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KERALA
GHG INVENTORY
METHODOLOGY NOTE
ENERGY SECTOR

JUNE, 2024

ENERGY SECTOR

Key Highlights

- Energy sector accounts for ~79% of the gross GHG emissions (excluding LULUCF) in 2021 in Kerala.Emissions from the Energy sector declined from 18.12 Mt CO_2e in 2005 to 17.24 Mt CO_2e in 2021.
- Emissions from this sector peaked in 2019 at 20.05 Mt CO_2e, and declined significantly to 16.96 Mt CO_2e in 2020. This significant decline in emissions could be attributed to reduction in emissions from the Transport sector, primarily due to the strict imposition of Covid-19 related mobility restrictions in the state.
- Within the Energy sector, the Transport sector was the key contributing sub-sector in 2021, accounting for ~62%. This was followed by the Residential sub-sector (~19%) and Industrial Energy (~10%).
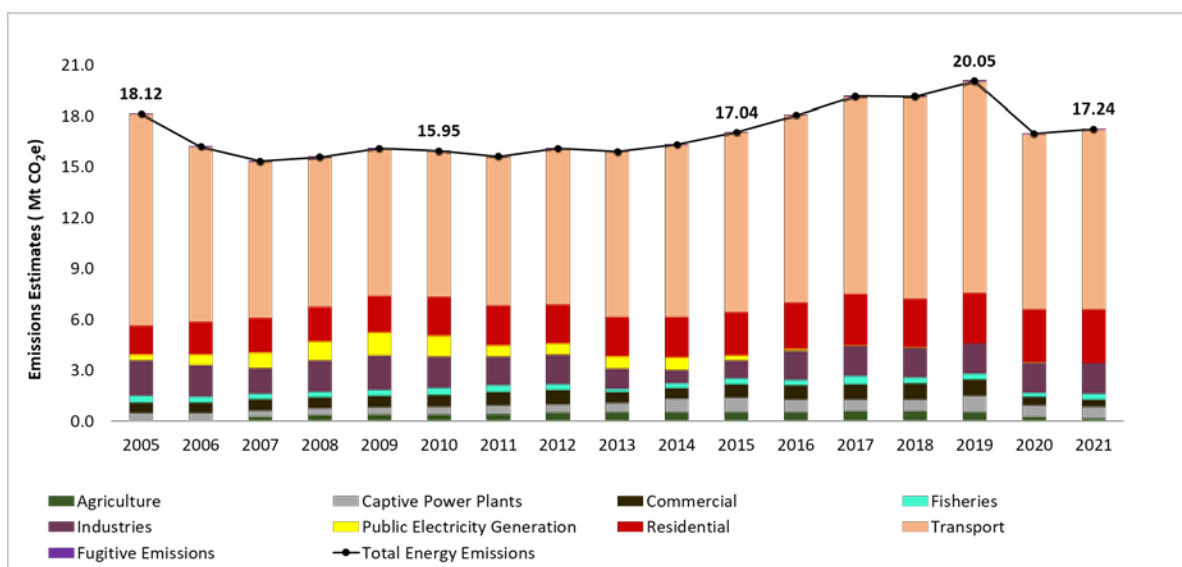

Figure 1 : GHG Emissions Estimates of Energy Sector – Kerala (2005 to 2021)

Sector Description:

Energy systems are for most economies largely driven by the combustion of fossil fuels. During combustion the carbon and hydrogen of the fossil fuels are converted mainly into carbon dioxide (CO_2) and water (H_2O), releasing the chemical energy in the fuel as heat. This heat is generally either used directly or used (with some conversion losses) to produce mechanical energy, often to generate electricity or for transportation.[3](IPCC,2006)

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[3] 2006 IPCC Guidelines for National Greenhouse Gas Inventories,Volume 2, Chapter-1
https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/2_Volume2/V2_1_Ch1_Introduction.pdf

The Energy sector emissions comprises emissions from Fuel Combustion and Fugitive emissions. The following are the key sub-sectors/categories covered in the Energy sector's emissions estimates:

- 1A1   Energy Industries
  - o 1A1 ai Public Electricity Generation
  - o 1A1 aii Captive Power Plants

- 1A2 Industrial Energy

- 1A 3 Transport
  - o 1A3a Civil aviation
  - o 1A3b Road transportation
  - o 1A3c Railways
  - o IA3d Water-borne navigation

- 1A4 Other Sectors
  - o 1A4a Commercial/Institutional
  - o 1A4b Residential
  - o 1A4c- Agriculture/Fisheries

- 1B Fugitive Emissions From Fuels

Methodology:

The sources of activity data used for estimating emissions from the Energy sector is detailed below in Table 1. The fuel consumption data used for estimating emissions from sector/category for the years 2019, 2020, 2021 is detailed in Table 2.

Table 1: Source of activity data[4] used for estimating emissions from Energy sector

Sub-sector/ Category	Fuels	Years	Sources/ Assumptions
Energy Industries			
Public Electricity Generation	1. High Speed Diesel (HSD) and Naphtha fuels from State/ Private-owned Gas power plants; LSHS and Diesel Oil from State/Private -owned Diesel power plants	(a) 2004-05 to 2010-11 and 2012-13 to 2017-18 (b) 2011- 12 (c) 2018-19 to 2021-22	(a) Central Electricity Authority. A*ll India Electricity Statistics: General review* Reports *(accessed from hardcopy)* (b) CAGR method (c)Central Electricity Authority. *All India Electricity Statistics: : General review* Reports 2020 , 2021, 2022 and 2023
	2. High Speed Diesel (HSD) and Naphtha fuels from Centrally- owned NTPC- Rajiv Gandhi Combined Cycle Power Plant	(a) 2004-05 to 2016-17 (b) 2017-18 and 2021-22	(a) NTPC- Rajiv Gandhi Combined Cycle Power Plant's Proforma (b) HSD fuel data estimated using CAGR method. Whereas, the Naphtha fuel data was estimated based on Electricity Generation data from Kerala State Electricity Board's Power Statistics and Specific Gas consumption. (derived from Generation and Fuel Consumption value given in the Pro-forma)
Captive Power Plants	Coal, Gas and Diesel	(a) 2004-05 to 2010-11 and 2012-13 to 2017-18 (b) 2011- 12 (c) 2018-19 to 2021-22	(a) Central Electricity Authority. *All India Electricity Statistics: : General review* Reports *(accessed from hardcopy)* (b) CAGR method (c) Central Electricity Authority. *All India Electricity Statistics: : General*

[4] Activity data provided in financial year (FY) format was converted to calendar year (CY) format using the following equations:

CY Activity data = [¼*FY Activity Data$_{Preceding\ year}$] + [¾*FY Activity Data$_{Succeeding\ year}$]

Sub-sector/ Category	Fuels	Years	Sources/ Assumptions
			review Reports 2020 , 2021, 2022 and 2023
Industrial Energy			
Industrial Energy	1. Naphtha	(a) 2007-08 to 2017-18 (b) 2004-05 to 2006-07 (c) 2018-19 to 2021-22	(a) Pillai, V. & AM Narayanan. (2019) (b) Naphtha consumption was assumed to be the same as the value reported for 2007-08. (c) CAGR method
	2. High Speed Diesel (HSD)	(a) 2007-08 to 2017-18 (b) 2004-05 to 2006-07 and 2018-19 to 2021-22	(a) Pillai, V. & AM Narayanan. (2019) (b) CAGR method
	3. Light Diesel Oil (LDO)	(a) 2007-08 to 2017-18 (b) 2004-05 to 2006-07 and 2018-19 to 2021-22	(a) Pillai, V. & AM Narayanan. (2019) (b) CAGR method
	4. Furnace Oil (FO)/ Low Sulphur Heavy Stock (LSHS)	(a) 2007-08 to 2017-18 (b) 2004-05 to 2006-07 and 2018-19 to 2021-22	(a) Pillai, V. & AM Narayanan. (2019) (b) CAGR method
	5. Natural Gas	(a) 2007-08 to 2017-18 (b) 2004-05 to 2006-07	(a) Pillai, V. & AM Narayanan. (2019) (b) Natural Gas consumption was assumed to be zero considering the values reported in year 2007-08

Sub-sector/ Category	Fuels	Years	Sources/ Assumptions
		(c) 2018-19 to 2021-22	(c) Average value was applied based on 2016-17 and 2017-18 estimates.
Transport			
Civil Aviation	Aviation Turbine Fuel (ATF)	(a)2003-04,2005-06, 2007-08 to 2010-11 and 2012-13 to 2021-22 (b)2004-05, 2006-07 and 2011-12.	(a) Ministry of Petroleum and Natural Gas, Economic and Statistic Division, Government of India. *Indian Petroleum and Natural Gas statistics* 2003-04, 2005-06, 2007-08, 2008-09, 2009-10, 2010-11, 2012-13 ,2013-14, 2014-15, 2015-16, 2016-17, 2017-18, 2018-19, 2019-20, 2020-21 and 2021-22 reports. (b) Interpolation method
Road Transport	1. Compressed Natural Gas (CNG)	(a) 2017-18 to 2020-21 (b) 2016-17 and 2021-22 (c) 2015-16 (d) 2004-05, 2006-07 and 2011-12.	(a) Ministry of Petroleum and Natural Gas, Economic and Statistic Division, Government of India. *Indian Petroleum and Natural Gas statistics* 2020-21, 2019-20, 2018-19, 2017-18 reports. (b) Ministry of Petroleum and Natural Gas, Economic and Statistic Division, Government of India. *Indian Petroleum and Natural Gas statistics* 2021-22 report. (c) Data not available hence assumed to be zero. (d) Indian Petroleum and Natural Gas Statistics reports have not been published for these years.

Sub-sector/ Category	Fuels	Years	Sources/ Assumptions
	2. AutoLPG	(a) 2007-08 to 2017-18 (b) 2004-05 to 2006-07 (c) 2018-19 to 2021-22	(a) Pillai, V. & AM Narayanan. (2019) (b) Auto LPG consumption was assumed to be zero considering the values reported in year 2007-08. (c) CAGR method.
	3. Motor Spirit/ Petrol	**(a) Motor Spirit/ Petrol consumption data of Kerala** (i) 2003-04, 2005-06, 2007-08 to 2010-11 and 2012-13 to 2021-22 (ii) 2004-05, 2006-07 and 2011-12.	(i) Ministry of Petroleum and Natural Gas, Economic and Statistic Division, Government of India. *Indian Petroleum and Natural Gas statistics* 2003-04,2005-06,2007-08,2008-09, 2009-10,2010-11,2012-13,2013-14, 2014-15,2015-16,2016-17,2017-18, 2018-19,2019-20,2020-21 and 2021-22 reports. (ii) Interpolation method
		(b)Petrol-Retail (percentage share) consumption in Road Transport sector of Kerala 2012-13	All India study on sectoral demand of Diesel and Petrol Report, 2013 *(Petroleum Planning and Analysis Cell, 2013)*

Sub-sector/ Category	Fuels	Years	Sources/ Assumptions
		(c) National level Motor Spirit/Petrol consumption in retail 2012-13 to 2021-22	Ministry of Petroleum and Natural Gas, Economic and Statistic Division, Government of India. *Indian Petroleum and Natural Gas statistics* 2012-13,2013-14,2014-15,2015-16, 2016-17,2017-18,2018-19,2019-20, 2020-21 and 2021-22 reports.
	4. High Speed Diesel Oil (HSD)	**(a) National-level HSD consumption data:** (i) 2004-05 to 2021-22 for Road Transport sector and Retail sector (ii) 2004-05 to 2006-07 of private sales sector	(i)Ministry of Petroleum and Natural Gas, Economic and Statistic Division, Government of India. *Indian Petroleum and Natural Gas statistics* 2005-06,2007-08,2008-09, 2009-10,2010-11,2012-13,2013-14, 2014-15,2015-16,2016-17,2017-18, 2018-19,2019-20,2020-21 and 2021-22 reports (ii) Ministry of Petroleum and Natural Gas, Economic and Statistic Division, Government of India. *Indian Petroleum and Natural Gas statistics* 2005-06 and 2009-10
		(b) HSD consumption data of Kerala (i) 2003-04, 2005-06, 2007-08 to 2010-11 and 2012-13 to 2021-22	(i) Ministry of Petroleum and Natural Gas, Economic and Statistic Division, Government of India. *Indian Petroleum and Natural Gas statistics* 2003-04,2005-06,2007-08,2008-09, 2009-10,2010-11,2012-13,2013-14, 2014-15,2015-16,2016-17,2017-18, 2018-19,2019-20,2020-21 and 2021-22 reports (ii)Interpolation method.

Sub-sector/ Category	Fuels	Years	Sources/ Assumptions
		(ii) 2004-05 , 2006-07 and 2011-12	
		(c)Diesel-Retail (percentage share) consumption in Road Transport sector of Kerala (i) 2012-13 (ii) 2021-22	(i) All India study on sectoral demand of Diesel and Petrol Report, 2013 *(Petroleum Planning and Analysis Cell, 2013)* (ii) All India study on sectoral demand of Diesel and Petrol Report (PPAC), 2021 *(accessed from hard copy)*
Railways	1. HSD	**(a) Railways Consumer Depot (RCD)/Kannur** (i) 2007 to 2021 (ii) 2005 to 2006	(i) Southern Railway Department. (ii) CAGR method
		(b) Railways Consumer Depot (RCD)/ Palakkad (i) 2014 to 2021 (ii) 2005 to 2013	(i) Southern Railway Department. (ii) CAGR method
	2. Diesel	**Thiruvananthapuram Division** (i) 2019 to 2021 (ii) 2005 to 2018	(i)Southern Railway Department. (ii) CAGR method
	3. LDO	**Electrical (GS) Palakkad Division** (i) 2014 to 2022 (ii) 2005 to 2013	(i) Southern Railway Department. (ii) CAGR method
Water-borne Navigation	1. Diesel	(a) 2010 and 2022	(a) Kerala Maritime Board (b) CAGR method

Sub-sector/ Category	Fuels	Years	Sources/ Assumptions
		(b) 2011 to 2021	
	2. Petrol	(a) 2010 and 2022 (b) 2011 to 2021 (c) 2005 to 2009	(a) Kerala Maritime Board (b) CAGR method (c) Average fuel consumption value (of years 2010 to 2016)
	3. High Speed Diesel (HSD)		2005 to 2021 fuel consumption data estimated based on the thumb-rules provided by the State Water Transport Department.
Other Sectors (Energy)			
Commercial/Institutional	1. Liquified Petroleum Gas (LPG)	**(a) National Level Commercial sector LPG consumption data:** (i) 2003-04, 2009-10 to 2021-2022 (ii) 2004-05 to 2008-09	(i) Ministry of Petroleum and Natural Gas, Economic and Statistic Division, Government of India. *Indian Petroleum and Natural Gas statistics* 2003-04,2009-10,2010-11,2012-13, 2013-14,2014-15,2015-16,2016-17, 2017-18,2018-19,2019-20,2020-21 and 2021-22 reports (ii) CAGR method
		(b) National level Total LPG consumption data: 2003-04 to 2021-22	Ministry of Petroleum and Natural Gas, Economic and Statistic Division, Government of India. *Indian Petroleum and Natural Gas statistics* 2003-04,2005-06,2007-08,2008-09, 2009-10,2010-11,2012-13,2013-14, 2014-15,2015-16,2016-17,2017-18, 2018-19,2019-20,2020-21 and 2021-22 reports

Sub-sector/ Category	Fuels	Years	Sources/ Assumptions
		(c) LPG consumption data of Kerala: (i)2003-04,2005-06, 2007-08 to 2010-11 and 2012-13 to 2021-22	(i) Ministry of Petroleum and Natural Gas, Economic and Statistic Division, Government of India. *Indian Petroleum and Natural Gas statistics* 2003-04,2005-06,2007-08,2008-09, 2009-10,2010-11,2012-13,2013-14, 2014-15,2015-16,2016-17,2017-18, 2018-19,2019-20,2020-21 and 2021-22 reports
		(ii) 2004-05 and 2006-07	(ii) Interpolation Method
	2. High Speed Diesel Oil (HSDO)	**(a) Commercial sector HSDO consumption data:** (i) 2007-08 to 2017-18 (ii) 2004-05 to 2006-07 and 2018-19 to 2019-20	(i) Pillai, V. & AM Narayanan. (2019) (ii) CAGR method
		(b) National level HSDO consumption data: 2020-21 and 2021-22 for the retail sector and total national-level consumption.	Ministry of Petroleum and Natural Gas, Economic and Statistic Division, Government of India. *Indian Petroleum and Natural Gas statistics* 2020-21 and 2021-22 reports
		(c)HSDO consumption data of Kerala 2020-21 and 2021-22	Ministry of Petroleum and Natural Gas, Economic and Statistic Division, Government of India. *Indian Petroleum and Natural Gas statistics* 2020-21 and 2021-22 reports

Sub-sector/ Category	Fuels	Years	Sources/ Assumptions
		(d) Diesel Consumption (percentage share) in Non- Transport sector of Kerala 2021-22	All India study on sectoral demand of Diesel and Petrol Report (PPAC) 2021 *(accessed from hard copy)*
		(e) National-level Diesel (percentage share) in Commercial sector	GHGPI Phase III[5]
Residential	1. Kerosene	(a) 2007-08 to 2017-18 (b) 2004-05 to 2006-07 and 2018-19 to 2021-22	(a) Pillai, V. & AM Narayanan. (2019) (b) Estimated using Pillai, V. & AM Narayanan. (2019) study and Economic Review Reports (2004-05, 2005-06, 2006-07, 2018-19, 2019-20, 2020-21 and 2021-22) of Kerala
	2. Liquified Petroleum Gas (LPG)	**(a) LPG consumption data of Kerala** (i) 2007-08 to 2017-18 (ii) 2003-04, 2005-06, 2007-08 and 2018-19 to 2021-22 (iii) 2004-05 to 2006-07	(i) Pillai, V. & AM Narayanan. (2019) (ii) Ministry of Petroleum and Natural Gas, Economic and Statistic Division, Government of India. *Indian Petroleum and Natural Gas statistics* 2003-04, 2005-06, 2007-08, 2018-19, 2019-20, 2020-21 and 2021-22 reports (iii) Interpolation Method

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[5] Mohan, R.R., Dharmala, N., Ananthakumar, M. R., Kumar, P., Bose, A. (2019). *Greenhouse Gas Emission Estimates from the Energy Sector in India at the Subnational Level (Version/edition 2.0)*. New Delhi. GHG Platform India Report - CSTEP. Available at https://www.ghgplatform-india.org/wp-content/uploads/methodology/phase-3/GHGPI-PhaseIII-Methodology%20 Note-Energy-Sep%202019.pdf

Sub-sector/ Category	Fuels	Years	Sources/ Assumptions
		(b) National level LPG consumption data (i) 2004-05 to 2007-08 and 2018-19 to 2021-22 of domestic LPG (ii) 2004-05 to 2006-07 of Private sales sector	Ministry of Petroleum and Natural Gas, Economic and Statistic Division, Government of India. *Indian Petroleum and Natural Gas statistics* 2005-06,2007-08,2018-19,2019-20, 2020-21 and 2021-22 reports
Agriculture	Diesel/High Speed Diesel Oil	**(a) HSDO consumption data of Kerala** (i) 2003-04, 2005-06, 2007-08 to 2010-11 and 2012-13 to 2021-22 (ii) 2004-05, 2006-07 and 2011-12	(i) Ministry of Petroleum and Natural Gas, Economic and Statistic Division, Government of India. *Indian Petroleum and Natural Gas statistics* 2003-04,2005-06,2007-08,2008-09, 2009-10,2010-11,2012-13,2013-14, 2014-15,2015-16,2016-17,2017-18, 2018-19,2019-20,2020-21 and 2021-22 reports (ii) Interpolation method.
		(b) National level HSDO consumption of Agriculture Sector (i) 2007-08 to 2021-22	(i) Ministry of Petroleum and Natural Gas, Economic and Statistic Division, Government of India. *Indian Petroleum and Natural Gas statistics* 2007-08,2008-09,2009-10,2010-11, 2012-13,2013-14,2014-15,2015-16, 2016-17,2017-18,2018-19,2019-20, 2020-21 and 2021-22 reports

Sub-sector/ Category	Fuels	Years	Sources/ Assumptions
		(ii) 2004-05 to 2006-07	(ii) CAGR method
		(c)National level HSDO consumption of Retail sector 2004-05 to 2021-22	Ministry of Petroleum and Natural Gas, Economic and Statistic Division, Government of India. *Indian Petroleum and Natural Gas statistics* 2005-06,2007-08,2008-09,2009-10, 2010-11,2012-13,2013-14,2014-15, 2015-16,2016-17,2017-18,2018-19, 2019-20,2020-21 and 2021-22 reports
		(d) Diesel Consumption (percentage share) in Non- Transport sector of Kerala (i) 2012-13 (ii) 2021-22	(i) All India study on sectoral demand of Diesel and Petrol Reports (PPAC), 2013 (ii) All India study on sectoral demand of Diesel and Petrol Reports (PPAC),2021 *(accessed from hard copy)*
Fisheries	1. Kerosene	(a) 2007-08 to 2017-18 (b) 2004-05 to 2006-07 and 2018-19 to 2021-22	(a) Pillai, V. & AM Narayanan. (2019) (b) CAGR method
	2. Diesel	2005 to 2021	Fisheries Department-Govt of Kerala
	3. Petrol	2005 to 2021	Fisheries Department-Govt of Kerala
Fugitive Emissions from Fuels			
Refinery Throughput		2004-05 to 2021-22 *(BPCL Kochi)*	Ministry of Petroleum and Natural Gas, Economic and Statistic Division, Government of India.

Sub-sector/ Category	Fuels	Years	Sources/ Assumptions
			Indian Petroleum and Natural Gas statistics 2005-06,2007-08,2008-09,2009-10, 2010-11,2012-13,2013-14,2014-15, 2015-16,2016-17,2017-18,2018-19, 2019-20,2020-21 and 2021-22 reports.

Table 2: Fuel Consumption data used for estimating emissions from Energy sector

IPCC ID	Sub-sector/ Category	Fuels	Units	2019	2020	2021
1A1	**Energy Industries**					
1A1ai	**Public Electricity Generation**	Naphtha	kilolitres	36.45	12491.55	4163.85
		LSHS	kilolitres	791.25	1469.50	1649.00
		HSD	kilolitres	141.53	64.48	24.16
1A1 aii	**Captive Power Plants**	Diesel	kilotonnes	13.36	14.04	13.49
		Gas	kilotonnes	129.78	142.55	168.36
		Steam	kilotonnes	322.42	135.84	103.33
1A 2	**Industrial Energy**	Natural Gas	kilotonnes	230.93	230.93	230.93
		FO/LSHS	kilotonnes	242.21	241.07	239.95
		LDO	kilotonnes	0.51	0.32	0.20
		HSD	kilotonnes	116.97	121.71	126.64
		Naphtha	kilotonnes	2.42	1.59	0.00
1A3	**Transport**					
1A3a	Civil Aviation	ATF	kilotonnes	518.50	269.08	271.78
1A3b	Road Transport	CNG	kilotonnes	4.71	4.73	10.09

IPCC ID	Sub-sector/ Category	Fuels	Units	2019	2020	2021
		Auto LPG	kilotonnes	5.10	4.78	4.49
		MotorSpirit/ Petrol	kilotonnes	1501.52	1387.10	1433.11
		High Speed Diesel Oil	kilotonnes	1751.77	1545.05	1577.67
1A3c	Railways	LDO	kilotonnes	0.024	0.017	0.014
		HSDO	kilotonnes	102.49	8.83	11.05
1A3d	Water-borne Navigation	Petrol	kilotonnes	1.42	1.44	1.47
		Diesel	kilotonnes	10.67	10.72	10.86
1A4	**Other Sector (Energy)**					
1A4a	Commercial/ Institutional	LPG	kilotonnes	100.40	80.65	84.21
		HSDO	kilotonnes	220.74	92.88	53.05
1A4b	Residential	LPG	kilotonnes	894.70	959.23	994.64
		Kerosene	kilotonnes	32.34	22.00	12.09
1A4c	Agriculture	HSDO	kilotonnes	19.23	16.09	14.67
		Diesel- Retail	kilotonnes	161.06	69.70	41.91
1A4c	Fisheries	Kerosene	kilotonnes	24.80	22.23	19.92
		Diesel	kilotonnes	77.14	51.55	88.77
		Petrol	kilotonnes	2.85	2.34	3.84
1B	**Fugitive Emissions from Fuels**		kilotonnes	16399	14090.25	14872

1A1 Energy Industries

The emissions arising from the fuel usage primarily for Electricity Generation are estimated under this category. For Kerala, the emissions have been estimated for Public Electricity Generation and Captive Power Plants sub-sectors and use a combination of Tier 1 (T1) and Tier 2 (T2) approaches. The activity data, methodology and emission factors used for emission estimations are detailed below:

1A1ai Public Electricity Generation

The emissions from the Public Electricity Generation category were estimated from the electricity generating utility-based power plants.

Methodology:

Emissions from the Public Electricity Generation category were estimated using a combination of   Tier 1 (T1) and Tier 2 (T2) approaches (see Table 3)

Table 3: Type of emissions factors and the level of methodological tier employed for GHG estimation

IPCC ID	GHG Sources and sink categories	CO_2		CH_4		N_2O	
		Method Applied	Emission Factor	Method Applied	Emission Factor	Method Applied	Emission Factor
1A1 ai	Public Electricity Generation	T1, T2	CS	T1	D	T1	D
T1: Tier 1 , T2: Tier 2, D: IPCC Default, CS: Country-Specific							

The Net Calorific Value (NCV) of fuels and emission factors of Carbon dioxide (CO_2) were taken from INCCA Report (2010) and the emission factors of Methane (CH_4) and Nitrous Oxide (N_2O) were taken from 2006 IPCC Guidelines.[6] Density of Diesel and Low Sulphur Heavy Stock (LSHS) were obtained from a Petroleum Planning and Analysis Cell, (2022) report, while the density of Naphtha was obtained from Central Electricity Authority, (2010) Annual fuel consumption report (see Table 4 and Table 5)

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6 Emission Factors for Methane (CH4)and Nitrous oxide (N2O) were obtained from the 2006 IPCC Guidelines. There were no refinements made in the 2019 IPCC Guidelines.

Table 4 : Emissions Factors of Fuels

Fuels	INCCA		2006 IPCC	
	NCV (Tj/kt)	CO_2 EF (t/TJ)	CH_4 (kg/TJ)	N_2O (kg/TJ)
Diesel/High Speed Diesel	43.00	74.10	3.00	0.6
Low Sulphur Heavy Stock (LSHS)	40.20	73.30	3.00	0.6
Naphtha	43.00	74.10	3.00	0.6

Table 5 : **Density of Fuel used for the emissions estimates**

Density of Fuels	Value
Naphtha[*]	1.35 kL/t
Diesel	1.21 kL/t
Low Sulphur Heavy Stock (LSHS)	1.042 kL/t

[*]As per CEA Annual Fuel consumption Report (2010) , 1 KL of Naphtha = 0.74 MT

The Activity data provided in financial year (FY) format was converted to calendar year (CY) format using the following equations:

$$\text{CY Activity data} = [¼ * \text{FY Activity Data}_{Preceding\ year}] + [¾ * \text{FY Activity Data}_{Succeeding\ year}]$$

Equations used for emissions estimates:

The emissions from this category were estimated by applying the Net Calorific Value (fuel type-wise) and corresponding fuel type-wise emission factor to the type of fuel consumed for generating electricity. The equations used for estimations are mentioned below:

$$Emissions_{Gas} = Activity\ Data_{Fuel}\ x\ Net\ Calorific\ Value_{Fuel}\ x\ Emission\ Factor_{Gas}$$

(slightly modified version of IPCC 2006 Equation 2.1)

Emissions in terms of CO_2e (both GWP and GTP) were calculated using the following equations:

$$Emissions_{CO2e}\ (GWP) = Emissions_{CO2} + (GWP_{CH4}\ x\ Emissions_{CH4}) + (GWP_{N2O}\ x\ Emissions_{N2O})$$

$$Emissions_{CO2e}\ (GTP) = Emissions_{CO2} + (GTP_{CH4}\ x\ Emissions_{CH4}) + (GTP_{N2O}\ x\ Emissions_{N2O})$$

1A1 cii Captive Power Plants

Emissions from the Captive Power Plant category were estimated based on the non-utility power plants.

Methodology:

Estimation of Specific Fuel Consumption:

Specific fuel consumption for Captive Power Plants have been estimated using national estimates as reported in CEA General Review Report. The fuel- wise specific consumption calculations are explained below :

a. Specific diesel consumption was estimated from the generation and fuel consumption data of diesel power plants for 2018.[7]

b. Since the gas-based power was almost entirely generated from consumption of natural gas, the specific gas consumption was estimated based on natural gas consumption and the corresponding electricity generated.

c. For coal/lignite (steam) based generation, year-wise specific fuel consumption were provided in General Review 2021, 2022 and 2023 for the years 2009-10 to 2021-22.

A mix approach of Tier 1 (T1) and Tier 2 (T2) was used for estimating GHG emissions from the Captive Power Plant category (see Table 6)

Table 6: Type of emissions factor and the level of methodological tier employed for GHG estimation

IPCC ID	GHG Sources and sink categories	CO_2		CH_4		N_2O	
		Method Applied	Emission Factor	Method Applied	Emission Factor	Method Applied	Emission Factor
1A1 a ii	Captive Power Plants	T1,T2	CS	T1	D	T1	D
T1: Tier 1 , T2: Tier 2, D: IPCC Default, CS: Country-Specific							

The Net Calorific Value of fuels and emission factors of Carbon dioxide (CO_2) were taken from INCCA Report (2010) and BUR (Biennial Update Report) 2 (2018). The emission factors of Methane (CH_4) and Nitrous Oxide (N_2O) were taken from 2006 IPCC Guidelines. The Density of Diesel and Gas were obtained from the Petroleum Planning and Analysis Cell, (2022) Report. (see Table 7 and Table 8).

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7 Majority of generation in 2018 was by diesel and not by other petroleum fuels such as LSHS or Diesel oil. Also, the specific diesel consumption may not vary much as the Gross Calorific Value of Diesel, LSHS, LDO and HSD are more or less the same.

Table 7 : Emissions Factors of Fuels

Fuels	INCCA and BUR 2		IPCC	
	NCV (Tj/kt)	CO_2 EF (t/TJ)	CH_4 (kg/TJ)	N_2O (kg/TJ)
Non-coking Coal	17.09	96.76	1.00	1.40
Diesel/ Light Diesel Oil (LDO)	43.00	74.10	3.00	0.60
Compressed Natural Gas (CNG)	48.00	56.10	1.00	0.10

Table 8 :Density of Fuel used for the emissions estimates

Density of Fuels	Value
Diesel (HSD)	1.21 kL/t
Natural Gas	0.76 kg/scm

***Source** : Petroleum Planning and Analysis Cell, (2022)*

Limitations:

The current emission estimates are based on the generation data of Captive Power Plants above 1 MW as the generation data of Captive Power Plants less than 1MW was not available.
Equations used for emissions estimates:

The equations used for estimations are mentioned below:

$Emissions_{Gas}$ = Fuel-wise electricity generated x Specific Fuel Consumption$_{Fuel}$ x Net Calorific Value$_{Fuel}$ x Emission Factor$_{Gas}$ (slightly modified version of IPCC 2006 Equation 2.1)

Emissions in terms of CO_2e (both GWP and GTP) were calculated using the following equations:

$Emissions_{CO2e}$ (GWP) = $Emissions_{CO2}$ + (GWP_{CH4} x $Emissions_{CH4}$) + (GWP_{N2O} x $Emissions_{N2O}$)

$Emissions_{CO2e}$ (GTP) = $Emissions_{CO2}$ + (GTP_{CH4} x $Emissions_{CH4}$) + (GTP_{N2O} x $Emissions_{N2O}$)

1A2 Industrial Energy

The emissions from the Industrial Energy sub-sector were estimated for Naphtha, High Speed Diesel (HSD) , Light Diesel Oil (LDO), Furnace Oil (FO)/ Low Sulphur Heavy Stock (LSHS) and Natural Gas fuels. The emissions from these fuels have been estimated using the activity data (see Table 1) and the following assumptions

Assumptions:

1. **Naphtha:**

   a. The Naphtha consumption reported in the study conducted by Pillai, V. & AM Narayanan, (2019) is assumed to be inclusive of the Naphtha consumption accounted under Public Electricity Generation.

   b. For years 2004-05 to 2006-07, the Naphtha consumption was assumed to be the same as the value reported for 2007-08. This was because the derived value using CAGR appeared to be out of proportion.

   c. The final values of Naphtha consumed for industrial usage, for the years 2004-05 to 2021-22 was adjusted based on the Naphtha consumption data already accounted under the Public Electricity Generation category.

   d. Since the reported/estimated quantity of naphtha for industry usage were miniscule in comparison to other years, and adjusted figures resulted in negative values, naphtha consumption for the years 2016-17, 2017-18, and 2020-21 was considered as zero.

2. **High Speed Diesel (HSD):**

   a. HSD consumption reported by Pillai, V. & AM Narayanan, (2019) is assumed to be inclusive of the HSD consumption accounted under Public Electricity Generation and Captive Power Plants.

   b. Hence, the final HSD values for industrial usage for the years 2007-08 to 2017-18 was calculated by adjusting the Diesel consumption data accounted under Public Electricity Generation and Captive Power Plants categories.

   c. For the period 2004-05 to 2006-07 and 2018-19 to 2020-21, the High Speed Diesel consumption data was estimated using the CAGR method.

3. **Furnace Oil (FO)/ Low Sulphur Heavy Stock (LSHS)**

   a. The FO/LSHS consumption reported by Pillai, V. & AM Narayanan, (2019) is assumed to be inclusive of the LSHS consumption from the Public Electricity Generation category.

   b. Hence, the FO/LSHS consumption for industrial usage for the years 2007-08 to 2017-18 was estimated by adjusting with the LSHS consumption values already accounted under Public Electricity Generation.

   c. For the years 2004-05 to 2006-07 and 2018-19 to 2020-21, the FO/LSHS consumption data was estimated using the CAGR method.

4. **Natural Gas :**

   a. For the years 2004-05 to 2006-07, the Natural Gas consumption was assumed to be zero considering the values reported in year 2007-08.

   b. The Natural Gas consumption reported by Pillai, V. & AM Narayanan, (2019) is assumed to include the Natural Gas consumption from Captive Power Plants.

   c. The consumption data reported by the Pillai, V. & AM Narayanan, (2019) was minuscule between 2013-14 and 2015-16. Thus, the Natural Gas consumption values for industrial

use were adjusted only for the period 2016–18 by deducting corresponding values accounted under Captive Power Plant category.

d. Since the Natural Gas consumption data was not available for the 2018-19 to 2021-22, an average value of 230.93 kt (based on 2016-17 and 2017-18 estimates) was applied.

Methodology:

Emissions from the Industrial Energy category was estimated using the Tier 1 (T1) and Tier (2) approaches (see Table 9)

Table 9: Type of emissions factor and the level of methodological tier employed for GHG estimation

IPCC ID	GHG Sources and sink categories	CO$_2$		CH$_4$		N$_2$O	
		Method Applied	Emission Factor	Method Applied	Emission Factor	Method Applied	Emission Factor
1A 2	Industrial Energy	T2	CS	T1	D	T1	D
T1: Tier 1 , T2: Tier 2, D: IPCC Default, CS: Country-Specific							

The Net Calorific Value (NCV) of fuels and emission factors of Carbon dioxide (CO_2) were taken from INCCA Report (2010) and the emission factors of Methane (CH_4) and Nitrous Oxide (N_2O) were taken from 2006 IPCC Guidelines. (see Table 10)

Table 10 : Emissions Factors of Fuels

Fuels	INCCA		IPCC	
	NCV (Tj/kt)	CO$_2$ EF (t/TJ)	CH$_4$ (kg/TJ)	N$_2$O (kg/TJ)
Naphtha	43.0	74.1	3	0.6
Diesel	43.0	74.1	3	0.6
Furnace Oil/LSHS	40.4	77.4	3	0.6
Natural Gas	48	56.1	3	0.6

Equations used for emissions estimates:

The emissions from this category was estimated by applying the Net Calorific Value (fuel type-wise) and corresponding fuel type-wise emission factor to the type of fuel consumed . The equations used for estimations are mentioned as follows:

$Emissions_{Gas}$ = $Activity\ Data_{Fuel}$ x $Net\ Calorific\ Value_{Fuel}$ x $Emission\ Factor_{Gas}$

(slightly modified version of IPCC 2006 Equation 2.1)

Emissions in terms of CO_2e (both GWP and GTP) were calculated using the following equations:

$$Emissions_{CO2e} \text{ (GWP)} = Emissions_{CO2} + (GWP_{CH4} \times Emissions_{CH4}) + (GWP_{N2O} \times Emissions_{N2O})$$

$$Emissions_{CO2e} \text{ (GTP)} = Emissions_{CO2} + (GTP_{CH4} \times Emissions_{CH4}) + (GTP_{N2O} \times Emissions_{N2O})$$

Activity data provided in financial year (FY) format was converted to calendar year (CY) format using the following equations:

$$CY \text{ Activity data} = [\tfrac{1}{4} \times FY \text{ Activity Data}_{Preceding\ year}] + [\tfrac{3}{4} \times FY \text{ Activity Data}_{Succeeding\ year}]$$

Limitations:

The Industry-wise and Fuel type-wise fuel consumption data were not available for this category, emissions were estimated based on overall fuel consumed in this sub-sector.

1A 3 Transport

The Transport sector emissions covers four different modes of transport viz Aviation, Road Transport, Railways and Water-borne Navigation sub-sector. The Transport sector emissions estimates used a combination of Tier 1 (T1) and Tier 2 (T2) approaches. The activity data for emissions estimation were obtained from Indian Petroleum and Natural Gas statistics (Ministry of Petroleum and Natural Gas) ; study conducted by Pillai, V. & AM Narayanan, (2019); Southern Railways Department- Indian Railways; Kerala State Water Transport and Kerala Maritime Board. The data sources, methodology, assumptions and emission factor considered for these 4 sub-sectors have been detailed below:

1A3a Civil Aviation

The emissions from this category arise due to combustion of fuels and for current assessment Aviation Turbine Fuel (ATF) was considered for emissions estimates.

Methodology
The GHG emissions were estimated based on the Tier 1 (T1) and Tier (2) approaches (2006 IPCC Guidelines)[8]   (see Table 11).

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[8] Emissions from the aviation category were estimated based on 2006 IPCC Guidelines, since no refinements were made in 2019 IPCC Guidelines.

Table 11: Type of emission factor and the level of methodological tier employed for GHG estimation

IPCC ID	GHG Sources and sink categories	CO$_2$		CH$_4$		N$_2$O	
		Method Applied	Emission Factor	Method Applied	Emission Factor	Method Applied	Emission Factor
1A3a	Civil Aviation	T1,T2	CS	T1	D	T1	D
T1: Tier 1 , T2: Tier 2, D: IPCC Default, CS: Country-Specific							

The Net Calorific Value (NCV) of fuels and emission factors of Carbon dioxide (CO$_2$) were taken from INCCA Report, (2010) and the emission factors of Methane (CH$_4$) and Nitrous Oxide (N$_2$O) were taken from 2006 IPCC Guidelines (see Table 12)

Table 12 : Emissions Factors of Fuel

Fuel	INCCA		IPCC	
	NCV (Tj/kt)	CO$_2$ EF (t/TJ)	CH$_4$ (kg/TJ)	N$_2$O (kg/TJ)
Aviation Turbine Fuel (ATF)	44.10	71.5	0.50	2.00

Equations used for emissions estimates

The emissions from this category is estimated by applying the Net Calorific Value (fuel type-wise) and corresponding fuel type-wise emission factor to the type of fuel consumed. The equations used for estimations are mentioned below:

$$Emissions_{Gas} = Activity\ Data_{Fuel}\ x\ Net\ Calorific\ Value_{Fuel}\ x\ Emission\ Factor_{Gas}$$

(slightly modified version of IPCC 2006 Equation 2.1)

Emissions in terms of CO$_2$e (both GWP and GTP) were calculated using the following equations:

Emissions$_{CO2e}$ (GWP) = Emissions$_{CO2}$ + (GWP$_{CH4}$ x Emissions$_{CH4}$) + (GWP$_{N2O}$ x Emissions$_{N2O}$)

Emissions$_{CO2e}$ (GTP) = Emissions$_{CO2}$ + (GTP$_{CH4}$ x Emissions$_{CH4}$) + (GTP$_{N2O}$ x Emissions$_{N2O}$)

1A3b Road Transport

Emissions from the Road Transport category are estimated for fuels such as Compressed Natural Gas (CNG), Auto LPG, Motor Spirit/Petrol and High Speed Diesel Oil (HSDO) . The following steps and assumptions have been used for estimating the emissions from Road Transport sector:

1. **Compressed Natural Gas (CNG)** :

   Assumptions:

   i. CNG sales data of Kerala (reported in Indian Petroleum and Natural Gas statistics) is considered as consumption activity data solely for road transport.

   ii. For the years 2005-16, the CNG sales data for the state of Kerala was not available from Indian Petroleum and Natural Gas Statistics. Therefore, CNG consumption for the said period has been assumed to be zero.

(2) Auto LPG :

   Assumptions:

   i. For the years 2004-05 to 2006-07, the Auto LPG consumption data was assumed to be Zero considering the values reported in the year 2007-08.

   ii. The Auto LPG consumption data for the years between 2018-19 to 2021-22 was calculated using the CGAR method.

 (3) Motor Spirit/ Petrol :

   a. **Steps followed to estimate state's Motor Spirit consumption activity data:**

   i. The national-level percentage share of Motor Spirit consumption in the retail sector was calculated for the period 2012-13 to 2021-22 using Indian Petroleum and Natural Gas Statistics (MoPNG) .

   ii. This estimated percentage share (nation-level) of Motor spirit consumption in retail sector and the percentage share of Petrol-Retail consumption data in Kerala's road transport sector *(as published in PPAC 2013 report)* was then applied to the Motor Spirit consumption data of Kerala to derive consumption data in Kerala's road transport sector.

   Scope for improvement : *The estimations can be refined if the year-on-year percentage share of fuels consumed in transport and retail sectors at national level is replaced with their state-level equivalence.*

   b. **Assumptions:**

   i. The percentage share of Petrol-Retail consumption data of year 2012-13 was applied for years between 2004-05 to 2021-22, due to unavailability of data for any other year in the evaluation period.

   ii. Since the National-level Motor Spirit consumption data in retail sector was not published in Indian Petroleum and Natural Gas Statistics for the period 2004-05 to 2011-12, the percentage share (national-level) of Motor Spirit consumption in retail sector of year 2012-13 was used to calculate Kerala's Motor Spirit consumption in road transport sector for the said period.

4. **High Speed Diesel Oil (HSDO) :**

   a. **Steps followed to estimate state's HSDO consumption activity data:**

      i. The percentage share of HSDO consumption in the Road transport and in Retail sector at national level was calculated for the period 2004-05 to 2021-22.

      ii. The national level percentage share in Road transport was applied to HSDO consumption data of Kerala to derive the consumption data in Kerala's road transport sector.

      iii. The national level percentage share in Retail sector and the end-use percentage share of Diesel in retail *[as published in PPAC 2013 and 2021 report]* were applied to HSDO consumption data of Kerala to derive the consumption data in Kerala's retail sector.

      iv. The percentage share of HSDO consumption by the private sales sector at national level was calculated for the years 2004-05 to 2006-07.

      v. This percentage share (national level) of the private sales sector was then applied to the HSDO consumption data of Kerala to derive the consumption data by private sales sector in Kerala for the period 2004-05 to 2006-07.

      vi. The total HSDO consumption in Road transport was calculated by adding HSDO consumption data by private sales sector and from road transport and retail sector.
      Scope for improvements : *The estimations can be refined if year-on-year percentage share of fuels consumed in transport and retail sectors at national level is replaced with their state-level equivalence.*

   b. **Assumptions:**

      Since fuel sales through retail stream was not provided in the MoPNG's Indian Petroleum and Natural Gas Statistics for the years 2004-05 to 2009-10, sales reported under Miscellaneous category were used, assuming it includes retail sales as well. However, for the years 2010-11 to 2021-22, retail sales of fuel was separately reported in the Indian Petroleum and Natural Gas Statistics, and was thus used as one of the activity data.

   c. **Limitations:**

      i. The HSDO consumption data by Private sales sector was not available for the period 2007-08 to 2021-22 from Indian Petroleum and Natural Gas statistics

      ii. The HSDO consumption data by the Private imports sector (reported in Indian Petroleum and Natural Gas Statistics) were negligible, and hence was not considered for emissions estimations.

Methodology:

A combination of Tier 1 (T1) and Tier 2 (T2) approaches were used for emissions estimation (see Table 13)

Table 13:Type of emissions factor and the level of methodological tier employed for GHG estimation

IPCC ID	GHG Sources and sink categories	CO_2		CH_4		N_2O	
		Method Applied	Emission Factor	Method Applied	Emission Factor	Method Applied	Emission Factor
1A3b	Road Transport	T1,T2	CS	T1	D	T1	D
T1: Tier 1 , T2: Tier 2, D: IPCC Default, CS: Country-Specific							

The Net Calorific Value (NCV) of fuels and emission factors of Carbon dioxide (CO_2) were taken from INCCA Report, (2010) and the emission factors of Methane (CH_4) and Nitrous Oxide (N_2O) were taken from 2006 IPCC Guidelines (see Table 14)

Table 14 :Emissions Factors of Fuels

Fuels	INCCA		IPCC	
	NCV (Tj/kt)	CO_2 EF (t/TJ)	CH_4 (kg/TJ)	N_2O (kg/TJ)
Diesel	43.00	74.10	3.90	3.90
Compressed Natural Gas (CNG)	48.00	56.10	92.00	3.00
Liquified Petroleum Gas (LPG)	47.30	63.10	62.00	0.20
Gasoline	44.30	69.30	33.00	3.20

Equations used for emissions estimates

The emissions from this category is estimated by applying the Net Calorific Value (fuel type-wise) and corresponding fuel type-wise emission factor to the type of fuel consumed.The equations used for estimations are mentioned below:

$$Emissions_{Gas} = Activity\ Data_{Fuel} \times Net\ Calorific\ Value_{Fuel} \times Emission\ Factor_{Gas}$$

(slightly modified version of IPCC 2006 Equation 2.1)

Emissions in terms of CO_2e (both GWP and GTP) were calculated using the following equations:

$$Emissions_{CO2e} (GWP) = Emissions_{CO2} + (GWP_{CH4} \times Emissions_{CH4}) + (GWP_{N2O} \times Emissions_{N2O})$$

$$Emissions_{CO2e} (GTP) = Emissions_{CO2} + (GTP_{CH4} \times Emissions_{CH4}) + (GTP_{N2O} \times Emissions_{N2O})$$

1A3c Railways

The emissions of Railways category was estimated for the High Speed Diesel Oil (HSDO) and Light Diesel Oil (LDO) fuels and have been provided below:

Methodology

The Railways category's emissions were estimated using the Tier 1 (T1) and Tier (2) approaches for fuels such as High Speed Diesel Oil (HSDO) and Light Diesel Oil (LDO) as provided in Table 15

Table 15:Type of emissions factor and the level of methodological tier employed for GHG estimation

IPCC ID	GHG Sources and sink categories	CO_2		CH_4		N_2O	
		Method Applied	Emission Factor	Method Applied	Emission Factor	Method Applied	Emission Factor
1A3c	Railways	T1,T2	CS	T1	D	T1	D
T1: Tier 1 , T2: Tier 2, D: IPCC Default, CS: Country-Specific							

The Net Calorific Value (NCV) of fuels and emission factors of Carbon dioxide (CO_2) of Diesel and LDO were taken from INCCA Report (2010) and the emission factors of Methane (CH_4) and Nitrous Oxide (N_2O) were taken from 2006 IPCC Guidelines (see Table 16)

Table 16 : Emissions Factors of Fuels

Fuels	INCCA		IPCC	
	NCV (Tj/kt)	CO_2 EF (t/TJ)	CH_4 (kg/TJ)	N_2O (kg/TJ)
Diesel	43.00	74.10	4.15	28.60
Light Diesel Oil (LDO)[9]	43.00	74.10	10	0.6

[9] Factors for LDO were taken from IPCC methodology note for Road Transportation as the section on Locomotives had only values available for Diesel

Equations used for emissions estimates

The emissions from this category is estimated by applying the Net Calorific Value (fuel type-wise) and corresponding fuel type-wise emission factor to the type of fuel consumed. The equations used for estimations are mentioned below:

$$Emissions_{Gas} = Activity\ Data_{Fuel}\ x\ Net\ Calorific\ Value_{Fuel}\ x\ Emission\ Factor_{Gas}$$

(slightly modified version of IPCC 2006 Equation 2.1)

Emissions in terms of CO_2e (both GWP and GTP)* were calculated using the following equations:

$$Emissions_{CO2e}\ (GWP) = Emissions_{CO2} + (GWP_{CH4}\ x\ Emissions_{CH4}) + (GWP_{N2O}\ x\ Emissions_{N2O})$$

$$Emissions_{CO2e}\ (GTP) = Emissions_{CO2} + (GTP_{CH4}\ x\ Emissions_{CH4}) + (GTP_{N2O}\ x\ Emissions_{N2O})$$

1A3d Water-borne Navigation

The emissions from this category was estimated for Diesel and Petrol fuels. The activity data for emission estimation were sourced from Kerala Maritime Board and State Water Transport Department.

Methodology

1. **Source- Kerala Maritime Board**

    a. Vessel type-wise registration and fuel consumption data were obtained from the Kerala Maritime Board for the years 2010 to 2022.
    b. Diesel and Petrol fuel consumption data of Inland Vessels were estimated for the years 2010 to 2022 by applying the thumb-rules provided by Kerala Maritime Board-Govt. of Kerala.

       The thumb-rules include vessel type-wise average hourly fuel consumption and vessel type-wise average annual operational hours.

    c. The vessel type-wise Diesel fuel consumption data for years 2011 to 2021 was estimated using the CAGR method.
    d. The Petrol consumption data was estimated for the years 2011 to 2021 using the CAGR method and for years 2005 to 2009, the average fuel consumption value of years 2010 to 2016 were taken.

    Limitation:

    In the absence of year-on-year active/live vessels, the cumulative number of registered vessels were considered to be in operation for each year of the evaluation period, starting from 2010, the year since when the fleet data was available.

2. Source- State Water Transport Department

High Speed Diesel (HSD) fuel consumption data was estimated between 2005 and 2021 using thumb-rules provided by the State Water Transport Department – Govt. of Kerala.

   a. Thumb-rules include fuel-wise average number of boats in operation, average operation hours per day, number of days in operation in a year and average fuel consumption per hour.

   b. The thumb-rules to estimate HSD fuel consumption was considered to be same from 2005 to 2021 due to unavailability of other supporting data

C. Estimation of Total Diesel fuel consumption activity data for years 2005 to 2021

   a. The total diesel fuel consumption activity data for years 2005 to 2021 was calculated by adding the diesel consumed through above two sources.

   b. For the years 2005 to 2009, the total diesel consumption was calculated using the CAGR method.

Emissions from Diesel and Petrol fuels consumption were estimated for the Water-borne Navigation sub-sector using the Tier 1 (T1) and Tier 2 (T2) approaches (see Table 17).

Table 17:Type of emissions factor and the level of methodological tier employed for GHG estimation

IPCC ID	GHG Sources and sink categories	CO_2		CH_4		N_2O	
		Method Applied	Emission Factor	Method Applied	Emission Factor	Method Applied	Emission Factor
1A3d	Water-borne Navigation	T1,T2	CS	T1	D	T1	D
T1: Tier 1 , T2: Tier 2, D: IPCC Default, CS: Country-Specific							

The Net Calorific Value of fuels and emission factors of Carbon dioxide (CO_2) of Diesel and Petrol fuels were taken from INCCA Report (2010). Emission factors of Methane (CH_4) and Nitrous Oxide (N_2O) for Diesel and Petrol fuel were taken from 2006 IPCC Guidelines. Density of Diesel and Petrol fuels were obtained from PPAC Report,(2022) (see Table 18 and Table 19).

Table 18 : Emissions Factors of Fuels

Fuels	INCCA		IPCC[10]	
	NCV (Tj/kt)	CO_2 EF (t/TJ)	CH_4 (kg/TJ)	N_2O (kg/TJ)
Diesel / High Speed Diesel	43	74.1	3.9	3.9
Petrol	44.3	69.3	33	3.2

Table 19 : Density of Fuel used for the emissions estimates

Density of Fuels	Value
Diesel (HSD)	1.210 kL/t
Petrol	1.411 kL/t

Source : *Petroleum Planning and Analysis Cell, (2022)*

Equations used for emissions estimates

The emissions from this category is estimated by applying the Net Calorific Value (fuel type-wise) and corresponding fuel type-wise emission factor to the type of fuel consumed. The equations used for estimations are mentioned below:

$$Emissions_{Gas} = Activity\ Data_{Fuel} \times Net\ Calorific\ Value_{Fuel} \times Emission\ Factor_{Gas}$$

(slightly modified version of IPCC 2006 Equation 2.1)

Emissions in terms of CO_2e (both GWP and GTP) were calculated using the following equations:

$Emissions_{CO2e}$ (GWP) = $Emissions_{CO2}$ + (GWP_{CH4} x $Emissions_{CH4}$) + (GWP_{N2O} x $Emissions_{N2O}$)

$Emissions_{CO2e}$ (GTP) = $Emissions_{CO2}$ + (GTP_{CH4} x $Emissions_{CH4}$) + (GTP_{N2O} x $Emissions_{N2O}$)

The activity data of Aviation Turbine Fuel provided in financial year (FY) format was converted to calendar year (CY) format using the following equations for emissions estimations *(2005 to 2021)* :

CY Activity data = [¼*FY Activity Data*Preceding year*] + [¾*FY Activity Data*Succeeding year*]

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[10] The emissions factor of Methane (CH_4) and Nitrous oxide (N_2O) for Diesel and Petrol fuels is assumed to be the same as that of Road Transport due to unavailability of emission factors specific to water-borne navigation

1A4 Other Sectors (Energy)

The Other Sectors (Energy) consist of three sub-sectors, viz. Commercial, Residential and Agriculture/Fisheries. The emissions from this sector arise due to combustion of fuels used for various activities. Emissions from this sector have been estimated using the Tier 1 (T1) and Tier 2 (T2) approaches. The activity data for Other Sectors' emissions estimates were obtained and calculated using Indian Petroleum and Natural Gas statistics (Ministry of Petroleum and Natural Gas) ; Centre for Development Study Report, Kerala and Economic Review Reports (State Planning Board-Govt of Kerala). The data sources, methodology and assumption used for emission estimations have been outlined below:

1A4a Commercial/Institutional

Liquified Petroleum Gas (LPG) and High Speed Diesel Oil (HSDO) were the fuels for which emissions were estimated under the Commercial sub-sector. The following steps/assumptions were used for estimating the emissions in Commercial sector:

1. **Liquified Petroleum Gas (LPG) :**

   Steps followed to estimate LPG consumption activity data :

   i. The percentage share of LPG consumption by the commercial sector at national level was calculated for the years 2004-05 to 2021-22 using the Indian Petroleum and Natural Gas Statistics reports (MoPNG).

   ii. This estimated national-level percentage share was then applied to the state's overall LPG consumption data to estimate state's LPG consumption at commercial level, for the period 2004-05 to 2021-22.

   iii. The derived LPG consumption data was in financial years which was converted into calendar years format using the following equations (2005 to 2021) :

   $$\text{CY Activity data} = [¼ * \text{FY Activity Data}_{Preceding\ year}] + [¾ * \text{FY Activity Data}_{Succeeding\ year}]$$

   Scope for improvement : The estimations can be refined if year-on-year percentage share of fuels consumed in the commercial sector at national level is replaced with their state-level equivalent.

2. **High Speed Diesel Oil (HSDO) :**

a. **Steps followed to estimate HSDO consumption activity data of years 2020-21 to 2021-22** :

   i. The percentage share of HSDO consumption by the retail sector at national level was calculated for the period 2020-21 to 2021-22.

ii. The national level percentage share in *Retail sector* and percentage share of Diesel consumption in Non-Transport sector[11] *[as published in PPAC report 2021]* was applied to HSDO consumption data of Kerala to estimate the state's retail sector consumption data.

(Percentage share of Diesel in Non-Transport sector data were applied for the years 2020-21 and 2021-22).

iii. For the years 2020-21 and 2021-22, the national-level percentage share of Diesel in the Commercial sector (GHGPI Phase III[12]) was then applied to the state's overall HSDO consumption data to estimate the consumption data in the Commercial sector.

iv. The estimated total HSDO consumption data in financial years was converted into calendar years format using the following equations (2005 to 2021) **:**

CY Activity data = [¼*FY Activity Data$_{Preceding\ year}$] + [¾*FY Activity Data$_{Succeeding\ year}$]

Scope for improvement : The estimations can be refined if 2020-21 and 2021-22's percentage share of fuels consumed in retail and commercial sectors at national level is replaced with their corresponding state-level values.

b. Limitations:

i. The HSDO consumption data by Private sales sector was not available for the period 2020-21 to 2021-22 from Indian Petroleum and Natural Gas statistics

ii. The HSDO consumption data by the Private imports sector (reported in Indian Petroleum and Natural Gas Statistics) were negligible, and hence was not considered for emissions estimations.

Methodology:

The Tier 1 (T 1) and Tier 2 (T2) approaches were used to estimate emissions from the Commercial category (see Table 20)

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[11] The Non-transport sector includes Gensets and Others (include Mobile Tower and other segments).
[12]   Mohan, R.R., Dharmala, N., Ananthakumar, M. R., Kumar, P., Bose, A. (2019). *Greenhouse Gas Emission Estimates from the Energy Sector in India at the Subnational Level (Version/edition 2.0)*. New Delhi. GHG Platform India Report - CSTEP. Available at

Table 20: Type of emissions factor and the level of methodological tier employed for GHG estimation

IPCC ID	GHG Sources and sink categories	CO$_2$		CH$_4$		N$_2$O	
		Method Applied	Emission Factor	Method Applied	Emission Factor	Method Applied	Emission Factor
1A4a	Commercial	T1,T2	CS	T1	D	T1	D
T1: Tier 1 , T2: Tier 2, D: IPCC Default, CS: Country-Specific							

The Net Calorific Value (NCV) and Carbon dioxide (CO$_2$) emission factors of fuels were taken from INCCA Report (2010). Emission factors of Methane (CH$_4$) and Nitrous Oxide (N$_2$O) for Diesel and LPG fuels were taken from 2006 IPCC Guidelines. The state- level Diesel consumption data of other sectors for the year 2020-21 was taken from the PPAC Report (2021) and the national-level percentage-share of Diesel consumption data by Commercial sector was taken from GHGPI Phase III[13] (see Table 21, Table 22 and Table 23).

Table 21 : Emissions Factors of Fuels

Fuel	INCCA		IPCC	
	NCV (Tj/kt)	CO$_2$ EF (t/TJ)	CH$_4$ (kg/TJ)	N$_2$O (kg/TJ)
Diesel	43	74.1	10	0.6
Liquified Petroleum Gas (LPG)	47.3	63.1	5	0.1

Table 22 : State-level Diesel consumption of other sectors

Parameter	2020-21
Gensets	0.27
Others (include Mobile Tower and other segments)	4.23
Total	**4.50**

Source: *PPAC Report,2021*

Table 23 : Nation-level percentage share of Diesel in Commercial sector

Sector	Diesel (%)
Commercial	66.1

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[13] Mohan, R.R., Dharmala, N., Ananthakumar, M. R., Kumar, P., Bose, A. (2019). *Greenhouse Gas Emission Estimates from the Energy Sector in India at the Subnational Level (Version/edition 2.0)*. New Delhi. GHG Platform India Report - CSTEP. Available at

Source : GHGPI Phase III[14]

Equations used for emissions estimates

The emissions from this category is estimated by applying the Net Calorific Value (fuel type-wise) and corresponding fuel type-wise emission factor to the type of fuel consumed. The equations used for estimations are mentioned below:

$$Emissions_{Gas} = Activity\ Data_{Fuel}\ x\ Net\ Calorific\ Value_{Fuel}\ x\ Emission\ Factor_{Gas}$$

(slightly modified version of IPCC 2006 Equation 2.1)

Emissions in terms of CO_2e (both GWP and GTP) were calculated using the following equations:

$$Emissions_{CO2e}\ (GWP) = Emissions_{CO2} + (GWP_{CH4}\ x\ Emissions_{CH4}) + (GWP_{N2O}\ x\ Emissions_{N2O})$$

$$Emissions_{CO2e}\ (GTP) = Emissions_{CO2} + (GTP_{CH4}\ x\ Emissions_{CH4}) + (GTP_{N2O}\ x\ Emissions_{N2O})$$

1A4b Residential

The emissions from Kerosene and Liquified Petroleum Gas (LPG) fuels were estimated for the Residential category.The following assumptions and steps were used for estimating the emissions from the Residential sector:

1. **Kerosene:**
   a. Kerosene consumption data for the residential sector of Kerala were obtained for the years 2007-08 to 2017-18 from the study conducted by Pillai N, V., Am, N. (2019).
   b. For the years 2004-05 to 2006-07 and 2018-19 to 2021-22, the quantity of Kerosene consumption in the residential sector was calculated by applying its average consumption in the state for domestic usage to the overall consumption of Kerosene in the state.

      i. The average percentage share (60%) of Kerosene consumption of Domestic usage in the state was calculated from the study conducted by Pillai N, V., Am, N. (2019).

      ii. The overall consumption of Kerosene in the state was obtained from Economic Review Reports of Kerala.

2. **Liquified Petroleum Gas (LPG) :**

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[14] Mohan, R.R., Dharmala, N., Ananthakumar, M. R., Kumar, P., Bose, A. (2019). *Greenhouse Gas Emission Estimates from the Energy Sector in India at the Subnational Level (Version/edition 2.0)*. New Delhi. GHG Platform India Report - CSTEP. Available at https://www.ghgplatform-india.org/wp-content/uploads/methodology/phase-3/GHGPI-PhaseIII-Methodology%20Note-Energy-Sep%202019.pdf

Steps followed to estimate LPG consumption activity data of years 2004-05 to 2006-07 and 2018-19 to 2021-22

i. The percentage share of LPG consumption by domestic sector at national level was calculated for the period 2004-05 to 2006-07 and 2018-19 to 2022.

ii. The national level percentage share by domestic sector was then applied to the state's total LPG consumption data to derive residential sector consumption data.

iii. The percentage share of LPG consumption by private sales sector at national level was calculated for the year 2004-05 to 2006-07.

iv. This percentage share (national level) of private sales sector was then applied to the LPG consumption data of Kerala to derive the consumption data by private sales sector in Kerala for the period 2004-05 to 2006-07.

v. The total LPG consumption in Residential sector was calculated by summing up LPG consumption data of private sales and domestic sector.

Methodology

The Tier 1 (T1) and Tier 2 (T2) approaches were used to estimate emissions from the Residential category (see Table 24)

Table 24:Type of emissions factor and the level of methodological tier employed for GHG estimation

IPCC ID	GHG Sources and sink categories	CO_2		CH_4		N_2O	
		Method Applied	Emission Factor	Method Applied	Emission Factor	Method Applied	Emission Factor
1A4b	Residential	T1,T2	CS	T1	D	T1	D
T1: Tier 1 , T2: Tier 2, D: IPCC Default, CS: Country-Specific							

The Net Calorific Value (NCV) and Carbon dioxide (CO_2) emission factors of fuels were taken from INCCA Report (2010). Emission factors of Methane (CH_4) and Nitrous Oxide (N_2O) for Kerosene and LPG fuels were taken from 2006 IPCC Guidelines (see Table 25)

Table 25 : Emissions Factors of Fuels

Fuels	INCCA		IPCC	
	NCV (Tj/kt)	CO_2 EF (t/TJ)	CH_4 (kg/TJ)	N_2O (kg/TJ)
Kerosene	43.8	71.9	10	0.6
Liquified Petroleum Gas (LPG)	47.30	63.10	5	0.1

Equations used for emissions estimates:

The emissions from this category is estimated by applying the Net Calorific Value (fuel type-wise) and corresponding fuel type-wise emission factor to the type of fuel consumed. The equations used for estimations are mentioned below:

$$Emissions_{Gas} = Activity\ Data_{Fuel} \times Net\ Calorific\ Value_{Fuel} \times Emission\ Factor_{Gas}$$

(slightly modified version of IPCC 2006 Equation 2.1)

<u>Emissions in terms of CO_2e (both GWP and GTP) were calculated using the following equations</u>:

$$Emissions_{CO2e}\ (GWP) = Emissions_{CO2} + (GWP_{CH4} \times Emissions_{CH4}) + (GWP_{N2O} \times Emissions_{N2O})$$

$$Emissions_{CO2e}\ (GTP) = Emissions_{CO2} + (GTP_{CH4} \times Emissions_{CH4}) + (GTP_{N2O} \times Emissions_{N2O})$$

Activity data provided in financial year (FY) format was converted to calendar year (CY) format using the following equations:

$$CY\ Activity\ data = [¼ * FY\ Activity\ Data_{Preceding\ year}] + [¾ * FY\ Activity\ Data_{Succeeding\ year}]$$

1A4c Agriculture Energy

For current assessment ,the emissions from Agriculture category have been estimated only for Diesel fuel, due to unavailability of other fuels consumption data. The activity data for this category were taken from Indian Petroleum and Natural Gas Statistics (MoPNG) and the have been detailed below:

(1) Diesel/ High Speed Diesel Oil:

a. **Steps followed to estimate consumption activity data** :

i. The percentage share of HSDO consumption in Agriculture sector and in the Retail sector at national level was calculated for the period 2004-05 to 2021-22 using Indian Petroleum and Natural Gas Statistics (MoPNG).

ii. The national level percentage share in the Agriculture sector was applied to HSDO consumption data of Kerala to derive consumption data in the agriculture sector.

iii. The national level percentage share in Retail sector and state's percentage share of Diesel consumption in Non-Transport sector[15] *[as published in PPAC reports - 2013 and 2021]* were applied to HSDO consumption data of Kerala to estimate the state's retail sector consumption data.

iv. The estimated HSDO consumption data *(Agriculture and Retail sectors)* in financial years were converted into calendar years format using the following equations (2005 to 2021) :

$$CY\ Activity\ data = [¼ * FY\ Activity\ Data_{Preceding\ year}] + [¾ * FY\ Activity\ Data_{Succeeding\ year}]$$

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[15] The Non- Transport sector includes the Tractors, Agri Implements and Agri pumpsets

b. Assumptions:

i.Since fuel sales through retail stream was not provided in the MoPNG's Indian Petroleum and Natural Gas Statistics for the years 2004-05 to 2009-10, sales reported under Miscellaneous category were used, assuming it includes retail sales as well. However, for the years 2010-11 to 2021-22, retail sales of fuel was separately reported in the Indian Petroleum and Natural Gas Statistics, and was thus used as one of the activity data.

ii. The percentage share of Diesel consumption data in the Non- Transport sector of Kerala was obtained for the years 2012-13 and 2021-22 from All India study on sectoral demand of Diesel and Petrol Reports (PPAC) 2013 and 2021.

- *Percentage share of Diesel in Non-Transport sector data were applied in following format:* The 2012-13 data was applied for the years 2004-05 to 2019-20 and 2020-21 data was applied for the years 2020-21 to 2021-22.

Methodology:

For the Agriculture category, Tier 1 (T1) and Tier 2 (T2) approaches has been used for emission estimations (see Table 26)

Table 26: Type of emissions factor and the level of methodological tier employed for GHG estimation

IPCC ID	GHG Sources and sink categories	CO_2		CH_4		N_2O	
		Method Applied	Emission Factor	Method Applied	Emission Factor	Method Applied	Emission Factor
1A4c	Agriculture	T1,T2	CS	T1	D	T1	D
T1: Tier 1 , T2: Tier 2, D: IPCC Default, CS: Country-Specific							

The Net Calorific Value (NCV) and Carbon dioxide (CO_2) emission factors of fuel were taken from INCCA Report (2010). Emission factors of Methane (CH_4) and Nitrous Oxide (N_2O) for Diesel were taken from 2006 IPCC Guidelines. The state- level Diesel consumption data of Agriculture sector for the year 2012-13 and 2020-21 were taken from the PPAC Report (2013 and 2021) (see Table 27 and Table 28)

Table 27: Emissions Factors of Fuels

Fuel	INCCA		IPCC	
	NCV (Tj/kt)	CO_2 EF (t/TJ)	CH_4 (kg/TJ)	N_2O (kg/TJ)
Diesel	43.00	74.1	10	0.6

Table 28 : State-level Diesel consumption in Agriculture sector

(a) Percentage share of Diesel from Non-Transport Sector in Kerala : 2012-13

Parameter	2012-13
Tractor	3.76
Agri Implements	2.15
Agri Pumpsets	1.43
Total	**7.34**

Source : PPAC, 2013

(b) Percentage share of Diesel from Non-Transport Sector in Kerala : 2020-21

Parameter	2020-21
Tractor	0.71
Agri Implements	0.33
Agri Pumps	1.31
Total	**2.35**

Source : PPAC, 2021

Equations used for emissions estimates

The emissions from this category is estimated by applying the Net Calorific Value (fuel type-wise) and corresponding fuel type-wise emission factor to the type of fuel consumed. The equations used for estimations are mentioned below:

$$Emissions_{Gas} = Activity\ Data_{Fuel} \times Net\ Calorific\ Value_{Fuel} \times Emission\ Factor_{Gas}$$

(slightly modified version of IPCC 2006 Equation 2.1)

Emissions in terms of CO_2e (both GWP and GTP) were calculated using the following equations:

$$Emissions_{CO2e}\ (GWP) = Emissions_{CO2} + (GWP_{CH4} \times Emissions_{CH4}) + (GWP_{N2O} \times Emissions_{N2O})$$

$$Emissions_{CO2e}\ (GTP) = Emissions_{CO2} + (GTP_{CH4} \times Emissions_{CH4}) + (GTP_{N2O} \times Emissions_{N2O})$$

1A4c Fisheries

The emissions from Kerosene Diesel and Petrol fuels were estimated for the Fisheries category using the following thumb-rules,equations and assumptions

1. **Kerosene**

   Equations used for estimating Diesel fuel consumption data

   Emissions$_{Gas}$ = Activity Data$_{Fuel}$ x Net Calorific Value$_{Fuel}$ x Emission Factor$_{Gas}$

2. **Diesel**

   a. **Thumb-rules followed**:

      i. The thumb-rules to estimate Diesel fuel consumption was directly obtained from the Fisheries Department-Govt. of Kerala for the years 2005 to 2021. The thumb-rules contain:

         ● Fuel consumption and operations data comprising Fuel type-wise craft, engine type and horsepower of craft; average fuel consumption (Liters/hour and Liters/Trip) and average trip/month data.
         ● The number of active months of fishing in the state was taken based on the inputs received from the Fisheries Department-Govt of Kerala.

      ii. Craft type-wise and fuel type-wise fleet registration *(ReALCRaft)* data was directly obtained from Fisheries Department-Govt. of Kerala for the years 2005 to 2021.

   b. **Equations used for estimating Diesel fuel consumption data for years 2008 to 2021**

      Fuel consumed = Fleet Stock $_{(craft-based)}$ x   Average Fuel consumption $_{(Trips/Month)}$ x Months of Active Fishing

   c. **Assumptions:**

      i. Based on the availability of reliable data , the diesel fuel consumption data was estimated only for the period 2008 to 2021.

      ii. For years 2005,2006 and 2007 the diesel consumption data was estimated using the CAGR method.

      iii. The average diesel consumed (Trips/Month) was calculated based on the thumb-rules provided for Total Motorised Mechanical craft, since the category-wise fleet stock data for Motorised Mechanical craft (Trawlers,Thanguvallam and Gill netters) were not provided.

3. **Petrol** :

   a. **Thumb-rules followed:**

      i. The thumb-rules to estimate Petrol fuel consumption was directly obtained from the Fisheries Department-Govt. of Kerala for the years 2005 to 2021. The thumb-rules contain:

         ● Fuel consumption and operations data comprising Fuel type-wise craft, engine type and horsepower of craft; average fuel consumption (Liters/hour and Liters/Trip) and average trip/month data.

- The number of active months of fishing in the state was taken based on the inputs received from the Fisheries Department-Govt of Kerala.

ii. Craft type-wise and fuel type-wise fleet registration *(ReALCRaft)* data was directly obtained from Fisheries Department-Govt. of Kerala for the years 2005 to 2021.

b. Equations used for estimating Petrol fuel consumption data for years 2008 to 2021

Fuel consumed= Fleet Stock $_{(craft-based)}$ x Average Fuel consumption (Liters/Trip) $_{Lowest\ HP\ of\ engine}$ x Average Trip/Month $_{Lowest\ HP\ of\ engine}$ x Months of Active Fishing

c. Assumptions:

i. Based on the availability of reliable data , the diesel fuel consumption data was estimated only for the period 2008 to 2021.

ii. For years 2005,2006 and 2007 the petrol consumption data was estimated using the CAGR method.

iii. The Average fuel consumption (Liters/Trip) and Average Trip/Month data of crafts with lowest HP of engine *(provided in the thumb-rules)* were considered for calculations based on inputs received from the Fisheries department.

Scope for Improvement :

The Diesel and Petrol fuel consumption data for the entire evaluation period can be refined if fuel sold data is provided by Matsyafed.

Methodology:

The emissions from the Fisheries category was estimated using Tier 1 (T1) and Tier 2 (T2) approaches (see Table 29)

Table 29 :Type of emissions factor and the level of methodological tier employed for GHG estimation

IPCC ID	GHG Sources and sink categories	CO_2		CH_4		N_2O	
		Method Applied	Emission Factor	Method Applied	Emission Factor	Method Applied	Emission Factor
1A4c	Fisheries	T1,T2	CS	T1	D	T1	D
T1: Tier 1 , T2: Tier 2, D: IPCC Default, CS: Country-Specific							

The Net Calorific Value (NCV) and Carbon dioxide (CO_2) emission factors of fuels were taken from INCCA Report (2010). Emission factors of Methane (CH_4) and Nitrous Oxide (N_2O) for Diesel were taken from 2006 IPCC Guidelines. Density of Diesel and Petrol were obtained from PPAC (2022) Report and the data on the estimated number of active months of fishing

was taken based on the inputs received from the Fisheries Department- Govt. of Kerala   (see Table 30, Table 31 and Table 32).

Table 30 : Emissions Factors of Fuels

Fuels#	INCCA		IPCC	
	NCV (Tj/kt)	CO_2 EF (t/TJ)	CH_4 (kg/TJ)	N_2O (kg/TJ)
Diesel	43.00	74.1	33	3.2
Kerosene	43.8	71.9	10	0.6
Petrol	44.3	69.3	3.9	3.9

\#
  Note: The Fisheries sub-sector is considered under mobile combustion.

(a) For Diesel and Petrol fuels, emission factors of Methane (CH4) and Nitrous Oxide (N2O) were not available for fishing-mobile combustion in IPCC guidelines. Therefore, the emission factor was assumed to be the same as that of Road transportation.

(b) Due to unavailability of Methane(CH_4) and Nitrous Oxide (N_2O) emission factors for Kerosene specific to fishing-mobile combustion activity , corresponding proxy factors from fishing-stationary combustion were used.

Table 31: Density of Fuel used for the emissions estimates

Density of Fuel	Value
Diesel	1.210 kL/t
Petrol	1.411 kL/t

Source : Petroleum Planning and Analysis Cell, (2022)

Table 32: Number of active months of Fishing in the state

Parameter	Data
Estimated no. of active months of fishing	10

Equations used for emissions estimates

Emissions in terms of CO_2e (both GWP and GTP) were calculated using the following equations:

$$\text{Emissions}_{CO_2e} \text{ (GWP)} = \text{Emissions}_{CO_2} + (\text{GWP}_{CH_4} \times \text{Emissions}_{CH_4}) + (\text{GWP}_{N_2O} \times \text{Emissions}_{N_2O})$$

$$\text{Emissions}_{CO_2e} \text{ (GTP)} = \text{Emissions}_{CO_2} + (\text{GTP}_{CH_4} \times \text{Emissions}_{CH_4}) + (\text{GTP}_{N_2O} \times \text{Emissions}_{N_2O})$$

1B Fugitive Emissions from Fuels

Fugitive emissions arise from various activities in fossil fuel production at mines and wells, where coal, oil, and natural gas are produced (Mohan, R.R, 2019). However, in Kerala, BPCL Kochi Refinery was the only source identified for the fugitive emissions.

Methodology

The current assessment uses the Tier 2 method to estimate the Methane (CH_4) emissions from the refinery's crude throughput (see Table 33). The country-specific emission factor of refinery Throughput was obtained from the INCCA (2010) report (see Table 34).

Table 33: Type of emissions factor and the level of methodological tier employed for GHG estimation

IPCC ID	GHG Sources and sink categories	CO_2		CH_4		N_2O	
		Method Applied	Emission Factor	Method Applied	Emission Factor	Method Applied	Emission Factor
1B	Fugitive Emissions	-	-	T2	CS	-	-
T2 : Tier 2, CS: Country-Specific							

Table 34: Emission Factors used for Methane (CH_4) estimation

Parameter	Emission Factor (INCAA)	Emission Factor used
Refinery Throughput	6.75904×10^{-5} Gg / million tons	0.0675904 tons/Mt

Note : Gg refer to Gigagrams

Equations used for emissions estimates

The equation used for estimating Fugitive Emissions are as below:

$$Emissions_{Gas} = \ Refinery\ Throughput\ x\ Emission\ Factor_{Gas}$$

Emissions in terms of CO_2e (both GWP and GTP) were calculated using the following equations:

$$Emissions_{CO2e}\ (GWP) = \ Emissions_{CH4}\ x\ GWP_{CH4}$$

$$Emissions_{CO2e}\ (GTP) = Emissions_{CH4}\ x\ GTP_{CH4}$$

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