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Određivanje emisije gasova staklene bašte u industriji nafte i gasa

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Abstract **-** Reducing greenhouse gas emissions is one of the main targets of national strategies in European countries. As a main contributor to emissions, the energy sector is recognized as the most promising to apply measures and actions aimed to decrease GHG emissions. The Oil and Gas industry as a significant contributor to global greenhouse gas emissions is facing a growing need for estimating, mitigating, and reducing the impact of their operations on the atmosphere to stay competitive in a newly arising green economy. The goal to reduce GHG emissions emphasizes the need for identification of the main sources of emission in the Oil and Gas industry. This paper presents the comprehensive blueprint for the development of a greenhouse gas emissions inventory for the case of complex industries such as Oil and Gas, including its specifics related to processes of Oil and Gas production and processing (flaring, fugitive emissions, etc.). The model is implemented for a case of a typical upstream oil and gas company, with the aim to identify the main sources of emission. It was shown that the major source of emission is gas flaring, while the key contributor is uncombusted methane.

Index Terms - Energy transition, Greenhouse gas emissions, Industry, Oil&Gas.

Rezime **-** Smanjenje emisije gasova staklene bašte jedan je od glavnih ciljeva nacionalnih strategija Evropskih zemalja. Energetski sektor prepoznat je kao glavni sektor koji doprinosi emisijama ali i najperspektivniji za primenu mera i aktivnosti u cilju smanjenja emisija gasova staklene bašte. S obzirom na značajan doprinos globalnom efektu staklene bašte, industrija nafte i gasa se suočava potrebama za procenom, ublažavanjem i smanjenjem uticaja njihovog poslovanja na atmosferu kako bi ostala konkurentna u novonastaloj zelenoj ekonomiji. Cilj smanjenja emisija gasova staklene bašte, ističe potrebu za identifikacijom glavnih izvora emisija u industriji nafte i gasa. Ovaj rad predstavlja sveobuhvatni pristup analize emisija gasova staklene bašte složenih industrija kao što je industrija nafte i gasa, sintezujući sve specifičnosti vezane za procese proizvodnje i prerade (spaljivanje na baklji, fugitivne emisije, itd.). Model je implementiran za slučaj tipične kompanije za proizvodnju nafte i gasa, s ciljem identifikacije glavnih izvora emisija. Pokazano je da je glavni izvor emisija sagorevanje gasa, pri čemu ključni doprinos daje neizgoreli metan.

Ključne reči – energetska tranzicija, emisije gasova staklene bašte, industrija, nafta & gas.

I INTRODUCTION

The global population growth and industrial development, and rising level of living standard have been accompanied by increased demand for various forms of energy. Most of the world's energy is still derived from fossil fuels. In 2021 the share of fossil fuels amounts 80.9%, while the share of biofuels and waste amounts 9.4%, indicating that more than 90% of annually consumed primary energy in the world, is transformed by combustion processes [1].

The problems of climate change and greenhouse gas (hereinafter GHG) concentrations are observed through monitoring various indicators over time. The concentration of CO_2 in the atmosphere has increased from 294 ppm (parts per million) a century ago to the current level of 420 ppm [2, 3]. The concentrations of CO_2 and CH_4 in 2019 were the highest recorded in recent history [4]. It is assumed that human influence has led to the global retreat of glaciers since the 1990s and the retreat of the surface of the Arctic Sea ice between 1979–1988 and 2010–2019 [4]. Global surface temperatures have risen by 1.09°C from 2011–2020 compared to the period of 1850–1900 [5]. Among others, changes observed in extremes such as heat waves, heavy precipitation, droughts, and tropical cyclones have increased [4].

The increase in GHG concentrations in the atmosphere is largely the result of anthropogenic activities. Different countries around the world are organizing themselves to monitor GHG emissions, develop strategic documents, and implement activities focused on reducing negative anthropogenic effects. With the Paris Agreement in 2015, signatory countries achieved international consensus to limit increases in the global average temperature to well below 2°C compared to pre-industrial levels, and to make efforts to limit the temperature increase to 1.5°C compared to pre-industrial levels [6]. The task set before the countries that signed the agreement is not easy to accomplish, as confirmed by emissions data for the period after its signing [7]. Fulfilling undertaken obligations assumes the identification of emission sources, ensuring evaluation of emitted gases, implementation of energy efficiency measures, and switching to renewable energy sources.

The contribution of fossil fuels combustion to energy-related carbon dioxide emission is as follows: coal has the major share of 44%, oil of 33.7%, and natural gas of 21.6% [1]. The Oil and Gas (hereinafter O&G) related activities contribute more than

50% of global GHG energy-related emissions mainly through hydrocarbon extraction, processing, and subsequent combustion processes [1,2,8]. The O&G sector has been continuously impacting the global economy due to intense energy demand, however, it mirrored the GHG emissions too [2]. The abovementioned clearly shows the importance of O&G in meeting energy needs and as such its importance with respect to GHG emissions.

By signing the Paris Agreement, the participating countries are committed to fulfilling stringent emission reduction targets, and large efforts must be made within all sectors of the energy chain: production, transformation, and consumption.

In the previous period, more attention was given to evaluating emissions of the main GHG contributors: the energy transformation sector (for example, electricity generation, and heat production in centralized supply systems) and energy consumption at end users. However, in mitigating climate change all sources of emission need to be assessed and identified, which brings to attention the production and processing of fuels, including the oil and gas industry.

Emissions generated during oil and gas extraction are not negligible. In some countries, this activity is responsible for more than 20% of the country's overall emissions [9]. Thus, the need to reduce emissions is setting ambitious targets to the oil and gas industry [10]. In addition, the oil and gas sector has an indispensable role in the global methane profile, especially the production and gathering stages [11]. In [12] was shown that these activities were the source for about 65% of total fossil methane emissions or one-quarter of global anthropogenic methane emissions.

Recent studies had in focus evaluation of the effects of the implementation of various energy efficiency measures regarding the optimal operation of equipment [13], shifting to low carbon electricity and heat generation by introducing carbon-less intensive fuels, renewable and alternative fuels, or implementation of the more efficient combined cycle [14].

A major reduction of emissions can be achieved if the major sources of emissions are targeted. The ambition of this paper is to identify major sources and provide a breakdown by activity and by consequently emitted greenhouse gas for a typical onshore oil and gas production and processing facility, including fugitive emission and flaring.

The calculation is based on data specifically derived to represent a typical upstream oil and gas company, which encompasses the various activities involved in production and processing. It considers the company's efforts toward reducing flaring by employing the gas processing unit to utilize the gas that would otherwise be flared. Therefore, it provides a comprehensive representation of the typical activities and emissions associated with the upstream sector. However, it should be noted that even with these efforts, some flaring is still associated with oil production.

By utilizing this specific dataset, the paper aims to provide valuable insights into the emissions profile of a common upstream oil and gas company, highlighting the significance of flaring in the overall emissions inventory and evaluating the magnified methane emissions effect, as a potent greenhouse gas of high global warming potential, which is closely associated to the gas flaring. This information can assist policymakers and industry stakeholders in understanding the impact of gas flaring and stress the importance of developing targeted strategies to further reduce flaring and minimize the environmental impact of oil production.

II Methodology

There are various sources of GHG emissions, including the exploration and exploitation of energy sources, conversion of primary energy sources into usable forms in refineries and power plants, transmission and distribution of fuels, and the use of fuels in stationary and mobile applications. These activities result in emissions of carbon dioxide (CO_2) from the combustion of fossil fuels, as well as from non-combustion sources. Most of the emissions come from combustion, while a small amount arises as fugitive emissions from extraction, transformation, and transportation of primary energy carriers.

During combustion, most of the carbon is emitted as CO_2, with some released as carbon monoxide (CO), methane (CH_4), and nitrogen oxides (NOx). The amount of CO_2 emitted depends on the carbon content of the fuel combusted, while the emissions of non-CO_2 gases mainly depend on the combustion technology and parameters.

The methodological approach for estimating CO_2 emissions is classified into tiers, as per the guidelines of the Intergovernmental Panel on Climate Change (IPCC). Three tiers are used for estimating CO_2 emissions, with different tiers used for different source categories based on data availability, measurements, and models.

Tier 1 methodology estimates CO_2 emissions based on the quantity of fuel combusted. This methodology uses average emission factors and assumes that emissions from all sources of combustion can be estimated solely based on the amount of fuel combusted and the average emission factors. Since most of the carbon is emitted as CO_2 during fuel combustion, and only a small amount is emitted as non-CO_2 gases, the tier 1 methodology only considers the quantity of fuel combusted and not the combustion technology, maintenance, and other factors that may affect the emission of non-CO_2 gases.

In addition to the quantity of fuel combusted, tier 1 methodology also considers average emission factors. However, the quality of emission factors differs between gases. For CO_2, the emission factor depends on the carbon content and heating value of the fuel and is not influenced by combustion conditions. On the other hand, emission factors for non-CO_2 gases, such as methane and nitrous oxide, depend on technology and operating conditions and vary significantly between different combustion sources and over time. This leads to large uncertainties in the estimation of emission factors for non-CO_2 gases using tier 1 methodology.

In contrast, the tier 2 methodology represents a more detailed approach to estimating CO_2 emissions compared to the tier 1 methodology, as it uses country-specific emission factors instead of average emission factors. Country-specific factors can vary between fuels, technologies, individual plants, etc. The use of country-specific emission factors derived from detailed information is expected to reduce the uncertainties in the estimation of emission factors and result in a more accurate estimate of CO_2 emissions.

The most detailed approach to estimating CO_2 emissions is the tier 3 methodology, which uses detailed emission models or measurements and data at the individual plant level to better estimate emissions of non-CO_2 gases.

Emissions from Stationary Combustion

Combustion in stationery (non-transport) processes results in the following GHG emissions: carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O). Sources of emissions from stationary combustion include boilers, heaters, furnaces, kilns, ovens, flares, thermal oxidizers, dryers, and any other equipment or machinery that combusts any fuel.

The selected procedure for determining amounts of emitted GHG depends on available input data. Depending on the availability of data, their consistency, and time series different tier approaches are applied. A tier represents a level of methodological complexity.

Tier 1 Approach

Tier 1 represents the least complex approach, while requested input data are of the least extent and complexity. Input data for inventorying emissions from the stationary combustion process are:

- Fuel consumption, i.e., data on the amount of heat energy produced in combustion processes,
- Default emission factor for each gas and each fuel used (Equation 1).

$$E_{GHG,fuel} = FC_{fuel} \cdot EF_{GHG,fuel} \tag{1}$$

where:

$E_{GHG,fuel}$ ($Emissions_{GHG,fuel}$) - Emission of a GHG by type of fuel, [kg];
FC_{fuel} ($Fuel\ Consumption_{fuel}$) - Amount of heat energy produced in combustion processes, [TJ];
$EF_{GHG,fuel}$ ($Emission\ Factor_{GHG,fuel}$) – Average emission factor of a given GHG by type of fuel, [kg/TJ].

Tier 2 Approach

The tier 2 approach is more complex, thus providing more accurate results. Instead of average emission factors, country or region-specific emission factors are applied. In case the physical measurements of emitted GHG are available the inventory compiler can derive the emission factors and use them in this tier, ensuring that all the actions are transparent and well documented. Input data for inventorying emissions from stationary combustion processes are:

- Fuel consumption, i.e., data on the amount of heat energy produced in combustion processes, (Equation 2).
- Country or region emission factor for each gas and each fuel.

$$E_{GHG,fuel} = FC_{fuel} \cdot EF_{GHG,fuel} \tag{2}$$

where:

$E_{GHG,fuel}$ ($Emissions_{GHG,fuel}$) - Emission of a GHG by type of fuel, [kg];
FC_{fuel} ($Fuel\ Consumption_{fuel}$) - Amount of heat energy produced in combustion processes, [TJ];
$EF_{GHG,fuel}$ ($Emission\ Factor_{GHG,fuel}$) - Country-specific or calculated emission factor of a GHG for a specified fuel, [kg/TJ].

Tier 3 Approach

Tier 3 approach, as the most complex, requires a detailed GHG emissions model or measurements at facility level. Due to high information requirements and increased costs this approach is rarely chosen. Input data for inventorying emissions from stationary combustion processes are:

- Fuel consumption, i.e., data on amount heat energy produced in combustion processes, (Equation 3).
- Measured or calculated emission factor for each gas and each fuel.

$$E_{GHG,fuel} = FC_{fuel} \cdot EF_{GHG,fuel} \tag{3}$$

where:

$E_{GHG,fuel}$ ($Emissions_{GHG,fuel}$) - Emission of a GHG by type of fuel, [kg];
FC_{fuel} ($Fuel\ Consumption_{fuel}$) - Amount of heat energy produced in combustion processes, [TJ];
$EF_{GHG,fuel}$ ($Emission\ Factor_{GHG,fuel}$) - Calculated emission factor of a given GHG for a specified fuel, [kg/TJ].

EMISSIONS FROM NON-STATIONARY (MOBILE) COMBUSTION

Mobile sources produce direct GHG emissions of carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) from the combustion of various fuel types. GHG emissions from mobile combustion are most easily estimated by major transport activity. The source description shows the diversity of mobile sources and the range of characteristics that affect emission factors.

Procedure applied for nonstationary combustion is the same as the one for stationary processes under tier 1 approach but with introduction of default emission factors for non-stationary combustion.

Fugitive Emissions

Fugitive emission refers to intentional or unintentional release of GHG that occurs during the exploration, production, processing, and delivery of fossil fuels to users. Methane leaks being the major source of GHG emissions under this category. Commonly used methodologies in estimating fugitive emissions in O&G operations include:

- Direct Measurement: Requires usage of instrumentation and equipment to measure actual emissions at the source location. This approach provides high accuracy on fugitive emissions but requires specialized equipment and imposes additional costs.
- Emission Factors: The emission factors represent the empirically derived value of GHG released to the atmosphere related to activity levels (e.g., equipment types, facility types, operating hours etc.). Therefore, when multiplied with activity data they yield emissions

estimate. The methodology is of low complexity and widely adopted.

- Engineering Calculations: The methodology covers the usage of engineering models, technical domain equations, and general engineering principles to estimate fugitive emissions under certain operating conditions. This approach can be of high complexity.
- Mass Balance: The methodology which relies on proper hydrocarbon accounting. The fugitive emissions are estimated as a difference between sums of all hydrocarbon fluid volumes entering facility, and volumes that leave facility.

The simplest and most widely used methodology is based on Facility-Level Average Emission Factors (Equations 4 & 5) [8]. The API Compendium 2021 provides the tables for O&G processing facilities based on Onshore or Offshore types of production. The emission factors are usually expressed with respect to relative concentrations of CH_4 and must be adequately scaled to Methane content in the facility-associated gas composition before being applied. Additionally, CO_2 can also be released from fugitive sources if CO_2 is present in the gas stream. In this case, the Methane emission factor is scaled based on CO_2 content in the gas stream.

$$E_{CH_4} = FT_{oil/gas} \cdot EF_{oil/gas} \cdot \frac{Actuall\ _{CH_4\ mol\ \%}}{Reference\ _{CH_4\ mol\ \%}} \tag{4}$$

$$E_{CO_2} = E_{CH_4} \cdot \frac{Mw\ CO_2}{Mw\ CH_4} \cdot \frac{Actuall\ _{CO_2\ mol\ \%}}{Reference\ _{CH_4\ mol\ \%}} \tag{5}$$

where:

E_{CH4} - Emissions of CH_4;
$FT_{oil/gas}$ - Facility Throughput of oil or gas;
$EF_{oil/gas}$ - Emissions Factor for oil or gas;
E_{CO2} - Emissions of CO_2.

Emissions from gas flaring

Oil and Gas exploitation processes very often carry a significant appearance of hydrocarbon gases. As transportation and commercialization of the produced gas are very often not economically attractive, companies in these situations tend to combust the produced gas on the production site directly. This process leads to significant emissions of CH_4 and CO_2. Aside from intentional flaring at the production site, the flaring process can take place during hydrocarbon processing as non-routine flaring.

The gas flaring process is characterized as very often being a non-complete combustion process. This leads to a portion of Methane being directly emitted into the atmosphere and in this way enlarges the overall greenhouse effect.

One of the widely used methodologies for determining emissions from flaring is presented by API Compendium 2021. The methodology recognizes the flare combustion process as incomplete and therefore recommends the usage of Combustion Efficiency. In case that Combustion Efficiency is not provided by the manufacturer, or it is measured, the usage of 98% and 99.5% for Production Flare and Refinery Flare respectively is recommended. This clearly indicates that along with the carbon dioxide emitted from combustion of flared gas, a significant portion of emissions will come from uncombusted methane. The quantity of methane emitted directly depends on methane share in the flared gas composition. In cases when flared gas composition is unknown API Compendium recommends default gas composition (CH_4 - 80 mole%, C_2H_6 - 15 mole%, C_3H_8 - 5 mole%).

The CO_2 emission factor for gas flaring can be most accurately calculated by using the stoichiometric equation [8]:

$$C_xH_yO_z + \left(x + \frac{y}{4} - \frac{z}{2}\right) \cdot O_2 \quad \rightarrow \quad xCO_2 + \left(\frac{y}{2}\right) \cdot H_2O \tag{6}$$

where:

x - stoichiometric coefficient for carbon;
y - stoichiometric coefficient for hydrogen;
z - stoichiometric coefficient for oxygen.

The carbon content of hydrocarbon compound can be calculated using the equation [8]:

$$Wt\%C_{Cj} = \frac{\frac{12\ lb\ C}{lb\ mole\ C} \cdot \frac{X\ lb\ mole\ C}{lb\ mole\ Cj}}{Mw_{Cj} \cdot \left(\frac{lb}{lb\ mole}\right)} \cdot 100\% \tag{7}$$

where:

j - any hydrocarbon compound from Equation 6;
12 - molecular weight of carbon;
X - Stoichiometric coefficient for carbon;
Mw - molecular weight of individual hydrocarbon compound.

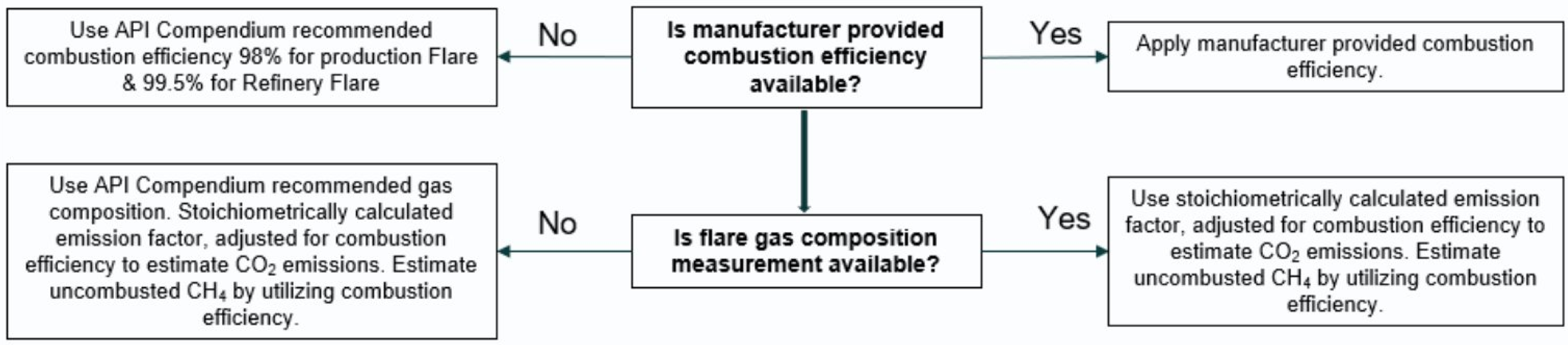


Figure 1. Flare Gas Emissions- Decision Schema

The carbon content of the fuel mixture can be calculated using the equation [8]:

$$Wt\%C_{mixture} = \frac{1}{100}\sum_{i=1}^{components}\left(Wt\%_i \cdot Wt\%_{Ci}\right) \quad (8)$$

where:

$Wt\%_i$ - weight percent of component i;

$Wt\%_{Ci}$ - carbon content of component i on a weight basis.

The CO_2 emission factor can be calculated by using the following equation [8]:

$$E_{CO_2} = FC \cdot \left(\frac{1}{mol.\ vol.\ conv.}\right) \cdot Mw_{mix} \cdot Wt\%C_{mix} \cdot \frac{44}{12} \cdot CF \quad (9)$$

where:

FC - fuel consumed;

mol. vol. conv. - conversion from molar volume to mass (379.3 scf/lbmole or 23.685 m^3/kgmole);

Mw_{mix} - molecular weight of mixture;

CF - combustion efficiency.

The emission factor can then be adjusted by flare combustion efficiency. The high-level decision schema based on API Compendium methodology is presented in Figure 1.

III Model – Case Study

For the purpose of presenting the mentioned approach in monitoring and calculation of GHG, a realistic case study of an onshore upstream O&G company is created. Within this company, three major emitters are identified: flow station, gas plant, and field offices. The synthetic data used is based on actual data from similar facilities in the industry. This data is used to model the emissions generated by each entity in a realistic way, allowing us to access the total direct (Scope 1) GHG emissions produced by the company. Analysis of the case study results in an integrative manner, gives a better understanding of the environmental impact of the O&G industry, and identifies opportunities for mitigation and reduction of GHG emissions. The detailed emitters activity data is provided in Table 1 and Table 2.

Table 1. Facility Stationary Activity Data

Facility	Year	Stationary Combustion			
		Fuel Gas [MMscf]	Flared Gas [MMscf]	Diesel [liters]	Petrol [liters]
Flowstation	2020	300	800	260000	-
	2021	330	900	220000	-
	2022	340	1050	210000	-
Gas Plant	2020	400	50	10000	-
	2021	440	65	12000	-
	2022	460	70	10000	-
Offices	2020	-	-	110000	-
	2021	-	-	80000	-
	2022	-	-	70000	-

In recent years, the accurate estimate and reporting of GHG emissions has become increasingly important in the O&G industry. This is due in part to growing concerns over climate change and the need to mitigate its effects. As a result, O&G companies are investing more effort in improving the quality of their data and measurements, particularly in relation to GHG emissions. Until recently, the gas composition of flared gas and fuel gas was not measured in a consistent and reliable manner. This has resulted in incomplete or inaccurate estimates of GHG emissions from these sources. However, with the adoption of new technologies and improved measurement techniques, companies are now able to gather more accurate data on the composition of these gases.

Table 2. Facility Mobile Activity, Throughputs and Glycol Data

Facility	Year	Mobile Combustion		Facility Throughput		Glycol Dehyd.
		Diesel [liters]	Petrol [liters]	Crude Oil [bbl]	Gas [MMscf]	Gas [MMscf]
Flowstation	2020	20000	30000	5000000	-	-
	2021	18000	27000	4700000	-	-
	2022	15000	31000	4400000	-	-
Gas Plant	2020	15000	18000	-	58000	57950
	2021	14000	18000	-	65000	64935
	2022	13000	19000	-	75000	74930
Offices	2020	12000	11000	-	-	-
	2021	10000	13000	-	-	-
	2022	9000	15000	-	-	-

Taking this into account, the case study presented in this paper will assume a single gas composition measurement available for Flowstation and Gas Plant facilities (Table 3). This resembles a realistic case of which inventory compilers can face when compiling emissions inventories for upstream O&G companies. As well this leaves space for further research on how the emissions estimate could vary with gas composition changes, or usage of default gas compositions recommended by API Compendium.

Table 3. Gas Compositions

Component	Flowstation	Gas Plant
(N_2) Nitrogen	0.62	0.35
(CO_2) Carbon Dioxide	0.80	1.13
(CH_4) Methane	81.76	88.53
(C_2H_6) Ethane	8.76	6.34
(C_3H_8) Propane	3.98	2.14
(C_4H_{10}) Isobutane	1.44	0.56
(C_4H_{10}) n-Butane	1.21	0.51
(C_5H_{12}) Isopentane	0.54	0.20
(C_5H_{12}) n-Pentane	0.29	0.12
(C_6H_{14}) Hexanes	0.60	0.12

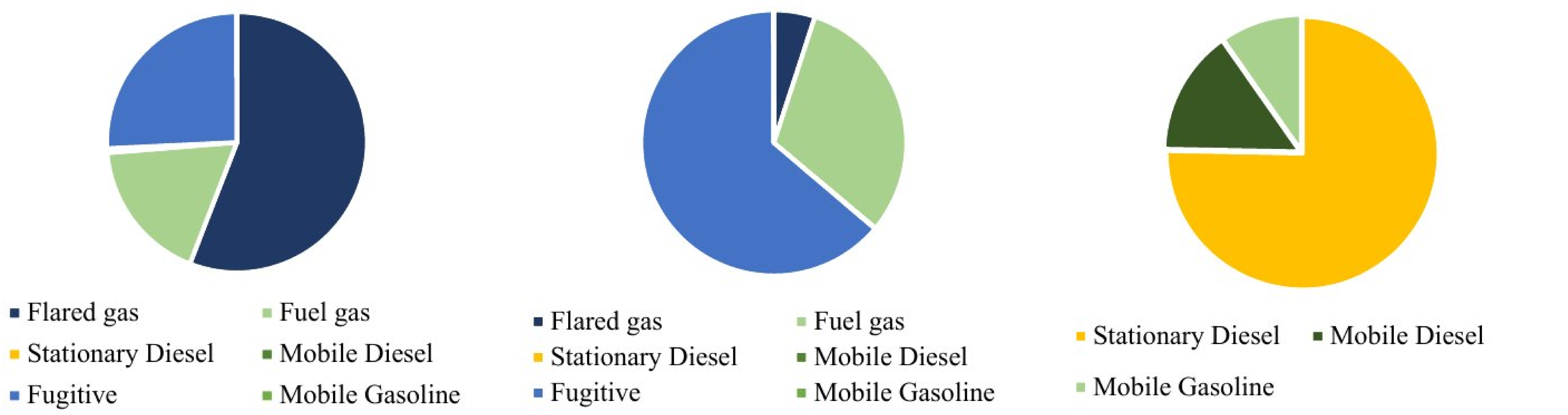
Accurate GHG modelling requires the use of reliable and up-to-date emission factors. In this study, emission factors from the Intergovernmental Panel on Climate Change (IPCC 2006 Guidelines for National Greenhouse Gas Inventories) guidelines and the American Petroleum Institute (API) Compendium 2021 are applied. These sources provide a comprehensive and authoritative set of factors for estimating GHG emissions from O&G operations. The emission factors cover a range of activities and sources, including upstream and downstream O&G operations, and are based on the latest scientific research and data. Factors used for the case study are presented in Table 4.

Table 4. **Factors used in the model [8,9]**

Source	Factors	Values	
API Compendium 2021	Global Warming Potentials (GWP)	CO_2	1
		CH_4	28
		N_2O	265
API Compendium 2021	Fugitive Emissions	Onshore Oil Production [tCH_4/bbl]	0.0002346
		Onshore Gas Production [tCH_4/MMscf]	0.02601
		Reference CH_4 content [%]	78.8
IPCC	Stationary Combustion	Natural Gas [tCO_2/TJ]	56.1
		Diesel [tCO_2/TJ]	74.1
		Natural Gas [tCH_4/TJ]	0.001
		Diesel [tCH_4/TJ]	0.003
		Natural Gas [tN_2O/TJ]	0.0001
		Diesel [tN_2O/TJ]	0.0006
IPCC	Mobile Combustion	Diesel [tCO_2/TJ]	74.1
		Petrol [tCO_2/TJ]	69.3
		Diesel [tCH_4/TJ]	0.003
		Gasoline [tCH_4/TJ]	0.003
		Diesel [tN_2O/TJ]	0.0006
		Gasoline [tN_2O/TJ]	0.0006
API Compendium 2021	Flaring Combustion Efficiency	Production Flare [%]	95
API Compendium 2021	Densities	Diesel [kg/m^3]	847.31
		Petrol [kg/m^3]	742.39
IPCC	Heating Values	Diesel [TJ/t]	0.043
		Petrol [TJ/t]	0.0443
API Compendium 2021	Glycol Dehydrator Emissions	Processed Gas Emissions[tCH_4/MMscf-processed]	0.005286

IV Results and Discussion

Using the input data described in Section 3, the GHG emissions are calculated for the case of the upstream O&G company. The model is developed based on the most up-to-date emission factors available, presented in Table 4. The input data consists of fuel consumptions, flare gas volumes, and facility throughputs. By applying the relevant emission factors to each of these data inputs, the GHG emissions from each source are estimated. The model output provides a comprehensive view (Figure 2) of the company's GHG emissions profile, broken down by facility and source. Results presented in Figure 2 contain total emissions of CO_2e for Flowstation (a), Gas plant (b) and Office (c). Accurate values of mentioned total emissions per facility and source are provided in Table 5. These estimates can be used to identify areas where emissions can be reduced or mitigated, helping the company to meet its environmental goals and regulatory requirements.



a) Total emissions of CO_2e per source for Flowstation [tonnes CO_2e]

b) Total emissions of CO_2e per source for Gas Plant [tonnes CO_2e]

c) Total emissions of CO_2e per source for Office [tonnes CO_2e]

Figure 2. Overview of the company's GHG emissions profile

Table 5. Result of total emissions per facility

Sources	Total Emissions per facility [tonnes CO_2e]		
	Flowstation	Gas Plant	Office
Flared gas	209178.91	12785.86	-
Fuel gas	66619.06	79087.24	-
Stationary Diesel	1868.96	86.68	704.25
Mobile Diesel	145.35	115.18	139.87
Fugitive	96191.56	162207.87	-
Mobile Gasoline	205.54	128.46	91.09

Results of total emissions CO_2e per year of analysis for each facility are presented in Figure 3.

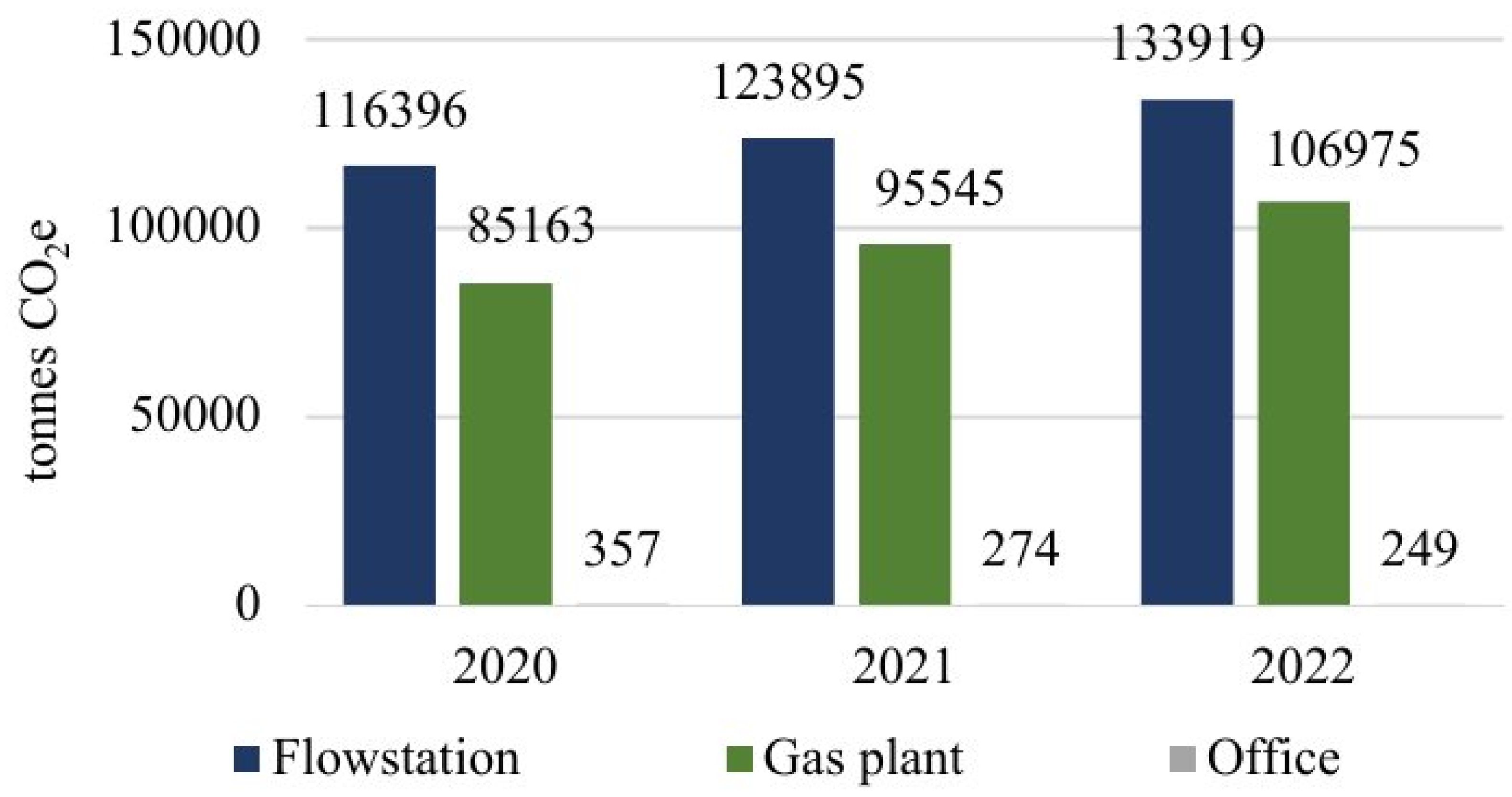


Figure 3. Total emissions CO_2e per year for each facility

Results of emissions overview per source type are presented in Figures 4-7. All values are presented per year and facility in unit tonnes CO_2e.

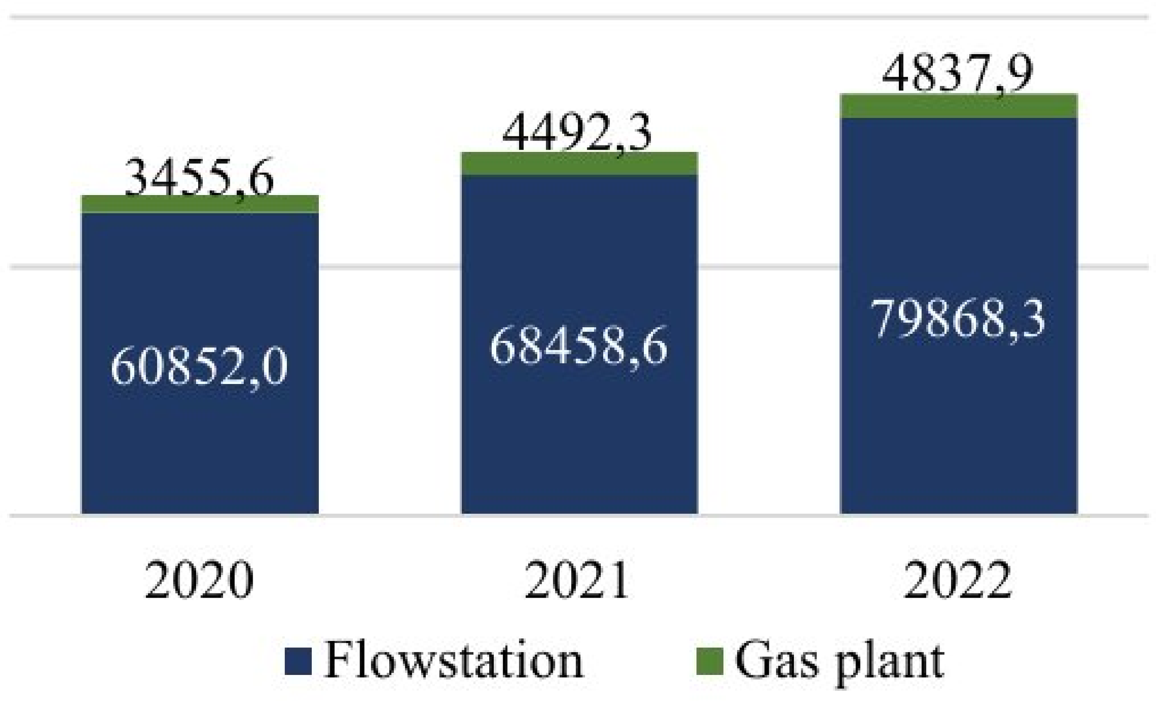


Figure 4. Flare gas CO_2e

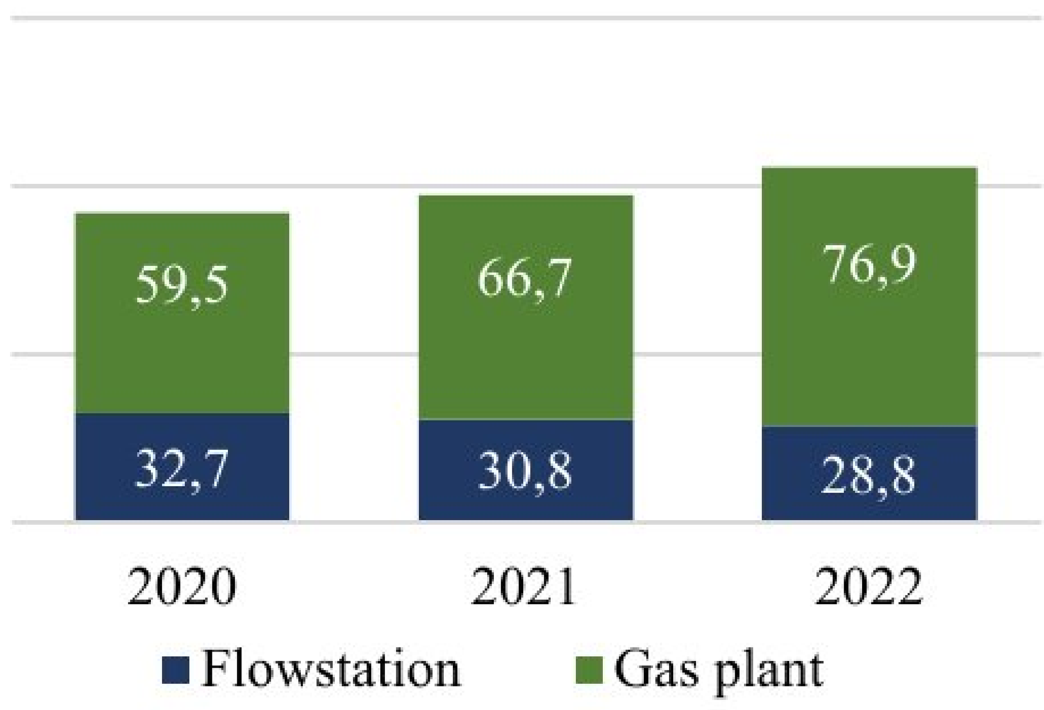


Figure 5. Fugitive gas CO_2e

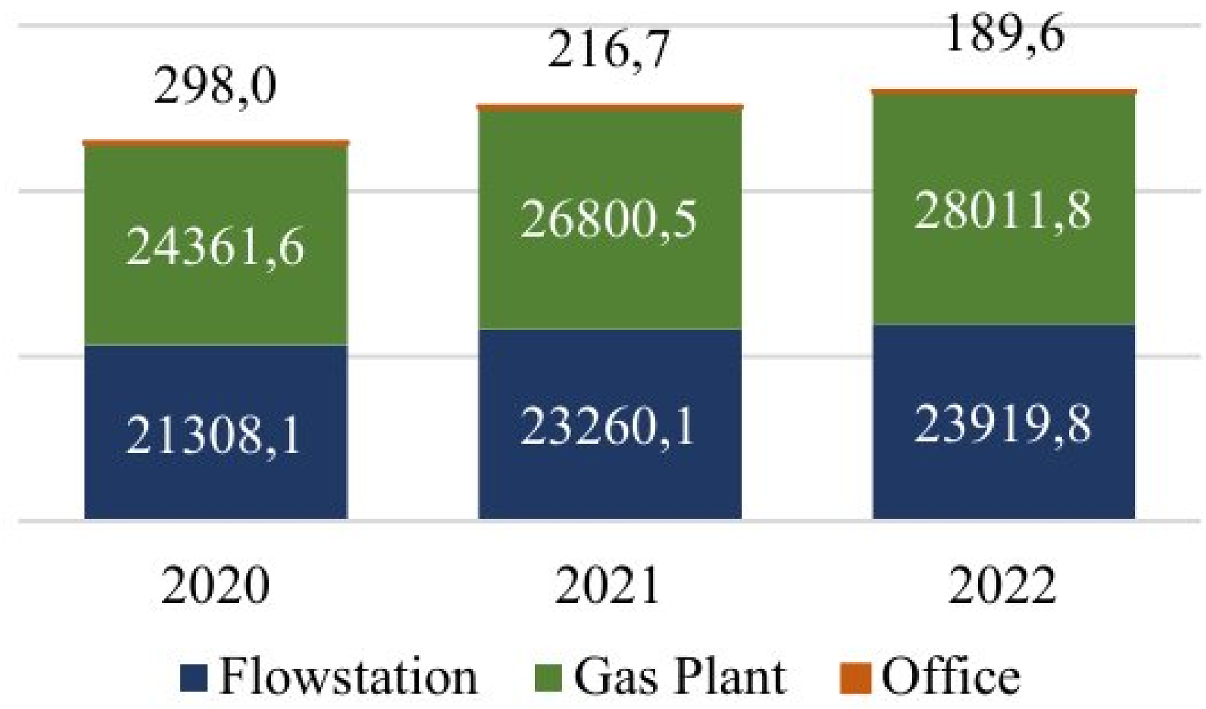


Figure 6. Stationary Combustion emissions of CO_2e

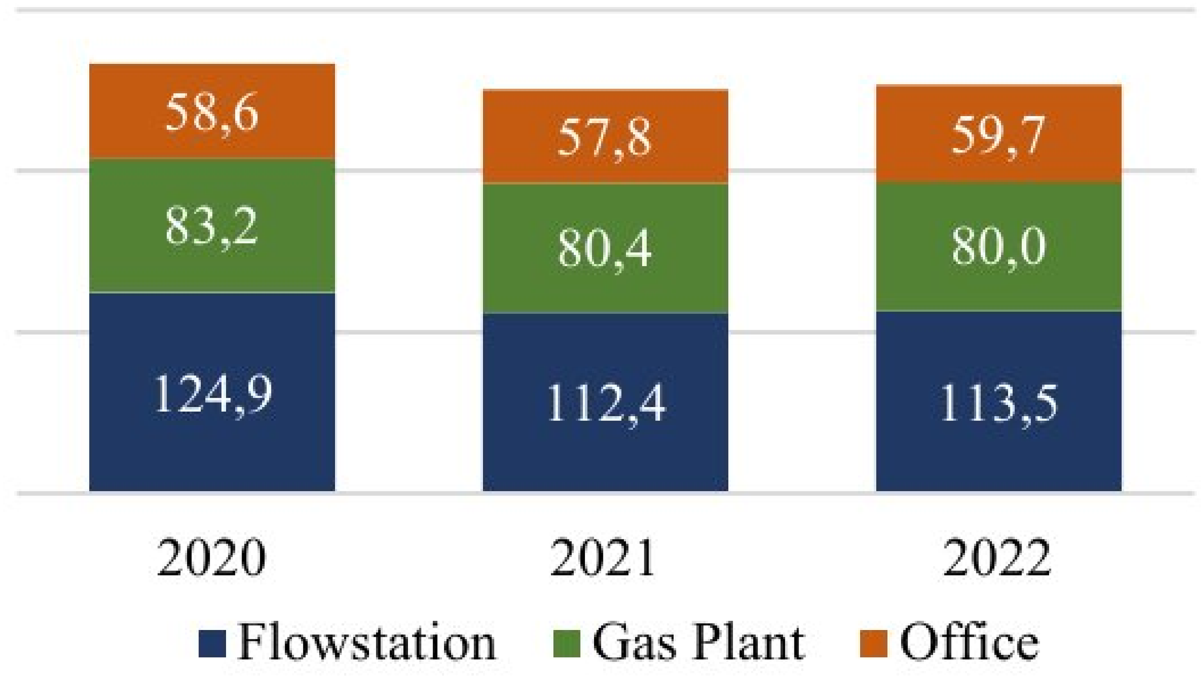


Figure 7. Mobile Combustion emissions of CO_2e

V CONCLUSION

Monitoring and calculation of GHG emissions is the starting point for the long-term goal of preserving the atmosphere. Different industries sectors generate GHG emissions during different stages of exploitation, production, processing, etc. The developed world countries direct their activities in the determination of all negative effects of the process of product creation. Negative effects in some cases cannot be eliminated, but efforts must be made to reduce them to a minimum value. The energy sector is in direct correlation with various industries. The O&G industry has a domain role in the energy sector with a space for optimization of production and processing with the aim of reducing GHG emissions. The first prerequisite is developing the methodology for mapping and calculating emissions.

This paper presented a comprehensive assessment of forming the GHG model for mapping and calculating emissions in the O&G industry. The presented GHG model was verified through Case Study of annual emissions if a typical upstream company where different facilities (Flowstations, Gas Plant, Office) and sources (Flared gas, Fuel gas, Stationary Diesel, Mobile Diesel, Fugitive, Mobile Gasoline) were analysed.

The results of the GHG model clearly indicate that the major source of emissions from the typical upstream O&G company is gas flaring, mainly due to emission of uncombusted methane.

In addition, the presented model highlights the fact that in O&G production, the expected lifecycle of oil reservoirs is such that due to reservoir depletion and pressure drop the gas production surges with time. Companies which do not utilize this gas can therefore expect to see an increase in emissions over time, as more gas is flared or vented. This underscores the importance of developing and implementing effective abatement strategies for gas utilization, such as reinjection or conversion to power generation. By doing so, companies can reduce their GHG emissions and minimize their environmental impact, while also benefiting from increased energy efficiency and cost savings.

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