only for the marine environment but also for the local communities that relied on fishery. The deployment of zero discharge technologies using ‘smokeless’ flares and $H_2S$ scavengers minimized these threats and enabled Aramco to capture an additional 4,000 barrels and 480 thousand cubic feet per well instead of flaring these quantities. This paved the way to a new era of greenfield development for Aramco.

Aramco deployed utility flare systems at the GOSPs. These are safety devices that provide adequate performance for relief capacity and hydrocarbon destruction efficiency. This mitigates any non-routine gas flaring that occurs during operational upsets, high gas line pressures or for safety reasons. To ensure flare efficacy, Aramco’s company standards were significantly revised, and staff were trained to operate, anticipate problems, and proactively manage flaring operational upsets (Mashour, Smith, Palfreeman, and Seefeldt 2010).

To reduce the routine flaring of gas, in 2008 Aramco began to upgrade most of its GOSPs with smokeless flare technologies to reduce black smoke, as well as flare gas recovery systems, which aimed to minimize waste gas routed to the flare systems (Mashour, Smith, Palfreeman, and Seefeldt 2010). As a result, gas flaring at Aramco facilities decreased significantly from 2.3% to 0.5% of total raw gas production (Figure 7) (Al-Ghamdi 2018).

**Figure 7.** Hypothetical (flaring 65% of total gas) vs. actual gas production.

---

Source: Organization of Arab Petroleum Exporting Countries (OAPEC) Data Bank, Saudi Aramco

Note: MMscf/d= million standard cubic feet per day
The partitioned ‘neutral’ zone

Aramco Gulf Operations Company (AGOC), a subsidiary of Saudi Aramco, operates the Saudi government’s share of the offshore oil and gas fields in the partitioned zone between Saudi Arabia and Kuwait. AGOC commenced its activities when the Japanese-owned Arabian Oil Company’s concession agreement with the Saudi government expired in 2000.

**Figure 8.** The partitioned zone.

There are no official disclosed figures of associated gas volumes, but they are likely to be in the range of 30 to 60 million scf per day, most of which is flared. A portion of the gas has been recycled into the reservoirs to artificially lift heavy crude oil in many wells to lighten the oil column and induce oil to the surface. In 1988, nearly 25 mcf per day of gas was allocated for artificial lift operations, which was increased gradually (Ghoniem, Samizo, and Al-Thuwainy 2005).

AGOC extended the lessons learned from Saudi Aramco by applying best-in-class reservoir management and operational excellence in its field development plan. It sought to monetize the associated gas and collaborated with Kuwait Gulf Operations Company, which operates Kuwait’s interest in the Khafji oilfield.

Aramco used its leverage and experience in mitigating gas flaring in the offshore partitioned zone. In 2010, contracts were awarded to expand the field, upgrade its gas processing facilities, and construct a new NGL plant at Khafji (NS Energy 2020). Major facility upgrades were required, and it was necessary to shut down oil production until March 2020, when the upgrades were completed.
Lessons and scalability of the Saudi case

The lessons learned from this process can be scaled up. They can help both governments and oil enterprises be prepared, and they can be adopted and scaled on national or corporate levels to reduce gas flaring. This is especially valuable where ownership of the hydrocarbon assets belong 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 consumer markets.

Strategic partnerships between governments and the private sector remain the main catalyst for development and can form part of the circular carbon economy framework. It is crucial to highlight that gas flaring mitigation is a continuous and evolutionary process. Saudi Arabia has come a long way in harnessing and using gas as feedstock in its power and petrochemical sectors due to the beneficial relationship it has with Saudi Aramco. Governments around the world can help their private sectors to support climate change initiatives by offering tax cuts, or land permits to develop intrinsic pipelines.

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 if that gas is not marketable. Mid-stream networks and functioning gas markets are crucial for justifying additional investments from operators in harnessing gas.

On a different note, eliminating gas flaring entirely is not always applicable, and much of the emphasis on gas flaring focuses on routine flaring. The latter occurs because of the absence of sufficient facilities or amenable geologies for recycling gas or dispatching it to nearby markets. Examples include the flaring of gas production at wellheads or flaring at gas processing facilities that produce gas in excess of infrastructure capacities.

Non-routine flaring is an important safety feature of oil- and gas-producing and -processing facilities. It provides a safe and effective means for burning gas during a plant emergency, such as a valve leak, purge, or a terrorist attack. This feature proved effective during the attacks on the Abqaiq and Khurais processing facilities in 2019 and helped diffuse system pressure, preventing any damage from spreading. Non-routine flaring will persist for a long time, but for now much of the emphasis is on curbing routine flaring at wellheads and processing facilities, with much of the technological development aimed at this.

The heightening awareness of climate change has put pressure on many oil operators to reduce their GHG emissions and secure social licenses to operate in the communities or countries where they work. Many oil companies have now set targets to curb the GHG emissions produced by their operations. For example, BP and Total have recently announced goals of becoming net-zero emission companies by 2050. These might be ambitious goals, given the complexity of their overseas operations and the need to collaborate with governments to achieve such targets.
In the case of the partitioned zone between Saudi Arabia and Kuwait, facility upgrades to capture the gas required major shut-downs, which will impact the profitability of these companies.

Environmental regulations were not the primary driver for Saudi Arabia to mitigate gas flaring. It was Saudi Aramco's decision to harness gas to offset the increasing domestic demand for gas from power generation. To further solidify its commitment to gas flaring mitigation, in November 2019, Saudi Aramco joined the World Bank’s Zero Routine Flaring by 2030 initiative. Thirty-nine global oil companies have endorsed this initiative so far, and the list is growing. By joining this cause, these companies are demonstrating their environmental stewardship and accountability, and their commitment to eliminating gas flaring. It is highly likely that Saudi Aramco will eliminate routine flaring before 2030, given the progress it has made thus far. It is demonstrating to other players in the industry how proactive measures can result in long-term economic benefits for everyone.

References


**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 LNG imports is an option for the Kingdom. This project looks at the challenges and opportunities for developing Saudi Arabia's natural gas production further.
About KAPSARC

The King Abdullah Petroleum Studies and Research Center (KAPSARC) is a non-profit global institution dedicated to independent research into energy economics, policy, technology and the environment, across all types of energy. KAPSARC’s mandate is to advance the understanding of energy challenges and opportunities facing the world today and tomorrow, through unbiased, independent, and high-caliber research for the benefit of society. KAPSARC is located in Riyadh, Saudi Arabia.

Legal Notice

© Copyright 2020 King Abdullah Petroleum Studies and Research Center (“KAPSARC”). This Document (and any information, data or materials contained therein) (the “Document”) shall not be used without the proper attribution to KAPSARC. The Document shall not be reproduced, in whole or in part, without the written permission of KAPSARC. KAPSARC makes no warranty, representation or undertaking whether expressed or implied, nor does it assume any legal liability, whether direct or indirect, or responsibility for the accuracy, completeness, or usefulness of any information that is contained in the Document. Nothing in the Document constitutes or shall be implied to constitute advice, recommendation or option. The views and opinions expressed in this publication are those of the authors and do not necessarily reflect the official views or position of KAPSARC.