Gas Flaring, Composition, Emission, Measuring, Environmental Impacts and Recovery Methods: An Overview

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Abstract

Gas Flaring is a combustion process in many industrial operations, such as oil and gas mining, refineries, chemical plants, coal production, and landfills, to burn related, unused, or unnecessary gases and liquids produced during the natural or unplanned overpressure process. approximately 145 billion cubic meters (bcm) of flared gas worldwide annually. Gas flaring is a major cause of emissions of greenhouse gases. It also creates noise, heat and offers large uninhabitable regions. A main concern is a decline or recovery from gas flaring. There is also an immediate need to assess the flared gas by its known composition, distribution and volume, in addition to implementing the appropriate flare gas recovery or disposal method. This paper offers a description of the structure of the flaring gas and its related environmental impacts. By observing the various methods of flare gas recovery systems, it also explains the flaring estimation techniques and the decrease of flare gas.

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1. INTRODUCTION

In the 21st century, climate change mitigation is a global challenge because anthropogenic greenhouse gas emissions from human activity have the temperature increased and the human habitats became adversely affected (Asadi & Farahani 2018). To achieve the aim of restricting global warming to 1.5º C, reducing the harmful pollution of all industrial plants is necessary (Rogelj et al., 2016). In addition, global energy demand has now significantly risen due to the rise in world population, economic production and living conditions, which illustrates the importance of energy recovery and usage in energy-intensive sectors such as the oil and gas industry. The flaring of undesired and waste gas streams is a standard method for safe activity during irregular or repair conditions in oil production and hydrocarbon processing plants.

The flaring process, however, contributes to critical environmental concerns such as acid rain and global warming (Johnson & Coderre, 2012). In the oil and gas industry, flare gases fall into two major groups; associated gas and non-associated gas. As the ambient pressure drops from formation to ambient pressure, the term 'associated gas' refers to gases initially trapped in oil at the formation pressure and emitted during the processing of oil. This type of flare gas is predominantly vented into the atmosphere, based on its nature and volume. The word "non-associated gas" applies to gases collected as well as start-up and shut-down processes during irregular conditions. Compared to the related gas flaring, this form of flare gas has a marginal environmental effect due to its low quantity (Yazdani et al., 2020).

Most of these gases have a high fuel value and for other process units they may be used as feed. Not only does the combustion of these gases have environmental issues related to emissions of greenhouse gases, but it also results in economic opportunities being wasted. Roughly 17% of the overall natural gas output was flared in 2011, (Tofigh & Abedian, 2016).The petroleum industry fires about 140 billion cubic meters of natural gas annually in 2017, this represents about 3.5% of the world's consumption of natural gas in 2012 (Asadi & Farahani, 2018), Polluting the atmosphere with approximately 400 million tons of CO2 equivalent per year (Hamidzadeh et al., 2020). This compares roughly to the African continent's average energy use, which is equivalent to 750 billion kWh (World Bank, 2020).

2. THE WORLD-WIDE STATE OF COMBUSTION

Global data on gas flaring is available from a number of outlets, including the US Energy Information Administration, the World Bank, the International Energy Agency, oil producers, and the Oil Exploring Countries Association**.** Satellite data showed that every cubic meter of flared gas emitted 2.5 kg of CO2, and a total of 400 million tons of CO2 were released from approximately 145 billion cubic meters (bcm) of flared gas worldwide in 2018 (Gai et al., 2020). Almost 50% of worldwide flaring is accounted for by complete gas flaring from Russia, Iraq, Iran, the United States, and Algeria (**Table 1**). In the United States, gas flaring increased by 4.6 bcm (billion cubic meter) from 2017 to 2018, largely because of the booming production of shale gas. The US Energy Information Administration announced that in 2017, about 12.85 % of the Bakken shale gas produced (equivalent to 88 billion cubic feet) was flared or vented in the United States, and since the beginning of the Bakken production, no gas has been injected. (World Bank, 2019).

Table 1. The Global Ranking of Flaring Countries (2013-16) in billion cubic meters. (World Bank, 2017)

Country	2014 bcm	2015 bcm	2016	2017 bcm	2018 bcm	2017-18 change bcm	2014-18 change bcm
Russia	18.3	19.6	22.4	19.9	21.3	1.4	3
Iraq	14	16.2	17.7	17.8	17.8	0	3.8
Iran	12.2	12.1	16.4	17.7	17.3	−0.4	5.1
United States	11.3	11.9	8.9	9.5	14.1	4.6	2.7
Algeria	8.7	9.1	9.1	8.8	9	0.2	0.3
Venezuela	10	9.3	9.3	7	8.2	1.2	−1.7
Nigeria	8.4	7.7	7.3	7.6	7.4	−0.2	−1.0
Libya	2.9	2.6	2.4	3.9	4.7	0.8	1.8
Mexico	4.9	5	4.8	3.8	3.9	0.1	−1.0
Angola	3.5	4.2	4.5	3.8	3.9	−1.0	−0.7
Oman	2.6	2.4	2.8	2.6	2.5	−0.1	−0.1
Saudi Arabia	1.9	2.2	2.4	2.3	2.3	0	0.3
Egypt	2.8	2.8	2.8	2.3	2.3	−0.1	−0.5
Malaysia	3.4	3.7	3.2	2.8	2.2	−0.6	−1.1

Indonesia	3.1	2.9	2.8	2.3	2.1	−0.3	−1.0
Kazakhstan	3.9	3.7	2.7	2.4	2	−0.4	−1.9
China	2.1	2.1	2	1.6	1.8	0.3	−0.3
Rep of the Congo	1.3	1.2	1.1	1.1	1.6	0.4	0.3
Turkmenistan	2	1.8	1.8	1.7	1.5	−0.2	−0.5
Gabon	1.5	1.6	1.6	1.5	1.4	−0.1	−0.1
India	1.9	2.2	2.1	1.5	1.3	−0.2	−0.5
Canada	2.1	1.8	1.3	1.3	1.3	0	−0.7
United Kingdom	1.3	1.3	1.3	1.4	1.2	−0.1	−0.1
UAE	1.9	1	0.8	1	1.2	0.2	0.2
Cameroon	0.9	1.1	1.1	1	1.1	0	0.2
Brazil	1.5	1.3	1.4	1.1	1	−0.1	−0.5
Qatar	1.3	1.1	1.1	1	1	0	−0.3
Ecuador	1	1.1	1.2	1.1	0.9	−0.2	−0.1
Kuwait	1.4	0.9	1.1	0.8	0.9	0.1	−0.5
Australia	1.1	1.1	0.7	0.7	0.9	0.2	−0.3
Rest of the world	25.2	23.6	21.8	20	18.8	−1.2	−6.4
Global total	143.9	145.6	147.6	140.6	145	4.4	1.1

In 2017, about 140 bcm of gas was flared, which was equal to the gas consumption of Africa. Almost 270 million tons of CO2 were emitted during the flaring process in total. The projected black carbon emissions in the Arctic are dominated by gas flaring, although this amounts to 3% of global black carbon emissions (Stohl et al., 2013).

3. COMPOSITION OF FLARING GAS

The gas flaring contains of a mixture of different gases (Table 2). The composition will depend upon the source of the gas going to the flare system. Associated gases released during oil-gas production mainly contain natural gas. methane (CH4) more than 90% of natural gas with ethane and a small number of other hydrocarbons; also, inert gases such as N2 and CO2 may be present.

Refineries Gas flaring and other process operations contain a mixture of hydrocarbons and in some cases H2. Mixture of CH4 and CO2 are most commonly in bio gas or digester gas and landfill gas small amounts of other inert gases. It is necessary to define some group of gas flaring according to the actual parameters of the gas due to there is no standard composition. The heat transfer capabilities of the gas affect by changing of the composition of the gas and also the performance of the measurement by flow meter affect by it (Peterson et al., 2007).

Table 2. Waste gas compositions at a typical plant (Peterson et al., 2007).

Gas flaring constituent	symbol	gas flaring %	
		Minimum	Maximum
Methane	CH_4	7.17	82.0
Ethane	C_2H_6	0.55	13.1
Propane	C_3H_8	2.04	64.2
n- Butane	C_4H_{10}	0.199	28.3

Isobutene	C_4H_{10}	1.33	57.6
N- Pentane	C_5H_{12}	0.008	3.39
Isopentane	C_5H_{12}	0.096	4.71
Neo-pentane	C_5H_{12}	0.000	3.42
n-Hexane	C_6H_{14}	0.026	3.53
Ethylene	C_2H_4	0.081	3.20
Propylene	C_3H_6	0.000	42.5
1-Butene	C_4H_8	0.000	14.7
Carbon Monoxide	CO	0.000	0.932
Carbon dioxide	CO_2	0.023	2.85
Hydrogen sulfide	H_2S	0.000	3.80
Hydrogen	H_2	0.000	37.7
Oxygen	O_2	0.019	5.43
Nitrogen	N_2	0.073	32.2
Water	H_2O	0.000	14.7

4. GAS FLARING EMISSIONS

When waste oil-gas and oil-gas-water solutions are burnt, a large number of hydrocarbons are formed. With combustion being more influenced by atmospheric winds and the fuel's heating value, flaring is ineffective. Inadequate burning releases raw fuel (Argo, 2002). Flare performance will rely on many variables, such as flare gas flow rate, flare stream composition, wind speed, hydrocarbon droplet presence in the flare stream, atmospheric turbulence, and water droplet presence in the flare stream. Flaring is a method of high-temperature oxidation used to burn waste gases from manufacturing activities using combustible materials, often hydrocarbons. 95% of the flared waste gases include natural gas, propane, ethylene, propylene, butadiene and butane (Table 2) (Ismail & Umukoro, 2012).

Gaseous hydrocarbons react in combustion to form carbon dioxide (CO2) and water with atmospheric oxygen. The main combustible ingredient is carbon monoxide (CO) in certain waste gases. Several intermediate compounds are formed during a combustion reaction and, ultimately, most of them are converted into CO2 and water, as emissions, certain concentrations of solid intermediate products such as carbon monoxide, hydrogen, and hydrocarbons can escape (Gervet, 2007). The sum of produced hydrocarbon emissions depends on the degree of combustion. Theoretically, full-combustion combustion systems contain relatively harmless gases such as carbon dioxide and water. In fact, since the flaring efficiency depends on wind speeds, stack escape velocity, stoichiometric mixing ratios, and heating value, flaring is rarely effective in achieving maximum combustion. In any process with flaring, decreased combustion efficiency must be considered the standard (Argo, 2002).

The emissions of contaminants from flaring may consist of unburned fuel elements, such as methane and non-methane volatile organic compounds, depending on the composition of the waste gas and other factors. Sulphur oxides, partly combusted materials, CO, CO2, NOx and soot are also by-products of the combustion process. The purpose of the flare is to turn compounds in the flare gas stream to their safest possible state by oxidation. In the case of hydrocarbons, carbon dioxide and water vapor are the most attractive things. Sulphur is converted to sulfur dioxide in compounds like hydrogen sulphide. Some oxides are less suitable, such as nitrogen oxides, or partly oxygenized compounds, such as carbon monoxide or formaldehyde.

It is not feasible to completely absorb poisonous compounds such as poly-nuclear aromatic hydrocarbons, aromatics and volatile organic compounds produced in these diffusion fires (Kostiuk et al., 2004).

5. PRODUCTION OF OIL AND FLARING OF GAS: EMISSION FACTOR

The emission factor is called the ratio of the volume of associated gas to the barrel of oil produced. It ranges considerably, from roughly 1 to more than 50 cubic meters per barrel of oil for various oil fields. The estimated global five-year from (2007 to 2011) emission factor is roughly 5 cubic meters of gas per barrel of extracted crude (table 1). In 1974, Rotty suggested the first connection between gas flaring and the output of gasoline. Based on the available data set in the period from 1968 to 1971, he compared the gas flaring volume to crude oil output for two areas of the US and non-US countries (Soltanieh et al., 2016).

6. GAS FLARING MEASUREMENT

In varying quantities all oil fields contain associated gas and it is released as oil is brought up from the deep rock strata in which it is found. Identifying how much gas is being released is the challenge because of lack of monitoring equipment and limited oversight make. Many countries do not disclose quantities of gas flaring openly, contributing to considerable confusion as to the scale of the issue GAO 2004). Finding out the most accurate database and knowing that these datasets display various data is the challenge in determining gas flaring emissions. The procedure for calculating gas flaring emissions is based on the quantity of vented and flared gas registered to the EIA (assuming that all gas is flared) (Gervet 2007).

6.1. Government legislation

Measurement of gas flaring and venting has been described as an important topic in which the Global Gas Flare Reduction could make a substantial contribution to the global flaring reduction agenda by gathering and disseminating best practice. Regulations related to the assessment of fuel and flare gas for the estimation of the CO2 tax for petroleum operations were imposed on the Norwegian continental shelf in 1993. Recently, new regulatory regulations on the horizon, factories, refineries and chemical plants have been pursuing cost-effective ways to mitigate emission and control both the monitoring of spills and the balance of masses (Emam, 2015).

Guide 60 of the Alberta Energy and Services Board (EUB) strengthens Canada's flare. The guide notes that measurements are needed at traditional oil-gas production and processing facilities for continuous or routine flare and vent sources where the average total flared and vented volumes per facility exceed 500 m3/day (CAAPP 2002). EUB Guide 60 (references EUB Directive 017) which is the Official Publication of Calculation Criteria for Upstream Oil and Gas Activities on February 1, 2005, it defines the following uncertainties in this Directive that must be met: Gas flaring estimation variability must be ± 5%, Dilution gas estimation variability must be ± 3%, and Acid gas estimation volatility must be ± 10%. The total range ability of the process conditions is protected by precision requirements (Emam, 2015).

6.2. Gas Flow Meters

Ultrasonic flow meters, optical flow meters, insertion generators, pitot average tubes, and thermal mass meters are the available tools for calculating flared and vented gas flow rates associated with oil output. Factors such as high flow velocities, large pipe diameters, changing gas content, low humidity, gravel, damp gas, wax, condensate, and high concentrations of pollutants such as CO2 and H2 S are limited to some of these conventional systems, such as insertion generators, pitot tubes, differential pressure flow meters and thermal mass meters (Sekyi, 2017).

Since 1987, ultrasonic flow measurers have been in use. By defining the time, it takes for an ultrasonic pulse to pass between two fixed transducers positioned in the vessel, they calculate flow velocity. Ultrasonic meters are an affordable solution for calculating the amount of flare gases. They are independent of the size of the pipe and are not influenced by excessive rates of flow and changing composition of gas. They may not have any mechanical moving parts and self-diagnosis minimizes their maintenance. Their measuring precision varies from 2.5 percent to 5 percent of the real values. Orifice and venturi meters can be used with safe gas flows instead of ultrasonic meters and are specific to contaminant-containing wet and dry gas streams. However, for a large variety of flow speeds, they do not perform well and need to be regularly calibrated for changing gas composition (Buzco-Guven & Harriss 2010).

6.3. Smart Automation Systems

British Petroleum has developed a 'Smart Automation Well Venting Device' technology that integrates remote terminal units and programmable logic controls with artificial intelligence tools in gas wells in an attempt to minimize gas emissions by venting. By changing the gas lifting cycle, the program tracks and analyzes data from wellhead instruments and helps the PLC to improve well efficiency. Starting in 2000, British Petroleum installed pilot systems on about 2, 200 wells and cut venting by about 50 percent between 2000 and 2004, with a total of approximately 114 billion cubic meters of related gas savings (Sekyi, 2017).

7. ENVIRONMENTAL GAS FLARING AFFECTS

Flaring gas is one of the world's most daunting energy and environmental issues today. The environmental effects associated with gas flaring have a major effect on local economies, frequently contributing to serious health problems. In general, gas flaring is usually evident and both noise and heat are released. About 250 toxins released from flaring have been reported. Includes carcinogens such as benzene, benzo pyrene, carbon disulfide toluene (CS_2) and carbonyl sulfide (COS); arsenic, chromium and mercury metals; SO_2 and H_2S sour gases; nitrogen oxides (NO_x); methane (CH_4) and carbon dioxide (CO_2) that lead to greenhouse gases (Ismail and Umukoro, 2012). These pollutants cause increased temperature, acridity, impact on the immediate environment, particularly on plant growth and human health.

7.1. Thermal Effects

Many studies showed the thermal effect of the flame on the surrounding area. In a study carried out by (Anomohanran, 2012) to investigate, the thermal influence of gas flaring on the Delta State city of Ebedei, Nigeria. They state that for both the rainy and dry seasons, temperature difference measurements with distance from the flare point were collected. Results reveal that thermal emission existed in the wet season over a span of 2.15 km and in the dry season of 2.06 km (Anomohanran, 2012). Residential buildings are affected by flames at a distance of less than 210 meters (Julius, 2011). High temperatures are detrimental to human health, physical, chemical and biological environments, plant and soil microorganisms (Anomohanran, 2012). The thermal radiation and noise level were summarized by (Ghadyanlou and Vatani, 2015) as a result of distance from the flare Table 3).

Table 3. Flaring thermal and noise emission

Distance, m	Thermal radiation, kW/m^2	Noise level, dB
10	5.66	86.3
20	5.87	86.19
30	6.04	86.02
40	6.14	85.78
50	6.17	85.50
60	6.14	85.18

70	6.04	84.83
80	5.88	84.46
90	5.67	84.08
100	5.42	83.68

Note: Sound is quantified in decibels: (dB). A whisper is about 30 dB, regular talk is about 60 dB, and it is about 95 dB for a motorcycle engine to run. Noise over 70 dB can begin to affect hearing for an extended period of time. Loud noise above 120 dB will damage your ears instantly.

7.2. Acidity Effects

When fuel vapors are burned into the atmosphere, the acid rains form in turn, particularly in the offshore humid climate. In nature, acid rain is corrosive, causing significant environmental destruction, devastating crops and surface water (Hassan and Kouhy, 2013)**.** Acid rain has a major effect on freshwater, marine and mangrove habitats. Acid rain from elevated amounts of SO_4^{2-} and NO^{3-} is visible in pH values ranging from 4.98 to 5.15 and a mean value of 5.06 (Ite, & Ibok, 2013). Rainwater acidity differed dramatically and decreased with an increasing distance from gas flare sites during the study period (Efe, 2010). Gas flaring has a severe depreciation impact on the galvanized roofing layer, 500 m away from the source of the flare a maximum weight loss of 7.62 mg followed by 4.23 mg at 1000 m from the flare source, while a weight loss of 1.17 mg was achieved in the non-flaring region (Ovri & Iroh, 2013).

Fig. 1. Impact of Rain Acid (Sekyi, 2017).

7.3. Agriculture effects

For certain petroleum pollutants, such as toluene, ethyl benzene, xylene and benzene, polycyclic aromatic hydrocarbons and aliphatic hydrocarbons, soil and sediments have been the final drain. Due to the mutagenicity and carcinogenicity of some of these compounds and the propensity to bio accumulate in organic tissues due to their lipophilic character and electrochemical stability, polycyclic aromatic hydrocarbons and aliphatic comprising from two to five merged aromatic rings are of considerable concern (Ite, & Ibok, 2013). The thermal emission from gas flares impacts the microbial communities involved in the process of decomposition of organic matter and the formation of nitrogen, resulting in a reduction in organic matter and total nitrogen, as well as in microbial populations, wet formation, supply of nutrients and soil fertility. Consequently, gas flaring has a negative influence on soil productivity and biogeochemical nutrient cycles and the negative effects of soil physiochemical properties on certain crops due to microclimate changes in the area.

Some marine species could be affected by the toxicity of contaminant mixtures from gas flare and vent systems by shifting their phylogenetic role and reducing their relative vulnerability as the strength of gas flares increases. (Soltanieh, 2016).

The temperature of the air, vegetation, and leaves increased and the relative humidity of the air decreased within 110 m of the flare sites. Agricultural crops that react negatively to high temperature fluctuations are recommended not to be planted in this region (Anomohanran, 2012). The relative humidity, soil moisture and all the chemical parameters of the soil decrease towards the flare with the increase in air and soil temperatures of the flare site. The induced microclimate situation decreased maize yields in such a way that the production of maize is not economically feasible within 2 km of the flare site (Odjugo & Osemwenkhae, 2009).

7.4. Health effects

The health effects of air pollution are common, and those who rely on food grown locally, whether from their own cultivation or imported on the market, are at risk of contamination (Christiansen & Haugland, 2001). Widely known toxins are found in the flares, for example Benzene, which pollutes the air, Area persons complain of lung conditions such as bronchitis and asthma. The US Environmental Protection Agency (EPA) has confirmed that benzene toxicity in humans causes acute leukemia and a host of other blood-related disorders. Many reduced Sulphur species are produced in a sour gas flare. Several powerful toxic chemicals include hydrogen sulphide and carbon disulphide. Spontaneous abortion is associated with exposure to H2S at amounts below the level at which it can be felt. Thyroid cancers are caused most often by radioactivity. Thyroid cancers in some regional areas with substantial flaring activities have an elevated overall incidence ratio. (Argo, 2002). Endocrine failure, immune dysfunction, reproductive defects and autoimmune rheumatic conditions have also been linked with chemical pollutants. Gas flaring leads to elevated health risks for local populations, including premature mortality, infectious infections, asthma and cancer. Another emission is thermal, and there is a limit at which the human body can withstand the fluxes emitted during the flaring of steam. In addition, there is also a heat threshold for both homes and concrete structures nearby (Ismail & Umukoro, 2012).

7.5. Financial Consequences

In terms of the lack of funds and profits that it would have known if it had conserved gas instead of flaring the same gas, gas flaring often has a gross effect on the economy of a country. The flaring of this related gas is, from an economic viewpoint, a massive waste for the populations. The economic cost of the overall flared gas is very staggering, suggesting for the private sector great investment prospects. As a result, more gas-intensive development modes are encouraged, more private sector participation is encouraged in the sector, and governments can recycle and explore more trade opportunities for the gas sector (Madueme, 2010).

8. REDUCTION AND RECOVERY FROM GAS FLARING

The use of flare gas recovery systems (FGRS) to reduce the amount of gas being flared has enhanced environmental and economic considerations (Duck, 2011). Flared gas recovery decreases noise and thermal radiation, operational and maintenance costs, air pollution and gas emissions, and reduces the consumption of natural gas and steam. There has been an international direction in recent years to reduce gas flaring and venting through the Global Gas Flaring Reduction (GGFR) collaboration of the World Bank and the

Global Methane Initiative (GMI) (AndalibMoghadam, 2007).

The World Bank Report discusses various proven gas utilization technologies for various applications (Strategy, 2004).

8.1. Natural Gas Hydrates (NGH)

Natural gas hydrates (NGH) are crystallized natural gas, a solid material that is chemically stable at -20 degrees Celsius in the ice state. The stabilizing temperature is slightly higher than the temperature of -162 degrees Celsius for liquefied natural gas (LNG), resulting in lower prices for capital, transport and storage. NGH, however, is much less dense than Liquefied Natural Gas (LNG) and correspondingly smaller than LNG technology is the volume of gas transportable in hydrate form. As a tool for the use of related gas, NGH is still in the Study process, however attempts to establish gas-to-solid technologies to manufacture and transport NGHH are being led by Mitsui and Mitsubishi, the British Gas Group (BG), and Marathon Crude. Technologies that transform gas to dimethyl ether and ammonia Methane can also be converted to methanol in natural gas and its related gas. Dimethyl ether (DME) and olefins such as ethylene and propylene are further developed using methanol in basic reactor systems, traditional operating conditions and industrial catalysts. Methane can also be converted to ammonia in the corresponding gas via the Haber process for the manufacture of nitrogen fertilizers. This method is very popular in the oil producing states of the Persian Gulf, especially in Saudi Arabia, Qatar and the UAE, as well as in Trinidad, another major producer of methanol and ammonia (Marcano & Cheung, 2007).

8.2. Liquefied Natural Gas (LNG)

Liquefied natural gas (LNG) technology utilizes a basic method of refrigeration. For impurities such as CO2, sulfur, water and other pollutants, the gas is pretreated, converted into liquid by cooling to -162 ?? C and stored until it is transported on board LNG tankers. Liquefied natural gas (LNG) has a volume of gas at room temperature equal to 1/600. The liquefied gas is re-gasified during shipment to the receiving terminal for use in the gas markets (Buzco-Guven, & Harriss, 2010). A recent term for LNG technology that is yet to be developed and commercially proven is called floating LNG (FLNG). This method is a mix of offshore processing technology for traditional LNG and floating Deepwater. Combined FLNG vessels can include on-board liquefaction installations and can be quickly transported to small and remote oil fields without the need to construct massive, new installations at each site. This definition is primarily championed by Shell, and at remote Browse Basin gas fields in Australia, the first commercial implementations are likely to be (Marcano and Cheung, 2007).

According to the international agency for energy, when the associated gas volumes are below 10 million cubic meters per day and the oil field is located more than 2, 000 km from the nearest market, none of the current gas utilization technologies and methods are economical. In certain cases, to avoid flaring practices, the IAE proposes economic benefits and governmental legislation. Where the volume of gas reaches 10 million cubic meters a day and the path to the market exceeds 2000 km, there are several other choices for the use of gas, including LNG or Gas To Liquid (GTL) plants, and for the transport of liquids provided by tankers to the marketplace so that they can be reused as useful feedstock (Sekyi, 2017).

Any of the small-scale liquefaction plants currently in service, such as Xinao LNG Project, 170,000 scmd flared gas in Weizhou Island, China; Naturgass Vest in Bergen, Norway, 120 tons/day; Texas, USA, 100,000 gallons/day (Cornitius, 2006). LNG plants are large-scale, long-term (20 years or more) and require large gas reserves of > 85 Bscm and US$ 1 billion for train production of about 14 million cubic meters per day (Thomas & Dawe, 2003).

8.3. Liquefied petroleum gas (LPG)

Because of its fast storage and transport to local markets and because of thehigher percentage of propane and butane in associated gas compression relative to non-associated gas, this technology is an alternative way of using associated gas. The related gas must first be treated to eliminate impurities, including CO2, H2S, mercury vapor, water vapor, and mercury vapor, before removing liquefied petroleum gases. Until removing the material of LPG, traditional LPG processes handle the entire gas source. For associated gas generated in much lower quantities, such methods are not economical and practical and have a lower pressure than non-associated gas from gas wells. Some businesses have also developed technology to handle only the recycled LPG material of the related gas in order to eliminate pollutants and therefore to minimize the scale of the plant and the associated cost of capital (Buzco-Guven Harriss, 2010).

8.4. Gas reinjection

Gas reinjection is widely used for better oil recovery or clearance of heavily polluted gases where the reinjection costs are smaller than the expense of the method of extracting sulfur (Bachu & Gunter, 2005). This approach is introduced, particularly when there is no beneficial alternative for the recovery and use of flare or related gases. In order to improve oil recovery by retaining reservoir pressure and simultaneously minimizing or removing the need for gas transportation infrastructure, reinjection or recycling is often used offshore. For limited amounts of associated gas, this is also an appealing option; it is aimed at using small quantities of gas that were historically flared due to the comparatively small amount during processing. It is also seen in situations where investment in facilities for manufacturing or export will make the prospect uneconomical. Reinjection, however, is also considered uneconomic for reservoirs with large gas supplies (Odumugbo, 2010). A Southeast Asian oil field reinjection project lowers GHG emissions by 2.65 million tons of CO2eq by storing the gas from the oil field to be vented or flared (BuzcoGuven et al., 2010). Around 31.45 MMscmd of natural gas is reinjected in Iran. Since 2000, the adoption of this gas reinjection technology in Kazakhstan has prevented the release of more than 49 million tons of CO2 a year into the atmosphere (Soltanieh et al., 2016).

8.5. Pipeline natural gas (PNG

The simple way to treat related gas in the offshore oil and gas sectors is to send flare gas to pipelines. This strategy typically has the lowest cost in situations where short distances and wide audiences are open. A domestic gas grid, power stations, and LNG or GTL plants may be on the market. Often, the related gas can be delivered to the market without additional compression using pipelines. Limiting considerations that have a substantial effect on the project's needed expenditure and must thus be considered include the distance of transport, the integration of pressure boost stations, the crossing of heavily populated areas, coastal barriers, political and environmental issues (Woldeyohannes & Abd Majid, 2011). The longer the distance of transmission, the more pipelines and pressure boost stations would be required. The price of building offshore pipelines is even greater than that of onshore pipelines (Moshfegian & Hairston, 2013). The cost of constructing onshore pipelines increases significantly when pipelines pass through environmentally sensitive areas or areas with high population density (Rui et al., 2011).

The amount of gas that can be supplied is determined by the pressure of the pipeline diameter, but an increase in the overall quantity can be accomplished by inserting compressors to the route, additional piping in the form of loops, or by raising the average pipeline pressure. Depending on the building material and the age of the conduit, pipeline pressures are typically 700–1100 psig (Thomas and Dawe, 2003).

8.6. Compressed natural gas (CNG)

Compressed natural gas (CNG) technology is an effective tool for transporting natural gas over short to medium distances. Natural gas is compressed up to 100-250 bar in the Compressed Natural Gas phase in order to minimize volume. Transport to the market may take place by way of trucks, trains, or specialized ships. Around 90% of transport costs are paid for by moving CNG by rail. Small installations make it easy to load and unload CNG (Busetto & Cijan, 2017). Compared to LNG, there are a variety of benefits of CNG that have created the very strong interest in CNG that exists today.

There are: No need to liquefy or regasify it; It is not necessary to clean the gas to the same degree as it is necessary for the pre-processing of LNG. Instead of the considerably more costly high-nickel steel, aluminum or stainless steel required to ship cryogenic LNG, the CNG container can be made of fine grain standardized steel, such as API 5L pipeline grade steel. Technology (CNG) has the ability to become the preferred solution for the use of associated gas on offshore platforms where there is no feasible and inexpensive installation of pipelines or LNG plants (Odumugbo, 2010).

8.7. Gas to power

Power gas includes the use of connected or flare gas to Generate power for in-place use or for sale to the central grid system. There is a distinction between the use of natural gas to produce electricity and flare gas. The key goal of the use of natural gas for power generation is the consumption of minimum natural gas for the output of a defined quantity of power. In the generation of power using flare gas, however, the key concern is to produce the best possible minimum capital and operational costs for power expenditure using the feed with the requirements provided (Khalili-Garakani et al., 2020).

Converting flame gas as a primary source to electricity is another way to recover flue gas. To drive an electric generator, an electric power station uses a turbine, battery, water wheel or other related devices. The kinetic energy of a flowing fluid (liquid or gas) is converted to mechanical energy by a turbine. Gas turbines are widely employed when the consumption of electricity is in high demand (Razak, 2007). In order to produce hot combustion gases that pass directly through a turbine, gas flaring may be burned, rotating the turbine blades to generate electricity. It can also be used to generate power in gas-fired turbines known as "microturbines" in order to supply energy for industrial processes, such as pumping, compression and gas processing equipment. If they do not use any of it, the power can also be sold (Emam, 2015).The electrical energy generation using flared gas is represented in two scenarios. A simulation of power generation is a gas turbine running in a basic Brayton loop in the first example. In the second case, to increase the performance, the cooling inlet air of a basic gas turbine cycle is applied by the Fog process. In the second case, the power gene-ration condition is stronger, but the first one is more economically justified. In the first and second examples, electricity generation is 38.5 MW and 40.25 MW respectively, while payback times are 3.32 and 3.48 years respectively. A compressor with an efficiency of 90 percent is used to raise the fuel pressure from 6 bar to 23.7 bar (Heydari et al., 2015, June).

A major report by PFC Consulting was funded by the World Bank in 2007 to explore economic alternatives for the related monetization of gas in Russia. The most effective methods of using flared gas were found to be the generation of electricity and construction of gas processing plants. Moreover, it was concluded that close to 80 percent of Russia's related gas could be commercially extracted at a net expense of about $1.42 per MMBTU (Farina, 2011). The aero-derived gas turbine burns 0.45 million cubic meters per day of previously flared low Btu gas to produce approximately 40 MW of electricity in Argentina (Farina, 2010).

The use of flared gas as fuel cell feed can be viewed as a new solution to the gas recovery method. Fuel cells are power generation devices that transform the chemical energy of the fuel directly into electricity. Of the different types of fuel cells, a solid oxide fuel cell is more efficient (Petruzzi et al., 2003). It works at temperatures between 600-1000 °C and uses H2 containing a gas mixture as a feed and O2 of air as an oxidant, High operating temperatures result in versatility in the use of different forms of fuel such as methane, methanol, ethanol, biogas and so on (Yuan &Sundén, 2005). Solid oxide fuel cell technology decreases CO2 emissions by about 55%. In comparison, there are nearly negative emissions with pollutant parameters (NOx, SOx, CO, particulate matter and organic compounds) and very low noise emissions (Saidi et al., 2014).

8.8. Production of Methanol and Ammonia

Methane can be converted for methanolwhich in natural gas and associated gas. Methanol is used in basic reactor systems, traditional working conditions and industrial catalysts to generate dimethyl ether and olefins such as ethylene and propylene ((Odumugbo, 2010). The Mega Methanol, MTP, and Mega Syn technologies of Lurgi and the DME method of Topsoe have cost-effective and large-scale economies for gas conversion solutions (BuzcoGuven et al., 2010).

9. CONCLUSION

One of the most pollution challenges with greenhouse gases and other pollution is gas flaring. Such emissions have a high potential for global warming and are related to climate change. Reduction and recovery of flare gas is of high importance as it satisfies the priorities of environmental and economic performance. There are many kinds of FGRS, such as gas-to-liquid, reinjection of gas, compression and electricity generation. FGRS has been raised to minimize noise and thermal radiation, operation and maintenance costs, air pollution and gas emissions, and to reduce fuel gas and steam usage, based on environmental and economic considerations.

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