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DIRECTORATE OF ENVIRONMENT AND CLIMATE CHANGE
GOVERNMENT OF KERALA

KERALA GHG INVENTORY METHODOLOGY NOTE

INDUSTRIAL PROCESSES AND PRODUCT USE SECTOR

JUNE, 2024

INDUSTRIAL PROCESSES AND PRODUCT USE (IPPU) SECTOR

Key Highlights

- In Kerala, the IPPU sector represented ~6% of the gross GHG emissions (excluding LULUCF) in 2021.
- The total IPPU emissions declined from 1.47 Mt CO_2e to 1.32 Mt CO_2e between 2005 and 2021
- Within IPPU emissions, almost 55% of emissions emanated from ammonia production in 2021 . This was followed by emissions from carbon black (~15.46%) and cement (~14%).

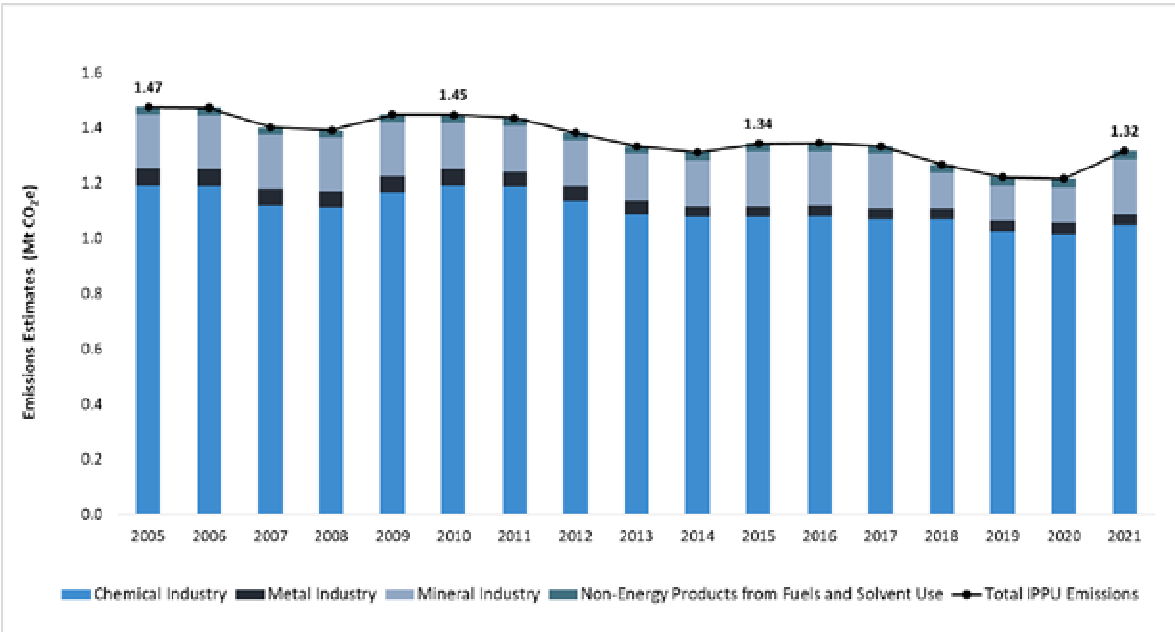

Figure 2: GHG Emissions Estimates of IPPU Sector – Kerala (2005 to 2021)

Sector Description

The category of Industrial Processes and Product Use (IPPU) encompasses emissions of greenhouse gases resulting from industrial processes, the utilization of greenhouse gases in products, and non-energy applications of fossil fuel carbon. Greenhouse gas emissions stem from a diverse array of industrial activities, with primary sources being the release of gases during processes that chemically or physically transform materials. These processes can yield various greenhouse gases, including carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), and perfluorocarbons (PFCs) (IPCC, 2006).

The key economic sectors/categories included in the emission estimates are

- 2A: Mineral Industry
    - 2A1 Cement production
    - 2A2 Lime production
    - 2A4b Other Uses of Soda ash

- 2B Chemical Industry
    - 2B1 Ammonia Production
    - 2B4 Caprolactam Production
    - 2B6 Titanium Dioxide Production
    - 2B7 Soda ash Production
    - 2B8f Carbon Black
- 2C Metal Industry
    - 2C1 Iron and Steel Production
    - 2C6 Zinc Production
- 2D Non-Energy Products from Fuels and Solvent Use
    - 2D1 Lubricant Use
    - 2D2 Paraffin Wax Use

Methodology

The table 35 below details the sources of activity data used for estimating emissions from the IPPU sector.The production data used for estimating emissions from each product for the year 2019, 2020, 2021 is detailed in table 36 .

Table 35: Source of activity data[16] used for estimating emissions from IPPU sector

Production	Year	Source*
Mineral Industry		
Cement	2005 to 2009, 2015 to 2017, 2021	Kerala State Pollution Control Board (Malabar Cements)
	2009-10 to 2014-15, 2017-18 to 2020- 21	Government of India, Ministry of Mines, Indian Bureau of Mines. Indian Minerals Yearbook IBM 2012 (for 2010-11, 2011-12) IBM 2013 (for 2012-13) IBM 2014 (for 2013-14) IBM 2015 (for 2014-15) IBM 2018 (for 2017-18) IBM 2011 (for 2009-10) IBM 2021 (2020- 21) IBM 2019 (2018-19) IBM 2020 (2019-20)
Lime	2005-2021	KSPCB

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

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

Production	Year	Source*
Other uses of soda ash -consumption	2004-05 to 2005- 06, 2007-08, 2009-10 to 2015-16	GHGPI Phase III
	2006-07, 2008-09	Interpolation
	2016-17 to 2021- 22	CAGR calculated between 2012-13 and 2015-16
Chemical Industry		
Ammonia	2005- 2021	KSPCB
Caprolactam	2004-05	GHGPI Phase III Methododology- Annexure 9
	2005-06 to 2021-22	Annual Reports of The Fertilisers and Chemicals Travancore Limited 2014-15, 2015-16, 2016-17, 2017-18, 2018-19, 2019-20, 2020-21, 2021-22
Titanium Dioxide	2005-2008 2011-2016 2021	KSPCB (Kerala Minerals and Metals Limited (KMML) and Travancore Titanium Products Limited (TTPL)
	2009-2010	Indian Minerals Yearbook 2011
	2017-2020	KMML master plan 2030 and KSPCB (TTPL)
Soda ash	2005-2021	KSPCB (FACT Udyogamandal)
Carbon black	2005-2018	KSPCB (Philips Carbon black and BDT Industries)
	2019-2021	Department of Economics and Statistics, GoK (Philips carbon black) and KSPCB (BDT Industries)
Metal Industry		
Iron and steel	2005-2021	KSPCB
Zinc	2005- 2010	KSPCB (Binani Zinc Ltd)
	2010-11 to 2013-14	Indian Minerals Yearbook 2012,2014
	2014-15 to 2021-22	Production is zero since the plant is shut down.
Non-energy Products from Fuels and Solvent Use		
Lubricant use	2005-06, 2007-08 to 2010-11, 2012-13 to 2021-22	Indian Petroleum and Natural Gas statistics, Ministry of Petroleum and Natural Gas, Economic and Statistic Division, Government of India 2020-21,2021-22, 2018-19, 2019-20, 2017-18, 2016-17, 2015-16, 2014-15, 2013-14, 2012-13, 2010-11, 2009-10, 2008-09, 2007-08, 2005-06

Production	Year	Source*
	2004-05, 2006-07, 2011-12	Interpolation and CAGR
Paraffin wax use		Kerala Small Industries Corporation SIDCO website Data applied to all the years between 2005 and 2021

*Wherever direct data was not available, suitable statistical methods were applied for estimation of annual production. These are mentioned against the applicable cases.

Table 36 : Production/Consumption data (000 tonnes) used for estimating emissions from IPPU sector

IPCC ID	Industrial product	2019	2020	2021
2A	**Mineral Industry**			
2A1	Cement Production	400	400	638.75
2A2	Lime Production	14.80	14.80	14.80
2A4b	Other uses of soda ash	7.51	9.00	10.78
2B	**Chemical Industry**			
2B1	Ammonia Production	361.35	361.35	361.35
2B4	Caprolactam Production	0.00	0.00	15.63
2B6	Titanium Dioxide Production	45.04	44.39	54.15
2B7	Soda Ash Production	10.95	10.95	10.95
2B8f	Carbon Black	90.33	87.51	77.65
2C	**Metal Industry**			
2C1	Iron and Steel Production	500.67	500.67	500.67
2C6	Zinc Production	0.0	0.0	0.0
2D	**Non-Energy Products from Fuels and Solvent Use**			
2D1	Lubricant Use	41.8	44.43	43.93
2D2	Paraffin Wax Use	7.2	7.2	7.2

Assumptions

- Wherever year on year actual production/consumption data was not available, the installed capacity or average annual production data were obtained from Kerala State Pollution Control Board (KSPCB) and other line departments concerned.
- As per expert opinion from KSPCB the installed capacity itself was taken as the average production quantity where average production data was not available.

Table 37 provides insights on the tier level of methodology and emission factors used in estimating GHG emissions.

Table 37: Tier approach followed for the IPPU category

IPCC ID	GHG Source and Sink categories	CO_2		CH_4		N_2O	
		Method applied	Emission factor	Method applied	Emission factor	Method applied	Emission factor
2A	**Mineral Industry**						
2A1	Cement Production	T1	CS	NA	NA	NA	NA
2A2	Lime Production	T1	D	NA	NA	NA	NA
2A4b	Other uses of soda ash	T1	CS	NA	NA	NA	NA
2B	**Chemical Industry**						
2B1	Ammonia Production	T1	CS	NA	NA	NA	NA
2B4	Caprolactam	NA	NA	NA	NA	T1	CS
2B6	Titanium Dioxide Production	T1	CS	NA	NA	NA	NA
2B7	Soda Ash Production	T1	D	NA	NA	NA	NA
2B8f	Carbon Black	T1	CS	T1	CS	NA	NA
2C	**Metal Industry**						
2C1	Iron and Steel Production	T1	CS	NA	NA	NA	NA
2C6	Zinc Production	T1	CS	NA	NA	NA	NA

IPCC ID	GHG Source and Sink categories	CO_2		CH_4		N_2O	
		Method applied	Emission factor	Method applied	Emission factor	Method applied	Emission factor
2D	**Non-Energy Products from Fuels and Solvent Use**						
2D1	Lubricant Use	T1	CS	NA	NA	NA	NA
2D2	Paraffin Wax Use	T1	CS	NA	NA	NA	NA
T1: Tier 1; T2: Tier 2; T3: Tier 3; CS: Country-specific; D: IPCC Default; NA: Not Applicable							

2A Mineral Industry

2A1:Cement

Equation used

$$CO_2\,Emissions = \left[\sum_i (M_{ci} \bullet C_{cli}) - Im + Ex\right] \bullet EF_{clc} \quad \textit{(IPCC 2006 Equation 2.1)}$$

Where:

CO_2 Emissions = emissions of CO_2 from cement production, tonnes

M_{Ci} = weight (mass) of cement produced of type i, tonnes

C_{cli}= clinker fraction of cement of type i, fraction

Im = imports for consumption of clinker, tonnes

Ex = exports of clinker, tonnes

EF_{clc}= emission factor for clinker in the particular cement, tonnes CO_2/tonne clinker

The table below provides the emission factor and clinker fraction used

Table 38: Factors used for estimating emissions from Cement industry

Factors	Value	Source
Emission factor for CO_2 (EF_{clc})	0.537 t CO_2/t clinker	NATCOM 2
Clinker fraction of Portland pozzolana cement (C_{cli})	53.5%[17]	IPCC 2006

[17] The percentage clinker was taken as 53.5% considering the only source of cement production in Kerala i.e., Malabar Cements produces Portland pozzolana.

Emissions from the production of imported clinker cannot be included in emissions estimates as these emissions were produced and may have accounted for in another state. Similarly, emissions from clinker that are ultimately exported should be factored into estimates of the state where the clinker is produced. Based on expert opinion from KSPCB , there is no export of clinker from Kerala. As such based on expert inputs from KSPCB, the export and import of clinker was entirely not accounted for within these emission estimates.

2A2 Lime

Equation Used

$$E_{CO2} = PP \bullet EF$$ *(slightly modified version of IPCC 2006 Equation 2.6)*

Where:

E_{CO2}= CO_2 emissions from production of lime, tonnes

PP= annual production of lime, tonnes

EF = CO_2 emission factor for lime, tonnes CO_2 /tonne lime produce (high calcium lime)

The table 39 below provides the emission factor used in estimating emissions from production of lime.

Table 39: Emission factor used for emissions estimation

Factors	Value	Source
Emission factor for CO_2 (high calcium lime) (E_{CO2})	0.75 t CO_2/t lime	IPCC 2006

2A4b Other uses of soda ash

Equation Used

$$CO_2\ Emissions = M_c \bullet \left(0.85EF_{ls} + 0.15EF_d\right)$$ *(IPCC 2006 Equation 2.14)*

Where:

CO_2 Emissions = emissions of CO_2 from other process uses of carbonates, tonnes

M_c = mass of carbonate consumed, tonnes

EF_{ls} or EF_d= emission factor for limestone or dolomite calcination, tonnes CO_2/tonne carbonate

Soda ash is primarily sodium carbonate, not limestone or dolomite. Therefore, the Tier 1 method for soda ash does not require the default fraction of 85%/15%. Emissions are estimated by multiplying the quantity of soda ash consumed on the state level by the emission factor (see table 40) for sodium carbonate.

Table 40: Emission factor used for emissions estimation

Factors	Value	Source
Emission factor for CO_2	0.41492 t CO_2 /t carbonate	NATCOM 2

2B Chemical Industry

2B1 Ammonia

Equation Used

$$E_{CO2} = AP \bullet FR \bullet CCF \bullet COF \bullet 44/12 - R_{CO2}$$ *(IPCC 2006 Equation 3.1)*

Where:

E_{CO2} = Emissions of CO_2, kg

AP = Ammonia production, tonnes

FR = fuel requirement per unit of output, GJ/tonne ammonia produced

CCF = carbon content factor of the fuel, kg C/GJ

COF = carbon oxidation factor of the fuel, fraction

R_{CO2} = CO_2 recovered for downstream use (urea production), kg

Table 41: Factors used for emissions estimates

Factors	Value	Source
Fuel requirement per unit of output	38.11624 GJ/t ammonia	NATCOM 2
Carbon content factor of the fuel	99.5%	NATCOM 2
Carbon oxidation factor of the fuel	14.4 Kg C/GJ	NATCOM 2
CO_2 recovered for downstream use (urea production)	0	IPCC 2006

2B4 Caprolactam

Equation Used

$E_{N20} = EF \bullet CP$ *(IPCC 2006 Equation 3.9)*

Where:

E_{N2O} = N_2O emissions, kg

EF = N_2O emission factor (default), kg N_2O/tonne caprolactam produced

CP = caprolactam production, tonne

Table 42: Emission factor used for emissions estimation

Factors	Value	Source
Emission factor for N_2O	9 kg N_2O/tonne caprolactam	NATCOM 2

2B6 Titanium Dioxide

Equation Used

$E_{CO2} = \sum_i \left(AD_i \bullet EF_i\right)$ *(IPCC 2006 Equation 3.12)*

Where:

E_{CO2} = emissions of CO_2, tonnes

ADi = production of titanium slag, synthetic rutile or rutile TiO_2 (product i), tonnes

EFi = CO_2 emissions per unit of production of titanium slag, synthetic rutile or rutile TiO_2 (product i), tonnes CO_2/tonne product.

Table 43: Emission factor used for emissions estimation

Factors	Value	Source
Emission factor for CO_2	1.385 tCO_2/t TiO_2 produced	NATCOM 2

2B8f Carbon black

Equation Used

$E_{CO2} = PP \bullet EF$ *(IPCC 2006 Equation 3.15)*

Where:

E_{CO2} = CO_2 emissions from production of carbon black, tonnes

PP = annual production of carbon black, tonnes

EF = CO_2 emission factor for carbon black, tonnes CO_2/tonne product produced

$ECH4 = PP_i \bullet EF$ *(IPCC 2006 Equation 3.23)*

Where:

ECH_4 = emissions of CH_4 from production of carbon black, kg

PP = annual production of carbon black, tonnes

EF= CH_4 emission factor for carbon black, kg CH_4/tonne product

Table 44: Emission factors used for emissions estimation

Factors	Value	Source
Emission factor for CO_2	2.62 tCO_2/t carbon black produced	NATCOM 2
Emission factor for CH_4	0.06 kg CH4 /t carbon black produced	NATCOM 2

2B7 Soda Ash

Equation Used

$E_{CO2} = AD \bullet EF$ *(IPCC 2006 Equation 3.14)*

Where:

ECO_2 = emissions of CO_2, tonnes

AD = tonnes natural soda ash produced

EF = emission factor per unit of natural soda ash output

Table 45 : Emission factor used for emissions estimation

Factors	Value	Source
Emission factor for CO_2	0.138 tCO_2/t natural soda ash produced	IPCC 2006

2C Metal Industry

2C1 Iron and steel

Equation Used

CO_2 Emissions from Iron and Steel Production *(IPCC 2006 Equation 4.4)*

Iron & Steel: $E_{CO2,\ non\text{-}energy} = BOF \bullet EF_{BOF} + EAF \bullet EF_{EAF} + OHF \bullet EF_{OHF}$

Where:
E_{CO2}, non-energy = emissions of CO_2 to be reported in IPPU Sector, tonnes
BOF= quantity of BOF crude steel produced, tonnes
EAF = quantity of EAF crude steel produced, tonnes
OHF = quantity of OHF crude steel produced, tonnes
EFx= emission factor, tonnes CO_2 /tonne x produced

Table 46 : Emission factor used for emissions estimation

Factor	Value	Source
Emission factor -EAF	0.08 t CO_2/t production	NATCOM 2

As per expert opinion from KSPCB, it has been understood that the Iron and Steel making process in the state uses only Electric Arc Furnaces (EAF). Therefore, CO_2 emissions from the Iron and steel industry have been estimated by using Equation 4.4.

Further, as per KSPCB, there has been no occurrence of emissions from production of Pig iron, direct reduced iron , sinter and pellets, due to the absence of such processes in the respective industries. Hence, CH_4 and CO_2 emissions for these categories are regarded as zero.

2C6 Zinc

Equation Used

CO_2 Emissions from Zinc Production *(IPCC 2006 Equation 4.33)*

$$E_{CO2} = Zn \bullet EF_{default}$$

Where:
E_{CO2} = CO_2 emissions from zinc production, tonnes
Zn = quantity of zinc produced, tonnes
$EF_{default}$ = default emission factor, tonnes CO_2 /tonne zinc produced

Table 47: Emission factor used for emissions estimations

Factor	Value	Source
CO_2 emission factor	0.53 t CO_2/t zinc produced	NATCOM 2

2D Non- Energy Products from Fuels and Solvent Use

2D1 Lubricant Use

Equation Used

$$CO_2\ Emissions = LC \bullet CC_{Lubricant} \bullet ODU_{Lubricant} \bullet 44/12$$ *(IPCC 2006 Equation 5.2)*

Where:
CO_2 Emissions = CO_2 emissions from lubricants, tonne CO_2
LC = total lubricant consumption[18], TJ
$CC_{Lubricant}$ = carbon content of lubricants (default), tonne C/TJ (= kg C/GJ)
$ODU_{Lubricant}$ = Oxidised During Use (ODU) factor (based on default composition of oil and grease),
fraction 44/12 = mass ratio of CO_2/C

Table 48: Emission factor used for emissions estimates

Factor	Value	Source
Carbon content of lubricants	20 t-C/TJ	NATCOM 2
Oxidised During Use (ODU) factor	0.2	NATCOM 2

Limitation
Due to lack of segregated data, lubricants' consumption by 2-stroke engines have also been accounted for within the IPPU sector. Due to this, the emissions from this category were calculated using a Tier-1 approach.

2D2 Paraffin wax use

Equation Used

$$CO_2\ Emissions = PW \bullet CC_{Wax} \bullet ODU_{Wax} \bullet 44/12$$ *(IPCC 2006 Equation 5.4)*

Where:
CO_2 Emissions = CO_2 emissions from waxes, tonne CO_2
PW = total wax consumption[19], TJ
CC_{Wax} = carbon content of paraffin wax (default), tonne C/TJ (= kg C/GJ)
ODU_{Wax} = ODU factor for paraffin wax,
fraction (44/12) = mass ratio of CO_2/C

[18] Lubricant consumption data was multiplied by NCV (40.2 Tj/Kt) (Indian Network for Climate Change Assessment, 2010) to get consumption data in TJ

[19] Paraffin wax consumption data was multiplied by NCV (40.2 Tj/Kt) *(Conversion factors, 2013)* to get consumption data in TJ

Table 49: Emission factors used for emissions estimates

Factor	Value	Source
Carbon content of paraffin wax	20 t-C/TJ	NATCOM 2
ODU factor	0.2	NATCOM 2

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