Global Gas Flaring -The Energy Waste with Serious Environmental Impacts: Case Study of Iran

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ABSTRACT

Gas flaring in oil production and oil and gas refining is a major environmental issue with great energy and economic loss. In this paper the global gas flaring and its adverse environmental impacts have been reviewed briefly. It is shown that emission factor, defined as the amount of gas flared per barrel of oil produced, varies widely among oil production sites. There is also great uncertainty in the composition of flare gases and the actual measurements are rather limited. Various available technological alternatives to reduce gas flaring are presented and compared. A special focus has been put in new technological options that still need to be developed. In addition, the best implemented projects in Iran as a major oil producing and the world's third largest gas flaring country are presented. Finally, techno-economical constraints for gas flaring reduction have been discussed for future planning.

Keywords: Gas flaring, emission, Environmental impact, Reduction technologies

1 INTRODUCTION

Since the inception of oil exploration, drilling and production in the world, more than one and a half century ago, gas flaring and venting has been practiced as a method of disposing the gases associated with petroleum, mostly for safety, operational and economic reasons. In 2011 the global gas flaring was around 140 billion cubic meters (Bcm) equivalent to 2.4 million barrels of oil equivalent per day with 10 billion USD lost revenue at \$2.00/MMBtu, and 400 million tonnes of CO_2 per year emission [1]. In spite of huge amount of annually wasted energy resources and adverse environmental impacts of gas flaring, the awareness activities on gas flaring have been enhanced only in the past few decades partly due to the concerns on global climate change. In this manner, several financial initiatives and technological solutions have been dedicated to conserve the flared gases. This study remarks the scale of tragedy of continued gas flaring and its environmental impacts. In addition, it is aimed to assess the possible technological solutions for gas flaring reduction, by reviewing the best practiced cases of Iran, as one of the biggest oil producing and the third gas flaring country in the world.

2 ENVIRONMENTAL IMPACTS OF GAS FLARING

The light hydrocarbon gases- mostly methane - are generally accompanied by volatile organic compounds (VOCs) and several other impurities such as sulfur gases, some inorganic salts, carbon dioxide, nitrogen, polyaromatic hydrocarbons (PAHs), water, etc. The amount and composition of these gases vary significantly with time and from well to well depending upon the region of oil production and the pressure and temperature of the oil in the underground reservoir [2]. Detailed measurement of flared gas volume and composition, in most parts of the world is not applied. However, the volume of the flared gas can be estimated by using emission factors – the ratio of the amount of associated gas in cubic meters to the barrel of produced oil. The emission factor varies significantly, from around 1 to more than 50 cubic meters per barrel of oil for different countries, calculated based on data provided by NOAA satellite measurements for gas flaring and EIA data for oil production. The global 5-year average emission factor is around $4.6m^3$/bbl; however, Iran's emission factor stands above the average gas flaring emission at about 7.2 cubic meters per barrel of oil (See Fig. 1).

Annually around 140 billion cubic meters gas is flared globally which is responsible for around 216 million tonnes of CO_2 in 2010 [3]. Low efficiency or poor combustion in the flare results in direct emission of methane which has 25 times higher global warming potential than CO_2 (in 100 year). Moreover, air pollutants such as sulfur compounds (e.g. hydrogen sulfide and sulfur oxides), nitrogen oxides, carbon monoxide, soot and carbon black particles, VOCs, PAHs and toxic heavy metals (e.g. mercury and nickel) and other inorganic salts (mainly as chlorate and sulfate of K, Mg, Na and Ca) are emitted to the atmosphere [4], causing severe local and regional ecological destruction and greenhouse effect. It is well known that the presence of NO_x and VOCs exacerbates the photochemical smog including ozone. In addition, gas flaring causes significant amount of local thermal and noise pollution near the flaring sites. The flared gas related pollutants under unfavorable atmospheric conditions (e.g. a temperature inversion) could origin serious diseases like asthma, blood disorder, cancer, or chronic bronchitis on human living in the surrounding areas [5,6]. One of the other impacts of gas flaring is that the combusted compounds form acid rain –especially in the humid environment of the offshore–with widespread damage to the environment, devastating the vegetation and surface water. Acid rain leaches nutrients from the soil, slows the growth of trees and makes lakes uninhabitable for fish and other wildlife [5, 7].

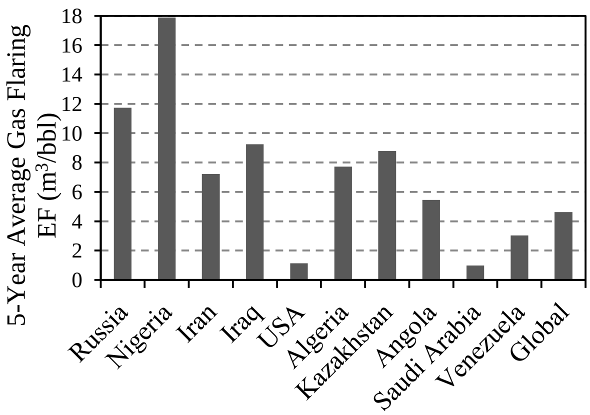

Figure 1: Five-year average gas flaring emission factor for global and the top 10 gas flaring countries in period of 2007–2011. (*Data from NOAA and EIA)*

3 GAS FLARING REDUCTION TACHNOLOGIES

3.1 Overview of Technologies

Depending on the region, proven technologies such as power generation, re-injection, gathering to add to central gas network, liquefied natural gas (LNG) and gas-to-liquids (GTL) will all have their place. These alternatives and practiced cases in Iran are summarized in Table 1.

Factors, including capital investment, technology risks, domestic market and its infrastructure, and political environment, companies' strategies, compete for decision making. A general comparison of all alternatives is difficult to make, therefore, some tips are suggested in literature.

- In offshore regions re-injection technology is often applicable in order to eliminate the need for gas transportation facilities. For offshore cases, pipeline becomes costly and challenging, with regard to the water depth and the transporting distance.
- In the case of relatively short distances to markets and low gas volumes, electricity generation or pipeline transport of the gas might be economical alternatives to flaring.
- In gas conversion to chemicals, i.e. GTL and LNG technologies, it is essential to pre-treat the gas for impurities such as sulfur and CO_2.Dong et al. [8] compared GTL and LNG and claimed that while a GTL facility is more complex, less efficient and more expensive than an LNG facility, their end-to-end supply chains are quite comparable and, thus, a decision to invest in either is challenging. Therefore, in the end, the decision to install either an LNG or GTL unit will be dependent on other factors such as local market needs, available resources, and companies' and governments' priorities, etc. [9].
- CNG is stored and transported in cylinders and can be implemented in small scale [10].

3.2 Required Technological Improvements

Although there are many available commercial technologies, it is still required to improve and develop some technologies which can be practiced in specific conditions and applications.

There are a number of advantages of CNG when compared to LNG, which have created the very strong interest in CNG that exists today. First there is no need for liquefaction or re-gasification; second the gas does not need to be cleaned to the same extent as it is necessary for LNG pre-processing [11]. CNG technology has the potential to become the preferred method of utilizing associated gas in offshore platforms where building pipeline or LNG plants are not economical and practical [12]. Since CNG is transportable, and therefore easily re-deployable, it can be used in fields with relatively short production horizons. Trans Ocean Gas is in the process of commercializing its CNG transport technology [10]. Floating LNG (FLNG) technology is also under development which is a combination of conventional LNG and floating deepwater offshore production technologies. The combined FLNG vessels will contain liquefaction facilities onboard, and can be moved to small and remote oil fields easily. Another immature associated gas utilization method is NGH or natural gas hydrate. It is crystallized form of natural gas, a chemically stable solid material in an ice state at -20°C. The advantage of this method compared to LNG is its higher stabilizing temperature. Mitsui and Mitsubishi, the BG Group, and Marathon Oil are leading the efforts to develop gas-to-solid technology [13]. GTL technology has involved high technical risks and some issues are still under study.

3.3 Best Practiced Cases

There are a number of implemented successful cases of utilization of flared gas in different countries such as Canada, Angola, Nigeria, Russia and Iran. Under the United Nations Framework Convention on Climate Change, gas flaring could be registered as a Clean Development Mechanism (CDM). The CDM program has only sparingly been used in associated gas flaring projects despite its great potential. However, since most gas flaring projects are large-scale, the total greenhouse gas reduction through these projects is considerable compared to many small-scale registered CDM projects.

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Technology	Market maturity[1]	Scale	Practiced in Iran	Flared gas reduction
Re-injection	Commercial	Large and small	Darkhoin-since 2010	7 MMscmd
Gas to pipeline	Commercial	Large and small	AMAK-since 2005	6.8 MMscmd
CNG	Not commercial	Small	–	–
LNG	Commercial	Large scale	Kharg-expected 2016 Siri-since 2011[2]	18.1 MMscmd 2.9 MMscmd
GTL	Near to Commercial	Large and small	–	–
Gas to power	Commercial	Distributed and large	–	–
Gas to chemicals	Commercial	Large and small	–	–

1. Commerciality of a technology depends on many factors such as technology availability, marketing, alternatives and economical factors and may differ from case to case.
2. It has been partially implemented. Although the project is almost completed, 1.4–1.7 MMscmd is flared.

Table 1: Proven alternative technologies for gas flaring reduction and practiced cases in Iran

By the thirteen registered gas flaring reduction projects, overall 69,274 Mtonnes CO_2 emission has been cut down by the end of 2012 [14]. Iran's only registered CDM project is Soroosh & Nowrooz Early Gas Gathering and Utilization project a part of Kharg and Behregansar project. This project has been commissioned in 2010 with around 0.08 MMscmd gas transporting to Kharg Island which was increased to 0.4 MMscmd in 2011 [15]. Other commissioned projects in Iran are AMAK since 2010, Siri since 2012, Ghalenar and Nargesi since 2013.

3.4 Flare Gas Reduction Challenges

There are several technical constraints for flared gas recovery and utilization including the lack of infrastructure to collect, treat, transport and utilize the associated gases; the detachment of market from production sites; the volume and impurities of the gas and its fluctuation. Besides, the limited financial resources, lack of policy and regulatory frameworks, domestic fuel pricing and constraints to access the required technologies, in particular by developing countries like Iran, gas flaring continues at alarming rate.

4 CONCLUSION

Iran's and the world's gas flaring can be reduced significantly provided that the political, financial and technological constraints are removed. One of the most important factors for considerable gas flaring reduction is technology availability and diversity. Thereby, flared gas regardless of its volume, composition, offshore or onshore can be converted into energy or product, which may lead to several economic and sustainable environmental benefits.

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