Reducing Gas Flaring in Arab Countries

A Sustainable Development Necessity

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Economic and Social Commission for Western Asia

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Introduction

For decades, the flaring of gas associated with crude oil production was considered unavoidable. National and international oil and gas companies attempted to reduce this wasteful and environmentally harmful burning of an exhaustible natural resource, but to no avail, except in a limited number of producing areas.

Following the adoption in December 1997 of the Kyoto Protocol to the United Nations Framework Convention on Climate Change (UNFCCC), which commits its parties to internationally binding emission reduction targets,[1] the need to address associated gas flaring became apparent. At the World Summit on Sustainable Development, held in Johannesburg in August 2002, the World Bank-led Global Gas Flaring Reduction (GGFR) public-private partnership was created.[2] The main objective of the GGFR partnership, comprising Governments, oil and gas companies and multilateral development institutions, is to raise awareness globally about the adverse impact of flaring, and to support Governments and the petroleum industry in reducing associated gas flaring.

According to GGFR, an average of 145 billion cubic meters (bcm) of gas has been flared annually over the last five years (2014-2018), resulting in over 350 million tons of carbon dioxide equivalent emissions per year.[3] This represents a small percentage of total emissions produced from burning fossil fuels globally, but it is equivalent to almost all the potential yearly emission reduction projects from projects submitted (as of 2018) under the Kyoto Protocol.[4] Furthermore, in some countries, gas flaring remains a key environmental issue to mitigate. Apart from its adverse climate change impact, flaring affects a wide range of sustainable development aspects.

Within the framework of the 2030 Agenda for Sustainable Development, associated gas flaring has an impact on the following Sustainable Development Goals (SDGs):[5]

- SDG 3 on good health and wellbeing;
- SDG 7 on energy;
- SDG 8 on decent work and economic growth;
- SDG 9 on industry, innovation and infrastructure;
- SDG 11 on sustainable cities and communities;
- SDG 12 on responsible consumption and production;
- SDG 13 on climate action;
- SDG 14 on life below water;
- SDG 15 on life on land.

Focusing on the Arab region, nine Arab countries are within the top 30 gas flaring countries worldwide. These Arab hydrocarbon producers accounted for about 30 per cent of associated gas flared globally in 2018. However, levels of gas flaring vary considerably among Arab countries. The volumes of associated gas flared by some producers remain relatively high. This is extremely critical given that the Middle East and North Africa (MENA) region is

expected to have one of the highest gas demand growth rates worldwide, with some countries already suffering from a rising gas supply deficit. Moreover, the MENA region is expected to be one of the regions that will be most affected by climate change.

The present paper reviews the gas flaring situation in Arab countries, identify the challenges and opportunities of gas flaring reduction in them, and make recommendations on key aspects to address, reduce and eventually eliminate associated gas flaring in Arab countries. It also outlines linkages between associated gas flaring and the SDGs. Moreover, it sets out how flaring mitigation and compliance efforts are reported (or not) and progressing, especially with respect to nationally determined contributions (NDCs).

1. Reducing Gas Flaring in the Context of Climate Action and Sustainable Development

A. The Arab region and energy vulnerability

Identifying the linkages between gas flaring and the SDGs requires an overview of the Arab region's energy situation, and more specifically its energy vulnerability. This vulnerability, which is the theme of a recent ESCWA study, is defined as: the absence of adequate safeguards to ensure that a country's energy demand and supply patterns are sustainable, to support socioeconomic growth and development in the long run.[6]

The study highlights the Arab region's high reliance on fossil fuels, making it the second fastest growing regional source of greenhouse gas emissions. Despite its relatively small total emission level compared with industrialized economies, the Arab region's carbon footprint is rising rapidly. This is increasingly worrying for Arab countries, which are facing significant risks from climate change. Several areas of the Arab region are already suffering from an increasing wave of extreme weather conditions.[7]

There is therefore a need to reiterate calls for a rethink of energy supply and demand patterns in the Arab region. Focusing on the supply side of the region's energy vulnerability, it is clear, that Arab countries, especially hydrocarbon producing countries, will continue to rely heavily on fossil fuels. However, they will need to consistently improve the way they use these natural resources to minimize their impact on their environment. The reduction and eventual elimination of gas flaring in Arab countries is one of many measures to address the region's energy vulnerability.

B. Gas flaring reduction and SDG linkages

The benefits of reducing and eventually eliminating all gas flaring are largely linked to SDG 13 on climate action. However, in reality, the benefits are associated with several SDGs, as mapped out in table 1.

One common aspect of gas flaring mitigation under some of the SDGs is how local communities are affected by it. In some Arab hydrocarbon producing countries, gas flaring occurs in remote desert areas far from human settlements, but this is not the case for all Arab producers. Furthermore, gas flaring affects not only human beings, but the whole ecosystem.

Table 1. Gas flaring mitigation and SDG linkages

Sustainable Development Goal	Gas flaring mitigation impact
SDG 3: Good health and wellbeing	Gas flaring has been proven to affect the health and wellbeing of communities located near flaring sites, so flaring mitigation will meet SDG 3.
SDG 7: Affordable and clean energy	The recovery of flared gas and its use as a cleaner fuel (compared with other polluting fuels) to generate electricity will ensure or improve access to energy, especially for local communities and/or regions not linked to an electrical grid.
SDG 8: Decent work and economic growth	The monetization of recovered gas to create projects that consume natural gas and/or liquefied petroleum gas (LPG) extracted from associated gas will create economic growth and employment opportunities.
SDG 9: Industry, innovation and infrastructure	Gas flaring reduction and elimination actions involve investment in infrastructure development. The availability of gas-fired electricity generation also facilitate the development or sustainability of small industries.
SDG 11: Sustainable cities and communities	The continuous flaring of gas near communities has significantly affected them. Reducing this flaring and preferably eliminating it altogether will result in a clear improvement in these communities' environment and health.
SDG 12: Responsible consumption and production	Stopping or adequately reducing the wasteful and environmentally harmful burning of gas associated with crude oil production is consistent with the responsible production of hydrocarbon resources.
SDG 13: Climate action	The reduction and eventual elimination of gas flaring has a direct link to climate change action, as it reduces carbon dioxide emissions. It is consistent with all climate change mitigation agreements, especially the Paris Agreement.
SDG 14: Life below water	Gas flaring produces greenhouse gas emissions that lead to acid rain, which water and its marine environment.[a]
SDG 15: Life on land	The flaring of gas produces atmospheric contaminants, including nitrogen, carbon and sulphur particulate matter, hydrocarbons and ash, photochemical oxidants, and hydrogen sulphide that acidify the soil and deplete soil nutrients.[b] Reducing or stopping gas flaring will therefore have a significant impact on land and ecosystems close to flaring sites. This could also be relevant to SDG 6, as gas flaring could affect water supplies through acid rains.

Source: Compiled by ESCWA.
Notes: [a] https://pdfs.semanticscholar.org/3451/a61c4bf288284f4f8d70b9f3689b00045fb8.pdf.
[b] http://pubs.sciepub.com/jephh/1/1/2/.

2. Overview of the Gas Flaring Situation in the Arab Region

A. Background

Concerns about wasteful flaring of associated gas are not new in the Arab region. Arab policymakers have been uneasy about this issue for several decades. For example, in 1963, Kuwait Oil Company was criticized by members of the Kuwaiti parliament for associated gas flaring. In 1966, four years after the independence of Algeria, its Government prohibited the gas flaring. In 1975, Saudi Arabia launched the Master Gas System project to recover associated gas flared in large volumes. Unfortunately, financial pressure to continue to produce oil, and a lack of commercially viable markets for natural gas, prevented a serious rethink of gas flaring in the Arab region and in other hydrocarbon producing countries, until the adoption of the Kyoto Protocol.

B. Gas flaring levels

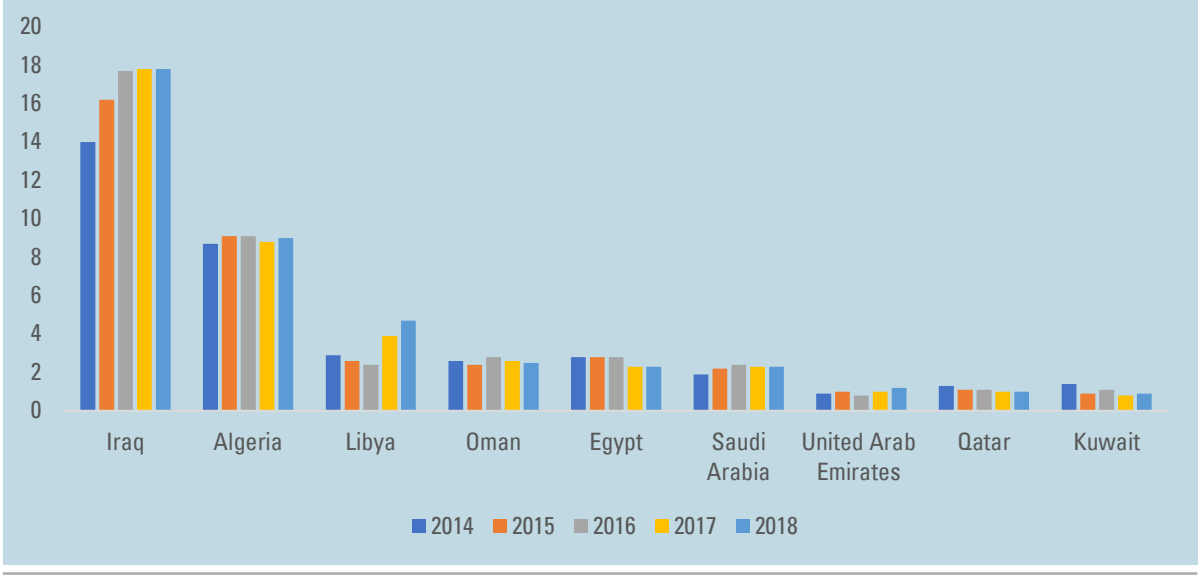
Since 2014, gas flaring has increased significantly in conflict-affected countries (Iraq and Libya), but decreased in some Gulf countries (Kuwait and Qatar), but from a much lower baseline. From 2014 to 2018, Arab countries flared on average a total of about 40 bcm per year, or the equivalent of about 10 per cent of their combined domestic consumption of natural gas in 2018. However, as shown in figure 1, gas flaring levels differ significantly between countries. In 2018, Algeria, Iraq and Libya accounted for close to 80 per cent of the Arab region's total gas flaring. If we add Egypt, Oman and Saudi Arabia, the total gas flaring of this group of six countries represents over 90 per cent of all the gas flared in the Arab region.

Figure 1 presents the volumes of flared gas. The situation is somehow different when comparing flaring volumes relative to each country's gas consumption, as presented in figure 2.

Figure 2 shows that four countries (Iraq, Libya and to a lesser extent Algeria and Oman) emerge as large gas flarers relative to their natural gas use. The two conflict-affected countries, Iraq and Libya, have extremely high levels of gas flaring, equivalent to 105 per cent and 85 per cent of their respective 2018 gas consumption. The volumes of gas consumed are seen as repressed or constrained gas consumption levels compared with their potential gas demand, owing to the political instability affecting these countries.

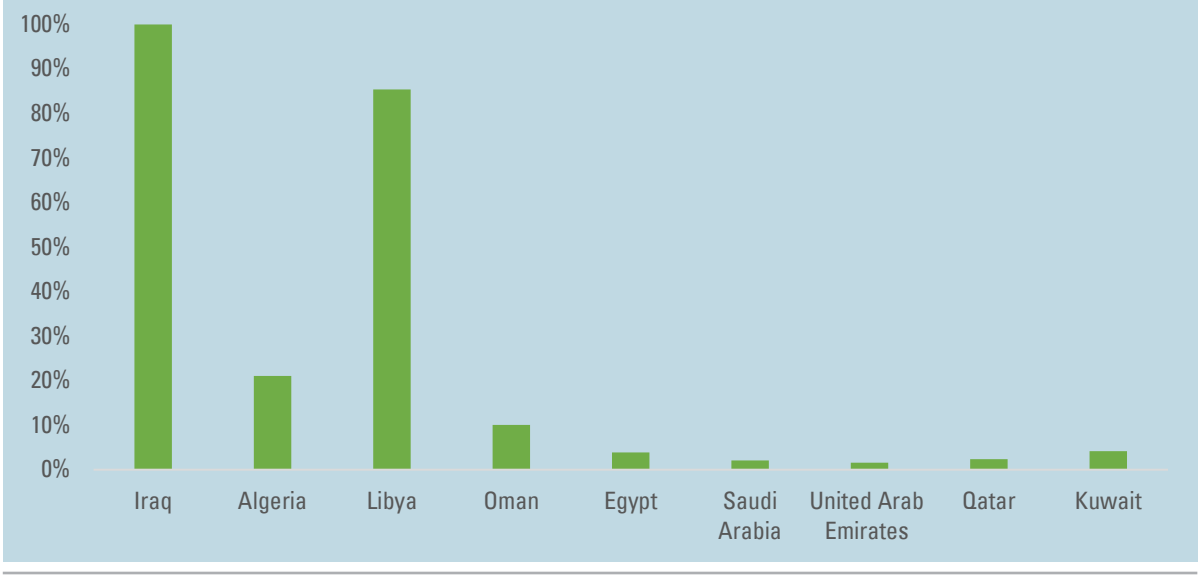
Gas flaring volumes in Algeria and Oman are the equivalent of 21 per cent and 10 per cent, respectively, of their gas consumption levels in 2018. Despite the much lower percentage levels compared with Iraq and Libya, the flared volumes remain relatively high for countries facing natural gas supply constraints.

Figure 1. Gas flaring in Arab countries (bcm), 2014-2018



Source: NOAA, Colorado School of Mines, GGFR Rounded numbers. Available at http://pubdocs.worldbank.org/en/603281560185748682/pdf/Gas-flaring-volumes-Top-30-countries-2014-2018.pdf.

Figure 2. Gas flaring as a percentage of 2018 gas consumption



Source: BP Statistical Review of World Energy 2019. Available at www.bp.com/content/dam/bp/business-sites/en/global/corporate/pdfs/energy-economics/statistical-review/bp-stats-review-2019-full-report.pdf.

Table 2. NDC gas flaring mitigation targets and zero-routine flaring in the Arab region

Country	NDC flaring mitigation target	Zero-routine flaring
Iraq	To the best of ESCWA knowledge, Iraq has not submitted an NDC.	The Government of Iraq has endorsed zero-routine flaring by 2030.
Algeria	Reduce flaring to 1 per cent by 2030. The deadline of this 1 per cent target has recently been shortened to 2021.	The Algerian Sonatrach has endorsed zero-routine flaring by 2030.
Libya	To the best of ESCWA knowledge, Libya has not submitted an NDC.	
Egypt	Flaring was included in a list of greenhouse gas emission reduction actions, without providing details.	The Egyptian Government has endorsed zero-routine flaring by 2030.
Kuwait	Flaring is not mentioned in NDC. Reference is made to the importance of diversifying the energy mix to avoid increases in greenhouse gas emissions by 2030.	Kuwait, through Kuwait Oil Company, has endorsed zero-routine flaring by 2030.
Oman	The reduction of flaring in oil industries is listed as one of the mitigation contributions for the period 2020-2030.	The Government of Oman and Petroleum Development Oman have endorsed zero-routine flaring by 2030.
Qatar	Flaring not mentioned in NDC.	International oil and gas companies operating in Qatar have endorsed zero-routine flaring by 2030.
Saudi Arabia	Minimizing flaring is mentioned in the methane recovery and flare minimization action, but with no quantified target or clearly defined time horizon.	The Saudi Arabian Government and Saudi Aramco have endorsed zero-routine flaring by 2030.
United Arab Emirates	No reference to a flaring reduction target. NDC indicates that ADNOC was the first national oil company in the region to promote the reduction of gas flaring.	International oil and gas companies operating in the United Arab Emirates have endorsed zero-routine flaring by 2030.

Source: NDC Registry. Available at https://www4.unfccc.int/sites/NDCStaging/pages/All.aspx.

For the remaining five Arab countries (Egypt, Kuwait, Qatar, Saudi Arabia and the United Arab Emirates), gas flaring represents between 2 per cent and 4 per cent of their 2018 gas consumption, as shown in figure 2. It would have been interesting to also show also gas flaring as a percentage of total gross gas production, especially associated gas output,[8] but no such data on gross gas production is publicly available for Arab hydrocarbon producers.[9]

C. NDC flaring reduction targets

The Governments of all Arab oil and gas producing countries have repeatedly expressed their aim to reduce or eliminate associated gas flaring, so as to reduce greenhouse gas emissions. However, few countries have put forward clearly quantified flaring mitigation targets, or emission targets in general, in their NDCs.[10] Furthermore, there is no publicly available information on each country's NDC national compliance or implementation plans, with relevant timeframes and details of planned mitigation efforts.

Table 2 presents gas flaring targets, if available, as set out in countries' NDCs submitted to UNFCC, in accordance with the Paris Agreement.

Table 2 also includes information on Arab countries that have endorsed the World Bank-led zero-routine gas flaring initiative. This initiative brings together Governments, oil companies and development institutions who recognize the flaring situation as unsustainable from a resource management and environmental perspective, and who have agreed to cooperate to eliminate routine flaring by 2030. The Initiative pertains to routine flaring and not to flaring for safety reasons or non-routine flaring, which nevertheless should be minimized.[11]

D. Gas flaring regulation in Arab countries

The lack of regulatory frameworks or effective and enforceable regulation to reduce and eventually stop associated gas flaring is a key challenge faced by Arab hydrocarbon-producing countries. As shown in table 3, this ranges from cases where there is no specific regulation of gas flaring, to cases where a country's oil and gas regulation clearly addresses the issue of gas flaring reduction or elimination and sets non-compliance penalties or taxes.

Table 3. Gas flaring regulation in Arab countries

Country	Regulation	Penalties or flaring taxes
Iraq	No specific gas flaring regulation. In the Kurdistan region of Iraq, where only about 20 per cent of Iraqi gas flaring takes place, production sharing agreements prohibit flaring (with some exceptions). A federal oil and gas draft law, proposed in 2011, includes detailed flaring conditions and mitigation actions, but it was not passed.[a]	

Country	Regulation	Penalties or flaring taxes
Algeria	Article 52 of the 2013 Hydrocarbons Law[b] prohibits gas flaring. However, routine flaring authorizations could be granted exceptionally for limited periods of time. Article 158 of the new 2019 Hydrocarbons Law prohibits the flaring and venting of gas. As stipulated in the previous law, routine flaring authorizations could be granted exceptionally for limited periods of time. Flaring required for safety reasons does not require such authorizations, but a detailed report must be submitted to the relevant regulatory authorities 10 days after the flaring. The new hydrocarbons law has been approved by the lower and upper houses of parliament, but the final version of the law has not been issued yet.	Any operator requesting this exceptional authorization will have to pay a non-deductible specific tax to the treasury of 8,000 Algerian dinar/'000m^3 of flared gas.[c] For isolated areas, a different flaring tax system applies. In the new 2019 Hydrocarbons Law, the above penalty has been increased to 12,000 Algerian dinars/'000m^3 to take into consideration the depreciation of the Algerian dinar.
Libya	No information available.	
Egypt	No specific gas flaring regulation. Flaring reduction or elimination is implied indirectly in the *Concession Agreement for Petroleum Exploration and Exploitation.* Flaring is addressed in the Environmental Law for Environmental Impact Assessments.	
Kuwait	No specific gas flaring regulation. Gas emissions regulated by environmental protection regulations (Kuwait Environmental Public Authority).	
Oman	Emission standards regarding associated gas flaring are regulated by Ministerial Decision No. 118/2004 issued by the Ministry of the Environment and Climate Affairs.	

Country	Regulation	Penalties or flaring taxes
Qatar	No specific gas flaring regulation, but the Environmental Protection Law and its executive regulations apply to flaring and set flaring limits. Furthermore, some upstream agreements also regulate gas flaring.	
Saudi Arabia	No specific gas flaring regulation. Air quality improvement aspects are regulated by the General Environmental Law.	
United Arab Emirates	According to articles 44 to 46 of the Petroleum Resource Conservation Law, a government authorization is required for associated gas flaring. But ADNOC has a no-flaring policy. The Environmental Protection Law requires that the burning of any type of fuel, including in the production of crude oil, be minimized and kept within prescribed limits.[d]	

Source: Thomson Reuters Practical Law, Oil and Gas Regulations – Oman, Qatar, Saudi Arabia, and UAE. Available at https://uk.practicallaw.thomsonreuters.com/Browse/Home/PracticalLaw?transitionType=Default&contextData=(sc.Default)&comp=pluk.

Notes: [a] Perrine Toledano and others, Iraq Associated Gas Utilization Study, Columbia Centre for Sustainable Development, 2016.

[b] Amended Hydrocarbons Law No. 13-01 of 20 February 2013.

[c] This was about $3/MMBtu when the law was issued, which is a heavy penalty considering that the wholesale (subsidized) price of natural gas in Algeria was and still hovers at around $0.50/MMBtu.

[d] https://thelawreviews.co.uk/edition/the-oil-and-gas-law-review-edition-6/1175793/abu-dhabi.

3. Identifying Challenges

A. Multifaceted challenges

Arab hydrocarbon producers face multifaceted and interlinked challenges in their efforts to reduce and eventually eliminate gas flaring. These challenges cover a wide range of constraints, including technical, operational, policy, regulatory, economic, financial and political factors. The importance of each of these challenges differs between countries, but all countries share a common fundamental concern: mitigating and ultimately eliminating the wasteful and environmentally adverse flaring of gas.

B. Technical and operational challenges

The flaring of associated gas is conducted during the production of crude oil. This flaring occurs when it is not possible for technical and operational reasons to recover the associated gas and use it. This happens when there is a lack of infrastructure to compress the raw gas, transport it, treat it and separate it from natural gas liquids (NGLs), or to reinject it into the reservoir. This type of flaring is defined as 'routine flaring'. Non-routine flaring or 'safety flaring' is when the gas has to be flared for safety reasons to prevent accidents that would affect the safety of the facilities and the operating personnel.

The absence of gas infrastructure is one of the fundamental barriers that prevent the reduction and eventual elimination of gas flaring. This factor is directly linked to the above-mentioned regulatory, economic, financial and political challenges. Iraq, the Arab region's largest gas flarer, is facing a severe lack of gas infrastructure. The volume of associated gas produced by far exceeds the existing capacity of Iraqi gas processing and transport facilities. Old or damaged infrastructure needs to be rehabilitated, and new facilities have to be developed. As Iraqi crude oil production continues to expand, this aspect is becoming increasingly challenging to address.[12]

However, big hydrocarbon producers with significant financial resources and a strong national oil and gas company are in a better position to tackle these barriers. Smaller hydrocarbon producers with limited financial resources, and countries undergoing political conflicts (such as Libya) or emerging from conflict (such as Iraq) will find difficulties in mobilizing funding and ensuring the required political stability to rehabilitate and develop new gas infrastructure. There is a small number of hydrocarbon producers with established large national oil companies (such as Sonatrach in Algeria) that continue to make efforts to reduce and eventually eliminate gas flaring.

In some cases, the volumes of associated gas flared are not metered or even reliably metered to estimate how much gas is being flared. Furthermore, there have been instances where the composition of the gas flared is also not established or the sampling and analysis of the

gas flared is not carried out correctly. This is critical, especially for gases that have a high NGL content that could significantly increase the commercial viability of gas flare recovery projects.

C. Policy and regulatory challenges

It is important to reiterate that all the challenges or barriers discussed in this section are closely interlinked. One of the key causes of continuous gas flaring in some producing countries is the lack of or inadequate policies and strategies to reduce flaring. There is often an absence of coordination or integration between energy policies and environmental policies addressing gas emissions, and more specifically gas flaring. This could explain why some of the NDCs submitted by Arab producers have generic gas flaring reduction actions or none at all. It should be stressed that this problem also exists in producing countries from other regions worldwide.

This lack of adequate policies and strategies translates into an absence of effective frameworks to regulate gas flaring. As shown in the previous section, a very limited number of Arab hydrocarbon producers have regulations that adequately cover the reduction/elimination of gas flaring. If a regulatory framework exists but is not properly enforced, or if too many exceptional cases are invoked to authorize the continual flaring of gas, a framework becomes ineffective. It should be acknowledged that some Arab producers that do not have explicit gas flaring reduction regulations have managed to reduce gas flaring significantly through financial endowments and government commitments and initiatives.

As mentioned above, the lack of coordination or even communication between different government agencies (mainly energy institutions and environment authorities) leads to inadequate action to mitigate gas flaring or an absence of action altogether.

D. Economic and financial challenges

Policies and regulations have a significant impact on the potential removal of economic and financial barriers to develop projects to reduce and eliminate gas flaring. Routine flaring is the remaining option when there are no commercially viable options to monetize the gas, when it is not possible to reinject the gas into the reservoir, or when the State is unable to fund (subsidize) the development of required infrastructure.

Associated gas is flared from a number of wells, sometimes quite distant from one another, in small volumes and at low pressure. Therefore, the compression, gathering, transport and processing of the recovered gas volumes could be commercially challenging owing to a lack of economies of scale to reduce unit costs of infrastructure, a lack of viable local markets, and perceived high-risk factors for certain countries (conflict countries) to obtain financing.

The attractiveness of a gas flare recovery project and the monetization of the recovered gas depends on the stakeholders involved in the project. In most of cases, the use of associated gas produced with crude oil is limited to the production site's needs (reinjection into oil fields for enhanced oil recovery, gas lift, electricity generation and other onsite applications). In many cases, the State legally owns the

associated gas that is not utilized onsite, but its State-owned oil and gas company is not always able or willing to invest in compression, processing and transport infrastructure to extract and monetize the gas. Therefore, because of prevailing ownership conditions of the associated gas, decisions to recover the flared gas are different for each stakeholder. The parties, especially private sector entities, who could fund flare recovery projects may not have the right incentives to reduce or stop gas flaring.

A private oil and gas entity will assess the project's financial or commercial viability within the boundaries of the project it is involved in, subject to its corporate sustainable development policy and local and international commitments. Investments in gas infrastructure for recovery and use of the associated gas would be limited to the project.

A State-owned hydrocarbon entity (Saudi Aramco or Sonatrach in Algeria), as a representative of the State, may consider the flare recovery and monetization project from a national economic point of view. It would assess its viability and impact beyond just the boundaries of the project and use non-financial evaluation criteria.

If not properly formulated to take into consideration the issue of gas flaring, regulatory and contractual aspects governing the operation of hydrocarbon production and marketing, the financial viability of flare recovery and utilization projects could be adversely affected. Most importantly, if recovered gas volumes are marketed locally, where heavily subsidized domestic gas prices prevail, as is the case in most Arab producing countries, investments in gas monetization projects would not be financially viable.

E. Conflicts and political instability

A number of countries worldwide are emerging or still suffering from local and regional conflicts affecting their political stability. Unfortunately, some hydrocarbon countries in the Arab region continue to bear the financial and environmental costs of such instability. In Iraq and Libya, this conflict situation is a major constraint for investments in capital-intensive infrastructure to recover the associated gas currently flared and to allow for its monetization, especially for the generation of electricity which is critical to countries' economic development.

4. Gas Flaring Reduction Experiences in Arab Countries

A. Common objective

There is today a common agreement among Arab hydrocarbon producers on the need to reduce and eventually eliminate associated gas flaring. Most top Arab gas flarers have endorsed the World Bank-led zero routine flaring by 2030 initiative (table 2).

However, the multifaceted challenges of implementing such an initiative are not easy to address for several Arab hydrocarbon producers, especially the financial commitments needed to meet the objective of gas flaring mitigation. Fortunately, some Arab countries had successfully managed to reduce gas flaring well before the initiative was launched, while other Arab hydrocarbon producers are progressing in their gas flaring reduction efforts. The present section covers some of these Arab experiences.

B. Saudi Arabia

Saudi Arabia was one of the first Arab countries to address the issue of gas flaring. The rapid increase of its crude oil production in the 1960s and 1970s led to large volumes of associated gas being produced alongside oil. Some of this gas was consumed locally for producing sites' operations, but the vast majority of gas had to be flared.[13] Consequently, in the early 1970s, the Saudi Government made the decision to recover and monetize these wasted associated gas resources for the development of gas-based industries. The recovered associated gas also fuelled power and water desalination plants and non-gas-based industries.

Firstly, the Government established the infrastructure needed to manage and host the future gas-based industries. In 1975, the Government set up the Royal Commission for Jubail and Yanbu to plan for the development of two major industrial cities: Jubail in the Eastern province and Yanbu in the Western region of Saudi Arabia on the Red Sea. To process and transport the recovered gas, the Government built a huge natural gas infrastructure network, the Master Gas System, which started operation in 1977. It consists of natural gas pipelines and gas processing plants throughout the Eastern province. Later, it developed an East-West system of gas pipelines linking hydrocarbon fields in the East to the Yanbu Industrial City in the West.

An elaborate flare minimization programme was carried out by the national oil and gas company, Saudi Aramco, with a flare minimization roadmap that aims to undertake the following:

- Establishing effective, reliable and consistent flare monitoring companywide by installing real-time flare monitoring systems in company facilities;

- Tracking flaring as one of the corporate environmental key performance indicators, and setting quantitative targets for flare minimization;
- Establishing a Saudi Aramco Engineering Procedure to specify internal guidelines for flare minimization and ensuring consistency in implementing flare minimization measures companywide;
- Developing and implementing facility specific flare minimization plans for company facilities.[14]

As a result of the above-mentioned initiatives and programme, gas flaring in Saudi Arabia accounts today for less than 1 per cent of gross gas production, and flaring is conducted only for safety reasons.

This successful experience in gas flaring reduction and monetization required a flow of large infrastructure investments, over a prolonged period of time, financed with State funds. This is a challenging requirement today for most Arab hydrocarbon producers.

C. Qatar

Qatar is endowed with the third largest proven reserves of natural gas globally, and is one of the largest gas exporters. However, its crude oil production is relatively limited compared with its large gas output, which is largely non-associated gas from the North Field. In 2018, Qatari oil production was estimated at 600,000 million barrels per day,[15] and most of the associated gas produced with oil is recovered and utilized (no longer flared).

The Qatari offshore Al-Shaheen oil field accounts for half of the country's crude oil production, and therefore a large share of the country's associated gas production. The Al-Shaheen field was initially operated by Maersk Qatar Oil in partnership with Qatar Petroleum. Between 1994 and 2004, associated gas produced from this field was mainly flared. Only about 3 per cent of the associated gas was utilized for onsite fuel needs.

In the early 2000s, a Clean Development Mechanism project under UNFCCC was initiated for the recovery and utilization of associated gas produced at the Al-Shaheen field. Following completion of this project, about 80 per cent of the associated gas output was recovered and utilized.[16] This gas flaring reduction and monetization project is the largest carbon dioxide reduction project in Qatar, and provides a significant contribution to the country's sustainable development objectives.

D. Kuwait

Kuwait holds one of the world's largest proven reserves of crude oil and is one of the biggest oil producers. It used to flare a large share of its associated gas. However, for around 20 years, Kuwait has deployed significant efforts to reduce its gas flaring to provide its power plants with gas supplies to meet a rapidly growing electricity demand, and to implement a substantial reduction in the country's carbon dioxide emissions.[17]

Between 2005 and 2012, it successfully managed to reduce its associated gas flaring from 17 per cent to 1 per cent of its gas production. Over the last five years (2014-2018), the remaining gas flaring volumes were reduced by about 40 per cent.

According to the Kuwait Oil Company (KOC), the successful reduction of associated gas flaring in Kuwait is the result of the following key drivers:

- A solid commitment from all levels of the company to make flare reduction a priority;
- Significant financial investments in state-of-the-art facilities and operations;
- Close cooperation within KOC departments and with downstream companies and customers to adapt to any unforeseen situations and limit the duration of flaring;
- A close, productive partnership with GGFR and other organizations to achieve the target.[18]

E. Algeria

Algeria is one of a small number of hydrocarbon producers in the world with regulations that impose penalties or taxes on the flaring of associated gas. Gas flaring was first prohibited in 1966. Since then, Algeria, through its national oil and gas company, Sonatrach, has invested heavily in more than 30 projects that have substantially reduced associated gas flaring, and allowed the monetization of the recovered gas and valuable LPGs. One of these gas recovery projects is the *Station de Récupération des Gaz Associés* of Hassi Rmel. Some of this recovered gas is used to fuel a hybrid gas/solar power plant.

According to Sonatrach, associated gas flaring has been significantly reduced from about 75 per cent in 1975 to 8 per cent in 2017.[19] However, significant efforts, especially investments, are necessary to achieve zero-routine flaring by 2030.

F. Oman

As a result of a constrained gas supply, the Government of Oman has made it a top priority to optimize the use of natural gas, especially of associated gas that is being flared. Recently, the dominant hydrocarbon producer in Oman, Petroleum Development Oman (PDO), began implementing a gas flaring reduction roadmap to reduce non-routine flaring in all its operations.[20]

This is outlined in a 2018 PDO report entitled "Pathways to sustainability".[21] The report's section on how to minimize gas flaring lists the different flaring reduction technologies that PDO is implementing to further minimize gas flaring. These range from capturing and using associated gas to improving equipment reliability and availability.

5. Other Gas Flaring Reduction Initiatives and Programmes

A. Same issues and challenges

Gas flaring has long affected hydrocarbon countries within and outside the Arab region. Producers in other regions have faced or still face the same challenges that Arab producers are dealing with today. The present section sets out the case of an area within a country that has successfully addressed the issue of gas flaring mitigation, and a country that is in the process of developing a gas flaring reduction programme.

B. Canada (Alberta)

Alberta province in Canada is often referred to as a successful example of gas flaring reduction. The World Bank-led GGFR partnership considers it as an example of international best practice in achieving and maintaining low flaring rates.[22] Alberta is the main hydrocarbon producing region in Canada, and used to flare large volumes of associated gas until the early 2000s. Between 2008 and 2012, Alberta was able to recover close to 96 per cent of the associated gas that would have been flared or vented.[23]

The main driver of this successful gas flaring reduction is Alberta's legal and regulatory regime. Furthermore, the Alberta provincial government adopted novel approaches, such as the decision tree,[24] and a consultative approach that involves industry engagement and commitment. It has also used novel policy approaches, such as financial incentives, for operators who conserve gas.

Alberta's main regulatory agency initially involved in the regulation of gas flaring was the Energy Resources Conservation Board (ERCB), which was an independent upstream energy regulator. It was created in 2008, when upstream and downstream regulation were separated. In 2013, the Alberta Energy Regulator[25] took over all the regulatory activities of ERCB.

C. Nigeria

Nigeria, Africa's biggest crude oil producer, is a country that has been marred by associated gas flaring problems for several decades. However, it appears to have finally launched a programme that may gradually solve the flaring issue.

Despite prohibiting gas flaring in 1969 through its petroleum (drilling and production) regulation, Nigeria has been consistently ranked as one of the world's largest gas flarers. There are about 180 onshore and offshore gas flaring sites in Nigeria, spread throughout the Niger Delta. In 2018, Nigeria was the seventh biggest flarer globally, with a flaring volume of 7 bcm. However, gas flaring levels have declined significantly over the last 10 years (by 70 per cent), but remain one of the highest worldwide in terms of volume.[26]

The Government of Nigeria has always declared its commitment to reducing gas flaring, but it is only over the last five years that it has started developing and implementing a serious gas flaring reduction initiative backed by relevant policies and regulations. In 2016, it endorsed the World Bank-led zero routine gas flaring by 2030 initiative, and ratified the Paris Agreement in May 2017. In June 2017, the Federal Executive Council approved the National Gas Policy, which stresses the objective of ending gas flaring. In the same year, the Government included Gas Flare Out as a component of its economic recovery and growth plan.

In order to implement the above-mentioned policy commitments, the government of Nigeria launched the Nigerian Gas Flare Commercialisation Programme (NGFCP) in December 2016. The objective of the NGFCP is to eliminate gas flaring through technically and commercially sustainable gas utilization projects developed by competent third-party investors invited to participate in a competitive and transparent bid process. NGFCP offers flare gas for sale by the Federal Government of Nigeria through a transparent and competitive bidding process. A structure has been devised to provide project bankability for flare gas buyers, which is essential to the success of the programme.[27]

It is still early to assess the performance of this new gas flaring reduction programme, but it is definitely a much more structured and well-prepared process compared with previous initiatives. It is supported both by the Government and by a necessary policy and regulatory framework.

6. Gas Monetization Opportunities

A. Different conditions and options

Addressing the key challenges presented above would provide opportunities to monetize associated gas that would have otherwise been flared. Monetization options for recovered associated gas could be site- or region-specific, and involve small- to medium-scale gas utilization projects supplying a hydrocarbon production site, surrounding local communities, a region or a whole country. Gas monetization opportunities depend on the following factors, among others:

- Number and locations of flaring sites;
- Volumes of associated gas flared;
- Composition of gas flared;
- Existing (or lack of) gas infrastructure to recover, treat, use and/or transport gas;
- Site distance from potential gas markets;
- Stakeholders involved in each site;
- Relevant regulations and upstream contractual framework.

If reinjection of associated gas is technically and/or commercially not possible, or if gas reinjection needs are lower than the volumes of associated gas that could be recovered instead of being flared, there is a plethora of gas monetization options. However, not all of them apply to all sources of gas flaring or flaring sites. There may be just a couple of options that could work for each case.

Gas flaring takes place during well testing in upstream operations. This is considered temporary non-routine flaring, and treated differently than routine flaring. However, regulatory authorities encourage producers to seek onsite utilization options for this flared gas.

B. Gas reinjection and gas lift

Gas reinjection in oil reservoirs is used to increase pressure in the formation to enhance hydrocarbon production. This method of enhanced hydrocarbon recovery could be a commercially and environmentally sound option for using associated gas rather than flaring it.[28]

Gas lift, which is an artificial lift method different from gas reinjection, could be an option to utilize associated gas that would otherwise be flared. It is another process to boost pressure in the reservoir to increase hydrocarbon production and minimize associated gas flaring.

C. Grid and off-grid power applications

The most common application, after gas reinjection, is to use associated gas to generate electricity for a site's production and related facilities. Usually, the gas is provided free of charge as part of the upstream production agreement between the State (or its representative national oil company) and oil and gas companies. Beyond the site's boundaries, there is the option to provide electricity to surrounding communities that are

not connected to the national or regional power grid. This could be done through small modular power units ranging from much less than 1 MW to a couple of MW capacity. Larger communities or areas could also be supplied with associated gas to fuel medium-size power units, and gas could also be transported through pipelines to fuel power stations connected to a regional or national electricity grid.

This monetization route for flare recovery projects presents clear social and economic benefits for local communities, regions and the whole country. However, the financial or commercial viability of such gas-to-power projects could be challenging if the gas and electricity offtakers (local municipality or utility) have credit-worthiness problems, low subsidized domestic energy prices, and payment collection issues. These constraints are even worse in conflict-affected countries or areas.

D. Compressed natural gas

To transport recovered and treated gas to distant potential markets when no gas pipeline infrastructure exists or is not financially viable, the gas could be compressed in compressed natural gas (CNG) units and transported by tankers to supply small-scale power and non-power markets. Although the volumes of gas transported are small compared to gas pipeline transportation, the CNG option reduces the volume of gas to be transported by 150-300 times that of gas at atmospheric pressure. Studies conducted for the GGFR partnership show onshore CNG transportation could be financially viable for volumes of up to 5 MMscfd.[29] This would suit small volume flaring sites and benefit markets that are not or cannot be linked to gas grids. However, in the case of large volumes of associated gas flaring, like for example in Iraq, such a small-scale monetization alternative could be quite limited and impractical.

Onshore small-scale gas transportation by CNG is a proven technology that has been in use for a long time. Transport of gas by CNG tankers is well developed in the United States to supply areas that are not linked to a regional or national gas network.

E. Mini liquefied natural gas

Another onshore mode to transport small volumes of gas to markets not connected to gas networks would be to transport gas as liquefied natural gas (LNG) by trucks. Mini LNG solutions, like small-scale CNG, act as a 'virtual pipeline' to link sources of recoverable associated gas and potential gas markets requiring small or medium gas loads. Compared with CNG, LNG provides a larger volume of gas because of its higher energy density and can cover longer distances than the CNG option.[30]

Small-scale LNG plants larger than 5 MMscfd and up to 40 MMscfd are available in modular and scalable units. One manufacturer can also provide LNG units up to 140 MMscfd. LNG supplies can be transported onshore by ISO container trucks or by barges (river transportation). Small-scale LNG alternatives to transport gas are also well developed and used in China and the United States.

However, the mini LNG option is more capital-intensive than CNG, and project economics are sensitive to the scale of the project. Transporting small gas volumes (< 5 MMscfd) could be commercially challenging for the mini LNG option. Furthermore, its attractiveness would also depend on existing or to-be-

developed safety regulations on LNG transport and their impact on costs.

F. Mini gas-to-liquids (GTL)

The small-scale gas-to-liquids (GTL) monetization option converts associated gas that would have been flared into synthetic crude oil (syncrude), a liquid that is easier and cheaper to transport. The GTL route can also produce petroleum products, as in the case of existing large-scale GTL projects. However, the small-scale of the project and small volumes of petroleum products produced would render the transport of products more expensive than transporting syncrude through an existing oil pipeline. Moreover, the development of small-scale GTL units is much more complex and costly than the direct gas monetization alternatives.

A number of small-scale GTL technologies have been developed, but none of them have really been able to move into commercially viable operation. The CompactGTL's 24 MMscfd project in Kazakhstan was expected to be the first commercial small-scale GTL project, but this project is reported to be on hold.

G. Mini gas-based alternatives

These small-scale gas monetization alternatives use associated gas (methane) as feedstock to produce ammonia for fertilizer (urea) production and methanol.

Technologies for these small-scale ammonia and methanol plants exist, and some new processes are being developed, but their commercial development and viability remains to be proven. In gas-based industries, the scale factor is an indispensable condition for the commercial viability of such industrial projects, and the focus remains on the development of world-scale projects.

H. Marketing of liquid petroleum gases

Associated gas is usually rich in valuable natural gas liquids (NGLs),[31] especially liquid petroleum gases (LPG) such as propane and butane, which could be extracted and marketed. The recovery of flared gas to separate and monetize LPGs is an attractive option to stop flaring. The marketing of LPGs would improve the financial attractiveness of gas flare recovery, and would benefit local and regional communities located close to gas flaring sites. The economics of the flare recovery project would also depend on the volumes of LPGs extracted that could be marketed.

However, this alternative would require the existence or development of gas processing facilities to extract LPGs, and would need to find a market for the gas (mainly methane) left after the extraction or separation of LPGs. This could be challenging if such a market is not available, and if project developers are interested only in the LPG fractions of the gas. Furthermore, relevant regulatory and contractual aspects would affect this project's economics (who owns the flared gas that would be recovered, pricing the gas, and access to existing gas infrastructure).

I. Injection into the gas transportation network

The easiest alternative to monetize recovered associated gas is to inject the gas into an existing gas pipeline network (after its

processing to meet pipeline quality standards), which would supply existing regional or national gas markets. However, a market has to also be secured for the extracted LPG volumes.

This is the most accommodating alternative for addressing the issue of gas flare recovery, provided that the required gas infrastructure (compression facilities, gas processing plant and gas transport pipelines) is available and accessible under reasonable terms and conditions, and/or investments are available to develop such infrastructure. This would assume that the gas injection project is commercially viable (this could be doubtful if gas is sold in domestic markets under low subsidized gas prices). As indicated above, the marketing of LPGs could improve the economics of the whole flare recovery project.

7. Conclusions and Recommendations

A. Conclusions

The Arab region is one of the world's largest sources of gas flaring, but this is changing and there is the potential for more profound changes, primarily for the benefit of communities and countries where gas is presently flared.

The levels of gas flaring differ between Arab countries, and some producers have already achieved significant gas flaring reductions. However, other countries have maintained their flaring volumes or have increased them, as more crude oil is produced.

Arab Governments consistently express their commitments to reduce greenhouse gas emissions, and in some instances have even included gas flaring reduction in their official statements. However, few Arab hydrocarbon producers have translated these commitments into concrete quantified emission mitigation targets with relevant implementation plans and timeframes. Among Arab producers that have submitted NDCs, only a couple of countries have included gas flaring reduction action and even fewer have provided quantified targets and a timeframe for achieving flaring mitigation targets.

The reasons for this reluctance to act or slow progress to address gas flaring are the multifaceted and interlinked challenges policymakers and oil and gas companies face. The dominant factor that these stakeholders invoke repeatedly is the lack of financing to invest in gas infrastructure to recover, treat, transport and use recovered gas. This is true, but this is the consequence of a fundamental problem that affects all other challenges or barriers, except in the case of conflict and political instability. Progress is hampered by the absence of an effective, consistent and implementable policy and regulatory framework to seriously reduce and eventually eliminate gas flaring.

Under an adequate framework and relevant institutions providing the right incentives, several gas utilization options could be considered to monetize recovered gas (if reinjection is not an option or not enough to stop flaring). However, not all of them could work for all gas flaring cases, and some options are yet to be proven commercially viable. Options are site- or region-specific, but will also depend on whether some stakeholders, mainly State-owned entities, are willing and able to fund non-commercial flare recovery projects.

Wherever possible, the extraction and monetization of LPGs could improve, sometimes considerably, the commercial viability of gas flaring reduction and utilization initiatives. However, the most practical and attractive option is to inject recovered gas into an existing gas transportation network to supply markets such as power plants. This is subject to the existence of an accessible gas infrastructure (processing and transport facilities) and incremental investment requirements.

The reduction and elimination of gas flaring is not only a question of stopping the wasteful burning of valuable natural resources. It is also a sustainable development necessity as it clearly addresses most of the 17 SDGs.

B. Recommendations

To achieve the above-mentioned sustainable development objectives, some recommendations on the key aspects of gas flaring mitigation are proposed as follows:

(a) Incorporate the issue of gas flaring reduction/elimination in an integrated national energy and environmental policy, with clearly defined targets and timeframes;
(b) Conduct the process of reporting and verification of associated gas flaring in full transparency and involve all stakeholders;
(c) Encourage the use of technologies that minimize associated gas flaring and improve flaring efficiency;[32]
(d) Promulgate and/or strengthen relevant regulatory frameworks to provide incentives to mitigate gas flaring, following consultations with all relevant private and public stakeholders;
(e) Identify and legally empower implementing institutions, and clearly define their roles and responsibilities;
(f) Avoid the multiplication and duplication of roles among government and regulatory agencies;
(g) Revisit upstream agreements regarding production of associated gas with crude oil to assess how gas flaring mitigation is addressed in these contracts and their consistency with policies and regulations;
(h) Draw on best international and regional practices to implement gas flaring mitigation measures.

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