Environmental analysis of Turkish upstream petroleum sector

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Abstract: In this manuscript, an environmental analysis of Turkish upstream petroleum sector has been performed from the methane emission point of view. Methane is emitted during the production of crude oil and natural gas. Although methane's lifetime in the atmosphere is much shorter than carbon dioxide, methane is more efficient at trapping radiation than carbon dioxide. The flared gas amount of Turkey resulting from upstream petroleum activities were estimated and compared with the satellite data, which shows consistency. It is observed that the flared gas amount of Turkey based on the upstream petroleum activities is low due to the production level and the characteristics of crude oils. The annual flared volume of associated gas is estimated as 15 million m^3 and the vented methane is estimated as 3 million m^3. Carbon dioxide emission of the sector were also estimated with some assumptions. [Received: July 28, 2020; Accepted: October 22, 2020]

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1 Introduction

In this study, the analysis of flared gas amount and methane emission resulting from petroleum production activities in Turkey was performed. The outcomes were also compared with the results of the global satellite data. Before the evaluation of the flare and emission amounts of Turkey, the global outlook on the topic were given and the overview of the Turkish upstream petroleum industry is presented with several statistical data.

The methane emission is mostly caused by the venting of associated gas produced with crude oil in the upstream petroleum sector. To reduce the methane emissions, the vented associated gas is flared at the field site. The international association, Global Methane Initiative (GMI), was established in 2004 to mitigate methane emission globally. The GMI is an international organisation (public and private partnership) composed of 45 partner countries and a project network with more than 1,200 members, including private companies, financial institutions, universities, and other governmental and non-governmental organisations (GMI, 2018). GMI focuses on reducing methane emissions from several key sectors: oil and gas systems, coal mines, and biogas (agriculture, municipal solid waste, and wastewater). Turkey is one of the members of GMI. Turkey became the part of GMI on 30 September 2010 and participates in the coal mines, municipal solid waste, and oil and gas subcommittees.

Natural gas is often produced as a by-product when producing crude oil and it is sometimes not economic to build facilities to utilise the gas for the market. An operator must therefore choose whether to use it on site, reinject it into the ground, vent it as methane to the atmosphere, or to flare it (IEA, 2018). Flaring gas includes valuable energy source that could be used to support economic growth and energy supply. It also has environmental advantage on climate change by releasing millions of tons of carbon dioxide (CO_2) to the atmosphere instead of methane (CH_4) emission although natural gas flares are still environmentally harmful (World Bank, 2018).

Billions of cubic metres of natural gas are flared annually at crude oil production fields around globally. Flared amounts of associated gas were around 180 billion cubic metres (bcm) during the mid-1970s, but the amount of gas flared dropped significantly during the early 1980s as more routes to market were established, larger volumes were reinjected, and policies were established to cut the volumes of gas wasted in this way (IEA, 2018). Measurements and estimates of amounts of gas flared and vented have been produced by a number of organisations: Emissions Database for Global Atmospheric Research (EDGAR), International Institute for Applied Systems Analysis (IIASA), Environmental Protection Agency (EPA), International Energy Agency (IEA) and The United Nations Framework Convention on Climate Change (UNFCCC). The global upstream petroleum sector methane emissions according to different data sources shows different estimates to some extent. Differences in flare values are due to the different equation parameters and assumptions. The US National Oceanic and Atmospheric Administration (NOAA) and Global Gas Flaring Reduction (GGFR) Partnership have developed the flaring estimates in cooperation with the Colorado School of Mines, based on observations from advanced sensors in a satellite launched in 2012. Based on the data released by satellite measurements, World Bank-managed GGFR Partnership publishes flaring estimates for several countries (IEA, 2018).

In the Table 1, the amount of flared methane emissions of countries was given for the period between 2014–2018. Annual volumes of gas flared started to drop in 2017 due to the renewed policy focus on this issue. Around 140 bcm of associated gas were flared in 2017 according to the data of NOAA and GGFR (World Bank, 2018). However, the latest satellite data indicates global gas flaring was an estimated 145 bcm in 2018, an increase of about 5 bcm from the previous year. This is possibly due to the increase in global oil production and effects of the production of new crude oil fields which have high gas content and lack of the infrastructure for the utilisation of the gas. In 2018, nearly half of the all flared gas globally was made by four countries: Russia for 15%, Iraq 12%, Iran 12%, and the USA 10%. The top 10 flaring countries also including

Algeria, Angola, Libya, Mexico, Nigeria, and Venezuela were responsible for nearly 75% of global flaring in 2018.

Table 1 Gas flaring data 2014–2018, billion m^3

	2014	*2015*	*2016*	*2017*	*2018*
Russia	18.3	19.6	22.4	19.9	21.3
Iraq	14.0	16.2	17.7	17.8	17.8
Iran	12.2	12.1	16.4	17.7	17.3
USA	11.3	11.9	8.9	9.5	14.1
Algeria	8.7	9.1	9.1	8.8	9.0
Venezuela	10.0	9.3	9.3	7.0	8.2
Nigeria	8.4	7.7	7.3	7.6	7.4
Libya	2.9	2.6	2.4	3.9	4.7
Mexico	4.9	5.0	4.8	3.8	3.9
Angola	3.5	4.2	4.5	3.8	2.8
Oman	2.6	2.4	2.8	2.6	2.5
Saudi Arabia	1.9	2.2	2.4	2.3	2.3
Egypt	2.8	2.8	2.8	2.3	2.3
Malaysia	3.4	3.7	3.2	2.8	2.2
Indonesia	3.1	2.9	2.8	2.3	2.1
Kazakhstan	3.9	3.7	2.7	2.4	2.0
China	2.1	2.1	2.0	1.6	1.8
Rep. of Congo	1.3	1.2	1.1	1.1	1.6
Turkmenistan	2.0	1.8	1.8	1.7	1.5
Gabon	1.5	1.6	1.6	1.5	1.4
India	1.9	2.2	2.1	1.5	1.3
Canada	2.1	1.8	1.3	1.3	1.3
UK	1.3	1.3	1.3	1.4	1.2
UAE	0.9	1.0	0.8	1.0	1.2
Cameroon	0.9	1.1	1.1	1.0	1.1
Brazil	1.5	1.3	1.4	1.1	1.0
Qatar	1.3	1.1	1.1	1.0	1.0
Ecuador	1.0	1.1	1.2	1.1	0.9
Kuwait	1.4	0.9	1.1	0.8	0.9
Australia	1.1	1.1	0.7	0.7	0.9
Rest of world	25.6	23.2	21.8	20.0	18.8
Global total	*143.9*	*145.6*	*147.6*	*140.6*	*145.0*

Source: World Bank (2018)

2 Turkish upstream petroleum sector and environmental analysis

There are about 120 producing crude oil fields in the southeast region of Turkey (GDMPA, 2019). The typical characteristic of the oil fields in Turkey is that they are black-oil type which has low dissolved gas content though there are few crude oil fields having high gas content. The weighted average of gas-oil-ratio (GOR) amount is nearly '70 scf (standard cubic feet)/stb (stock tank barrel)' for the Turkish oil fields. GOR is a commonly used term in the petroleum sector, which is the ratio of volumetric flow of produced gas to the volumetric flow of crude oil for crude oil and gas mixture sample at standard temperature and pressure conditions. In other words, GOR is the parameter showing the dissolved gas amount in crude oil. The associated petroleum gas released during the production of crude oil is vented at the storage tanks through the venting valves. Some of the emitted gas is flared instead of venting process. These are the main sources for the methane emission in Turkish upstream petroleum sector. The crude oil production is about 19.85 million barrels in 2018.

There are 70 producing natural gas fields in the northwestern part, also called Thrace Basin, of Turkey (GDMPA, 2019). The annual gas production is very low and has decreasing trend. The natural gas production is about 0.4 billion m^3 in 2018 and negligible methane emission is expected during the natural gas production.

During the crude oil production, the gas is released at the surface storage tanks as a result of pressure reductions. The gas is vented via valves at the storage tanks due to technical and safety reasons. The amount of emitted methane depends on the GOR of the crude oil. Every oil field has specific GOR value. To calculate the possible methane emission in 2018 for Turkey, the GOR of each Turkish crude oil field is multiplied by annual crude oil production of the related field; then they are summed up. The general equation is given below:

$$Amount\ of\ methane\ emission = \sum_{n=1}^{120} Annual\ crude\ oil\ production\ of\ field_n \times Gas\ oil\ ratio\ (GOR)\ of\ field_n$$

This estimation method can offer an acceptable alternative to continuous flow measurements. The limitations and potential accuracies of this method enable obtaining reliable results. This estimation method is perhaps the most common ways currently utilised by the petroleum sector to assess flare/vent volumes in the absence of on-site measurement (World Bank, 2018).

In the upstream petroleum sector of Turkey, associated gas is processed through venting at some of the fields and at the majority of the fields associated gas is flared. In terms of volume quantity, about 10% of the estimated liberated methane amount is vented and the other 90% is flared at the production sites in Turkey. The liberated methane amount is estimated based on the approach aforementioned. The amount of the flared methane for the upstream petroleum sector in Turkey in 2018 is estimated as about 15 million sm^3.

There are several flare points distributed in the southeastern part of Turkey; however, the super-emitters of Turkish upstream petroleum sector are very few. The satellite data based on the World Bank GGFR Partnership (World Bank, 2018) shows three hotspots in

Turkey located at southeastern part: Bahar, Yeniev, and Çamurlu crude oil fields, which is also detected by this study based on the analytical analysis of the reservoir and fluid parameters of the fields. The flare hotspots of Turkish upstream petroleum sector are presented in Figure 1.

Figure 1 Flare hotspots of Turkey (see online version for colours)

Bahar oil field has the highest GOR among the all fields in Turkey and is being operated by a private oil company in the city of Diyarbakır. The company started to utilise the about half of the produced associated gas instead of flaring process so that the flared amount of gas dropped half of the amount of the previous year. The company established a 0.5 megawatt (MW) power plant on-site to meet the electricity demand of the crude oil pumps and the facilities of the oil field. Yeniev oil field has also high GOR and is operated by same oil company in the city of Diyarbakır. The company is thinking of establishing small on-site power plant at the field soon. Çamurlu oil field is also gassy field due to the gas-cap reservoir drive mechanism and has a station collecting crude oils from other near-by fields for flare operations. The field is operated by national oil company 'Turkish Petroleum' and located at the Turkey-Syria border in the city of Mardin. There is a 2.0 MW power plant on the field which reduces the flare amount considerably. The characteristics of these hotspots is to include high-GOR-crude oil and to have relatively high production. The outcomes of satellite data for the flared methane emission in upstream petroleum sector shows that about 12 million cubic metres of methane was flared in 2018 in Turkey. Contrary to the increasing crude oil production tendency there is a decreasing trend in the flared gas amounts of Turkish upstream petroleum sector based on the satellite data given in Table 2 (World Bank, 2018; GDMPA, 2019). The reason of that is the utilisation of associated gas as feedstock in new small power plants at the high-GOR-fields. The result of the analytical approach in the study has similar outcome with that of the satellite data. Beside the how much methane is burned in flare operations; the vented amount of the methane is also estimated and 3 million cubic metre of methane is emitted via venting in Turkish upstream petroleum sector annually based on the information including non-flare sites in the industry.

Table 2 The flared methane and crude oil production amounts of Turkey based on the satellite data of 'World Bank'

Year	*Flared methane amount (million m^3)*	*Crude oil production (million barrel)*
2016	26	18.00
2017	19	17.90
2018	12	19.85

Source: World Bank (2018)

In addition to flaring and venting of methane, carbon dioxide emission is also important for upstream petroleum industry. The combustion of associated gas in flaring returns methane to carbon dioxide. In the report of International Association of Oil & Gas Producers (OGP) (2000) it is stated that combustion efficiencies in flare operations are often greater than 98%. Assuming 100% flaring efficiency, all methane is converted to carbon dioxide (CO_2) which makes 15,000,000 m^3 of CO_2 emission based on the flare amount resulting from Turkish upstream petroleum sector. The whole results were also presented in Table 3.

Table 3 Greenhouse gas emissions of Turkish upstream petroleum sector in 2018

Parameter	*Amount*
Annual crude oil production (barrel)	19,850,000
Average gas-oil-Ratio (scf / barrel)	70
Flared methane, m^3 (analytical data)	15,000,000
Flared methane, m^3 (satellite data)	12,000,000
Utilised methane at power plants, m^3	20,000,000
Emitted (vented) methane (m^3)	3,000,000
Emitted CO_2 (100% flare efficiency)	15,000,000

It is evident that Turkey's flared and vented methane emission levels are insignificant looking at the global emission value based on the upstream petroleum activities.

3 Conclusions and policy implications

In conclusion, the analysis and estimation of the methane and carbon dioxide emission resulting from petroleum production for Turkey is performed in the study. The methane emission of Turkey based on the upstream petroleum activities is low due to the production level and the characteristics of crude oils, forming the one in 10,000 of the global flared amounts. The estimated flared methane amount of 15 million m^3 based on the analytical approach in the study shows similarity to the results 12 million m^3 of the satellite data of 'World Bank'. In addition to the calculations made for flared methane, the amount of vented methane is also calculated as 3 million m^3. Moreover, the emitted CO_2 due to the flared associated gas is calculated as 15 million m^3.

There is much uncertainty about greenhouse gas emission estimates from the upstream petroleum sector. The reliability of the data is questionable in many cases because vented and flared amounts are not normally metered but inferred from the

production and GOR data; however, the estimation method including production and GOR data is an acceptable alternative enabling to obtain reliable results.

Turkey is one of the members of the GMI and is open to international collaborations for environmental issues. The decreasing trend of flared methane in Turkish upstream petroleum sector is the result of the establishment of on-site electricity generators within the crude oil fields in the last years. The establishing of the more flaring units at crude oil fields would decrease the amount of emitted gas and may provide extra energy source. Although the utilisation of emitted methane to the marketplace is problematic due to the standards for gas quality and inadequate pipeline capacity, it is better to burn off unwanted gas instead of venting methane into the air, which may help for the energy requirement of the petroleum field stations. The application of new technologies to keep the gas underground reservoir may be the better choice to avoid the need for flaring or venting. The gas injection method, one of the enhanced oil recovery techniques, is the most desired method to decrease the greenhouse gas emissions along with the increase of recovery rate in the crude oil production at petroleum fields in Turkey.

Leak detection and repair (LDAR) programs are one of the crucial instruments to reduce methane emissions and LDAR is becoming more popular and effective to tackle global methane emissions among the countries in the upstream petroleum industry (IEA, 2018). The active usage of LDAR globally in the sector will help fighting against greenhouse gas emissions.

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