Life Cycle Inventory Of Greenhouse Gas Emission Associated With Bitumen Production

Samuthirakani.V, Ashutosh Das

Abstract : Huge quantity of paving grade bitumen plays a vital role in the construction sector of Highways. The refineries functioning in India depends on 85 % of imported crude oil, especially from Middle East countries. This paper deals with the Life Cycle Inventory of greenhouse gas emission in the production of bitumen in India. The emission from the process of extraction of crude oil from oil wells, transporting to India through ships to the nearest ports, pumping the crude oil through pipe line, and distillation of bitumen are studied in this paper. Cradle to gate concept has been adopted. The inventory mainly focuses on the GHG emission only. The process of production of bitumen is on the basis of straight run bitumen, and the same has been adopted in this paper. Mass allocation procedure is followed in the process of extraction of crude oil, and transportation of crude oil, while in the refinery zone economic allocation with respect to the cost of the individual items of the bitumen and all other by products is followed, and finally the overall CO_2e emission in production of bitumen is arrived.

Index Terms: Greenhouse gas emission, bitumen, economic allocation, crude oil, refineries, life cycle inventory.

1. INTRODUCTION

The total length of road in India is 5.89 Million km which is the second largest in the world next to United States and has a road density of 1.80Km per Sqkm. The construction sector of the Highways requires a huge quantity of bitumen every year. The quantity of bitumen produced in India is 5277 TMT /year. For laying of one kilometre of the road , the approximate quantity of bitumen required is 70 MT, and the emission to the atmosphere for construction of one km of road using bitumen is 151 tons of CO_2e [1]. The total damage caused to the atmosphere, which is also called as social cost, due to construction of one km length of road using bitumen as main material is $12,470 [2]. As the bitumen finds vital role in the construction sector of highways, importance is being given to life cycle assessment in research field. Nowadays great importance is being given to quantify the impact of services and products on environment. Both the Government and the consumer are in demand of information about the sustainability of manufactured products. In order to do this much importance is necessary in the interest in comparing the potential solution based on the scientific data.

1.1 Goal of the Study

The aim of this study is to provide the greenhouse gas emission due to the production of bitumen which finds a vital role in the construction sector of Highways in India. Bitumen manufacturers and the organisation which study the environmental issues of greenhouse gas emission in production of bitumen like Highways Department, Educational institution, universities are the intended audience of the work.

1.2 Description of the Product

Paving grade bitumen is widely used in the construction of highways pavement in India.

- *Samuthirakani.V is currently pursuing PhD degree in Department of Civil Engineering, PRIST University, Vallam, Thanjavur-India vskani@gmail.com.*
- *Ashutosh Das is working as Director, Centre for Research and Development, PRIST University, Vallam, Thanjavur-India acadas@gmail.com*

While considering the production of bitumen the common method Straight run distillation method is adopted in this work.

1.3 Functional Unit

One ton bitumen of paving grade bitumen is taken as functional unit, in this work.

1.4 System Boundaries

Commencing from the extraction of raw material which is crude oil here, up to storage of bitumen has been studied in this paper. Cradle to gate system of Life Cycle inventory is adopted in this study. The total study has been divided into 4 parts.

1. Extraction of raw material, that is crude oil from oil wells.
2. Transportation of the crude oil to the refinery through ship, and through pipeline from ship to refinery..
3. Production of bitumen and allied products from crude oil in refineries.
4. Storage of manufactures bitumen in storage tanks.
5. The following figure shows the system boundary dealt in this paper

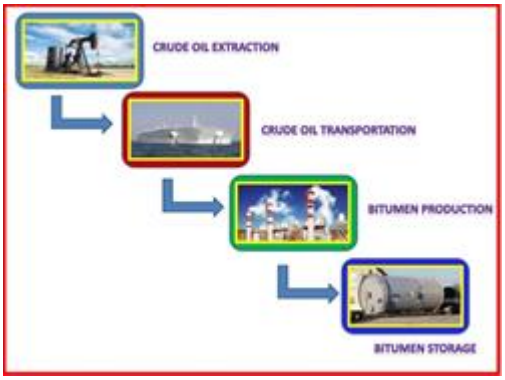

Figure 1. *System boundaries of bitumen production*

1.5 Allocation

The allocation is made as following

1. Mass allocation is followed in the extraction process.
2. Transportation of crude oil and in pumping through the pipeline, mass allocation is followed.
1. In the above process within the crude oil all by products are contained and as every by products are mingled each other, only mass relationship may be established.

2. During the production of bitumen in refineries the allocation is based on economic values of the individual products obtained from distillation like LPG, Diesel, Gasoline, naphtha fuel oil etc. The unit costs of each and every product are obtained and a relationship has been established between all products based on the market price of the individual products.

1.6 Data Sources

Sources for the data used in this paper.

1. As about 84.3 % of quantity of crude oil is imported from Middle East countries, the emission in crude oil extraction is based on the study made by Timo Blomberg [3] corresponding to the emission in Middle East country has been adopted.
2. During the transportation of crude oil through cargo ship, the fuel required for full loaded condition of 106000 DWT cargo ship is considered in this study. . The fuel required during transportation is based on the ballasted load condition, loading the crude oil and unloading from ship, as per the data collected from shipping corporations.
3. For pumping and pipeline transportation of crude oil from ship to refinery the electricity requirement is calculated and the corresponding emission is based on Indian electric grid.
4. The consumption of energy in production of all products in the refineries including bitumen in India is based on the research made by Avijit Choudhury [4].
5. The energy requirement for storage of bitumen has been collected from various refineries.

1.7 Quality of Data

The commonly used paver grade bitumen has been considered in this study. Data for source of crude oil has been taken from the energy requirement of Indian Oil refineries and all other things are related to Indian geographical representation.

2. ELECTRICITY GRID OF INDIA

India is the third biggest and consumer of the electricity in the world. Power generation plants are located all over the country with coal as primary sources of power plants. India is generating power through various sources like coal, Diesel, natural oil as fuel and nuclear, wind , hydro power plants are also common India. The production of electricity per year in India is as follows.

Table 1 *Production of Electricity in India*

Sl.No	Source/Type of Power Plant	Power Production in MW
1	Coal	205345
2	Hydro	50382
3	Wind	37669
4	Solar	34406
5	Bio mass	10001
6	Nuclear	6780
7	Gas	24955
8	Diesel	510

The following chart shows the percentage of power production in Indian grid.

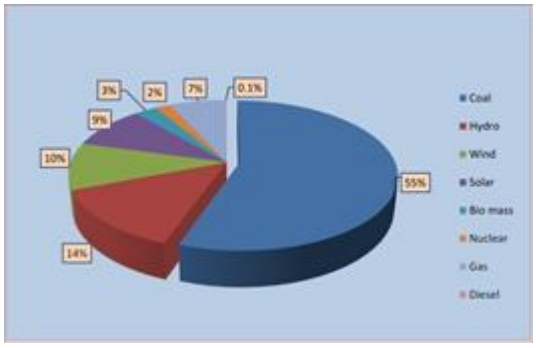

Figure 2*. Electricity Production of Indian Power Grid*

2.1 Emission in Power Generation.

Moti.L.Mital [5] estimated the emission from the coal fired thermal power plants functioning in Eastern, Western, Northern and Southern regions of India. Year wise production and the corresponding emission has been estimated in that study. Based on his study the average GHG emission of coal fired thermal power plants in India is 940 g/ton. International Hydro Power Association [6] deals with the emission from Hydro power plants. Based on previous research findings the emission different types of power plants and the weighted average of emission for production of one kWh of power in Indian grid has been arrived as 601.5 g/kWh.

Table 2*. Emission from Power Plants*

Fuel /Source of Power Plant	% of Total Production	Emission of CO_2 in Power Generation g/kWh	Weighted Emission g/kWh	Reference for CO_2 emission
Coal	55.5	940	521.7	Moti.L.Mittal [5]
Hydro	13.6	18.5	2.516	International hydropower Association [6]
Wind	10.2	12	1.224	Intergovernment Panel of Climatic change [7]
Solar	9.3	48	4.464	Intergovernment Panel of Climatic change [7]
Bio mass	2.7	1383	37.341	Standard CO_2 emission factor[8]
Nuclear	1.8	12	0.216	Intergovernment Panel of Climatic change [7]

Gas	6.8	490	33.32	Intergovernment Panel of Climatic change [7]
Diesel	0.1	754	0.754	Standard CO_2 emission factor[8]

3. GHG EMISSION IN EXTRACTION OF CRUDE OIL

The extraction of crude oil in India is about 18% of the total requirement and needs import of crude oil. . Most of the quantities of crude oil is being imported from Middle East countries like Iraq. The crude oil extraction data is based on International Association of Oil & Gas Producers [9] . The data includes drilling of bore well, and extraction of oil and gases. As per the report of International Association of Oil & Gas Producers, during the process of extraction of crude oil, the energy consumption is of 344 MJ/t to 1432 MJ/t which depends on the type of crude oil and the geographical location from which it has been extracted.

3.1 GHG Emission

CO_2 and CH4 are the principal contributor to GHG during the extraction process. The major contribution is from flaring and processing. It has been reported that 68% of $CO_2$is from energy use and balance from flaring, ventilation and fugitive loss. The following table shows the emission data during the extraction of crude oil from Middle East countries.

***Table 3**. Emission Data for Extraction of Crude Oil.*

Fuel consumption (Diesel)	12.3 Lit/t
CO_2 emission	70140
CH_4 emission	170
CO_2 e	74390

4. EMISSION DURING THE TRANSPORTATION BY SHIP

The crude oil is transported from Middle East countries to India by ship. The size of the ship varies from 70000 DWT to 130000DWT (Dead weight Ton). In this paper 106000DWT size ship is considered for calculation of emission due to transportation while carrying the crude oil while the ship is in fully loaded during onward journey and also with ballasted load for stability during the return journey. As per available data obtained from shipping corporations, the fuel requirement for the transportation of vehicles, with an average speed of 25 kmph is as follows.

***Table 4**. Fuel Requirement of Cargo Ship*

Description of condition	Fuel Requirement
Loaded with crude oil	56t/day
Ballasted load	40t/day
Loading	3.5 t
Unloading	19 t

4.1 Transportation Distance Through Sea

For calculation purpose the distance between Al-Basrah Oil Terminal, Iraq and all Indian ports handling the crude oil are considered. The nearest port of each refinery and the distance between Indian ports and Iraq port is tabulated here and the weighted average of the distance along with the capacity of crude oil processing is tabulated for major available refineries in India. Based on mass of crude oil processed and distance along sea route , the weighted average distance for transport of crude oil is calculated as per the following table.

***Table 4**. Port to Port Distance for Crude Oil Transportation*

Refinery Location	Port to Port Shipping Distance KM	Refinery capacity MMTPA	Weighted distance
Barauni, Bihar	3717	6.0	92.02
Kovali, Gujarat	1371	13.7	77.50
Haldia, West Bengal	3864	7.5	119.57
Mathura, U.P	1371	8.0	45.25
Panipat, Haryana	1371	15.0	84.85
Paradip, Odisha	3197	15.0	197.86
Mumbai, Maharashtra	1587	7.5	49.11
Visakhapatnam , AP	3182	8.3	108.97
Mumbai, Maharashtra	1587	12.0	78.58
Kochi, Kerala	2063	15.5	131.93
Manali, TN	2918	10.5	126.42
Nagapattinam, TN	2918	1.0	12.04
Mangalore, Karnataka	1883	15.0	116.54
Tatipaka, AP	3182	0.1	0.87
Bina, MP	1371	7.8	44.12
Bathinda, Punjab	1371	11.3	63.92
DTA-Jamnagar	1371	33.0	186.67
SEZ, Jamnagar, Gujarat	1371	35.2	199.12
Weighted Average Distance			1848.47

Based on the above distance the energy requirement for transportation of crude oil through ship is calculated, and based on Environment Protection Agency's marine engine emission factor, the GHG emission to air is calculated in grams/ton .

***Table 5**. Emission in shipping transport of crude oil*

Data on Sea Transport		Unit	Value
1	Vessel Type	DWT(t)	106000
2	Diatance	KM	1849
3	Speed	Km/hr	25
4	Duration	hr	73.96
5	Fuel Consumption Total	t/Trip	318.34
6	Fuel 2.7% Sulphur	t/Trip	295.84
7	Fuel 0.1% Sulphur	t/Trip	22.5
Consumption of Energy Source			
8	HeavyFuel oil	kg/t	3.00
Emission To Air			
9	CO_2	g/t	9385.02
10	CH_4	g/t	0.81
	CO_2e	g/t	9405.30

5. EMISSION DURING PIPELINE TRANSPORTATION OF CRUDE OIL

As per the report of the Petroleum Planning & Analysis Cell (Ministry of Petroleum & Natural Gas), India [10] the total pipeline network for transportation of crude oil from port to refineries is tabulated below.

***Table 6**. Transportation of Crude Oil Through Pipe Line*

Oil Company of India	Length	Capacity MMTPA
ONGC	1283	60.6
OIL	1193	9
CAIRN	688	10.7
HMEL	1017	11.3
IOCL	5301	48.6
BPCL	937	7.8

From the above data the weighted average transportation of crude oil from port to refineries is calculated based on the capacity of the refineries. The energy requirement for transporting one ton of crude oil for 100 km distance is 2 kwh/t. Electrical energy is assumed to be consumed in pipe line transportation as it is widely followed in India. The energy for Indian grid has been adopted for calculation of emission.

***Table 7**. GHG emission in transportation through ship and pipeline*

Sl.No	Mode of Transportation	CO_2e g/t
1	Ship	9405.30
2	Pumping through Pipeline	26.50
	Total	9431.80

6. EMISSION DURING THE DISTILLATION OF BITUMEN IN REFINERY

In Indian refineries, the bitumen is distilled from the crude oil by straight run distillation process. The low specific gravity by products like gas, Diesel, Gasoline etc. are collected separately during atmospheric distillation. The residue is further distilled in vacuum tower for the production of bitumen. The energy consumption in Indian refineries [4] for distillation of one ton of crude oil is, 523.82 kcal/litre of crude oil. The cost of each product has been collected from various market sources and the allocation of energy required to produce one ton of bitumen is calculated based of average weighted value of each product.

***Table 8**. Energy Allocation of by-products in Refinery*

Products obtained from Crude oil	Production /year (TMT)	Quantity of product per one t of crude oil [kg]	Cost allocation (%) based on individual cost of products	Energy distribution MJ	Energy allocation for one ton of product MJ/Ton
LPG	10170	40.7131	2.91	63.77	1566.43
Motor Sprit	37784	151.2588	22.20	486.77	3218.11
Naptha	18786	75.2051	6.96	152.67	2030.08
ATF	14588	58.3994	7.06	154.87	2651.98
SKO	4359	17.4502	1.62	35.51	2035.02
Diesel	108453	434.1645	51.77	1135.36	2615.04
Furnace Oil	9019	36.1053	1.27	27.74	768.35
Bitumen	5277	21.1252	0.99	21.69	1026.81
Lube Oil	1036	4.1474	0.39	8.63	2080.33
Petro Coke	14754	59.0640	0.51	11.12	188.33
Others	25571	102.3671	4.33	94.86	926.63

The energy mix for production of bitumen in India is 19.1% is from fuel oil, 79.2 % from refinery gas and 1.7% from electricity. Based on energy allocation and the average energy utilised in all Indian refineries, the requirement of heavy furnace oil, gas and electricity and the corresponding GHG emission to air has been arrived and tabulated here.

***Table 9**. GHG emission in distillation of bitumen in refinery*

Source of Energy	Energy Requirement MJ/t	Emission Factor g/MJ	Emission of GHC gCO_2e/ton
Heavy Fuel oil	196.12	73.34	14383.50
Refinery Gas	813.23	35.75	29073.11
Electricity	17.46	167.09	2916.69
Total			46373.30

7. EMISSION IN BITUMEN STORAGE

After the production of bitumen in refinery, the bitumen is stored in storage tanks before delivery. The temperature of

about 1750C is maintained in this chamber. To avoid clogging or choking of bitumen, it is continuously pumped within the storage chamber using an electric motor. The same motor is used to pump the bitumen to be supplied to the customers in the tanker vehicles. Hence the energy consumption required to pump the bitumen into chamber, maintaining the required temperature in the chamber, pumping the bitumen for internal circulation within the chamber and to pump the bitumen to tanker vehicles for suppliers, has been calculated as 100MJ/ton. The allocation of energy requirement for the same is 72.8% by gas, 17.5 by fuel oil and the balance 9.7 % by the electricity. For maintaining the temperature in the chamber, gas and fuel oil are used and to pump the bitumen, energy is obtained from electricity, and the corresponding emission is calculated and tabulated.

***Table 10**. GHG emission in storage of bitumen*

Source of Energy	Energy Requirement MJ/T	Emission Factor g/MJ	Emission of GHC gCO_2e/ton
Heavy Fuel oil	17.5	73.34	1283.45
Refinary Gas	72.8	35.75	2602.60
Electricity	9.7	167.09	1620.77
Total	100		5506.82

8. RESULTS AND DISCUSSION

Based on the pervious findings the total Greenhouse Gas emission due to production on one ton of bitumen from crude oil is tabulated.

***Table 10**. Overall emission of GHG in bitumen production*

Stage	GHG emission in gram CO_2 e/ton
Extraction of crude oil	74390
Transport by ship	9405
Pipe line transport	27
Refinery process	46377
Storage	5507
Total	135706

Hence for production of one ton of bitumen 135.7 Kg of CO_2e of greenhouse gas is emitted. A comparison of GHG emission in each and every stage has been furnished using a bar chart.

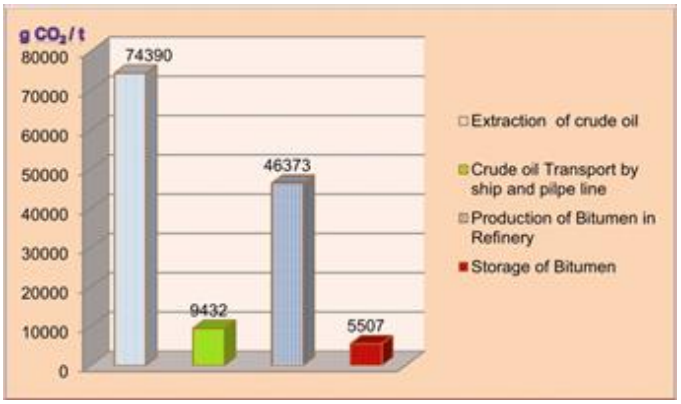

***Figure 3**. Greenhouse gas emission in bitumen production*

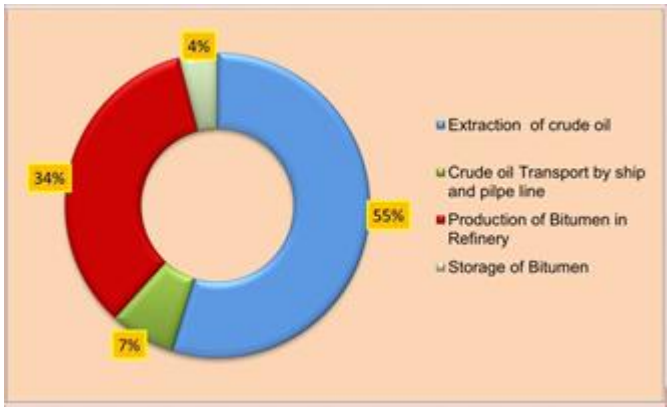

***Figure 4.** Overall emission of greenhouse gas in production of bitumen*

From the above chart, it is clear that the GHG emission is more in extraction of crude oil from oil well, and in production of bitumen in refinery, while transportation of crude oil and storage the emission less.

9. CONCLUSION

Life cycle inventory study has been made adhering to relevant ISO standards. The aim of this study, goal definition and scope are clearly defined in this work. Indian electricity grid has been analysed and the average GHG emission per unit production was arrived. For finding out the GHG emission in production of bitumen, five stages namely extraction of crude oil from refinery, transportation of crude oil through ships, pumping of crude oil from ship to the refinery through pipelines, distillation of bitumen in refinery and storage of bitumen within refinery are considered. Regarding allocation of bitumen among by products, mass allocation is followed in extraction, transportation and economic allocation is made in refinery. For each stage in bitumen production the GHG emission is calculated and tabulated. It is found that during the crude oil extraction stage and during the production of bitumen in refineries, the GHG emission is more. Summing up the GHG emission of all the individual stage of production, overall Green House Emission concerning to Indian topographical area was arrived.

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