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Carbon Footprint Estimation for an Oil & Gas Industry

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***Abstract*—** The rapid increment in the amount of greenhouse gases entering the atmosphere is badly impacting life on planet for almost all living organism including human. Nations from all over the world is doing efforts to reduce the amount of greenhouse gases mainly from main made activities in which burning of fossil fuel is the biggest source of today greenhouse gases. The purpose of this research is to recommend a suitable methodology for the estimation of carbon footprint for an oil and gas industry. This research explains how an oil and gas industry can estimate their own carbon footprint in a very easy and simple way. Step by step method is discussed to calculate carbon footprint from all direct emission sources and indirect emission sources like, stationary combustion sources, mobile combustion sources, vented sources and fugitive emission sources in detail. Once the carbon footprint become known to us, a comprehensive plan for its mitigation can be developed and applied which will ultimately lower the overall emission of the industry.

***Keywords*—** Carbon footprint, Oil & Gas Industries, Greenhouse Gases, Estimation, GHG

I. INTRODUCTION

If we define the term carbon footprint, it is in fact the total amount of unwanted greenhouse gases (GHGs) which is emitted as a result of an activity or in development of a product. All these greenhouse gases are multiplied by their respective global warming potentials and usually expressed in equivalent tons of carbon dioxide (CO_2) and is called carbon footprint of the activity or product [1]. When someone drive car, he contributes to his personal carbon footprint by emitting greenhouse gases, resulting from the burning of fuel in his car engine, while the amount of carbon footprint depends upon the quantity fuel and type of fuel and car. Similarly, heating one's house in cold weather by burning oil, coal, wood or natural gas, etc. also contribute to his personal carbon footprint. Even the burning of glucose inside human's body for the production of body energy also cause the generation of a greenhouse gas i.e. carbon dioxide. In short, all those activities which involve burning of fossil fuel like coal, gas, oil, all generate certain amount of greenhouse gases.

A. *Greenhouse Gases and Kyoto Protocol*

Greenhouse gases are those which have the ability trap heat in atmosphere. Due to these gases the average temperature of the earth is increasing day by day, causing global warming effect and climate change. Rising of sea level due to melting of glaciers in the Antarctica and the Himalayas is considered is a great threat for coastal cities. To counter with this global challenge for the first-time serious measures were taken as a result of which 84 countries from all over the world signed an international agreement on 11th December 1997 at Kyoto, Japan known is Kyoto protocol. Under this contract, 5.2 percent of overall emission reduction was targeted compared to1990 level [2]. Emission reduction was focused from the following six greenhouse gases:

- Carbon dioxide (CO_2).
- Methane (CH_4).
- Nitrous oxide (N_2O).
- Sulfur hexafluoride (SF_6).
- Hydrofluorocarbons (HFCs).
- Perfluorocarbons (PFCs).

1) Carbon dioxide: Carbon dioxide is the largest contributor to the global greenhouse gas emission entering the atmosphere resulting mainly from combustion of fuel to produce energy for industrial purpose and everyday usage. Additionally, a large amount carbon dioxide is emitted during certain chemical reactions inside industries. Volcanos eruption, heavy blasting and agriculture are also the sources of carbon dioxide to atmosphere. The Global warming potential of carbon dioxide is taken is unity. It is removed naturally by plants during a biochemical reaction called photosynthesis as a part of natural carbon cycle.

2) Methane: It enters to the atmosphere during the transportation and production, and processing of natural gas, oil and coal. Beside this, methane also enters to atmosphere during livestock, agriculture activities, and decay of organic solid wastes. The global warming potential of methane gas is 25.

*3) Nitrous oxide***:** It is emitted in large amount during some chemical reaction and in small proportion during combustion of

fossil fuel. The global warming potential of Nitrous oxide is 298.

4) Sulphur Hexafluoride: Sulfur hexafluoride is a powerful greenhouse gas. The effect of the release of one kilogram of SF_6 over a period of 100 years is equal to that of 23,500 kg of carbon dioxide. It has commercial applications, including semiconductor processing and transmission of electricity, and a variety of medical applications.

5) Fluorinated Gases or F-Gases: HFCs and PFCs are collectively called as fluorinated gases. As they do not harm the ambient ozone layer, F-gases are also used as replacements for ozone-depleting compounds. F-gases, however, are potent greenhouse gases, with a global warming effect up to 23,000 times higher than that of carbon dioxide (CO_2) and a large increase in its levels is observed [3].

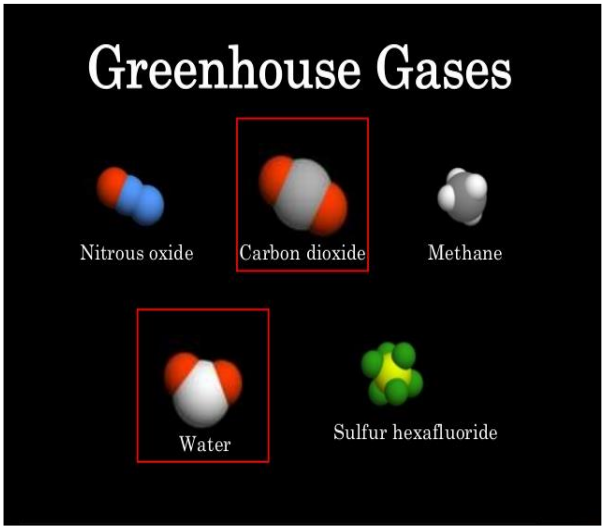

Figure 1. Kyoto Greenhouse gases

B. Sources of carbon footprint /ghg emission

1) Heat and Electricity Generation: According to 2010 emission statistics, about one-fourth of the global greenhouse gas emission is caused by the burning of fossil fuel like natural gas, coal and oil for the production of heat and electricity to fulfil the increasing need of power all over the world, so contributing to global greenhouse shares more than any other sector.

2) Industry: Compared to global emission up to 2010, twenty one percent of the global greenhouse gas emission is caused by the industrial sector. A variety of chemical, mechanical and mining processes are carried out inside industries producing hundred of thousands of commercial products. Most of these industrial activities are directly or indirectly producing greenhouse gases which enters to the atmosphere.

3) Agriculture, Forestry, and Other Land Use: Livestock and agricultural activities to fulfil the food and shelter requirements of mankind is also a main source of greenhouse gas emission with a share of twenty four percent of 2010 global emission. The population of the world is increasing day by day, so the need for their food, shelter is also increasing. New housing societies, new towns and cities are causing deforestation, increased waste material and many more.

4) Transportation: Billion of people use small and big vehicles for themselves and their goods movement from one place to another all over the world. These vehicles are mostly operated by burning of fossil fuel like gasoline and diesel producing greenhouse gases. In 2010, 14 percent global emission came from the transportation sector.

5) Building: Fuel is burnt inside homes and building for the purpose of heating and cooking. In 2010, six percent of the global greenhouse gas emissions were from this sector. Emission coming from electricity consumed in this sector is excluded and is already counted in the electricity and heat generation sector.

6) Other Energy: It is ten percent of 2010 global greenhouse gas emission and involves all those emissions related to energy sectors but not directly related to electricity and heat generation, extraction and refining of fuel and transportation etc. [4].

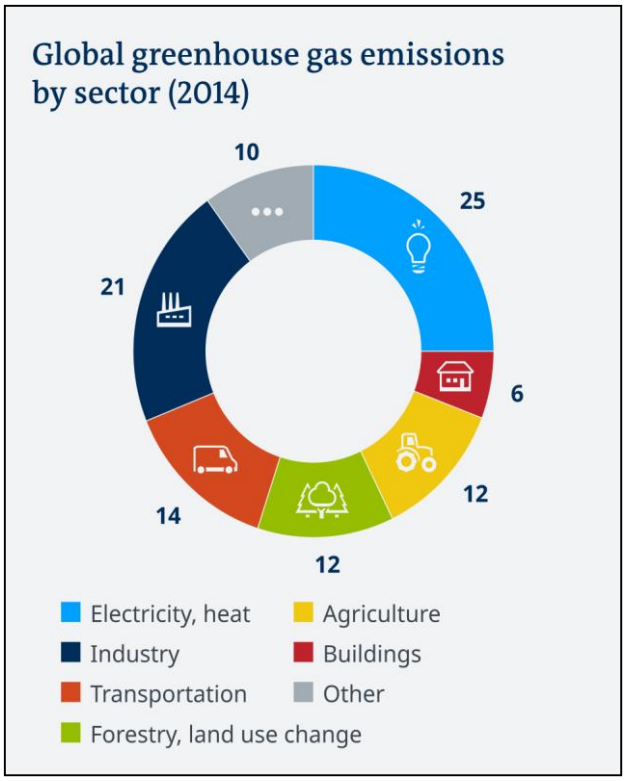

Figure 2. Global greenhouse Gas emission by Sector (2014)

Fig. 2 shows the graphical representation of the percentage of various economic sector contributing to global greenhouse emission in which heat and electricity have the greayest share of all.

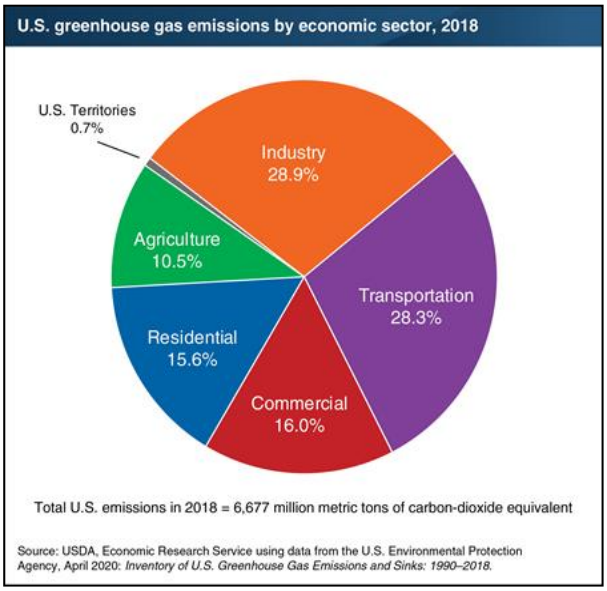

Figure 3. US Greenhouse Gas Emissions by Economic Sectors, 2018

II. CARBON FOOTPRINT'S ESTIMATION IN OIL & GAS INDUSTRY

The oil and gas received from wellhead are normally in the form of mixture of natural gas, crude oil and water. For the purpose of separation of the three-phase mixture into commercial standard products, there is always an oil and gas production and facility are required. Such facility consists of a complete phase separating system, utility system, power generation system, LPG extraction system, crude stabilization system, pneumatic system, instruments digital control system, Fire extinguishing system, water treatment systems, compression units, heating and cooling system which are required for the design process. In an oil and gas industry, a multitude of operations and equipment are involved which burn fossil fuel(s). Each process and equipment consume energy either directly or indirectly. Energy production usually contributes to a lot of carbon emissions to the environment. Gas leakages also occur from various equipment, pipelines, valves, etc. thus contributing to carbon footprints. Waste gas streams are flared, which is a continuous source of carbon emissions in an oil and gas industry. Likewise, oil and gas facility have a large number of static and rotary heavy equipment and variety of operation which leads to emission of huge amount of greenhouse gases in which carbon dioxide, methane and nitrous oxide are more prominent [5]. To estimate the carbon footprint of oil and gas industry following three steps are required:

- Identification of emission sources.
- Collection of data.
- Calculation of carbon footprint.

A. Identification of emission sources.

The very first step in the estimation of carbon footprint of an industry or a product over their life stages is to list out all the sources which directly or indirectly emit greenhouse gases to the atmosphere. All the emission sources are categorized on the basis of type greenhouse gas and way of emission. Table 1 shows a number of greenhouse gases emission sources for an oil and gas industry. However, Following are the two major categories of greenhouse gases emission sources.

1) Direct Emission Sources: This form of emission is from sources which are operated and managed themselves by the reporting organization like combustion sources which include turbines, engines, boilers, heater, flares, etc. point sources like process vents, condensate storage tanks, pneumatic devices (gas-driven) non-routine activities including maintenance and ATAs, Non-Point Sources e.g. fugitive type emissions all are the direct sources of emission.

2) Indirect Emission Sources: Some companies do not generate their own power and heat and purchase it from other power producing companies. So, the emissions which comes from the activities not controlled by the reporting company but are the consequences of the activities and operations of reporting company like purchasing of electricity etc. are termed as indirect emission sources.

TABLE I. SOURCES OF OIL AND GAS GHG EMISSION SOURCES AND CLASSIFICATION

S. No.	Greenhouse gases Emission Sources	Category	Type of Emission
1	Hot oil heaters	Stationary combustion sources	Direct Emission Sources
2	Furnaces		
3	Reciprocating compressor's engines		
4	turbines		
5	Electric generators		
6	Boilers		
7	Flares		
8	Residential camp kitchen		
9	Heavy lifting cranes	Mobile combustion sources	
10	Trucks		
11	Company owned vehicles for transport		
12	Hydrogen plants	Process emission sources	
13	Amine units		
14	Glycol dehydrators		
15	Fluid catalytic cracking unit		
16	Crude oil storage tanks	Vented emission sources	
17	Gas blanketed water and chemical tanks		
18	Chemical injection pumps		
19	Evaporating ponds		
20	Gas driven pneumatic devices		
21	Pressure relief valves		
22	Valves	Fugitive Emissions	
23	flanges		
24	connectors		
25	pumps		
26	compressor seal leaks		

27	Electricity generation (off-site)	Energy purchasing	Indirect emission sources
28	Steam generation (off-site)		

B. Collection of Data

Prepare preliminary data sheets and/or survey forms to gather

information. Identification and revalidation of potential emission sources by conducting on-site survey. Obtaining / recording all the relevant information from each source by reviewing fuel usage records, monthly / ATAs reports, interviews, etc. Beside all the most important thing in data is the amount of fuel used by a specific equipment, fuel flow rate, activity hours and the composition of the fuel used by a specific equipment. The carbon footprints' estimation is focus on following three prominent greenhouse gases inside oil and gas sector.

- Carbon dioxide (CO_2)
- Nitrous oxide (N_2O)
- Methane (CH_4)

The selection of above three GHG is made due to their noticeable prevalence and significance in oil and natural gas industry operations.

All conversions from volume to mass basis and vice versa are assumed at standard temperature and pressure conditions, i.e. 14.70 psia pressure and 60.0 °F temperature (which is equivalent to 1.01325 MPa and 15.60 °C) using the ideal gas law (PV = nRT). In estimating emissions, 100 % oxidation of carbon is assumed. Fuel Properties: The compositions and properties of fuel(s) as provided by the relevant section(s) are used in estimating emissions from fuel combustion. Quantities are expressed in SI units; units are expressed as and otherwise. The reporting year should be specified [6].

C. Calculation of Carbon footprint

There are a large number of proposed estimation methodology, while the selection of carbon footprint estimation approach depends on the availability of data, purpose of analysis and type of organization. However, the best suitable approach is "Fuel Analysis and Mass Balance Approach [7]."

1) Calculating Emissions from Combustion Sources

- Find total fuel consumed through out the year by multiplying fuel flow rate and activity hours.
- Find composition of the fuel used by doing laboratory tests.
- Calculate the molecular weight of fuel mixture.
- Convert the weight percent composition of fuel mixture to mole percent composition.
- Calculate the carbon content of fuel mixture.
- Calculate CO_2 emissions from the combustion of gaseous fuels using (1),

$$ECO_2 = FC \times MW_{Mixture} \times Wt\ \%\ C_{Mixture} \times \frac{44}{12} \times \frac{1}{molar\ volume\ conversion} \quad (1)$$

- Calculate CO_2 emissions from the combustion of liquid fuels using (2)

$$ECO_2 = FC \times D \times Wt\ \%\ C_{Mixture} \times 3.667 \quad (2)$$

- CH_4 and N_2O emissions are calculated separately using (3) and (4)

$$E_{CH4} = E_{in} \times EF_{CH4} \quad (3)$$

$$E_{N2O} = E_{in} \times EF_{N2O} \quad (4)$$

2) Calculating Emissions from Mobile Combustion Sources

Emission from mobile sources like company vehicles etc. can be readily calculated by using (5), (6) and (7)

Total fuel consumed =

Total distance covered /Fuel used per unit distance (5)

Total CO_2 emissions =

Fuel (consumed) × Emission Factor × 0.001 (6)

Total non-CO_2 GHG emissions =

Mileage × Emission Factor × 0.001 (7)

3) Calculating Emissions from Point Sources:

Calculate CH4 emissions for glycol dehydrator using (8) and (9)

$$E_{CH4} = V \times EF_{CH4} \times \frac{Mol\ \%\ CH4\ (facility)}{Mole\ \%\ CH4\ (default)} \quad (8)$$

$$E_{CO2} = E_{CH4} \times \frac{Mol\ \%\ CO2\ facility}{Mol\ \%\ CH4\ facility} \times \frac{MW\ CO2}{MW\ CH4} \quad (9)$$

4) Calculating Emissions from Non-Point Sources:

Calculate the Fugitive Emissions using the facility-level average fugitive emission factor for gas processing plants from Table 6-2 and using (10) and (11)

$$E_{CH4} = V \times EF_{CH4} \times \frac{Mol\ \%\ CH4\ (facility)}{Mole\ \%\ CH4\ (default)} \quad (10)$$

$$E_{CO2} = E_{CH4} \times \frac{Mol\ \%\ CO2\ facility}{Mol\ \%\ CH4\ facility} \times \frac{MW\ CO2}{MW\ CH4} \quad (11)$$

5) Calculating Emissions from Indirect Sources:

The purchase of energy is the major source of indirect emission in oil and gas industry. When fuel is combusted to generate electricity or to produce heat, steam, or cooling water, Carbon dioxide (CO_2), Methane (CH_4), and Nitrous oxide (N_2O) are emitted. Calculate the emissions from the use of electricity purchased from national grid using (12), (13) and (14)

$$E_{CO2} = E \times EF_{CO2} \quad (12)$$

$$E_{CH4} = E \times EF_{CH4} \quad (13)$$

$$E_{N20} = E \times EF_{N2O} \quad (14)$$

After calculating the tons of greenhouse gas emission carbon footprint can be calculated by summing out the product of each of greenhouse gas with respective global warming effect [8].

CONCLUSION

Estimation of carbon footprint is always the first step to reduce the greenhouse gas emission from an industry. A set of policy and procedures may be set forth for the assessment, reporting and mitigation of GHG and carbon footprints. The parameters like volume, pressure of the gas stream, temperature, operating flow rate, etc. may be optimized according to the system capacity to yield better performance and fewer emissions. A GHG emissions inventory should be developed and maintained at the plant. The potential GHG emissions sources should be identified and periodic monitoring may be done over a range of condition

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