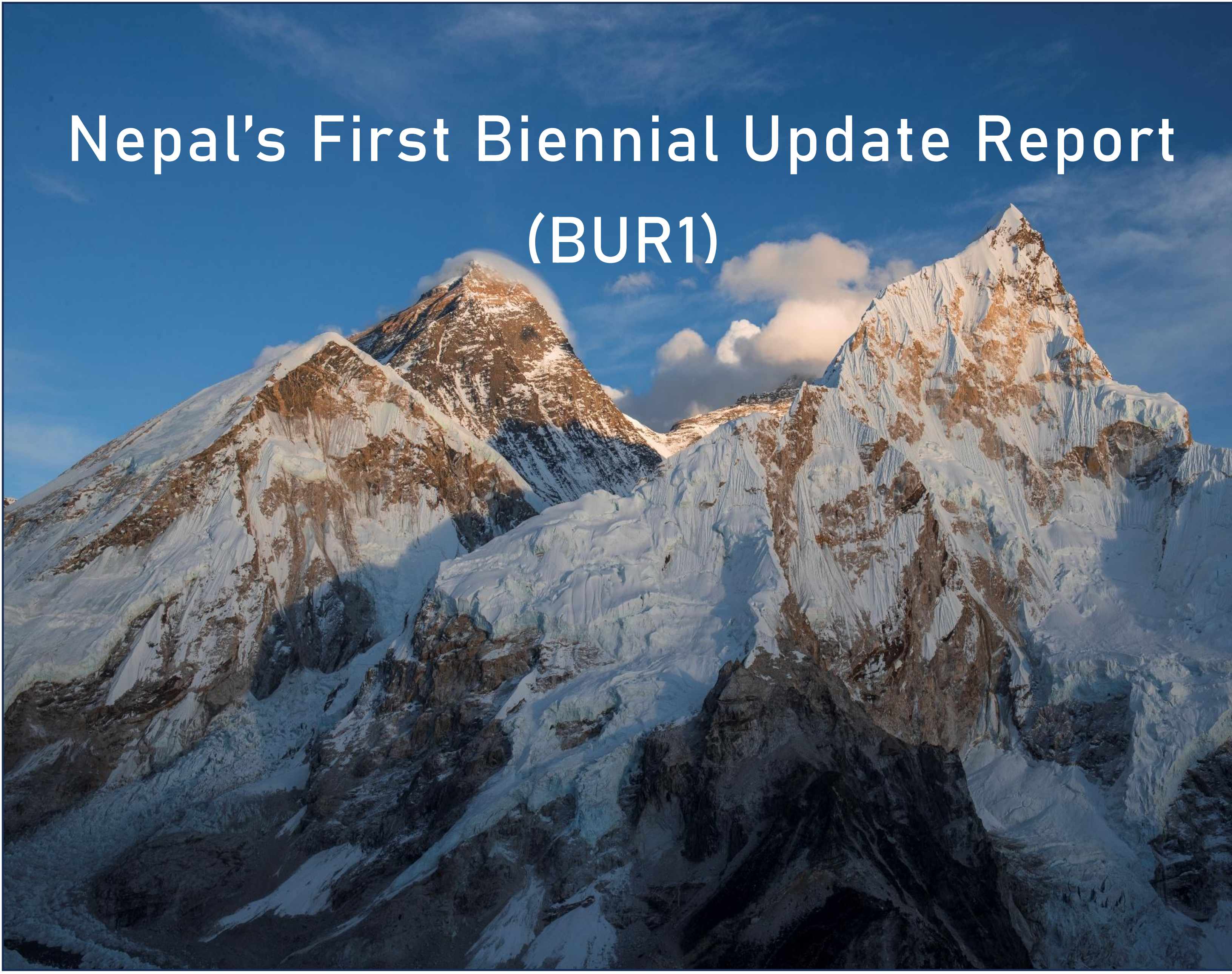
Nepal's First Biennial Update Report (BUR1)



Government of Nepal

Ministry of Forests and Environment

2025

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FOREWORD

The global climate crisis stands as one of humanity's greatest challenges, demanding shared resolve, fairness, and innovation. For Nepal, a country highly vulnerable to climate impacts, this crisis has far-reaching consequences for sustainable development, human well-being, and ecological stability. As climate change is a matter of common concern, the world must remain informed about national actions that contribute to the global response. In this regard, Nepal has prepared its First Biennial Update Report (BUR1), which represents a milestone in fulfilling our reporting obligations under the United Nations Framework Convention on Climate Change (UNFCCC) and in our transition toward the Enhanced Transparency Framework (ETF) under the Paris Agreement. This report communicates Nepal's climate actions and progress to the international community.

This BUR1 provides an overview of Nepal's greenhouse gas inventory, mitigation actions, and information on support received and needed. The report demonstrates Nepal's ongoing efforts to institutionalize transparency, strengthen data systems, and develop evidence-based policies in line with international guidelines. It also highlights our determination to integrate scientific knowledge, national policies, and practical action in addressing the climate emergency.

This achievement builds upon the foundation laid by earlier efforts such as Nepal's National Communications, National Adaptation Programme of Action, National Adaptation Plan, and Nationally Determined Contributions. I acknowledge the contribution of past leadership at the Ministry of Forests and Environment and the Climate Change Management Division, whose early initiatives on data and institutional arrangements have made this report possible.

The preparation of BUR1 was the result of close collaboration of stakeholders including sectoral ministries. I extend my sincere gratitude to the Climate Change Management Division and the BUR1 Project Execution Team for their technical expertise and dedication. I also recognize the valuable contributions from sectoral ministries, subnational governments, academia, national and international organizations, experts and civil society organizations, whose engagement ensured an inclusive and comprehensive process.

BUR1 is both a product and a process. It reflects Nepal's commitment to transparency and our readiness to engage more fully in the evolving global climate regime. It lays the groundwork for stronger systems, future reporting under the ETF, and enhanced national capacity to deliver on our climate commitments.

Govinda Prasad Sharma, PhD
Secretary, Ministry of Forests and Environment

ACKNOWLEDGEMENT

The submission of Nepal's First Biennial Update Report (BUR1) marks a significant milestone on climate change reporting as well as fulfills our commitment to the principles of transparency, accountability, and collective action under the United Nations Framework Convention on Climate Change (UNFCCC). BUR1 builds on earlier National Communications and represents a key step in our transition toward the Enhanced Transparency Framework (ETF) under the article 13 of the Paris Agreement.

This report provides a comprehensive update on Nepal's greenhouse gas inventory, progress on mitigation measures, domestic MRV system and information on support received and needed. By doing so, it strengthens Nepal's engagement with the international community and contributes to building mutual trust and understanding. BUR1 also serves as a vital instrument for identifying gaps in data, institutional capacity, and technical expertise, thereby guiding future investments in capacity building and system strengthening.

BUR1 is both a product and a process. It demonstrates Nepal's active participation in the global climate regime and our gradual transition toward the Enhanced Transparency Framework. It lays the foundation for future reporting cycles, stronger institutional arrangements, and enhanced national capacity. As Nepal advances on this pathway, we remain committed to aligning our national priorities with global responsibilities meeting the requirement of Enhanced Transparency Framework under Paris Agreement.

The preparation of BUR1 was a complex but rewarding effort, led by the Ministry of Forests and Environment in close collaboration with sectoral ministries, departments, and development partners. I express my sincere gratitude to our secretary for his guidance and support throughout the process. I also acknowledge the tireless contributions of departmental heads, sectoral focal points, and technical agencies who provided data and insights across agriculture, energy, industry, waste, and land-use sectors.

We are grateful for the contributions of the consulting team, whose analytical support and technical expertise were instrumental in preparing this report in accordance with UNFCCC guidelines. Their collaboration was critical in navigating the methodological and institutional challenges associated with BUR preparation.

I extend special recognition to the core writing, editing, and technical team for their dedication and professionalism. We also acknowledge the financial support provided by the Global Environment Facility (GEF) and the implementing role of the United Nations Environment Programme (UNEP), whose guidance and coordination were invaluable in bringing this report to completion. While I cannot name every contributor here, my appreciation extends to all individuals and institutions acknowledged in the contributors' section of this report.

Maheshwar Dhakal, PhD
Chief, Climate Change Management Division

ACRONYMS

ADS	Agricultural Development Strategy
AEPC	Alternative Energy Promotion Center
AFS	Agriculture and Food Security
BCRWME	Building Climate Resilience of Watersheds in Mountain Eco-Regions
BIMSTEC	Bay of Bengal Initiative for Multi-Sectoral Technical and Economic Cooperation
BTR	Biennial Transparency Report
BUR	Biennial Update Report
CBD	Convention on Biological Diversity
CBFM	Community-Based Forest Management
CBIT	Capacity Building Initiatives for Transparency
CBS	Central Bureau of Statistics
CC	Climate Change
CCBC	Climate Change Budget Code
CCFF	Climate Change Financing Framework
CCMD	Climate Change Management Division
CDD	Consecutive Dry Days
COP	Conference of the Parties
CSO	Civil Society Organization
CWD	Consecutive Wet Days
DFRS	Department of Forest Research and Survey
DHM	Department of Hydrology and Meteorology
DMG	Department of Mines and Geology
DWRI	Department of Water Resources and Irrigation
FBWC	Forest, Biodiversity, and Watershed Conservation
FY	Fiscal Year
GBV	Gender-Based Violence
GCA	Global Commission on Adaptation
GCF	Green Climate Fund
GEF	Global Environment Facility
GDP	Gross Domestic Product
GEDSI	Gender Equality, Disability, and Social Inclusion
GESI	Gender Equality and Social Inclusion
GESILG	Gender Equality, Social Inclusion, Livelihood and Governance
GHG	Greenhouse Gas
GHI	Global Hunger Index
`	Green, Resilient, and Inclusive Development

HDWS	Health, Drinking Water, and Sanitation
HEP	Hydroelectric Power
HKH	Hindu Kush Himalaya
ICIMOD	International Centre for Integrated Mountain Development
ICS	Improved Cook Stoves
IMCCCC	Inter-Ministerial Climate Change Coordination Committee
IPCC	Intergovernmental Panel on Climate Change
ITPI	Industry, Transport, and Physical Infrastructure
IUCN	International Union for Conservation of Nature
LAPA	Local Adaptation Plan of Action
LPG	Liquefied Petroleum Gas
MOFAGA	Ministry of Federal Affairs and General Administration
MoFE	Ministry of Forests and Environment
MRR	Monitoring, Review and Report
MRV	Monitoring Reporting and Verification
MW	Megawatt
NAP	National Adaptation Plan
NAPA	National Adaptation Program of Action
NARC	Nepal Agricultural Research Council
NAST	Nepal Academy of Science and Technology
NBS	Nature-Based Solutions
NCCP	National Climate Change Policy
NCCSP	Nepal Climate Change Support Program
NCEPCCM	National Council on Environment Protection and Climate Change Management
NDC	Nationally Determined Contribution
NDRRMA	National Disaster Risk Reduction and Management Authority
NEA	Nepal Electricity Authority
NPC	National Planning Commission
NRB	Nepal Rastra Bank
NSO	National Statistical Office
OPMCM	Office of the Prime Minister and Council of Ministers
PCCCC	Provincial Climate Change Coordination Committee
PPCR	Pilot Program for Climate Resilience
PROR	Peaking Run-of-River
PSP	Private Sector Participation
PVCA	Participatory Vulnerability and Capacity Assessment
RCP	Representative Concentration Pathway

REDD	Reducing Emissions from Deforestation and Forest Degradation
RUS	Rural and Urban Settlements
SAP	Strategic Action Plan
SASCOF	South Asian Climate Outlook Forum
TNCH	Tourism, Natural and Cultural Heritage
UN	United Nations
UNDP	United Nations Development Program
UNFCCC	United Nations Framework Convention on Climate Change
USAID	United States Agency for International Development
USD	United States Dollar
VRA	Vulnerability & Risk Assessment
WBG	World Bank Group
WECS	Water and Energy Commission Secretariat
WFP	World Food Program
WIM	Warsaw International Mechanism
WRE	Water Resources and Energy

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1 National Circumstances

Nepal is a landlocked country that lies along the slopes of the Himalayan Mountains between China and India. It has a land area of 147,516 km2 spanning 800-850 km from east to west, and 144-240 km north to south. Physiographically, it stretches between 80004' - 88012' E and 26022' - 30027' N, and has the largest elevational gradient in the world, extending from tropical alluvial plains as low as 67 meters above sea level (m asl) in the lowland Tarai to the Earth's highest mountain, Mount Everest at 8,848.86 m asl (FRTC, 2022, MoFE, 2021a).This diversity creates five distinct physiographic regions and seven monsoonal climatic zones (Figure 1, each characterized by unique temperature and precipitation patterns. This stark contrast between Nepal's tropical monsoon, which delivers 89.9% of the annual rainfall over four wet months and the eight dry months, including winter and spring, highlights the challenge of managing water resources (MoFE, 2021a). This climatic dichotomy, too much rain during the monsoon and too little during the dry season, poses critical adaptation challenges. Nepal's altitudinal and physiographic landscape is major in accelerating climate hazards, such as landslides, floods, droughts, and Glacial Lake Outburst Floods (GLOFs), causing widespread loss and damage.

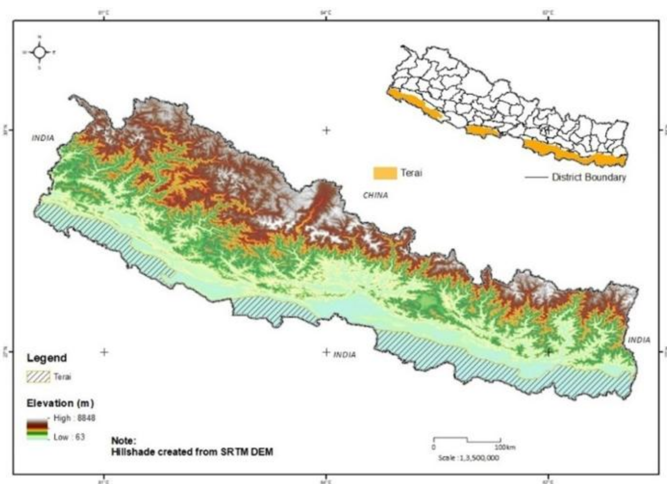

Figure 1: Map of Nepal

1.1 Population Profile

The country's population increased from 9.4 million in 1961 to 29.19 million in 2021 (see Table 1). However, the annual population growth rate has decreased from 2.66% in 1981 to 0.93% in 2021, indicating a demographic transition (NSO, 2021).

Table 1: Population and growth rate

Year	1961	1971	1981	1991	2001	2011	2021
Population (millions)	9.4	11.6	15.0	18.5	23.2	26.5	29.19
Annual growth rate (%)	1.65	2.07	2.66	2.09	2.24	1.35	0.93

The internal migration, defined as changes against the last registered prior residence, was 8,239,589 in 2021, which is 29.2 percent of the native-born population. The rate of recent migration shares the same percentage rate as the lifetime migration data (NSO, 2021).

Currently, approximately 66.03% of the total population of Nepal resides in municipalities, reflecting the significant milestone of urbanization in the country. The dense population is found in the major cities, such as the Kathmandu Valley and the cities of lowland Tarai (Figure 2). Regionally, 53.66% of the population lives in the Tarai, 40.25% in the Hill, and 6.09% in the Mountain region. The proportion of the population living in hills and mountains is projected to decrease to 47% by 2031. The number of people per household is decreasing, i.e., from 4.88 in 2011 to 4.37 in 2021. On the other hand, a remarkable increase in the proportion of the disabled from 1.94 to 2.2 and an increase in female-headed households by 5.5 percent in the same decade, an influential challenge in adaptation (NSO, 2021).

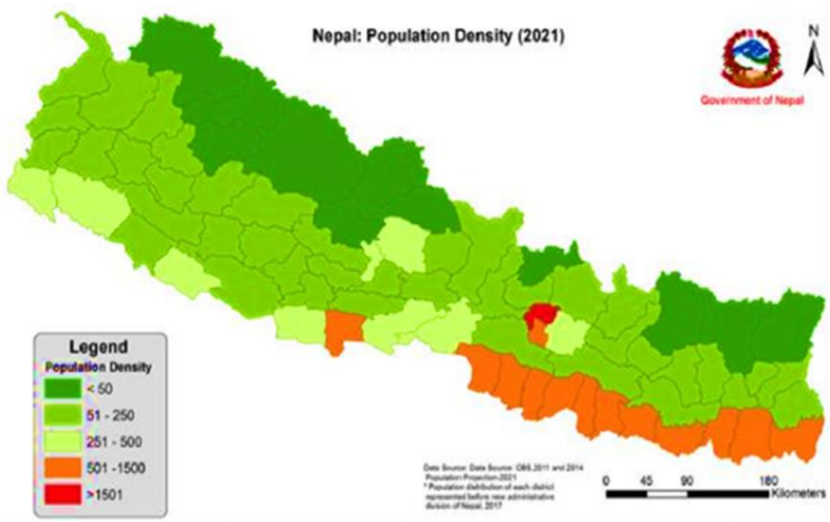

Figure 2: Population density (person/km²) in Nepal

As emphasized in the NAP, the growing population density in urban areas has increased their exposure to climate change vulnerability due to climate-induced hazards such as floods and landslides. These risks are often exacerbated by inadequate urban planning and underdeveloped infrastructure, thus failing to provide basic amenities to the growing urban populations. Moreover, urban environments face additional climate- related challenges, including the intensification of heat through the urban heat island effect, increasing water shortages, and heightened pollution levels. These factors amplify the impacts of climate change, emphasizing the need for resilient infrastructure and comprehensive urban planning to effectively manage the risk.

1.2 Economic Profile

Nepal is experiencing a structural shift in its economy, marked by a declining share of agriculture and a rising contribution from non-agricultural sectors to the GDP (MoF, 2023) (Figure 3). The country's GDP growth rate has been inconsistent over the years, with a significant rise after 2015 followed by a sharp decline during 2019–2020. While the average growth rate across the fourteen periodic plans was 7.4%, it dropped substantially to just 2.6% during the recently concluded fifteenth plan period. Between 2022 and 2026, Nepal is undergoing a transition from a least developed country to a developing nation (NPC, 2024). As of 2024, the country's GDP stands at NPR 5,348.53 billion, with a per capita income of USD 1,433.93 (MoF, 2023).

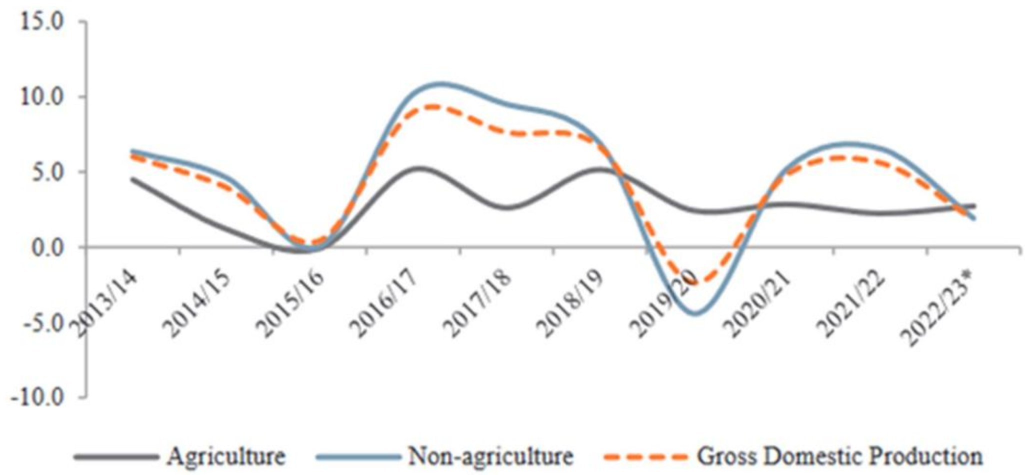

Figure 3: Gross domestic product growth rate in percentage

In 2022, the agriculture sector contributed 24.1% to GDP, and the non-agriculture sector contributed 75.9%. Agriculture remains the primary source of livelihood for a significant portion of Nepal's population, with about 62% of the total population relying on farming (MoF, 2023). Agricultural growth of 2.73% in 2023 was driven by a 6.9% rise in rice production but was limited by a decline in wheat, milk, meat, and eggs.

Meanwhile, non-agriculture growth slowed sharply to 1.92% from 6.56% the previous year, due to industry, construction, and retail trade declines, though other sectors grew. To sustain growth in this sector, Nepal must modernize agriculture through diversification and technology while fostering industrial and service sector expansion through infrastructure investment and productivity improvements.

The proportion of public debt to gross domestic product remained at 42.67% in 2081, slightly declining from 42.9% in 2080 (PDMO, 2024). The import of goods is around 10 times more than the export of the export. However, the trade deficit decreased by one percent in 2081 compared to the previous year, and the balance of payment situation is in surplus (MoF, 2024). Besides, the poverty level has decreased only by 3.5% over the past 10 years in 2024; the population living below the poverty line is 20.3%. Reliance on remittance has also increased, with remittances constituting around 27% of GDP in 2024. One of the income sources of 76.8 percent of households is remittance, and 72.4% of this income is used for daily consumption (NSO, 2024a).

1.3 Sectoral Details

1.3.1 Agriculture and Food Security

The arable land is the basis for Nepal's food security, agriculture's contribution to its GDP, rural employment, exports, and foreign exchange earnings. The agricultural household accounts for 62 percent of the total households of the country (NSO, 2023). The major crops grown in the country are rice, wheat, maize, millets, barley, and potatoes, whereas buffalo, cows, chicken, and pigs are major livestock.

The livestock population over the three years reveals a significantly declining trend (MoALD, 2023). The total livestock population in 2021 was 116,736,478, which declined by 6.2 % in the next year and with an additional decrease of 3.3% by 2023. Cattle, buffaloes, and sheep have experienced a consistent decline, with cattle dropping by 36.4%, buffaloes by 40.3%, and sheep by 36.7%. Similarly, pigs, fowl, milking cows, and milking buffaloes have also shown declines, with milking buffaloes experiencing the sharpest decrease of 47.8%. In contrast, goats have shown a steady increase of 8.2%, while ducks and laying ducks have experienced remarkable growth, increasing by 206.6% and 200.2%, respectively. Laying hens have also grown by 11.9%, following an initial dip. Similarly, with the exceptional increase of milk production of 5.4% and egg production by 7.6%, the meat production declined by 17.4%. Such drastic changes may lead to evolving agricultural practices, economic factors, or environmental challenges influencing livestock management.

Rice is the topmost cereal grown all over the country and a major staple food crop of the country (MoALD, 2023). The total annual production of cereal crops in Nepal displayed a mixed trend over the last three years. Production declined by 3.11% from 11.1 million MT in 2021 to 10.77 million MT in 2022, followed by a slight recovery of 1.31% to reach 10.91 million MT in 2023. This fluctuation highlights the sector's vulnerability to various factors, including climatic and economic challenges. On the other hand, the annual average production of cash crops shows a slight increase of 0.6%.

Nepal remains heavily dependent on agriculture for food security. Despite improvements in the production of major food crops and vegetables over the past decades, approximately 20% of the population still faces some level of food insecurity. While the 2024 Global Hunger Index (GHI) (GHI, 2024) indicates that hunger has reached moderate levels, malnutrition persists, with 24.8% of children under five years of age experiencing stunting. The adaptation gap is evident in Nepal's inability to fully meet domestic food needs, balance market supply and demand, and build resilience against environmental and economic vulnerabilities (WFP, 2022).

As revealed by the NAP report, women engaged in agriculture experience unique challenges from climate change compared to men, largely due to systemic inequalities such as limited access to resources, rights, and decision-making authority. These disparities leave women more vulnerable to climate impacts, exacerbating existing issues like the gender wage gap, restricted access to productive assets, and low labor force participation, despite noted progress. Additionally, Nepal's socio-economic vulnerability is heightened by factors such as geographical isolation, economic limitations, ethnic diversity, caste-based discrimination, and reliance on traditional livelihoods.

1.3.2 Forest, Biodiversity and Wetland

The forest area accounts for approximately 6.4 million hectares, covering 43.38% of its land area, with an additional 0.4 million hectares (2.8%) of other wooded land (FRTC, 2024). The total stem volume of Nepal's forests is estimated at 982.33 million cubic meters, with an average stem volume of 164.76 cubic meters per hectare (DFRS, 2015). Nepal's forests are categorized into ten major groups, including tropical, temperate, subalpine, and alpine scrub ecosystems.

Community-based Forest management in Nepal has been widely acclaimed as the most successful approach for participatory forest management and its governance, with 23,457 community forests managing 2.59 million hectares, contributing significantly to forest conservation and biodiversity protection. Collaborative, leasehold, and religious forests also play roles in ensuring forest resource sustainability and community benefits. During 2001 and 2016, the country experienced significant tree cover loss with notable spatial and temporal variations. This phenomenon is accelerated due to over-reliance on forests for wood fuel, forest invasive species, illegal timber trade, forest fire, and unplanned developmental activities, such as road construction and hydropower projects (MoFE, 2018).

Nepal is rich in biodiversity, hosting over 13,000 plant species across 118 ecosystems, 75 vegetation types, and 35 forest types. This includes 12 global terrestrial eco-regions, with 350 endemic plant species and 14 endemic animal species. Nepal contributes significantly to global biodiversity, harboring 5.2% of mammals, 9.5% of birds, and notable proportions of gymnosperms and bryophytes. Its agricultural biodiversity includes over 550 crop species and 400 horticultural varieties (MoFE, 2018)

Protected areas cover 23.39% of Nepal's land, including 12 national parks, 1 wildlife reserve, 1 hunting reserve and 6 conservation areas, with buffer zones benefiting over 176,000 households. Conservation efforts have increased species populations like the one-horned rhino, Bengal tiger, red panda, and gharial crocodile. Nepal's wetlands, crucial for migratory birds and threatened species, face degradation due to encroachment, pollution, climate change, and invasive species. Biodiversity conservation remains challenging, with 298 species classified as threatened under the IUCN Red List, and domestic breeds like the Siri cattle extinct, and others endangered.

Wetlands of Nepal are diverse and productive ecosystems that cover about 5% of the country's area and support many endemic and endangered wildlife species. Wetlands include natural and artificial wetlands like rivers, lakes, reservoirs, marshes, ponds, and paddy fields. Nepal has 10 wetlands listed as Ramsar sites (Table 2) and has international recognition.

Table 2: List of wetlands listed in Ramsar sites

S. No	Ramsar Sites	Area (Km²)
1.	Koshi Tappu	175
2.	Beeshazari & Associated Lakes	32
3.	Ghodaghodi Lake Area	25.63
4.	Jagadishpur Reservoir	2.25
5.	Gokyo & Associated Lakes	77.7
6.	Gosaikunda & Associated Lakes	10.3
7.	Phoksundo Lake	4.94
8.	Rara Lake	15.83
9.	Mai Pokhari	0.9
10.	Lakes Cluster of Pokhara Valley	261.06
	Total	605.61

Source: MoFE, 2018

1.3.3 Water Resources and Energy

Nepal, known for its abundant water resources with over 6000 rivers, has an average annual runoff of nearly 225 billion cubic meters. Rechargeable groundwater is estimated to range between 5.8 and 11.5 billion cubic meters (MoFE, 2020). The current water usage is approximately 28.8 billion cubic meters for irrigation, 0.5 billion cubic meters for industry, and 0.01 billion cubic meters for the service sector (MoEWRI, 2020).

Water security of Nepal is challenged by climate change, accelerating glacier melting, and expanding glacial lakes, unbalancing the water discharge. In 2020/21, hydropower production decreased by 6.9% due to reduced rainfall and river discharge (NEA, 2020). Future climate projections suggest increased water availability in some areas and reduced availability in others, with dry-season river flows potentially insufficient for hydropower. By 2100, renewable water availability may exceed the threshold for water stress, requiring adaptation strategies that improve water-use efficiency, diversify energy sources, and strengthen water infrastructure resilience (MoFE, 2021a).

The energy landscape in Nepal is primarily characterized by traditional fuels, with firewood, agricultural residues, and cow dung making up a significant 64.17% of total energy consumption. In addition, commercial sources such as coal, petrol, diesel, kerosene, LPG, ATF, and furnace oil account for 28.35%. Meanwhile, renewable energy contributes 2.52%, and grid electricity represents 4.96% of the overall energy mix (WECS, 2024).

Nepal's gross hydropower potential had been estimated at 72,544 MW (WECS, 2019). Nepal currently generates 3450 MW of hydroelectricity with an additional 500 MW under construction, in the solar sector, 800 MW is in pipeline, and 81.9 MW is already connected to the national grid. The total national energy demand from the grid is 48,655 MWh, and the national peak demand is 2,337 MW in 2024 (WECS, 2024). Nepal aims to generate 28500 MW (13500 internal consumption, 15000 export)

by 2035.

The total population with access to the grid network has reached 99 percent (NEA, 2024). The number of connected customers from the national grid reached 5.47 million in FY 2023/24. The government has a strategy to mobilize finance to build large-scale hydropower projects, construct inter-country electricity transmission systems, and engage people, including remittance, for developing hydropower with national importance. Electricity production and infrastructure developments are highlighted in Figure 4.

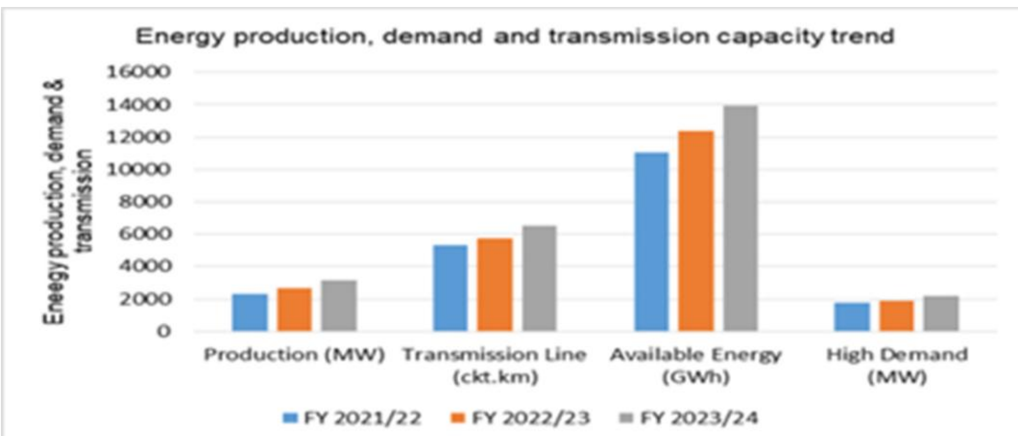

Figure 4: Electricity demand, consumption, production and physical structure

1.3.4 Industry, Transport, and Physical Infrastructures

The industrial sector contributes 13.45% of the national GDP (NRB, 2023). As of September 2024, 9519 industries were registered, including 1,491 large, 2139 medium, and 5,961 small industries. Industrial growth has been geographically uneven, heavily concentrated in Bagmati Province (MOICS, 2024).

The current infrastructure status of Nepal reflects significant progress across various sectors, demonstrating progress in connectivity, energy, urban development, and essential services. Transportation plays a crucial role in connecting Nepal's challenging terrain. Nepal had developed 34,339 km of federal roads, including 18,052 km of blacktopped roads, 7,696 km of gravel roads, and 8,591 km of earthen roads. Provincial and local governments contributed an additional 66,000 km to the road network. Nepal is gradually transitioning towards low-emission transport development pathways. According to the Department of Customs (2023), around 12.38% of all imported private four- and two-wheeler passenger vehicles were electric. In FY 2022/23, 4,232 out of 9,205 imported four-wheelers (46%) and 11,184 out of 115,364 imported two-wheelers (9.6%) were electric vehicles (EVs).

The Detailed Project Report (DPR) for the East-West Railway Network has been finalized, and the Terms of Reference (ToR) for Environmental Impact Assessments (EIA) have been approved section-wise for approximately 170 km; currently, 52 km out of the planned 68 km of the diesel-electric railway is in operation. Out of 54 domestic airports, 35 are operational, with new international airports inaugurated in Bhairahawa and Pokhara, enhancing air connectivity (NPC, 2024).

1.3.5 Tourism, Natural and Cultural Heritage

Nepal's tourism sector is rooted in its natural and cultural heritage, with expanding industries. In 2023, Nepal welcomed 1,014,882 tourists, a 65.05% increase from 2022, contributing $548.2 million. Tourism is a key contributor to the national economy as it is one of the sources of foreign exchange in Nepal. In 2022, foreign currency collections from foreign tourists visiting Nepal, driven by various objectives, increased by a significant 190.0%, reaching a total of Rs. 46.76 billion (MoF, 2023). According to the Nepal Tourism Board in 2023 (MoCTCA, 2024), the tourism industry contributed $2.7 billion to Nepal's GDP. Major attractions included trekking, mountaineering, holiday trips, and pilgrimage, with attractions accessible mainly during favorable weather. The tourism-recreation sector is recognized as a climate-sensitive economic sector. Trekking and mountaineering in Nepal are concentrated in Protected Areas that are at high risk of floods, landslides, glacier melt, avalanches, and GLOFs. Besides, many cultural heritage sites near rivers could be destroyed or heavily damaged by rising river waters, flash floods, and landslides (MoFE, 2021b).

1.3.6 Water, Sanitation, and Hygiene

In Nepal, climate change poses profound impacts on human health and well-being. The risks of vector- borne, waterborne diseases, respiratory infections, undernutrition, and mental illness have escalated. The most vulnerable and disadvantaged communities, such as women, the elderly, children, ethnic minorities, those who are disabled, and those who are destitute and displaced, are disproportionately affected by climate- sensitive diseases (CSDs) and health risks. The Tarai region had the largest concentration of cases of malaria (64%) and kala-azar (94%), whereas the Hill region had the highest concentration of cases of dengue (52%) and scrub typhus (44%) (MoHP, 2022). With rising mean temperature and precipitation, malaria cases are on the rise. Over the past decade, Kala-azar and Malaria cases have increased in Nepal's high mountains and hilly regions.

In Nepal, nearly 98% of households have access to improved drinking water sources. Among these, 86% have drinking water available on their premises, while 14% must fetch water, typically requiring a round trip of 30 minutes or less. About 43% of household members access piped water within their dwelling, yard, or neighbor's premises, while 8% rely on public standpipes and 38% use tube wells or boreholes. The use of improved drinking water sources has significantly increased from 65% in 1996 to 98% in 2022, with the share of households using piped water doubling from 22% in 2011 to 44% in 2022 (MoHP, 2023).

Water availability and quality are impacted by climate change in Nepal. Springs are the primary source of drinking water in the mid-hill region, and spring discharge has declined by 30% over the last 30 years. The increase in temperature also causes melting and thawing of glaciers, snow, and frozen ground, leading to changes in the seasonality of river flows and a reduction in water availability in summer (MoFE, 2021a). Nepal reveals significant progress in improving access to sanitation facilities. By 2022, 92% of the population used improved sanitation facilities, with 27% having facilities within their dwelling and 67% in their yard or plot. This marks a dramatic increase from 3% in 1996 and 83% in 2016. Approximately 73% of the population had access to at least basic sanitation services, while 20% used limited sanitation services.

With rapid urbanization and changing consumption patterns, Nepal faces significant challenges in waste management, particularly in major urban areas. The total waste collection increased significantly from 26,666 metric tons in 2017 to 35,536 metric tons in 2019 (Table 3). A recent baseline survey conducted by the Central Bureau of Statistics, National Planning Commission, shows that the annual average total waste collected per urban municipality amounted to 2231 mt in 2016/17, 2164.4 mt in 2017/18, and 2232.7 mt in 2018/19 (CBS, 2020).

Table 3: Annual average waste collection per municipality by waste types and categories

S.N.	Waste Type	Year	Metropolitan City (mt/Year)	Sub-Metropolitan City (mt/Year)	Municipality (mt/Year)	Annual Average of Municipalities (mt/Year/ Municipality)	Daily Average of Municipalities (mt/Day/ Municipality)
1	Organic	2016	12,734.0	2,269.8	829.8	1,153.3	3.2
		2017	13,478.0	3,044.2	950.0	1,214.6	3.3
		2018	10,669.5	4,088.2	824.2	1,206.1	3.3
2	Inorganic	2016	8,787.0	1,005.7	518.3	698.0	1.9
		2017	9,725.0	1,338.7	504.6	666.8	1.8
		2018	7,100.0	1,525.9	551.9	743.5	2.0
3	Other	2016	5,145.0	213.5	155.6	283.0	0.8
		2017	6,200.0	229.7	177.5	283.0	0.8
		2018	6,200.0	229.7	177.5	283.0	0.8

4	Total	2016	26,666.0	3,503.5	1,543.0	2,231.0	6.1
		2017	28,469.5	4,596.3	1,610.2	2,164.4	5.9
		2018	23,969.5	5,843.7	1,553.6	2,232.7	6.1

Source: CBS, 2020

1.3.7 Disaster Risk Reduction and Management

From extreme heatwaves, cold waves, drought, GLOF, floods, landslides, and thunderstorms, Nepal is already facing severe climate change impacts, causing widespread 'loss and damage' with tragic implications for affected communities in Nepal. The devastating impacts of the climate crisis are most dramatically and tragically demonstrated by the recent extreme climate events that took the lives and livelihoods of all three regions: mountain, hill, and plain land.

Floods, landslides, epidemics, and fires are the major climate-related disasters in Nepal. A hazard-wise comparison of the deaths, affected population, and economic losses shows that epidemics caused the most deaths (52.8%), followed by landslides (16.7%) and floods (12.7%). Floods affected about 71%, followed by landslides (9.5%) and epidemics (8.2%). Fires caused the most economic losses (56.6%), followed by floods (31%) and landslides (3.7%) (MoHA, 2018).

Based on the available data on losses and damage from different climate-induced disastrous events between 1971 and 2019, about 647 people on average die from climate-induced disasters in Nepal each year. A devastating cloudburst in Dodhara Chandani, Kanchanpur, marked the highest recorded rainfall of 624mm in 24 hours to date in the history of Nepal. Continuous rainfall from July 3, 2024, led to severe flooding, inundations, landslides, and thunderbolts across the country, particularly impacting Sudurpaschim Province. Nepal has developed various strategies and policies; however, the primary emphasis remains on disaster response activities (NDRRMA, 2024).

1.3.8 Gender Equality and Social Inclusion, Livelihoods and Governance

Nepal's Gender Development Index (GDI) value increased from 0.75 in 1995 to 0.885 in 2022 (UNDP, 2023) (Figure 5), reflecting an 18% rise over 25 years with an average annual growth rate of 0.75%. The most notable progress occurred between 1995 and 2015, while the trend leveled off or slightly declined after 2015. The higher GDI values during earlier years were attributed mainly to greater participation of women in education. Assuming the same annual growth rate of 0.75% continues, the GDI is projected to reach 0.92 by 2025 and 0.96 by 2030. This improvement suggests that gender disparities may be reduced further (UNDP, 2020).

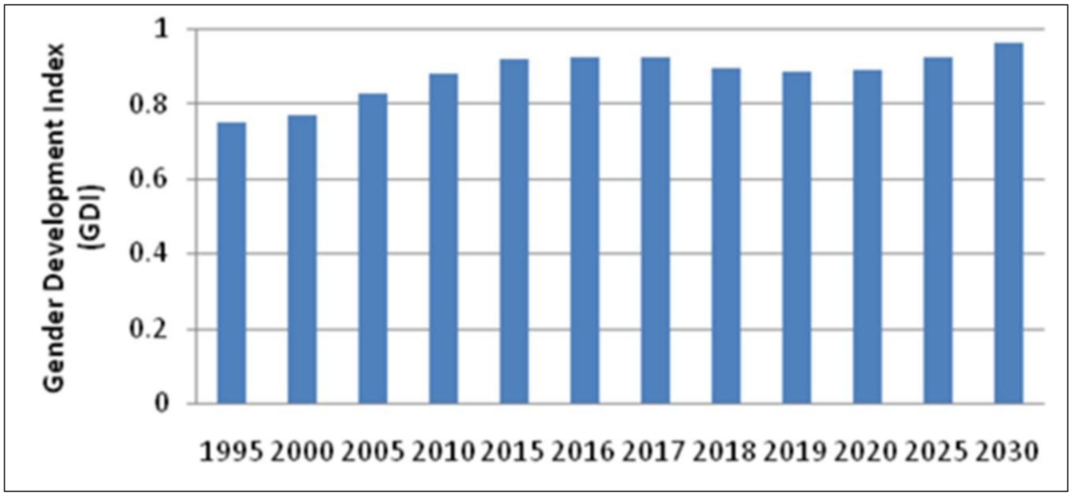

Figure 3: Trend and projection of gender development index (GDI) of Nepal

Nepal's Constitution ensures gender equality, granting women equal lineage rights and protecting LGBTQI individuals against discrimination. Seven-line ministries are implementing Gender Equality and Social Inclusion (GESI) policies to address gender-based violence (GBV) and promote inclusivity. GBV remains prevalent in various forms, influenced by cultural norms, with women disproportionately burdened by unpaid household work and time poverty. Women's ownership of land or property is limited to 19.71%, with urban areas showing slightly higher rates than rural regions. The gender wage gap is 29.5%, with women's labor force participation at 26.3%, compared to 53.8% for men (UNDP, 2023).

Despite representing 73% of the agricultural workforce due to male out-migration, women lack equitable access to resources like land, water, and training, making them vulnerable to climate shocks. Legislative measures, including constitutional quotas, have increased women's political representation to 33% at the federal and provincial levels, while ensuring rights for marginalized groups. However, intersectional factors such as caste and ethnicity continue to amplify vulnerabilities for rural and marginalized women. (MoFE, 2021c).

1.4 Climate Change Awareness Gaps in Nepal

As per the National Climate Change Survey 2022, among all households, only 35.8% were aware of climate change, while a significantly high proportion remained unaware across all three geographical regions. The Mountain region had the highest unawareness rate at 70.9%. Gender-wise, 61.3% of men and 74.0% of women were unaware of climate change impacts, highlighting the need for greater awareness efforts, particularly for women. Awareness levels also varied by location, with urban households (42.8%) being more informed than rural households 26.3% (NSO, 2024). Among ecological zones, households in the Hilly region (37.4%) were more aware than those in the Tarai (35.3%) and the Mountain regions.

1.5 Climate Change Profile

The impact of climate change is already a reality in Nepal. Ranging from the national economy to several other sectors like agriculture, livelihood, forest, and physical infrastructure, Nepal is already at the forefront of severe climate impacts, according to the climate change vulnerability and risk assessment report (2021). The average annual economic loss is about 0.08 percent of the FY2018/19 GDP (at the current price). Nepal's most devastating climate-induced disasters are floods, landslides, epidemics, and fires. Similarly, the policy recognized that increasing access to climate finance while establishing Nepal's climate change- related specialized issues as a common voice of countries at risk of climate change in an international forum is equally challenging.

For the detailed climate change profile, including trend projection, risk, and vulnerability, refer to chapter 5**, "Information Related to Climate Change Impact and Adaptation under Article 7 of the Paris Agreement."**

1.6 Legal and Institutional Arrangements

1.6.1 Legal, Policy Frameworks, and Regulations

Nepal has undertaken several policy initiatives and established institutional mechanisms to integrate climate change into development processes and adapt to its impacts. Nepal's constitution (2015) enshrines the right to a clean and healthy environment as a fundamental right, forming the basis for the country's commitment to addressing climate change. The Local Government Operation Act (2017) stipulates that Municipalities and Rural Municipalities are responsible for adopting low- carbon and environmentally friendly development practices. Specifically, Chapter 3, Article 11 of the Act outlines their authority to:

- Protect and manage various types of forests (community, rural, urban, religious, leasehold, and collaborative).
- Manage buffer zone forests, promote private forests, and carry out afforestation on open lands.
- Manage forest nurseries and promote local greenery.

Consequently, significant aspects of climate change policies and interventions are now managed at the provincial and local levels, with governments developing relevant policies, acts, guidelines, and laws at all tiers. Since federalization in 2015, Nepal has expanded its climate change coordination mechanisms to include sub-national levels, ensuring effective coordination among various organizations and functions. Several national policies have been developed to prioritize adaptation (Table 4).

Table 4: Major policy highlights for climate change adaptation and mitigation

Key policies, strategies, and regulations	Highlights

National Adaptation Programme of Action (NAPA), 2010	Identified nine priority adaptation programs across six sectors, setting a comprehensive response to climate change.
National Framework for Local Adaptation Plans for Action (LAPA), 2011	Provides a framework to integrate climate adaptation into local and national planning, emphasizing bottom-up, inclusive approaches
Climate Resilient Planning Tool, 2011	Developed by the National Planning Commission (NPC) to guide climate-resilient development planning.
Nepal Development Vision 2030, 2011	Emphasizes low-carbon development and the need for climate-resilient planning.
Climate Change Health Adaptation Strategies and Action Plans (2016-2020)	Focuses on public awareness, managing climate-related health risks, and protecting human health.
National Forest Policy 2019	Promotes sustainable forest management and equitable distribution of forest resources.
National Climate Change Policy 2019	Aims to build a climate-resilient society with sectoral and inter-thematic strategies.
National Environment Policy 2019	Ensures a clean environment through pollution control, waste management, and greenery promotion.
Environment Protection Act 2019	Consolidates environmental protection laws to safeguard the right to a clean environment.
Environment Protection Rules 2020	Covers pollution control, waste management, biodiversity conservation and environment impact assessment.
Sixteenth Five-Year Plan	Identifies climate change as a cross-cutting sector with objectives for mitigation, adaptation, and finance mobilization.
Second Nationally Determined Contribution 2020	Sets targets for a climate-resilient society and long-term low GHG emissions strategy.
NAP 2021-2050	Developed through a multi-stakeholder partnership, ensuring that decisions have been informed, socio-politically inclusive, transparent, and gender responsive. Emphasizing national ownership and building on the experiences of the NAPA, the NAP has been designed using a thematic working group approach aligned with the 8 thematic and 4 cross-cutting sectors identified in the NCCP 2019. It is recognized as an effective and successful model in

adaptation planning.

1.7 Institutional Coordination Mechanisms

1.7.1 Climate Change Coordination Mechanisms at the Federal Level

National Council on Environment Protection and Climate Change Management (NCEPCCM): Established by the Environment Protection Act (2019, Article 32), this council is chaired by the Prime Minister and includes four ministers, seven chief ministers (one from each province), a member of the National Planning Commission (NPC), two professors, three experts, and the Secretary of the Ministry of Forests and Environment. The NCEPCCM oversees the integration of environmental and climate change matters into long-term policies, provides policy guidance to provincial and local levels, and manages resources for these areas (Article 34 (1a, 1c, 1d).

Inter-Ministerial Climate Change Coordination Committee (IMCCCC): Established by the MoFE, this committee is chaired by the MoFE Secretary. Its members include Joint Secretaries from 22 federal ministries, the NPC, and representatives from the Nepal Academy of Science and Technology (NAST), the National Agriculture Research Council (NARC), and the Alternative Energy Promotion Centre (AEPC). Additional members may be invited at the discretion of the MoFE Secretary.

1.7.2 Climate Change Coordination Mechanisms at the Provincial Level

Provincial Climate Change Coordination Committees (PCCCCs): Each of the seven provinces has a PCCCC composed of provincial government agencies, civil society representatives, and local government officials. The Secretary of the Provincial Ministry, which is related to Forests and Environment, chairs these committees.

These mechanisms primarily function as horizontal coordination bodies. For vertical coordination, the Constitution mandates that the three levels of government operate on the principles of "cooperation, co-

existence, and coordination." The Office of the Prime Minister and Council of Ministers (OPMCM) and the Ministry of Federal Affairs and General Administration (MoFAGA) facilitate communication from the federal level to sub-national agencies. For Functional coordination, NAST, AEPC, and NAARC are part of IMCCCC.

1.7.3 Climate Change Coordination Mechanism at the Local level

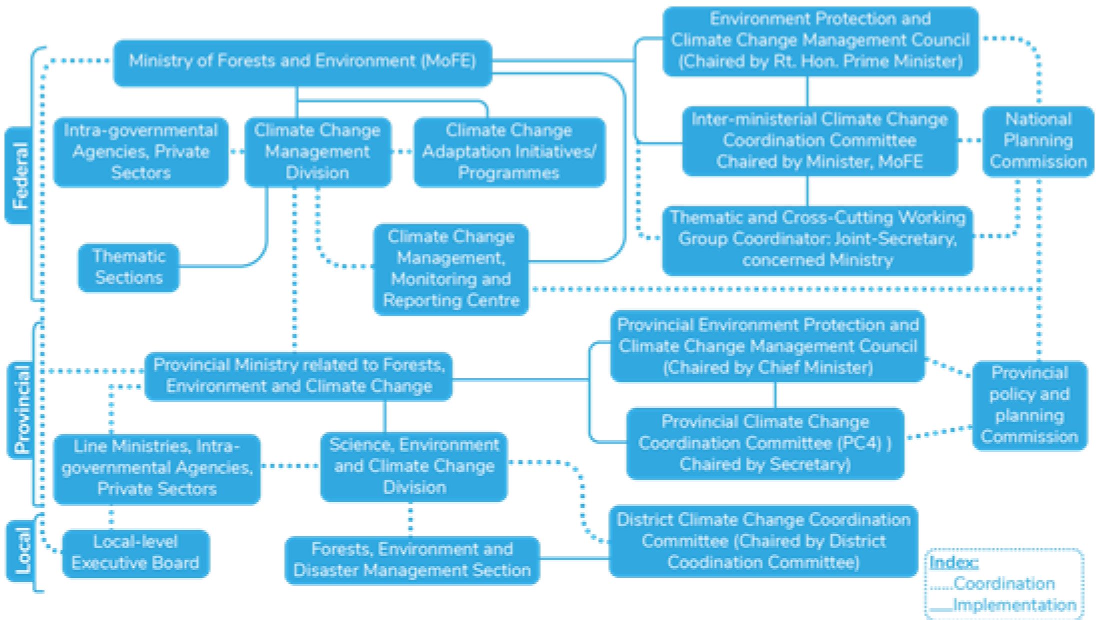

Figure 4: Climate change coordination mechanisms in Nepal (Source: GoN 2021-2050, NAP Report)

Forest, Environment and Disaster Management Section: This unit facilitates climate change activities, including adaptation, monitoring, evaluation of adaptation action, raising public awareness on adaptation, and implementing adaptation projects in areas under local jurisdiction. The institutional arrangement for the NAP implementation among the three tiers of government is presented in Figure 4.

1.8 Capacity Building and Support

To monitor NDC implementation and meet the Enhanced Transparency Framework (ETF) requirements under the Paris Agreement, Nepal is developing a national MRV system and strengthening institutional capacities. Through the GEF-CBIT project, efforts are underway to establish ETF mechanisms within line ministries, sectoral agencies, and provincial governments. The proposed MRV system will enable these entities to effectively track and report climate actions, including (a) mitigation measures and GHG inventories, (b) adaptation efforts and national vulnerabilities, (c) technology transfer and technical support for mitigation and adaptation, and (d) international climate finance received, and domestic finance mobilized for climate actions.

1.9 Climate Finance

Nepal has systematically tracked climate-related expenditures within its annual budgets since 2013/14 through the Climate Change Budget Code (CCBC). This initiative identifies, allocates, and monitors government spending on climate-responsive programs. The trend of climate budget allocation highlights

2 National Greenhouse Gas Inventory

Nepal is highly vulnerable to climate change despite its negligible contribution to global greenhouse gas (GHG) emissions. The country's diverse topography and fragile ecosystems make it susceptible to the impacts of rising temperatures and changing precipitation patterns. The agriculture sector, which employs a significant portion of the population, is particularly at risk, with potential consequences for food security. Additionally, Nepal's water resources, including glacial meltwater, are threatened, impacting hydropower generation and water availability. Nepal's Third National Communication to the UNFCCC and its Second NDC highlight these vulnerabilities and outline the country's efforts to mitigate climate change and adapt to its impacts.

GHG emissions from Nepal's energy sector arise from stationary sources, such as manufacturing and residential activities, and mobile sources like road transport and aviation. Nepal's energy sector is a major source of emissions.

The IPPU sector in Nepal is an emerging source of emissions, driven by the growth in industrial activities such as cement production and the use of synthetic gases. Emissions from IPPU have been increasing as industrialization expands, and Nepal's contribution is expected to grow if mitigation strategies are not implemented.

In Nepal, the livestock sector is one of the major sources of GHG emissions, specifically methane (CH4) from enteric fermentation that occurs in ruminant animals (i.e., cattle, buffalo, goat, sheep), which are the primary CH4 producers. The emissions from the livestock sector have been increasing, driven by the increasing livestock population.

Nepal's predominantly agrarian economy contributes significantly to its national GHG emissions. The crop subsector of agriculture in Nepal is an important growing source of emissions, driven by the growth of agricultural activities such as intensive farming, increased use of chemical fertilizers, especially urea, and the increasing flooded rice farming due to irrigation facilities being developed steadily (GoN, 2019). Emissions from this sector have been increasing as chemical-intensive and commercial farming systems are on the rise, and their contribution to the country's total GHG is expected to grow if mitigation strategies are not implemented (Ritchie, 2019).

In Nepal, household, commercial, institutional, and industrial waste generation is the main driver of the country's waste sector, a growing source of emissions. As cities grow, emissions from the waste sector have been rising, and if mitigating measures are not put in place, Nepal's contribution is predicted to increase in the future.

2.1 Brief Overview of Nepal's National Communications on GHG

The estimation of GHG emissions in Nepal began in 1994, and the first national GHG inventory report (with 1990 as the base year) was published in 1997 by the Department of Hydrology and Meteorology (DHM) under the USAID implemented program from 1994 and 1997. The first officially submitted GHG inventory (with base year 1994) was prepared by the Climate Change Study Group and reported in Nepal's Initial National Communication (INC). Nepal's Second National

Communication (SNC) was prepared by the Ministry of Population and Environment (MoPE), and it included the national GHG inventory with 2000/01 as the base year and was submitted in 2014. Third National Communication (TNC) prepared by the Ministry of Forest and Environment included the national GHG for the base year 2011 and was submitted in 2021.

2.1.1 National Institutional Arrangements on GHG Inventory System

The Ministry of Forests and Environment (MoFE) serve as the national focal point for GHG inventory management in Nepal, ensuring the development, archiving, and submission of the National GHG Inventory to the UNFCCC. The preparation of the GHG inventory for the period 2012-2022 and recalculation of the GHG inventory for the period 1994-2011 was led by MoFE through support from external consultants. The technical workgroup for the preparation of the GHG inventory consisted of experts in Energy, IPPU, Agriculture, Livestock, FOLU, and Waste sectors. Required data were collected from various sources, including literature, line ministries, government entities, private sectors, and associations. Some key sectoral line ministries that coordinated in providing data include the Ministry of Industry, Commerce, and Supplies (MoICS); the Ministry of Agriculture and Livestock Development (MoALD); the Ministry of Federal Affairs and Local Development (MoFAGA); and the Ministry of Energy Water Resources, and Irrigation (MoEWRI). These institutions play a critical role in coordinating with related organizations and other stakeholders to gather relevant activity data and emission factors.

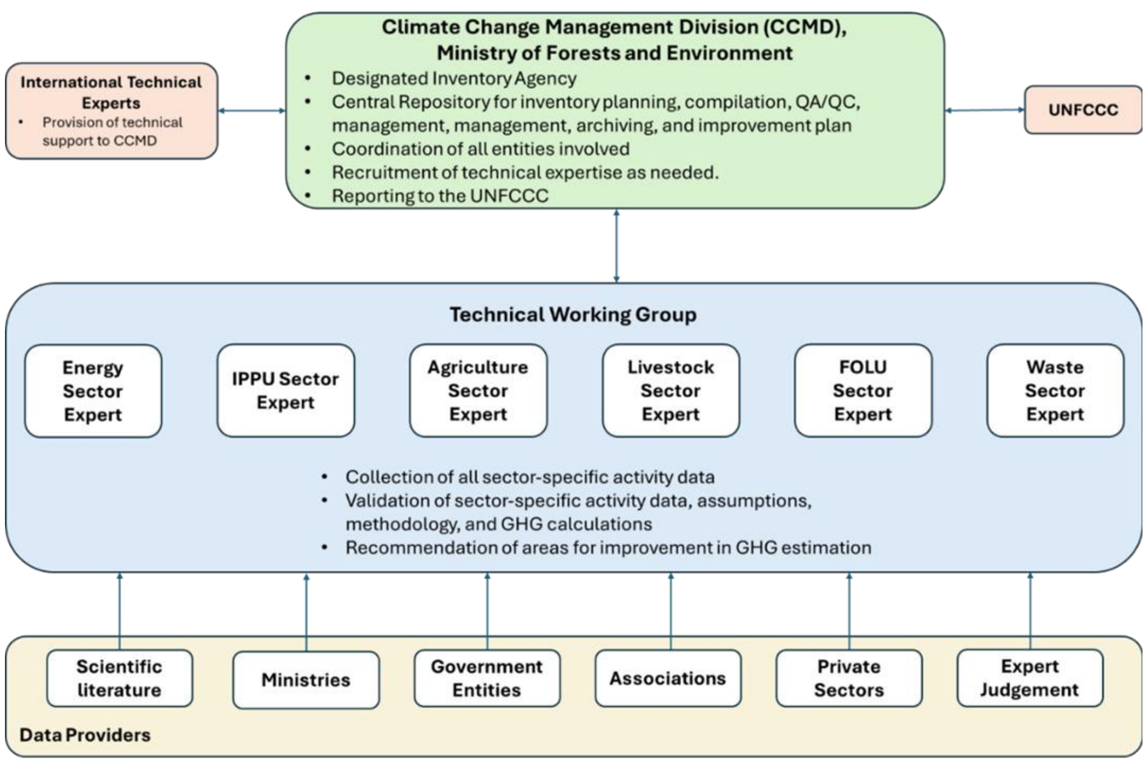

Figure 5: Institutional arrangements for Nepal's national inventory preparation

2.1.2 National Focal Point

The CCMD, MoFE is responsible for overall coordination, quality assurance, and oversight of GHG inventory processes, particularly working with stakeholders from relevant line industries, state-owned enterprises, development partners, industries, trade associations, academic institutions, local governments and private sector to gather and validate data for the preparation of national GHG inventory. Through multi- sectoral coordination and leveraging national and international partnerships, MoFE ensures the integrity and reliability of Nepal's GHG inventory, contributing to evidence-based policy-making and global climate action.

2.1.3 Inventory Preparatory Process

The preparation of the GHG inventory is led by MoFE. The MoFE prepares the inventory with the support from an external working group. The working group comprises team leaders and sectoral experts in energy, IPPU, agriculture, livestock, forestry, and other land use (FOLU) and waste sectors. This process is conducted in alignment with the IPCC 2006 Guidelines for National Greenhouse Gas Inventories, ensuring accurate and consistent estimation of emissions. Data sources include various line ministries, state-owned enterprises, local government, private sector, etc., and the use of emission factors specified by the IPCC or derived from national circumstances.

2.1.4 Overview of Inventory Planning

The GHG inventory for Nepal is developed through a structured planning process, which includes the identification of key emission sources. It also defines specific data collection methodologies and verification processes in line with the IPCC 2006 Guidelines. The planning process ensures that data collection is comprehensive, with relevant stakeholders engaged to ensure the accuracy of activity data and emission factors. Verification steps are built into the process to minimize uncertainties and maintain consistency with international reporting standards, such as the UNFCCC requirements.

2.1.5 Data Collection Process

Nepal currently lacks robust institutional arrangements for systematic data collection in preparation for the GHG inventory, and the process continues to be conducted on an ad-hoc basis. However, steps are being taken to improve and move towards an operational MRV with the support of the CBIT project. This will help Nepal to prepare a comprehensive document in the next cycle. The data collection process in the national inventory preparation is led by the sectoral experts. The sectoral experts identify the potential sources of data by scoping the categories, sub-categories, and types of GHGs. The data is requested from relevant line ministries, government divisions, state-owned enterprises, local government, and the private sector.

2.1.6 Archiving GHG Information

Nepal is currently working to maintain a centralized, secure, and comprehensive archive of GHG data to ensure long-term data integrity, transparency, and ease of verification. The archive will contain detailed records of emissions from each IPCC sector, including raw activity data, calculation sheets, emission factors used, and methodological documentation following the IPCC 2006 Guidelines. This archival system will ensure that all input data, intermediate calculations, and results are readily available for future review, recalculations, and verification audits. The GHG data archive will be managed by the Ministry of Forests and Environment (MoFE) and will be regularly updated with annual submissions from key sectors. Data storage will follow strict QA/QC protocols, with a digital backup system to prevent data loss.

2.2 Brief General Description of Methodologies and Data Processing

2.2.1 Use of 2006 IPCC Guidelines and It's Refinement in 2019

The 2006 IPCC Guidelines for National Greenhouse Gas Inventories, supplemented by the 2019 Refinement, serve as the primary methodological framework for estimating GHG emissions. These guidelines provide a tiered approach, allowing for the use of default (Tier 1) emission factors where sector-specific data is unavailable, and more detailed (Tier 2 and Tier 3) methods where higher accuracy is required or where measured data exists.

Both sets of guidelines provide detailed instructions on how to calculate emissions based on activity data, such as production volumes, raw material usage, and chemical reactions occurring within industrial processes. The methodology also includes recommendations for selecting appropriate data sources, managing uncertainties, and conducting recalculations when new or better data becomes available. Nepal adheres to these guidelines to ensure consistency with international reporting standards, using the most accurate data and methodologies applicable to the national context.

2.2.2 Decision Tree and Good Practices Method

The decision tree approach outlined in the 2006 IPCC Guidelines assists in selecting the most appropriate tier for calculating emissions based on data availability and the significance of emission sources. Nepal primarily employs Tier 1 methodologies for all sectors, which rely on default emission factors provided by the IPCC and national-level activity data, such as production volumes from industries like cement, lime, and metal production.

In cases where more detailed data is available, the decision tree guides moving to higher tiers (Tier 2 or Tier 3), which incorporate country-specific emission factors or direct measurements to improve the accuracy of GHG estimates.

Good practices, as defined by the IPCC, are strictly followed to ensure transparency, consistency, comparability, completeness, and accuracy (TCCCA) in data collection and reporting. This includes maintaining clear documentation of all data sources, assumptions, and methods used in the inventory. Nepal ensures that all activity data and emission factors are transparently reported, with clear references to industrial surveys, national databases, and international sources. Consistency is maintained across time series, allowing for accurate trend analysis. Comparability with international reporting standards is ensured by adhering to IPCC guidelines, and efforts are made to minimize uncertainties through quality assurance (QA) and quality control (QC) procedures.

2.3 Description of QA/QC Plan and Implementation

Verification is a crucial step in creating accurate and reliable greenhouse gas (GHG) inventories in Nepal. It ensures that the inventory meets high standards of quality, including transparency, consistency, comparability, completeness, and accuracy. This verification process is designed to be practical, cost-effective, and part of an ongoing effort to continually improve the inventory.

Verification involves a series of activities and procedures implemented throughout the entire lifecycle of the GHG inventory, from planning and development to its final use. To achieve this, a Quality Control and Quality Assurance (QA/QC) Plan is established and followed.

The QA/QC Procedures are illustrated in Figure 2. All QA/QC activities are conducted under the responsibility of the Climate Change Coordinator within the Climate Change Management Division under the Ministry of Forest and Environment. These activities are carried out by Sectoral Experts who are responsible for developing the inventory, in collaboration with the national and international technical experts who are responsible for quality assurance.

The sectoral leads are responsible for the QA/QC of the activity data and GHG estimation at the sectoral level. Activity data is collected under the supervision of sectoral experts. QC of activity data is either done by a Sectoral expert or an assistant under the supervision of a Sectoral expert. The final set of activity data is reviewed by the sectoral expert for QA.

The Sectoral experts are responsible for the estimates of GHG and the QC of the estimates. The GHG estimates at the sectoral level are verified by using the IPCC inventory software, which further assures the quality of the inventory calculated. Following the QA at the sectoral level, the Inventory Team Leader, in collaboration with the sectoral experts, prepares the national GHG inventory along with the National Inventory Report (NIR).

The national GHG inventory and NIR are verified by external reviews for QA. The external reviewers are national and international experts (including experts from UNFCCC) who are not involved in the national GHG preparation process. Following the feedback from external reviewers, the final national inventory is prepared under the leadership of the Team Leader. The final stage of the QA/QC procedure is the final validation workshop, which is considered the final QA, organized by the Climate Change Management Division.

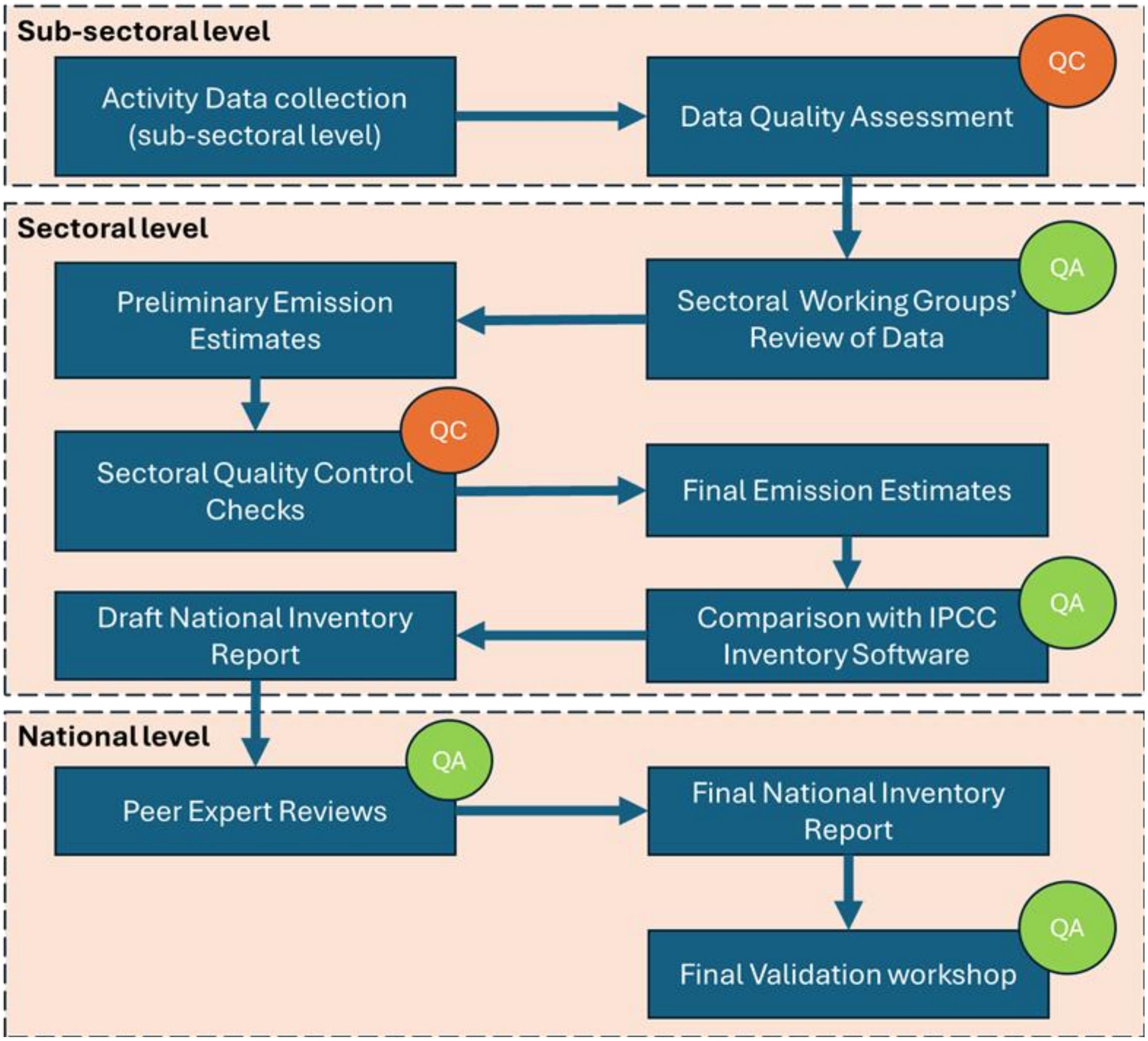

Figure 6: QA/QC procedures

Quality control procedures were conducted at different stages of GHG inventory preparation. The following quality control procedures were conducted for all sectors:

- Verification of the activity data received for mechanical errors.
- Verification of the entered data for mechanical errors.
- Verification of calculations to fill activity data gaps using mathematical methods.
- Verification of the entry of emission units, parameters, or conversion factors.
- Verification of greenhouse gas emission calculations.
- Verification of consistency of input and calculations in time series in changing method, emission factors/other parameters, or data.
- Verification of the correctness of entering formulas, calculations, etc., in modified worksheets according to national worksheet conditions.
- Verification of calculations in the development of national factors.

- Verification of emission source documentation (suppositions, assumptions, and criteria for selection of calculation methods, activity data, emission factors, and other multipliers).
- Verification of all references related to data and factors.
- Cross verification of data.

The inventory preparation process also includes quality assurance at various stages as shown in the QA/QC procedure diagram. The QA process includes the verification of the following at various stages:

- calculation method.
- activity data.
- factors and other parameters.
- emission data.
- Information on quality control conducted

2.4 Brief Description of Key Category of GHG Inventory

The national greenhouse gas (GHG) inventory utilized the IPCC Tier 1 methodology to analyses key categories, focusing on both the level and trend of emissions, as outlined in the 2006 IPCC Guidelines for National Greenhouse Gas Inventories. A key category is one that has a significant impact on the overall inventory, either through its absolute contribution to emissions or removals each year, or by influencing the trend of emissions over time. Identifying these categories is essential for prioritizing resources, refining estimation methodologies, and directing data collection efforts to improve the accuracy and completeness of the inventory.

Key source analysis identifies categories that cumulatively contribute 95% of total emissions, using two main criteria:

- Level Assessment: Categories that contribute significantly to the absolute level of emissions or removals in a particular year.
- Trend Assessment: Categories that have a substantial impact on the trend of emissions or removals over time, highlighting changes in emissions patterns.

The categories are ranked by their percentage contribution to total national emissions or trends, in descending order. This ranking enables the identification of both high-emission categories and those that exhibit rapid changes, facilitating targeted prioritization.

Key observations from the analysis include:

- Forest land remaining forest land (3.B.1.a) has shown a negative emission trend, indicating carbon sequestration. However, it still contributed 19.87% to the trend, reflecting the importance of sustainable forest management in mitigating GHG emissions.
- Settlements remaining settlements (3.B.5.a) also contributed significantly with a negative emission trend of 16.86% share.

- Enteric fermentation (3.A.1) remains a significant contributor to GHG emissions. Enteric fermentation accounted for 9.77% of the emissions trend, reflecting the impact of livestock on methane emissions.
- Moderate contributions were observed from cropland remaining cropland (3.B.2.a) and grassland remaining grassland (3.B.3.a), with 9.32% and 6.67% shares, respectively. These reflect the effects of agricultural intensification on CO2 emissions.
- Cement production (2.A.1) has become a notable source of CO2 emissions, contributing an
- 8.6% share to the trend. This reflects the rapid growth of industrial activities and infrastructure development.
- Fossil Fuels in Manufacturing: Emissions from manufacturing industries and construction using solid fuels (1.A.2) have increased, contributing 7.57% to the emissions trend. This highlights the growing reliance on fossil fuels in industrial energy consumption.
- Road transportation (1.A.3.b) has also seen a rise in emissions, contributing 4.04% to the trend. This indicates the increasing use of liquid fuels in the transportation sector, driven by urbanization and economic activity.
- The "Other Sectors - Biomass (Solid Fuels)" category (1.A.4) shows significant emissions, contributing 2.80% to the emissions trend. This indicates the ongoing reliance on traditional biomass for energy in rural regions.
- Rice cultivation (3.C.7) contributed moderately, with a 1.96% share, indicating the ongoing influence of agricultural practices on methane emissions.
- Solid waste disposal (4.A) and wastewater treatment and discharge (4.D) have contributed to GHG emissions, with 1.98% and 1.94% shares, respectively. These emissions are linked to urbanization and population growth, which have increased waste generation and the need for wastewater treatment.

The key category analysis highlights the continued dominance of agricultural activities in Nepal's GHG emissions, particularly from enteric fermentation and rice cultivation. Industrial growth, especially in cement production and manufacturing, has become a significant driver of CO2 emissions. The reliance on traditional biomass and fossil fuels in rural and industrial sectors, respectively, remains a challenge. Additionally, emissions from transportation, waste management, and agricultural intensification are on the rise, reflecting broader economic and demographic changes. Sustainable practices in agriculture, industry, and waste management will be critical to mitigating future emissions.

The detailed results of the key source analysis, along with the associated calculations, are presented in BTR1 Annex

III. These findings offer a comprehensive overview of the key categories in the national GHG inventory and their contributions to overall emissions trends. This analysis will inform strategic interventions, optimize resource allocation, and enhance future inventory processes, supporting the development of effective climate policies.

2.5 General Uncertainty Assessment

Uncertainty assessments play a pivotal role in enhancing the accuracy and reliability of the national greenhouse gas (GHG) inventory. These assessments are designed to identify the most significant sources of uncertainty within the inventory, allowing for a focused approach to data collection and guiding the selection of more precise estimation methodologies. Such efforts aim to improve the robustness of reported emissions and removals and to build confidence in the inventory results.

Uncertainty evaluations were conducted for all sectors and categories included in the inventory, following the IPCC Tier 1 methodology. Calculations were performed using a 95% confidence interval to quantify the range of potential variations in reported values. The primary drivers of uncertainty in GHG emissions are attributed to the variability and reliability of two key components: activity data and emission factors. These factors are influenced by data quality, availability, and representativeness for the specific inventory conditions.

The combined uncertainty of the national GHG inventory was estimated for two key years: the base year 2012 and the end year 2022. The overall combined uncertainty was determined to be 78.371%. Among the categories assessed, the highest uncertainty was recorded for 3.C.5 - Indirect N2O Emissions from Managed Soils, at an exceptionally high 515.28%. This indicates substantial variability in either the activity data, emission factors, or both for this category. Conversely, the lowest combined uncertainty was observed for

1.A.3.a.i – International Aviation, 1.A.3.a.ii. – Domestic Aviation and 2.F.1.a – Refrigeration and Stationary Air Conditioning, at a much lower value of 5%.

The outcomes of these uncertainty assessments are crucial for identifying areas where targeted improvements can yield significant benefits. For categories that exert the greatest influence on overall inventory uncertainty, priority actions include the adoption of higher-tier GHG emission estimation methodologies, which are typically more detailed and precise. Additionally, efforts will focus on the refinement and enhancement of activity data, including increasing the frequency, accuracy, and geographic coverage of data collection.

The detailed uncertainty calculations, encompassing both the overall inventory and individual sectors, are documented in BTR1 Annex IV. These results not only provide transparency in the reporting process but also serve as a roadmap for strategic improvements in future GHG inventories. By addressing the identified uncertainties systematically, the accuracy of national GHG estimates can be significantly improved, aligning with international best practices and reporting standards.

2.6 National Inventory for 2022

Nepal's total net GHG emissions amount to 38,211.96 Gg CO2-eq, with the largest contributions from the energy sector (65.4%) and industrial processes and product use (IPPU), 12.6%. Emissions from agriculture, forestry, and other land use (AFOLU) make up to 9.4% and the waste sector contributes 12.6%. The energy sector, driven by fuel combustion, is the largest emitter, reflecting Nepal's growing reliance on fossil fuels. IPPU emissions primarily come from the mineral industry, driven by industrial growth. AFOLU is a mixed contributor, with high methane (CH4) and nitrous oxide (N2O) emissions from livestock and cropland, but it also offsets a large share of emissions through significant carbon dioxide (CO2) removals from forests (20,021.96 Gg CO2). The waste sector's emissions stem mainly from wastewater treatment and solid waste disposal, highlighting inefficiencies in waste management. While Nepal benefits from natural carbon sinks in its forestry sector, rising emissions from energy and industrial sectors point to the need for renewable energy adoption, sustainable land-use practices, and improved waste management. The overall emission from each sector is given in Table 5.

Table 5: National Inventory of GHGs in Nepal in 2022

Inventory Year: 2022	**Emissions (Gg)**				**Net GHG Emissions**
Categories	**Net CO_2**	**CH_4**	**N_2O**	**HFC**	**(Gg CO_2 -eq)**
Total National Emissions and Removals	**- 1,474.073**	**1,235.852**	**19.115**	**0.012848**	**38,211.96**
1 - Energy	13,567.620	383.423	2.682	-	25,014.290
1.A - Fuel Combustion Activities	13,567.620	383.423	2.682	-	25,014.290
1.A.1 - Energy Industries	0.023	0.000	0.000		0.023
1.A.2 - Manufacturing Industries and Construction	6,999.824	2.157	0.301		7,140.070
1.A.3 - Transport	4,629.203	0.861	0.410		4,761.971
1.A.4 - Other Sectors	1,938.570	380.405	1.971		13,112.227
2 - Industrial Processes and Product Use	4,794.891	-	-	0.012848	4,811.594
2.A - Mineral Industry	4,792.239	-	-	-	4,792.239
2.A.1 - Cement production	4,792.239				4,792.239
2.D - Non-Energy Products from Fuels and Solvent Use	2.652	-	-	-	2.652
2.D.1 - Lubricant Use	1.900				1.900

2.D.2 - Paraffin Wax Use	0.752				0.752
2.F - Product Uses as Substitutes for Ozone Depleting Substances	-	-	-	0.012848	16.703
2.F.1 - Refrigeration and Air Conditioning				0.012848	16.703
3 - Agriculture, Forestry, and Other Land Use	- 19,916.207	733.118	11.172	-	3,571.787
Inventory Year: 2022	**Emissions (Gg)**				**Net GHG Emissions**
Categories	**Net CO_2**	**CH_4**	**N_2O**	**HFC**	**(Gg CO_2 -eq)**
3.A - Livestock	-	649.999	1.976	-	18,723.500
3.A.1 - Enteric Fermentation		595.951			16,686.635
3.A.2 - Manure Management		54.048	1.976		2,036.865
3.B - Land	- 20,021.958	-	-	-	-20,021.958
3.B.1 - Forest land	- 18,072.100				-18,072.100
3.B.2 - Cropland	6,345.516				6,345.516
3.B.3 - Grassland	- 38.794				- 38.794
3.B.5 - Settlements	- 8,256.580				-8,256.580
3.C - Aggregate sources and non- CO_2 emissions sources on land	105.751	83.119	9.197	-	4,870.245
3.C.2 - Liming	0.531				0.531
3.C.3 - Urea application	105.220				105.220
3.C.4 - Direct N_2O Emissions from managed soils			6.314		1,673.181
3.C.5 - Indirect N_2O Emissions from managed soils			2.576		682.552
3.C.6 - Indirect N_2O Emissions from manure management			0.307		81.425
3.C.7 - Rice cultivation		83.119			2,327.337
4 - Waste	79.623	119.311	5.260	-	4,814.291
4. A - Solid Waste Disposal		48.682			1,363.106
4. B - Biological Treatment of		0.320	0.018		13.843

Solid Waste					
4. C - Incineration and Open Burning of Waste	79.623	1.590	0.024		130.390
4.D - Wastewater Treatment and Discharge		68.718	5.218		3,306.952

Figure 9 highlights that the highest GHG emissions are from energy combustion, largely due to the inefficient burning of wood and biomass in the residential sector, which contributes significantly to CH4 emissions. Fossil fuel combustion and non-energy uses are the next major contributors to GHG emissions. When emissions and removals from land use are excluded, the agriculture and livestock sector become the largest contributor, followed by the energy sector. This shift shows the substantial impact of methane and nitrous oxide emissions from livestock and

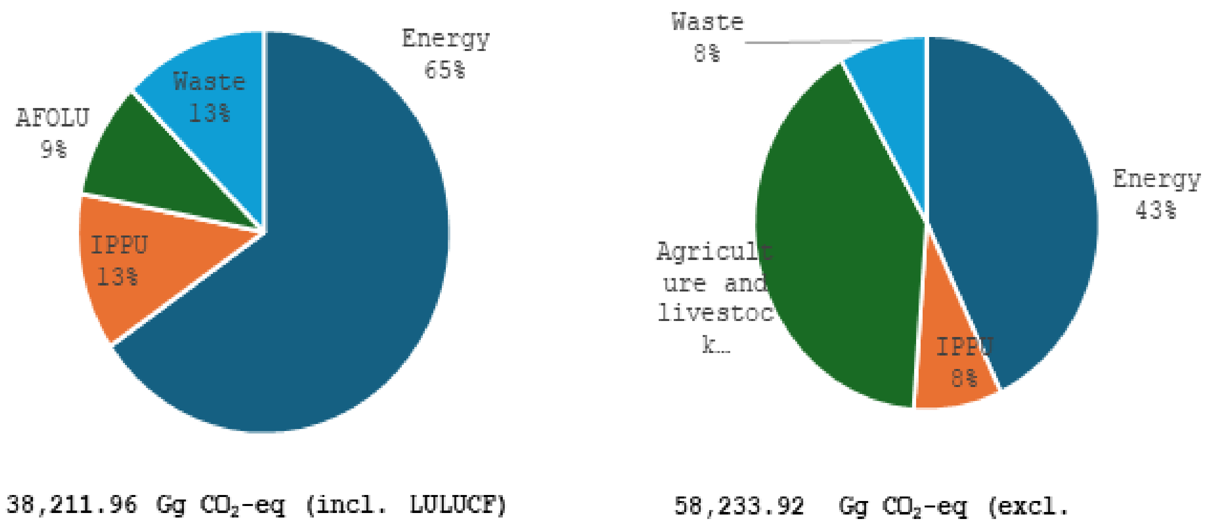

Figure 7: Shares of GHG emissions from different sectors in 2022

agricultural practices. Both charts emphasize that the energy sector should be the primary focus for GHG emission reduction strategies, as it offers more viable opportunities for abatement compared to agriculture or waste. Nepal's abundant potential for clean, renewable energy further reinforces the need to transition from traditional biomass and fossil fuels to sustainable energy sources.

2.7 Trends in Greenhouse Gas Emissions

Figure 10 shows the growth trend of GHG emissions in Nepal from 1994 to 2022. Nepal has experienced a steady growth in GHG emissions, with an average annual increase of 3.26% since 2011, as reported in the Third National Communication (MoFE, 2021). However, recalculations suggest a slightly higher growth rate of 4.2% per annum, using 2011 as the reference year. The energy sector remains the largest contributor, with emissions rising due to increased fuel combustion. This is driven by economic growth, population expansion, and enhanced access to modern fuels like LPG, which has reduced reliance on biomass. Biomass combustion still contributes significantly to CH4 emissions in rural areas. The Industrial Processes and Product Use (IPPU) sector has seen the fastest growth, attributed to the expansion of industrial activities such as cement production and improved data availability.

The Agriculture, Forestry, and Other Land Use (AFOLU) sector exhibits mixed trends, with a rise in emission removals due to effective land use and forest management policies. Livestock and agricultural practices remain key sources of CH4 and N2O emissions in this sector. The waste sector has experienced a decline in emissions, likely due to improved waste management practices and greater efficiency in wastewater treatment. Overall, the energy sector continues to dominate as the primary source of emissions, underscoring the need for mitigation strategies focusing on transitioning to clean, renewable energy sources. At the same time, IPPU and waste require targeted interventions to curb their increasing or persistent emissions.

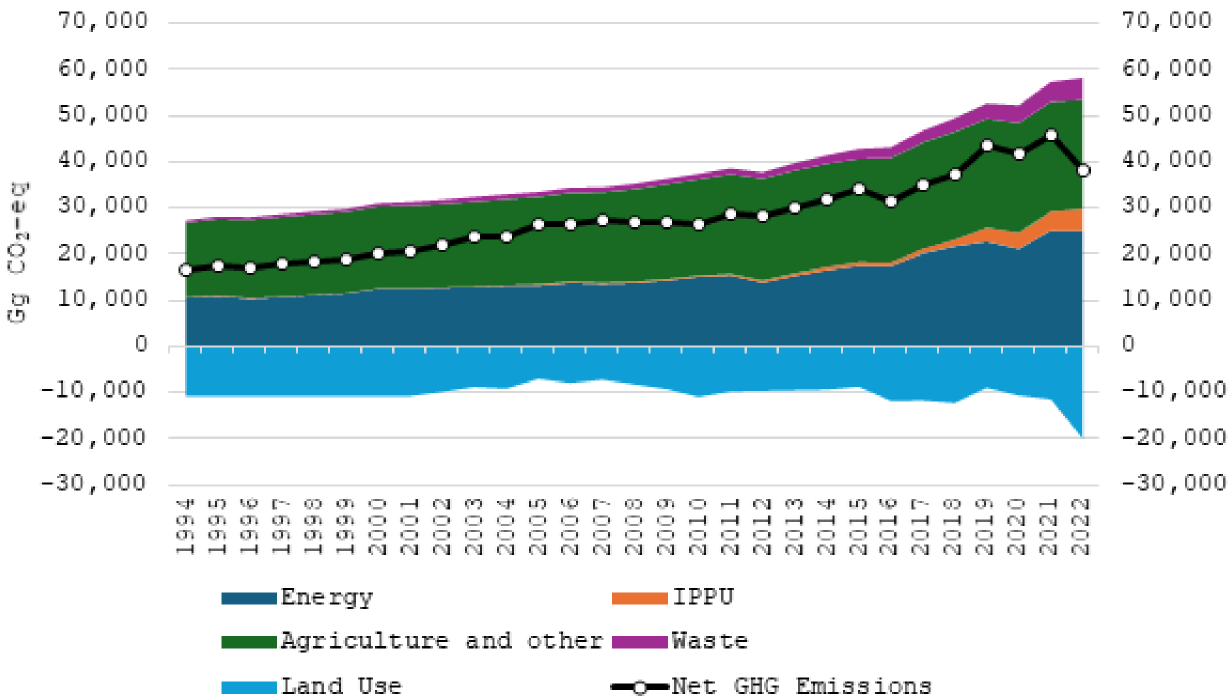

Figure 8: GHG emissions trend by sectors in Nepal from 1994 to 2022

Figure 7 illustrates the trend of Nepal's national greenhouse gas (GHG) emissions from 1994 to 2022, broken down by CO2, CH4, and N2O emissions, along with CO2 removals from land use. Over the years, CO2 emissions, primarily from the energy and industrial sectors, have steadily increased, which is mainly due to the increase in the combustion of fossil fuels. CH4 emissions remain the largest contributor to total GHG emissions, largely due to agricultural activities such as livestock rearing and rice cultivation, as well as biomass combustion. N2O emissions have shown a moderate increase over time, driven by fertilizer use in agriculture. Notably, CO2 removals from land use have grown significantly, reflecting Nepal's successful forest conservation and reforestation initiatives. Net GHG emissions show a steady upward trend, particularly after 2011, as industrialization, urbanization, and energy consumption intensified. However, the increasing carbon sequestration from land use has helped moderate the growth in net emissions, especially in recent years. This highlights the critical role of land use management as a carbon sink and emphasizes the need for targeted mitigation strategies to address rising CO2 and CH4 emissions from the energy and agriculture sectors.

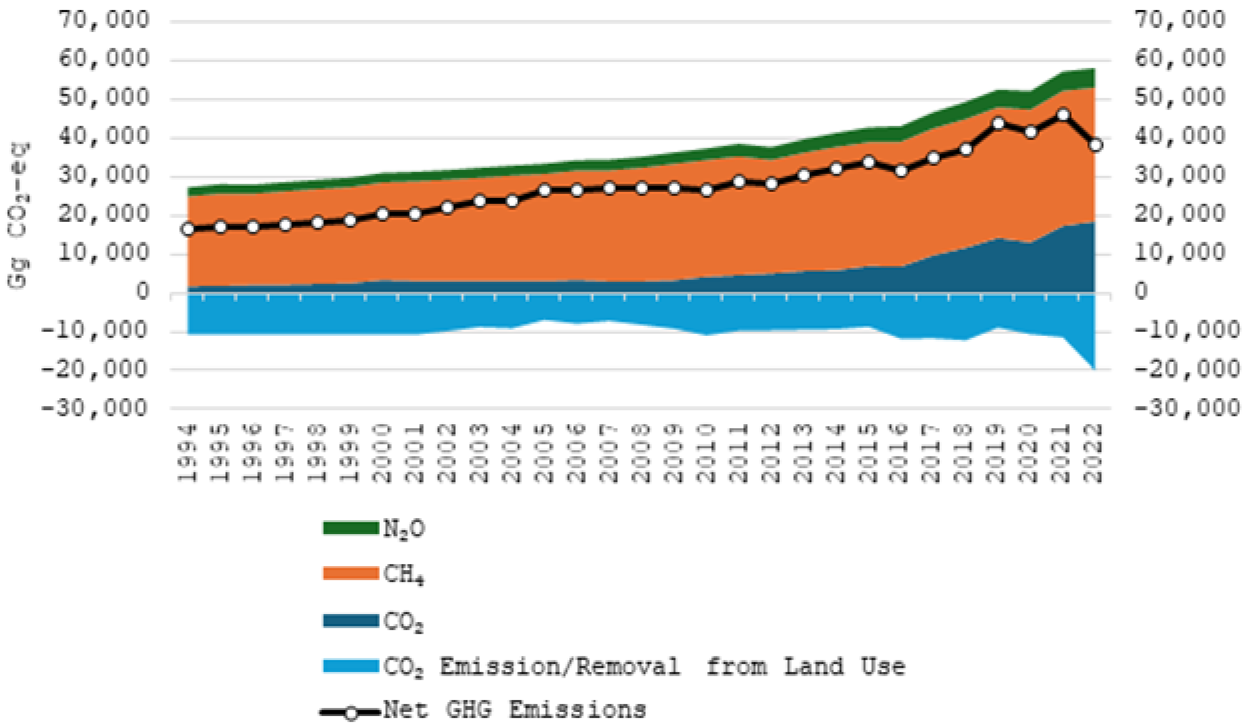

Figure 9: GHG emissions trend by gases in Nepal from 1994 to 2022

2.8 Energy

Nepal's energy sector is characterized by a mix of traditional, commercial, and alternative resources. Traditional energy sources, such as biomass fuels, including fuel wood, agricultural residue, and animal dung, still fulfill much of the country's vast energy demand. Commercial energy sources consist mainly of fossil fuels and electricity, while alternative options include micro-hydro, solar, wind power, biogas, and briquettes. Despite the growth in petroleum consumption over the past decade, which has significantly contributed to increased greenhouse gas (GHG) emissions, biomass remains a dominant energy source. To achieve sustainable development, Nepal must gradually reduce its reliance on biomass and imported fuels by promoting renewable energy.

GHG emissions from the energy sector arise from both stationary sources, such as electricity generation, manufacturing, and residential activities, and mobile sources like road transport and aviation. Following the IPCC Guidelines (2006), emissions from energy-related activities, listed in Table 6. The table reports various sectors and subsectors within the energy industry.

Table 6: IPCC emission categories in energy sector relating to Nepal

Category Code	Category Name	Remarks
1	Energy	
1 A	Fuel Combustion Activities	
1 A 1	Energy Industries	
1 A 1 a	Main Activity Electricity and Heat Production	
1 A 1 a i	Electricity Generation	Thermal Plants operated by Nepal Electricity Authority
1 A 2	Manufacturing Industries and Construction	
1 A 2 a	Iron and steel	
1 A 2 b	Non-Ferrous Metals	
1 A 2 c	Chemicals	
1 A 2 d	Pulp, Paper and Print	
1 A 2 e	Food Processing, Beverages and Tobacco	Nepal Standard Industrial Classification (NSIC) are as per ISIC 4th revision (2008),
1 A 2 f	Non-Metallic Minerals	IPCC categories are as per ISIC 3rd revision (1989)
1 A 2 g	Transport Equipment	The categories are grouped as per classification given by (WECS, 2021a, 2021b, 2022a, 2024)
1 A 2 h	Machinery	
1 A 2 i	Mining (excluding fuels) and Quarrying	
1 A 2 j	Wood and Wood Products	
1 A 2 k	Construction	
1 A 2 l	Textile and Leather	
1 A 2 m	Non-specified Industry:	
1 A 3	Transport	
1 A 3 a	Civil Aviation	

1 A 3 a i	International Aviation (International Bunkers)	Based on fuel sold by Nepal Oil Corporation
1 A 3 a ii	Domestic Aviation	Based on fuel sold by Nepal Oil Corporation
1 A 3 b	Road Transportation	Based on fuel consumption in sector
1 A 3 b i	Cars	Aggregate data
1 A 3 b ii	Light-duty Trucks	Based on the number of vehicles registered in category published by Department of Transport Management (DoTM, 2019; MoF, 2023)
1 A 3 b iii	Heavy-duty Trucks and Buses	
1 A 3 b iv	Motorcycles	
1 A 3 e	Other Transportation	
1 A 3 e ii	Off-road	Tractors/Trailers
1 A 4	Other Sectors	
1 A 4 a	Commercial/Institutional	Based on fuel consumption in sector
1 A 4 b	Residential	Based on fuel consumption in sector
1 A 4 c	Agriculture/Forestry/Fish Farms	
1 A 4 c i	Stationary	Based on fuel consumption in sector
1 A 4 c ii	Off-road Vehicles and Other Machinery	Based on fuel consumption in sector
1 A 4 c iii		Fishing (mobile combustion)
1 A 5	Non-Specified	

2.9 Methodology

2.9.1 Reference Approach

This top-down approach of the GHG emission estimation is based on the total energy supply of the fuels. The total fuel usage and hence the emissions by this method are generally higher than the real consumption due to possible unreported losses, stock changes, or inaccuracies in accounting for energy trade/fuel movements.

2.9.1.1 Activity data

For the reference approach, the overall energy supply data are collected from Trade statistics (DoC, 1970) Nepal Oil Corporation (NOC, 2024) and Economic Survey Reports by the Ministry of Finance (MoF, 2023). The following data are being obtained from each source.

Table 7: Activity data for Reference Approach

Institution	Energy Data	Remarks
Nepal Oil Corporation	Diesel, Gasoline, Kerosene, Jet Kerosene, LPG, Residual Fuel Oil,	Sales Data
Department of Customs	Coal, Residual Fuel Oil	Import Data
Ministry of Finance	Total Energy Consumption data by fuel groupings	Published in the annual Economic Survey reports

2.9.1.2 Apparent consumption of fuels

The apparent consumption of the fuel was estimated by using the formula Apparent consumption

= Production + Imports – Exports – International bunkers – Stock change

Among the fuels, the given fuels are produced indigenously, and/or imported.

The production data for wood/wood waste and other primary solid biomass for use in energy are not well recorded. Therefore, it is assumed that the quantity consumed is equal to the quantity produced/extracted. Similarly, accurate data for Coal imports and production are also not well recorded. Therefore, wherever the data are missing, it is assumed that the import of coal is equal to the consumption and the production of coal is zero, in case data is unavailable.

2.9.1.3 Sectoral approach

For the sectoral approach, which is a bottom-up approach, each sector and its activities were identified. The main source of such data is the Water and Energy Commission Secretariat, the National Statistics Office (the then Central Bureau of Statistics), the Department of Industries, the Department of Transportation, and other reports from government agencies.

For the estimation of emissions from each sector, the general equation given was used

$\text{Emissions}_{s,g,f} = \text{Activity}_{s,f} \times \text{Emission Factor}_{g,f}$

Where,

$\text{Activity}_{s,f}$ = the total Fuel f consumed by combustion in the Sector s ($_{TJ}$)

$\text{Emissions}_{s,g,f}$ = emission of given GHG g by specific type of fuel f in the specific sector s (kg)

$\text{Emission Factor}_{g,f}$ = default emission factor of a given GHG g by fuel f (kg /TJ). For CO_2, it includes the carbon oxidation factor, assumed to be 1

Therefore, the total emission would be

$$\text{Total Emissions}_{GHG} = \sum \sum \text{Emissions}_{GHG,Sector,Fuel}$$

The results of both approaches were compared and are discussed in a later section related to the comparison of the reference and sectoral approaches.

The total activity data was based on the energy consumption reports by WECS. Fuel-specific data is available for certain years and is provided in the BTR1 Annex. The missing data was derived by appropriate interpolation and splicing methods. The verification for such estimation was done by comparing supply and consumption data of fuels given by the annual Economic Survey reports by the Ministry of Finance. The data is presented in BTR1 Annex V.IV. The detailed methodology and assumptions are given in the sections below.

2.9.1.3.1 Energy generation:

The energy generation plants in Nepal are primarily thermal generators. The two main thermal plants in Nepal are operated by Nepal Electricity Authority (NEA) – Duhabi multifuel plant, which uses fuel oil, and Hetauda Thermal Plant, which uses diesel oil. Although there are decentralized generators being used by manufacturing industries and commercial institutions, there is no ample data for an exact approximation. Therefore, the use of fuel was included within each sector, and not in the Electricity Generation category. The activity data for electricity generation by NEA is given in BTR1 Annex V.V

2.9.1.3.2 Estimation methodology Categorization

Category Code	Category Name	Remarks
1	Energy Sector Fuel	--
1 A	Fuel Combustion Activities	--
1 A 1	Energy Industries	--
1 A 1 a	Main Activity Electricity and Heat Production	--
1 A 1 a i	Electricity Generation	Thermal Plants operated by Nepal Electricity Authority
1A1aii	Combined Heat and Power Generation (CHP)	- NE (Two 3 MW of CHP installed in Sugar mills, which are in operation only for a couple of years. Not enough data gathered.)

NE: Not Estimated

2.9.1.3.2.1 Data sources

Data	Source	Remarks
Generation	Nepal Electricity Authority (NEA-GD, 2023, 2020)	
Fuel Economy	Literature (Pokhrel, 2013; THT, 2012)	Cross-validated with Nepal Electricity Authority during KII

2.9.1.3.3 Manufacturing Industries and Construction

The manufacturing sector in Nepal is in growing stride, and thus the energy consumption is also growing accordingly. In totality, the manufacturing sector has been the second-largest consumer of energy (WECS, 2023, 2010). However, the quantity of energy has increased by a huge amount in the past decade. The major fuels used by manufacturing industries are fossil fuels, thus it has been the largest emission sector in the energy category past year 2000 (MoPE, 2017; MoSTE, 2014). The data on the number of industries and their output in the form of economic value are available in the industrial survey by the National Statistical Office. However, detailed data such as the specific production in each year and fuel consumption by each type are not readily available. Therefore, the activity data for Manufacturing Industries and Construction be estimated using data from the registration data from

Department of Industries (DOI), number, output and energy intensities from National Statistics Office (NSO), and energy consumptions from Water and Energy Commission Secretariat (WECS). Relevant data from previous communication reports and credible literature sources were used.

Note: The IPCC 2006 categories are based on the third revision of the International Standard Industrial Classification (ISIC) (UN, 1989), while the Nepal Standard Industrial Classification (NSIC) (CBS, 2019) is updated based on the Fourth revision of ISIC (UN-DESA, 2008). The categories have been adjusted accordingly to update respective groupings. The old and new categorizations are given in BTR1 Annex V.VI. The manufacturing industries are then categorized based on data availability from DOI, CBS, NSO and WECS. The construction and mining sector energy has not been estimated due to lack of historical data on their activity and energy consumption.

Table 8: Manufacturing Industries sub categorization

Category		Remarks
1 A 2 a	Iron and steel	Includes: 1A2b, 1A2g, 1A2h
1 A 2 b	Non-Ferrous Metals	IE: 1A2a
1 A 2 c	Chemicals	IE: 1A2m
1 A 2 d	Pulp, Paper and Print	IE: 1A2j

1 A 2 e	Food Processing, Beverages and Tobacco	
1 A 2 f	Non-Metallic Minerals	
1 A 2 g	Transport Equipment	IE: 1A2a
1 A 2 h	Machinery	IE: 1A2a
1 A 2 i	Mining (excluding fuels) and Quarrying	NE
1 A 2 j	Wood and Wood Products	Includes: 1A2d
1 A 2 k	Construction	NE
1 A 2 l	Textile and Leather	
1 A 2 m	Non-specified Industry:	Includes: 1A2c

IE: Included Elsewhere; NE: Not Estimated

2.9.1.3.3.1 Data Sources

Data	Source	Remarks
Industrial Categories	(CBS, 2019; UN-DESA, 2008; UN, 1989; WECS, 2021a, 2021b, 2022a, 2024)	Industrial categories have been updated as per 4th revision of ISIC and lates NSIC. The subcategories have been grouped as per data availability based on WECS reports.
Number of Industries	(CBS, 2022a; DoI, 2024)	
Total Energy consumption	(MoF, 2019a, 2024; WECS, 1996, 2010, 2022b, 2023)	
Industrial energy consumption	(WECS, 2024, 2023, 2022a, 2021a, 2021b, 2014, 2010, 1996, 1994)	Provincial level energy consumption and fuel wise energy share from provincial reports National level from synopsis reports

2.9.1.3.3.2 Transportation

The transportation sector is the next most energy-consuming sector after the manufacturing industries (WECS, 2023) and the second-most emissive sector from energy use (MoPE, 2017). This is because the transportation sector is also highly dependent on fossil fuels only.

In Nepal, the Department of Transport Management used to maintain the national vehicle registration data. However, after federal restructuring, the agencies responsible for doing so are the provincial authorities. The vehicle registered till date is given in BTR1 Annex V.VII.

The data on the number of operational vehicles is not available. Therefore, it was derived using indirect approach (Malla, 2014). The distance traveled and fuel economy foreach type of vehicle were estimated from transport research by CBS (CBS, 2014a) and provincial energy reports (WECS, 2024, 2022a, 2021c) to calculate the activity data.

2.9.1.3.3.3 Vehicle Categorization

IPCC Category	Nepal Registration Category	Remarks
1.A.3.a.i International Aviation		IE: International Bunkers
1.A.3.a.ii Domestic Aviation		
1.A.3.b.i Cars	Car/Jeep/Vans Tempo	
1.A.3.b.ii Light Duty trucks	Pickups	
1.A.3.b.iii Heavy Duty trucks and buses	Bus Minibus/minitruck Microbus	
1.A.3.b.iv Motorcycles	Motorcycles	
1.A.3.e.ii Off-road (Other vehicles)	Tractors/Power tillers	Other than used in Agriculture [category 1.A.4.c.ii]

NE: Not Estimated, IE: Included Elsewhere

2.9.1.3.3.4 Data Sources

Data	Source	Remarks
Vehicle Registration number	(DoTM, 2019; MoF, 2024)	
Operation Factor	(CBS, 2014a; Malla, 2014)	
Annual distance travelled (km)	(CBS, 2014a; WECS, 2021a, 2021b, 2022a, 2024)	
Fuel economy (km/liter)	(WECS, 2024, 2022a, 2021a, 2021b)	

Fuel/energy consumed	(WECS, 2024, 2023, 2022a, 2021a, 2021b, 2014, 2013, 2010, 1996, 1994)	

2.9.1.3.4 Other sectors

The other sectors category comprises commercial/institutional, residential, and agricultural energy use. The commercial/institutional sector is a service-oriented sector and most of the fossil fuels are consumed in Accommodation and Food Service Activities (ISIC and NSIC Division 55 and 56). In the residential sector, the majority of the fuel consumed is still biomass (WECS, 2023). Meanwhile, the agriculture sector is still largely dependent on non-mechanized techniques of agriculture.

2.9.1.3.4.1 Data Sources

Data	Source	Remarks
Residential sector energy Consumption	(WECS, 2023, 2022b, 2013, 2010, 1996, 1994)	Emission factor for biomass stoves (IPCC, 2006, Volume 2 Chapter 2 Table 2.9) and (MoPE, 2017)
Commercial sector energy consumption		
Agriculture sector energy consumption		1.A.4.c.i - Stationary = Irrigation and Threshers 1.A.4.c.ii - Off-road vehicles and other machinery = Tillers and other farm machineries

The main activity data relating to other sectors was obtained from WECS reports (WECS, 2023, 2022b, 2013) (BTR1 Annex V.III).

2.9.2 Trend of Emissions in Energy sector

The trend of emissions since the first communication report to 2022 is as shown in Figure 12. It indicates that he GHG emissions in Nepal has been growing at the rate of 3.18% per annum between 1994 and 2022. The type of emissions shows that CH4 was the highest emissions in 1994, which accounts for 81%, 14% being CO2 and rest as nitrous oxide of total GHG equivalent emissions. While coming to 2022, the mix changes to 54% CO2, 43% CH4 and 3% N2O. This change in mix of emission gases is due to change in fuel used. In the past, biomass use was significantly contributing to methane emissions. While with advancements, the use of fossil fuels has risen sharply, contributing to higher CO2 emissions.

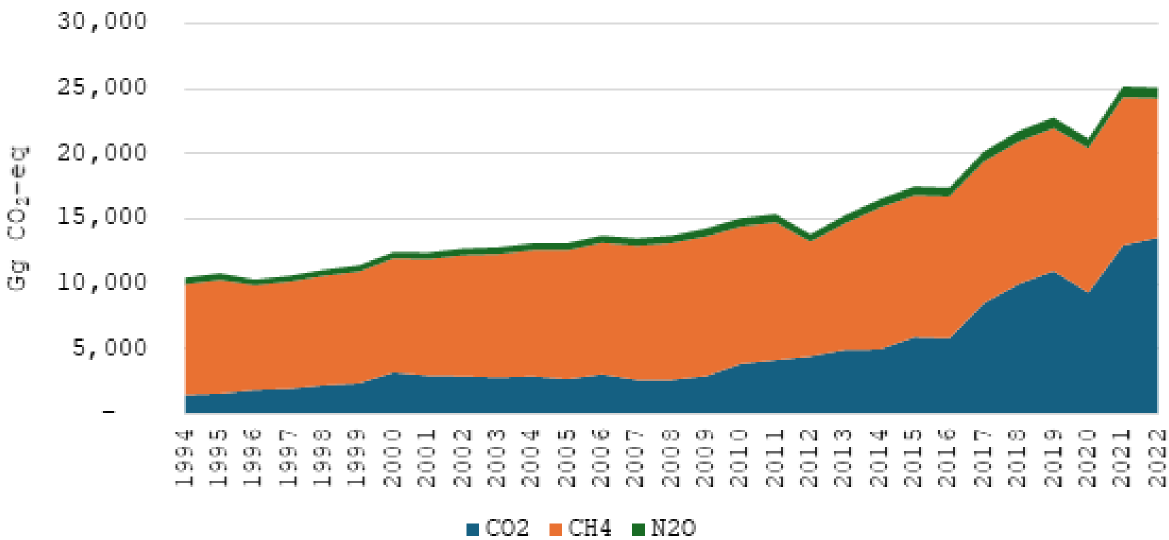

Figure 10: GHG emissions from Energy sector from 1994-2022

The Figure 9 illustrates the greenhouse gas (GHG) emissions from the energy sector across various sub- sectors between 1994 and 2022. Over this period, total emissions have shown a steady upward trend, with a sharp increase starting around 2015. The residential sector consistently dominates emissions, as indicated by its significant share, highlighting its reliance on high-emission energy sources. The transport sector has seen a notable rise in emissions since 2015, reflecting the growing impact of expanding transportation infrastructure. Similarly, emissions from manufacturing industries have grown steadily, contributing significantly to the overall increase. While electricity generation has a relatively smaller share, and it shows a declining trend, particularly after 2015, due to increased availability of clean electricity generation plants. In contrast, the commercial and agriculture sectors contribute minimally to total emissions. The overall trend reflects increasing energy demands across residential, industrial, and transportation sectors, driven by population growth, urbanization, and industrialization.

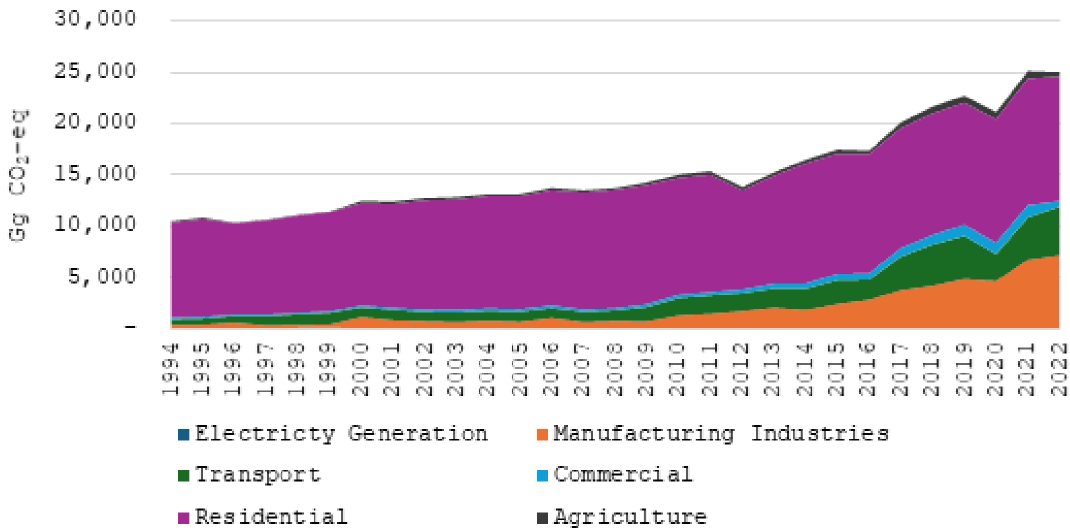

Figure 11: GHG emissions in energy sector by sub sectors from 1994 to 2022

2.9.3 Recalculation of emissions 1994-2011

The GHG inventory for the Initial National Communication (INC), Second National Communication (SNC), and Third National Communication (TNC) have been reevaluated. The major changes identified during the calculations are the revised and/or new emission factors in the IPCC 2006 guidelines, compared to those in the IPCC 1996 guidelines. Additionally, the later version provides a more detailed list of energy types. Furthermore, while the INC and SNC use the global warming potential (GWP) factor from the Second Assessment Report (SAR), the TNC uses the GWP factors from the Fourth Assessment Report (AR4). Moreover, the methane emission factor for wood stoves and other biomass stoves has been taken as the Tier 2 default factor from the TNC.

For recalculation purposes, all the emission factors have been updated as per IPCC 2006 including methane emission factor for residential wood and biomass stoves. In addition to that, the GWP factor has been taken as per the Fifth Assessment Report (AR5). The GWP for each assessment report is given in BTR1 Annex I.I. The recalculations of the GHG inventory gave out results as shown in Figure 11.

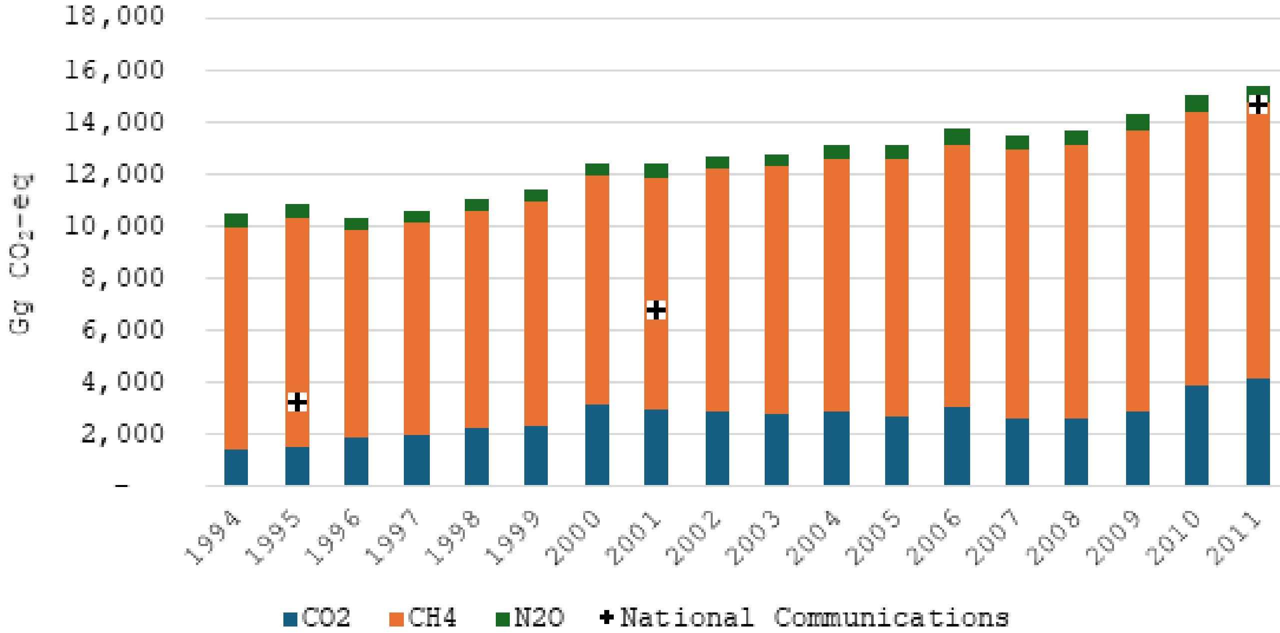

Figure 12: GHG emissions from Energy sector during 1994-2011

It can be observed that there are differences in total emissions in previously calculated GHG inventory and recalculations. The main factor of these differences being the updated emission factors and the GWP factors.

2.9.4 GHG Emissions Inventory of 2012-2022

Figure 12 illustrates the GHG emissions from the year 2012 to 2022. In recent years, CO_2 has accounted for the largest share of emissions due to increased fossil fuel consumption and a corresponding decline usage of biomass. Noticeable drops in emissions occurred during the periods 2015–2016 and 2019–2020. The decline in the earlier period is attributed to reduced energy and fuel use resulting from the political situation, while the later drop is due to the impact of the global COVID-19 pandemic.

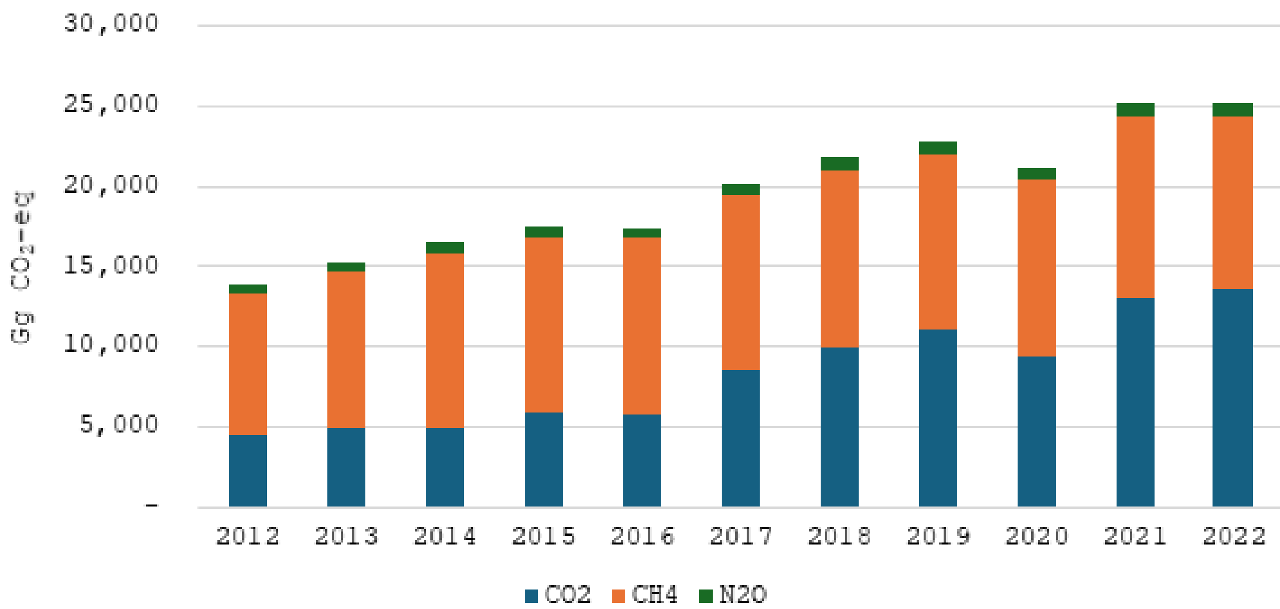

Figure 13: GHG emissions from Energy sector from 2012 – 2022

2.9.5 Sub Sectoral Emissions

Total GHG emissions have historically been dominated by methane emissions from biomass burning, particularly where biomass is widely used for cooking and heating in residential and commercials sectors. However, this sector's contribution is gradually decreasing due to shift to modern fuels like LPG, electricity, and renewables and have reached 52% in 2022 from 75% in 2012. As economies grow, energy consumption patterns are shifting towards more efficient, cleaner energy sources, reducing reliance on biomass and lowering methane emissions. At the same time, the manufacturing sector is seeing a rapid increase in emissions driven by higher production and consumption and thus their emission has reached 29% from 12 % in 2012. Similarly, emissions from the transport sector are rising, fueled by both population growth and economic development and thus reaching 19% in 2022 from 13% in 2012.

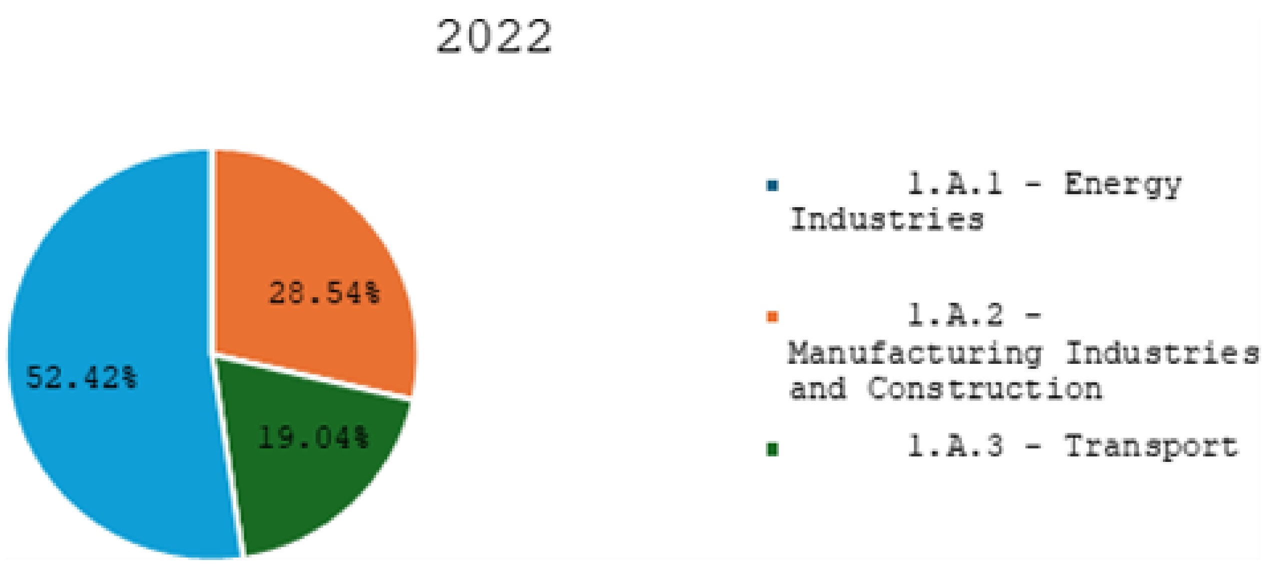

Figure 14: Subsector emission for year 2022

Table 9: GHG emissions from Energy sector in 2022

	CO_2	CH_4	N_2O	Total
Categories	**Gg CO2-eq**	**Gg CO2-eq**	**Gg CO2-eq**	**Gg CO2-eq**
1 - Energy	13,567.62	10,735.85	710.82	25,014.29
1.A - Fuel Combustion Activities	13,567.62	10,735.85	710.82	25,014.29
1.A.1 - Energy Industries	0.02	0.00	0.00	0.02
1.A.1.a - Main Activity Electricity and Heat Production	0.02	0.00	0.00	0.02
1.A.1.a.i - Electricity Generation	0.02	0.00	0.00	0.02
1.A.2 - Manufacturing Industries and Construction	6,999.82	60.40	79.84	7,140.06
7,140.07				
1.A.2.a - Iron and Steel	775.37	1.51	2.37	779.25
1.A.2.e - Food Processing, Beverages and Tobacco	346.61	8.95	11.52	367.08
1.A.2.f - Non-Metallic Minerals	4,643.46	18.36	25.36	4,687.17
1.A.2.j - Wood and wood products	98.61	19.04	24.10	141.75
1.A.2. - Textile and Leather	157.12	7.47	9.53	174.12
1.A.2.m - Non-specified Industry	978.66	5.07	6.96	990.70
1.A.3 - Transport	4,629.20	24.10	108.67	4,761.97

4,761.97				
1.A.3.a - Civil Aviation	159.16	0.03	1.18	160.37
1.A.3.a.i - International Aviation (International Bunkers) (1)	-	-	-	-
1.A.3.a.ii - Domestic Aviation	159.16	0.03	1.18	160.37
1.A.3.b - Road Transportation	3,930.51	23.22	52.31	4,006.03
1.A.3.b.i - Cars	675.20	6.16	8.67	690.03
1.A.3.b.ii - Light-duty trucks	224.34	0.33	3.13	227.80
1.A.3.b.iii - Heavy-duty trucks and buses	1,997.20	2.94	27.86	2,028.00
1.A.3.b.iv - Motorcycles	1,033.77	13.78	12.65	1,060.20
1.A.3.e - Other Transportation	539.54	0.85	55.18	595.57
1.A.3.e.ii - Off-road	539.54	0.85	55.18	595.57
1.A.4 - Other Sectors	1,938.57	10,651.34	522.31	13,112.22
3,112.23				
1.A.4.a - Commercial/Institutional	352.60	167.01	21.35	540.95
1.A.4.b - Residential	1,205.14	10,483.38	477.95	12,166.47
1.A.4.c - Agriculture/Forestry/Fishing/Fish Farms	380.84	0.95	23.02	404.81
1.A.4.c.i - Stationary	159.13	0.60	0.34	160.07
1.A.4.c.ii - Off-road Vehicles and Other Machinery	221.71	0.35	22.68	244.74
Categories				
Memo Items (3)	-	-	-	-
International Bunkers	230.83	0.05	1.71	232.59
1.A.3.a.i - International Aviation (International Bunkers) (1)	230.83	0.05	1.71	232.59
CO2 from Biomass Combustion	46,128.97	-	-	46,128.97

(2024 estimations. Extracted from IPCC GHG Inventory software 2.93)

Table 10: Other emissions from Energy sector in 2022

Branch	Sulfur Dioxide	Nitrogen Oxides	NMVOC	Carbon Monoxide
Energy Industries	0.00	0.00	0.00	-
Electricity Generation	0.00	0.00	0.00	-
Manufacturing Industries	59.58	25.14	20.84	34.52
Iron and Steel	5.32	3.56	0.47	6.20
Food Beverage and Tobacco	1.41	3.06	3.18	10.16
Non-metallic minerals	46.08	9.52	6.01	0.47
Wood and wood products and others	0.22	2.72	6.80	1.58
Textile and Leather	0.38	1.87	2.66	3.55
Other Industries	6.18	4.41	1.73	12.56
Transport	7.89	25.29	32.80	95.97
Civil Aviation	0.04	-	-	0.15
Road Transportation	7.85	25.29	32.80	95.82
Other Sector	9.14	23.18	210.43	103.45
Commercial Institutional	0.59	2.16	6.04	46.78
Residential	7.61	17.98	204.10	54.78
Agriculture	0.94	3.04	0.29	1.89
Total	76.61	73.61	264.07	233.93

Electricity Generation

The electricity generation in Nepal is almost all from clean energy sources. The only major fossil fuel-using plants are also not in use in the current year. They only operate for yearly maintenance. Therefore, their emission has become negligible as seen from Table 10.

Manufacturing Industries and Construction

This category has grown significantly and is now the second-largest emitter of greenhouse gases in Nepal, contributing approximately 29% of the total GHG emissions in 2022, which totals 7,140 Gg CO2-eq emissions. The largest share of emissions within this category comes from non-metallic minerals, primarily the brick, cement, and clay pottery industries in Nepal. The extensive use of coal and oil for thermal energy in these industries is the main source of emissions. Non-metallic minerals industries account for 66% of the total emissions within the manufacturing sector. The second largest emitter in this category is the “non-specified industries” subcategory, which contributes 14% of the total manufacturing emissions. This subcategory encompasses various small industries. Additionally, the iron and steel industry is a significant emitter, contributing about 11% to the total emissions within the manufacturing category. Together, these industries highlight the key sources of emissions in Nepal’s industrial sector.

Transport

The transport sector accounted for 4,762 Gg of GHG emissions - nearly 19% of total GHG emissions from fuel combustion in 2022. Like the manufacturing sector, the transport sector is expanding, primarily due to the growing economy and size of the vehicle fleet. The increase in transport activities can be attributed to several factors, including economic growth, population expansion, greater access to transportation, and rising economic capacity, which enables more people to afford vehicle ownership. According to the IPCC classification, the highest emissions within the transport sector come from heavy vehicles such as buses, minibuses, mini trucks, and trucks, which together contribute 43% of emissions in the sector. This represents about 8% of total emissions from fuel combustion. Following this, emissions from motorcycles, which have been increasing rapidly in number, and from cars, jeeps, and vans also contribute significantly to the overall transport emissions. This trend highlights the growing impact of personal and commercial vehicle use on GHG emissions as economies develop and urbanize.

Other Sector

The “other” sector is the largest emitter of GHGs from fuel combustion, contributing approximately 13,112 Gg of emissions. The largest share of these emissions comes from the residential sector, primarily due to the use of biomass stoves. While CO2 emissions from biomass burning are not included in the total GHG emissions, CH4 emissions from biomass stoves, particularly in developing regions, are notably high, as reported by the IPCC (2006). As a result, the CO2-equivalent GHG emissions from the residential sector alone account for about 49% of emissions from fuel combustion. In contrast, emissions from the commercial sector and agricultural activities contribute much smaller portions, with their share generally limited to single-digit percentages.

Emissions from biomass combustion

This category estimates the carbon dioxide (CO2) emissions from the combustion of solid biomass. These emissions are not included in the total greenhouse gas (GHG) emissions but are provided separately for informational purposes. The primary source of emissions in this category is the burning of fuelwood, which is commonly used for cooking and heating in households, especially in rural areas. In addition to fuelwood, emissions also come from the burning of other biomass materials, such as agricultural residues and animal waste. According to the estimated data, in 2022, the total CO2 emissions from biomass combustion in Nepal amounted to 46,128.97 Gg.

International bunker

Total GHG emissions do not include CO2 emissions from international bunkers. In Nepal, the only international bunker is related to aviation. In 2022, GHG emissions from the international aviation bunker amounted to 232.59 Gg CO2-eq.

2.9.6 Comparison of Reference and Sectoral approaches to assess CO_2 emissions from Fuel Combustion

In line with the IPCC Guidelines (2006), both the Reference and Sectoral approaches were applied to estimate CO2 emissions from fuel combustion activities, serving as a cross-check for total emissions. Table 5 presents the total CO2 emissions for each approach and the percentage difference between them. The differences between the Reference and Sectoral approaches are inconsistent, indicating variability in calculation methods and data accuracy. The largest deviation in the calculated values occurred for the historical year 1995, with subsequent years showing negative differences. Some key reasons for these discrepancies include:

- Informal energy sources and unaccounted energy consumption, which may lead to discrepancies.
- Lack of data on the non-energy use of fuels.
- Differences in energy accounting methods, with the net calorific value of fuels significantly influencing estimates. Accurate classification of fuels and their properties, as well as specific usage, should be determined through research.
- Including fuels used for non-energy purposes, such as cooking coal, which increases the total energy usage.
- Incomplete, underestimated, or misreported data in the sectoral approach, causing energy consumption to appear higher than the energy supply data suggests.
- Failure to properly reflect energy efficiency improvements in the sectoral approach, leading to overestimations of energy consumption for a given output.

Table 11: Comparison of CO2 emissions from Fuel Combustion

Year	Reference Approach	Sectoral Approach	Difference %	Year	Reference Approach	Sectoral Approach	Difference %
1994	1,752.38	1,470.16	19.20	**2012**	3,757.40	4,437.37	-15.32
1995	1,908.03	1,569.68	21.56	**2013**	4,251.86	4,937.38	-13.88
1996	2,184.76	1,851.78	17.98	**2014**	4,655.34	4,978.83	-6.50

1997	2,245.26	1,953.10	14.96
1998	2,347.84	2,226.95	5.43
1999	2,416.23	2,381.34	1.47
2000	3,206.44	3,202.88	0.11
2001	2,880.19	2,963.82	-2.82
2002	2,803.26	2,920.49	-4.01
2003	2,681.09	2,812.43	-4.67
2004	2,569.25	2,904.06	-11.53
2005	2,569.25	2,695.37	-4.68
2006	2,859.82	3,064.09	-6.67
2007	2,508.05	2,629.55	-4.62
2008	2,560.99	2,631.80	-2.69
2009	2,770.59	2,925.70	-5.30
2010	3,787.56	3,869.82	-2.13
2011	4,032.05	4,148.83	-2.81
2015	5,860.39	5,922.31	-1.05
2016	5,213.59	5,822.67	-10.46
2017	7,846.78	8,548.19	-8.21
2018	11,317.54	10,006.65	13.10
2019	9,752.84	11,013.06	-11.44
2020	9,752.84	9,348.14	4.33
2021	12,062.99	12,979.40	-7.06
2022	12,375.70	13,567.62	-8.79

2.9.7 Uncertainty assessment and time series consistency

The activity data uncertainty is assumed to be ±5% (as for countries with a less developed system of national statistics), except for biomass data (IPCC Guidelines 2006). The biomass data uncertainty is assumed to be about ±50%, since data on biomass as a fuel is not so reliable. The uncertainty ranges are derived based on the lower and upper limits of emission factors given in Table 2.2, 2.3, 2.4,2.5, 2.9, 3.2.1 and 3.2.2 of IPCC guidelines for each subsector. Since the ranges are different for each fuel within the same category, the lowest percentage value for lower range and highest percentage value for higher range are taken, within each category. The uncertainty ranges are given in BTR1 Annex V.XII. For uncertainty trend analysis, the base year has been taken as 2012, and the end year is 2022.

For maintaining consistency in the GHG estimation in the energy sector, the structure of sectors and subsectors has been made consistent so that there is the same level of disaggregation throughout 29 years (1994 to 2022). The following assumption on activity data has been made to ensure Time Series Consistency.

- The activity data of manufacturing industries has been calibrated using the value addition of each sub-sector, thus representing the level of activity in each period.

- The residential sector has not been divided into urban and rural areas, as there was an abrupt change in urban population, as per the definition by the government.
- The disaggregation in the transport sector has followed the registration format by the Department of Transport Management.
- In the absence of details of vehicles (and emission standards), the fuel economy and emission factors have been assumed to be the same.
- The newly added "Construction and mining sector", which has been reported very recently, has not been included in the analysis, but its energy consumption and thus emissions are estimated for other industries and other transport subsectors.
- Other assumptions are also mentioned in each sectoral section and the methodologies.

The same emission factors have been used to estimate the emissions throughout the year, and it is assumed that the net calorific values of fuels also remain the same. In addition to that, the range of uncertainty has also been assumed to be the same for all the years.

Category-specific QA/QC and verifications

Tier 1 QA/QC procedures were implemented for Category 1.A Energy Sector.

The QA/QC procedures followed the general principles and QA/QC plan guidelines. The verification process included the following:

- Ensuring proper documentation of energy-related emission sources.
- Checking data for transcription and mechanical errors.
- Validating the accuracy of formulas and units of measurement across the time series.
- Confirming the consistent application of emission factors for all subcategories.
- Verifying references to data sources and emission factors in the IPCC Inventory Software.
- Evaluating the selection of methodological tiers based on data availability and sectoral relevance.
- Reviewing trends for logical consistency throughout the time series.

The final activity data were cross-checked using the latest IPCC Inventory Software to ensure consistency with results from the national inventory calculation files, specifically developed for Nepal's energy sector.

2.9.7.1.1.1 Comparison of national estimates of CO2 related to fuel combustion with data from the International Energy Agency

The accuracy of estimated CO2 emissions from activities related to fuel combustion obtained in current inventory both from reference and sectoral approach has been compared with the similar data from International Energy Agency (IEA). The results show that they differ (in absolute terms) from IEA by 11% at an average for reference approach and 7% for sectoral approach (the median difference being 9 and 5% respectively).

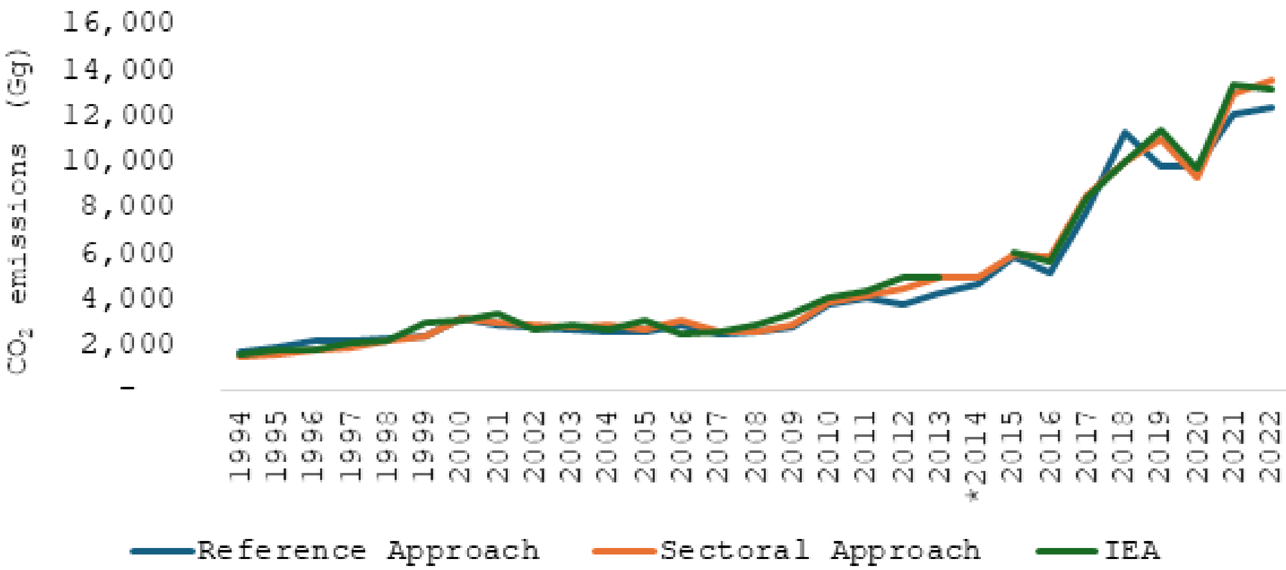

Figure 15: Current inventory results with IEA data on CO2 emissions from Fuel Combustion Activities (IEA, 2024) and Estimations

*2014 value of IEA has been adjusted to 2015 to make the trend comparable. This discrepancy should have arisen due to a difference in reporting for the fiscal year. In Nepal, the fiscal year generally begins on July 16 and ends on July 15 of the next year. A similar trend is in energy data.

2.9.8 Category-specific planned improvements

2.9.8.1 Challenges/Limitations and Necessities

Category	Challenges/Limitations	Necessity
Updated Data and Data Availability	- Lack of historical data for recalculation and trend analysis. - Limited centralized database for systematic updates. - Inconsistent data	- Accurate and updated data is essential for precise GHG estimation and tracking trends like energy mix changes, efficiency improvement, emission characteristics and so on.

Data Disaggregation Suitable for IPCC Guidelines	- Aggregated data does not align with IPCC guidelines (e.g., Vehicle registration data for certain categories are lumped into a single group, making it difficult to assess emissions from specific vehicle types. Energy consumption data for industrial sectors are aggregated, preventing detailed analysis of individual subsectors.).	- Disaggregated data enables compliance with IPCC standards and improves sector-specific emission calculations.
Research to Establish National Emission Factors	- Limited information on national- specific emission factors - Inconsistent fuel properties due to lack of standardization (For example in case of coal) - Validation and authenticity of available scientific data	- National emission factors improve accuracy as they reflect local fuel characteristics and conditions. - The available scientific data is to be validated by in-line agencies for their use and authenticity
Subsector-Level Studies	- Detailed bottom-up studies require significant time, effort, and dedicated resources. - Limited human resources and expertise for such studies.	- Bottom-up approaches enable accurate estimations by capturing subsector-level variations, improving overall inventory quality.
Inter-Agency Collaboration	- Lack of coordination among agencies. - Inconsistent data standards across sectors. - Absence of a unified data-sharing platform.	- Collaboration ensures high-quality data collection, sharing, and consistency in GHG inventory preparation.
Capacity Building and Training	- Shortage of trained personnel with an understanding of GHG inventories. - Limited awareness of IPCC guidelines among stakeholders.	- Skilled professionals are critical for accurate data collection, analysis, and reporting.

2.9.8.2 Recommendations and agencies

Category	Recommended Actions	Agencies

Updated Data and Data Availability	- Develop a centralized database for sectoral and historical data. - Encourage regular contributions from the public and private sectors. - Set guidelines for accurate data reporting.	WECS, NSO, MoEWRI, MoICS, MoPIT, NOC, DoC
Data Disaggregation Suitable for IPCC Guidelines	- Revise data collection frameworks to ensure disaggregation by sector/subsector. - Train agencies on IPCC requirements. - Implement digital tools for precise data collection.	WECS, MoEWRI, MoICS, MoPIT
Research to Establish National Emission Factors	- Conduct research to determine fuel properties and emission factors. - Repeat studies periodically to capture changes. • Collaborate with universities and research institutions for validation.	WECS, NAST, Uni
Subsector-Level Studies	- Assign a dedicated team under an authoritative agency. - Conduct progressive analyses by sector/subsector over time. - Integrate findings into developing the national GHG 6 inventory.	WECS, MoEWRI, MoICS, MoPIT, MoALD
Inter-Agency Collaboration	- Establish an inter-agency task force for coordination. - Develop a unified data-sharing platform managed by the National Statistics Office. - Conduct regular capacity-building programs for agencies. - Conduct collaborative research studies for estimation of GHG in respective sectors with one agency being ◆MoFE.	NSO, MoFE, WECS, MoEWRI, MoICS, MoPIT, MoALD
Capacity Building and Training	- Organize training programs for stakeholders on IPCC guidelines. - Partner with international organizations and donor 1) agencies for technical support and capacity building.	MoFE

DoC: Department of Customs; MoALD: Ministry of Agriculture and Livestock Development; MoEWRI: Ministry of Energy, Water Resources and Irrigation; MoFE: Ministry of Forest and Environment; MoICS: Ministry of Industry, Commerce and Supplies; MoPIT: Ministry of Physical Infrastructure and Transport; NSO: National Statistics Office; NAST: Nepal Academy of Science and Technology; NOC: Nepal Oil Corporation; Uni: Universities and Academic Research Laboratories; WECS: Water and Energy Commission Secretariat

Some subsector-wise recommendations for the energy sector that can be made as an initial step are as follows:

Sector	Activities
Manufacturing Industries and Construction	• Update the data of the actual number of industries running and their operational capacity • Take inventory of industries by type of product, technology, the use, and fuel they use • Take inventory of in-house electricity generation that is for self-use and/or sale. • Update on the basis of WECS provincial energy reports integration • Determined specific emission factors
Transport	• Take inventory of actual operational vehicles • Categorize vehicles on a more granular basis (by type of vehicle, type of registration, type of engine emission standards) • Take sample survey on operation (vehicle kilometer, capacity used, fuel economy etc., emission) • Determined specific emission factors
Commercial/ Institutional	• Update on basis of WECS provincial energy reports integration • Determined specific emission factors
Residential	• Update on basis of WECS provincial energy reports integration • Inventory of type of fuel based cookstoves, heating and other appliances used • Determined specific emission factors
Agriculture	• Take inventory of machinery used for agriculture (number, capacity, operation etc.) ◆ Update on basis of WECS provincial energy reports integration
Energy supply	• Identify the gaps in current information recoding system • Update energy recording structure and system

	• Harmonize the data specific to energy and fuels • Setup disaggregated energy information recording system 2) Conduct research on fuel quality and parameters

2.10 Industrial Processes and Product Use (IPPU)

The IPPU sector (IPCC Sector 2) contributes to greenhouse gas (GHG) emissions through chemical or physical transformations of raw materials into products. Unlike energy-sector emissions from fuel combustion, IPPU emissions stem from process-related activities. Examples include CO_2 released during cement and lime production, as well as emissions from iron, steel, ammonia, and aluminum manufacturing.

The sector also includes emissions from GHG containing products, such as hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulphur hexafluoride (SF_6), used in refrigeration and industrial applications. Non-energy uses of fossil fuels, like petrochemical products and lubricants, also contribute to emissions.

In Nepal, significant IPPU emissions come from cement production, which is a rapidly growing industry. Additional emissions arise from non-methane volatile organic compounds (NMVOCs) in food, beverage, pulp, and paper production, as well as imported refrigerators, such as HFCs and PFCs. While these refrigerants do not deplete the ozone layer, they have high global warming potential.

Emissions from non-energy fossil fuel uses, such as lubricants and paraffin waxes, are also notable. Nepal relies on imports for these products, with data sourced from customs and reports. Effective monitoring and sustainable management are critical as industrialization increases.

The Table 12 shows IPPU categories in Nepal considered in this inventory.

Table 12: Categories of Nepal's IPPU sector

Category Code	Category Name	Action
2A	Mineral Industry	
2A1	Cement Production	✓
2A2	Lime Production	IE
2B	Chemical Industry	NO
2C	Metal Industry	
2C1	Iron and Steel Production	✓

2D	Non-Energy Products from Fuels and Solvent Use	
2D1	2D1 Lubricant Use	✓
2D2	2D2 Paraffin Wax Use	✓
2E	2E Electronics Industry	NO
2F	2F Product Uses as Substitutes for Ozone Depleting Substances	
2F1a	2F1a Refrigeration and Stationary Air Conditioning	✓
2G	2G Other Product Manufacture and Use	
2G3a	2G3a Medical Applications	NE
2H	2H Other	
2H1	2H1 Pulp and Paper Industry	✓
2H2	2H2 Food and Beverages Industry	✓

NO- Not Occurring, NE- Not Estimated, IE- Included Elsewhere, ✓ Estimated

The Third National Communications (TNC) of Nepal estimated the emissions in Nepal for the base year 2011 in the following categories:

- Cement production
- Iron and steel production
- Product uses as substitutes for ozone depleting substances
- N2O from product uses
- Non-energy products from fuels and solvent use
- Paper production

The TNC used 2006 IPPC Guidelines to estimate the GHG inventory.

2.10.1 Methodology

The emissions from the IPPU sector in Nepal is estimated following the 2006 IPCC National GHG Inventory Guidelines. The 2006 Guidelines include Tier 1 Approach, using default emissions factors provided by the IPCC based on global averages for industrial processes, and Tier 2/3 Approach (when applicable), in cases where more detailed activity data is available, country-specific emission factors or more refined process- level data can be used. Table 13 summarizes the methods and data required in different sub-categories of the IPPU sector. In the preparation of Nepal's National GHG Inventory, the Tier 1 method will be applied for the IPPU sector, as we lack detailed activity data and country-specific emission factors.

GHG emissions are calculated for each IPPU source category by multiplying the corresponding activity data by the relevant emission factors in MS Excel and also in IPCC Inventory Software v2.95. Depending on reporting requirements, emissions are disaggregated by specific pollutants (e.g., CO2, CH4, N2O) or aggregated into total CO2 equivalent emissions. The activity data for various industries is obtained from the government documents such as annual reports and journals of the Ministry of Industry, Commerce and Supplies, the Department of Industry, the Department of Mines and Geology, the Department of Customs, the Nepal Rastra Bank, and the National Statistics Office. A collection of data quantifying the level of activity for each identified IPPU source category includes production data (e.g., tonnes of cement produced), consumption data (e.g., amount of limestone used), and other relevant data.

Table 13: IPPU categories and method used

Category	Subcategory	Gases	Method	Required Data	Data Source
2A. Mineral Industry	2A1. Cement Production	CO_2, SO_2	T1	Clinker production data, cement production data, import and export data of clinker	Ministry of Industry Commerce and Supplies, Ministry of Finance, Department of Industry, Department of Customs, Nepal Rastra Bank, Third National Communication
2C. Metal Industry	2C1. Iron and Steel Production	NMVOC, NO_2, SO_2, CO	T1	National iron and steel production data	Ministry of Industry, Commerce and Supplies, Department of Industry, Nepal Rastra Bank
2D. Non-Energy Products from Fuels and Solvent Use	2D1. Lubricant Use	CO2	T1	National data for non-energy uses of lubricants	Department of Customs
	2D2. Paraffin Wax Use	CO2	T1	National data for non-energy uses of paraffin waxes	Department of Customs

2F. Product Uses as Substitutes for Ozone Depletion Substances	2F1a. Refrigeration and Air Conditioning	HFC-134a	T1	National import data of refrigerants	Department of Customs
2H. Others	2H1. Pulp and Paper Industry	NMVOC	T1	National pulp and paper production data	Ministry of Industry, Commerce and Supplies, Department of Industry, Nepal Rastra Bank
	2H2. Food and Beverages Industry	NMVOC	T2	National food and beverage production data	Ministry of Industry, Commerce and Supplies, Department of Industry, Nepal Rastra Bank

To facilitate aggregate reporting of GHG values, expressed as carbon dioxide equivalents (CO2-eq), the global warming potentials (GWPs) values provided in the IPCC AR5 (temporal horizon 100 years) were used (see BTR1 Annex I.I).

2.10.2 Activity data

Data collection for the IPPU sector followed a detailed and structured approach, involving direct data requests from the Ministry of Industry, Commerce, and Supplies, the Department of Industries, the Department of Mines and Geology, the Department of Customs, Nepal Rastra Bank, supplemented by national statistics and surveys. The inventory requires industries involved in cement, lime and iron and steel, pulp and paper, and food and beverage production to report detailed activity data, including production volumes, raw material usage, and process-specific emission rates. For sources such as HFCs used in refrigeration and air conditioning, lubricants, and paraffin wax, data on import, consumption, and leakage rates were collected.

Cement Industry

The activity data for national cement production in Nepal was sourced from various institutions, including the Ministry of Finance (MoF), the Third National Communication (TNC), and the Nepal Rastra Bank (NRB), as detailed in BTR1 Annex VI.I. Cement production data for 1994 to 2007, extracted from the Economic Survey Reports published by the MOF and referenced in the TNC, lack specific information on national clinker production and clinker imports. Without this data, GHG emissions are likely to be overestimated.

For 2010 and 2011, data from the Nepal Energy Efficiency Programme (NEEP), referenced in the TNC, includes cement production only, limestone-based industries, allowing for a more accurate estimation of GHG emissions within Nepal. Data for 2015 to 2019, derived from NRB reports, includes total cement production, clinker production, and clinker import figures, aligning with clinker import data from the Department of Customs.

Due to the lack of continuous data from a single source, information from various references was combined to develop a comprehensive dataset. Missing values for the periods 2008-2009 and 2012–2014 were estimated

using linear interpolation, and for the period 2020-2022, activity data were estimated by applying the average annual growth rate of cement production, derived from national clinker data spanning 1994 to 2019. This approach ensures a consistent and accurate dataset for examining national cement production trends.

Lime Production

Activity data for national limestone production in Nepal was obtained from the Department of Mines and Geology and the National Statistics Office, covering the years 2003–2022. Over 50% of the limestone appears to be used for clinker production, which has been accounted for under the cement production subcategory for GHG emissions. However, the specific industrial usage of the remaining limestone and the actual quantity of lime production are unknown.

Due to the absence of data on lime production after accounting for clinker production, this subcategory has been marked as "Not Estimated," despite the activity occurring in Nepal. This approach ensures a consistent and comprehensive dataset for further analysis.

Iron and Steel Production

Activity data for national iron and steel production in Nepal was obtained from the Nepal Rastra Bank (NRB), the Ministry of Finance (MoF), and the Third National Communication (TNC). In Nepal, the production of iron and steel primarily relies on imported sponge iron as a raw material to manufacture various steel products. Additionally, some factories utilize scrap iron or import ingots and billets to produce different metallic products. In all these processes, there is no transformation of the material's inherent properties, meaning no significant greenhouse gas (GHG) emissions are generated from industrial processes. However, certain emissions, such as NMVOC, CO, SO_2, and NO_2, are released due to the presence of various chemicals involved in the production processes. As a result, only these specific emissions are accounted for in this inventory, as they represent the primary sources of air pollutants associated with iron and steel production in the country.

Lubricant Use

The activity data for lubricant consumption in Nepal was collected from the Department of Customs' annual Foreign Trade Statistics (FTS) report, recorded in kilograms (kg). For use in the

IPCC inventory software, the data was converted to terajoules (TJ). Data was available for the years 2008–2010 and 2014–2022. To address the missing data for the years 2011–2013, linear interpolation was applied, resulting in a complete and consistent dataset for analysis.

Paraffin Wax Use

The activity data for paraffin consumption in Nepal was collected from the Department of Customs' annual Foreign Trade Statistics (FTS) report, recorded in kilograms (kg). For use in the IPCC inventory software, the data was converted to terajoules (TJ). Data was available for the years 2007 and 2012–2022. To address the missing data for the years 2008-2011, linear interpolation was applied, resulting in a complete and consistent dataset for analysis.

Refrigeration and Air Conditioning

The activity data for HFC use in Nepal was collected from the Department of Customs' annual Foreign Trade Statistics (FTS) report. This data was recorded as an integrated quantity of PFC and HFC mixtures. However, the IPCC inventory software requires data for each refrigerant individually. Due to the lack of specific data on individual refrigerants, we estimated the quantity of HFC-134a using the aggregated data. While this approach may lead to an overestimation of HFC emissions, it was necessary to provide at least one calculated value for the inventory, as HFCs were previously calculated in the Third National Communication (TNC).

N2O from product use

The activity data for N_2O use in Nepal was sourced from the Export-Import Data Bank Version 7.1, published by the Government of India, Ministry of Commerce & Industry, Department of Commerce, as referenced in the Third National Communication (TNC) report. Since the data could not be obtained from Nepal's annual Foreign Trade Statistics (FTS) report, this category has been marked as "Not Estimated," although it is occurring.

Pulp and Paper Industry

The activity data for national pulp and paper production in Nepal was collected from the Nepal Rastra Bank (NRB), the Ministry of Finance (MOF), and the Third National Communication (TNC). Data for the years 1994–2008 were sourced from NRB, MOF, and TNC, while data for 2011–2022 were obtained from NRB. To address the data gap for the years 2009–2010, linear interpolation was applied, resulting in a complete and consistent dataset for analysis.

Food and Beverages Industry

The activity data for the national production of biscuit, sugar, animal feed, beer, and liquor in Nepal were collected from the Nepal Rastra Bank (NRB) and the Ministry of Finance (MoF). To address the gaps in the dataset, linear interpolation was applied, ensuring a complete and consistent dataset for analysis.

2.10.3 Emission factors

The emission factors and other relevant parameters, along with the supporting documentation and technical references, were obtained from the IPCC Emission Factor Database (EFDB) 2007 and the EMEP-EEA (2016) guidelines. The EFDB 2007 contains a comprehensive set of default emission factors, which are used to estimate the amount of greenhouse gases emitted during various industrial and natural processes. These factors are crucial for calculating emissions in the context of national inventories and reporting requirements.

The EMEP-EEA (2016) guidelines provide additional technical references and methodologies for emission estimation. Both sources are widely recognized for providing standardized, reliable data to support emissions calculations and ensure consistency across different reporting and regulatory frameworks. These databases and guidelines help in deriving accurate emission estimates and contribute to the transparency and credibility of national greenhouse gas inventories.

Table 14: IPPU Emission factors by subcategories

IPPU Sub-category	CO_2	SO_2	NO_2	CO	NMVOC	Carbon Content	EF from Installed Base	Source
2A1 Cement Production	0.52t CO_2/t cement produced	0.3Kg SO_2/t cement produced						2006 IPCC Guidelines
2C1 Iron and Steel Production		45g SO_2/t steel produced	40g NO_2/t steel produced	1g CO/t steel produced	30g NMVOC / steel produced			2006 IPCC Guidelines
2D1 Lubricant Use						20tC/TJ of Lubricant Use		2006 IPCC Guidelines
2D2 Paraffin Wax Use						20tC/TJ of Lubricant Use		2006 IPCC Guidelines
2F1a Refrigeration and Air Conditioning							15%	2006 IPCC Guidelines

2H1 Pulp and Paper Industry					2 kg NMVOC/ t dried pulp			EMEP/EEA Guidebook 2023
2H2 Food and Beverages Industry					1 Kg NMVOCs/t biscuit produced			EMEP/EEA Guidebook 2023
					10 Kg NMVOCs/t sugar produced			EMEP/EEA Guidebook 2023
					1 Kg NMVOCs/ t animal feed produced			EMEP/EEA Guidebook 2023
					2 Kg NMVOCs/t beer produced			EMEP/EEA Guidebook 2023
					2 Kg NMVOCs/t liquor produced			EMEP/EEA Guidebook 2023

2.10.4 Trend of Emission in IPPU Sector

The chart presented in Figure 15 visualizes the progression of GHG emissions within Nepal's IPPU sector over a span of nearly three decades, from 1994 to 2022. It reveals a significant and continuous upward trend in emissions, particularly after 2010. This trend aligns with the expansion of industrial activities in Nepal, highlighting the growing importance of the IPPU sector in the national emissions profile.

The chart underscores carbon dioxide (CO_2) as the dominant GHG emitted by the IPPU sector, primarily driven by industrial processes such as cement production. Emissions of hydrofluorocarbons (HFCs), specifically HFC-134a, began to appear in the data from 2014 onwards, reflecting the increasing use of refrigerants in various industrial applications. However, emissions of nitrous oxide (N_2O) and other HFCs could not be accounted for due to the lack of specific activity data on individual compounds, indicating gaps in data collection and reporting. Between 1994 and 2009, emissions from the IPPU sector remained relatively low and stable, likely reflecting limited industrial development and production activities during this period. A notable surge in GHG emissions is observed from 2010 onwards, coinciding with the rapid growth of Nepal's industrial base. This increase is attributed to expanded cement production, the adoption of energy-intensive processes, and the rising use of industrial chemicals and materials. By 2022, CO_2 emissions from the IPPU sector reached an estimated 4794.89 Gg CO2-eq, marking a substantial escalation compared to earlier years. Similarly, HFC-134a emissions, though relatively minor, showed a steady increase, reaching 16.703 Gg CO2-eq in 2022.

The industrial expansion driving these emissions is also a critical factor in Nepal's economic development, presenting a dual challenge of balancing growth with sustainability. The consistent and significant rise in GHG emissions from the IPPU sector, as demonstrated in the chart, signals a pressing need for proactive measures. These should focus on improving efficiency, adopting cleaner technologies, and enhancing data management systems to ensure sustainable industrial development while addressing the challenges posed by climate change.

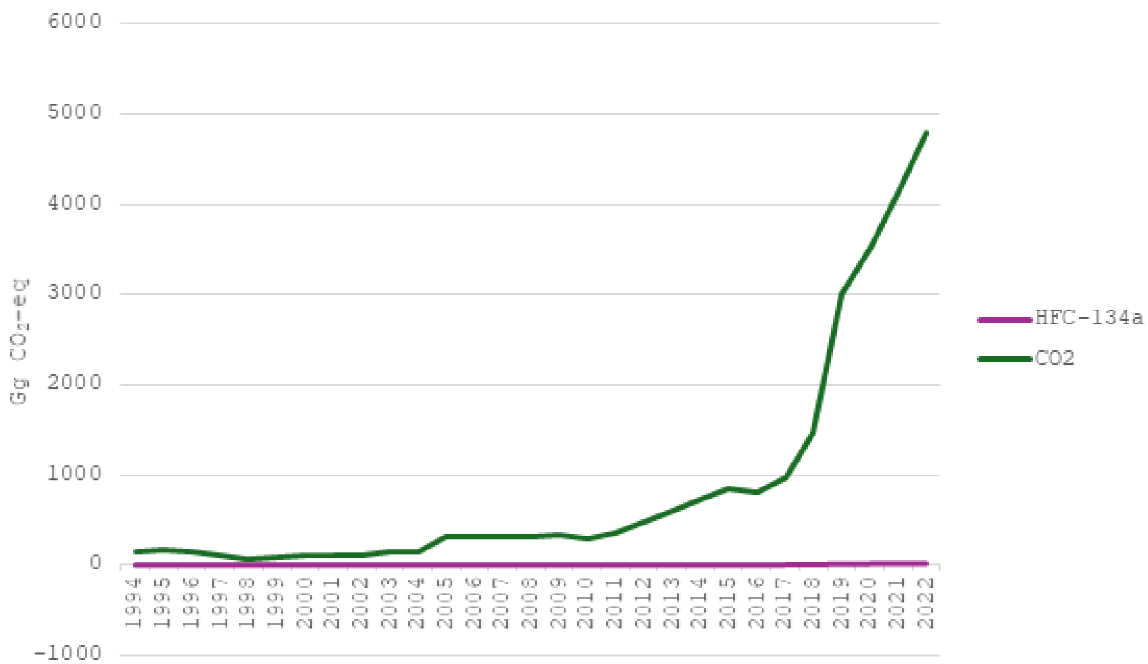

Figure 16: GHG emissions from IPPU sector from 1994-2022

2.10.5 Recalculation of emissions 1994-2011 with explanatory information and justifications

Figure 16 and Table 15 present the recalculated greenhouse gas (GHG) emissions from Nepal's Industrial Processes and Product Use (IPPU) sector for the years 1994 to 2011. These recalculations compare the emissions reported in the Initial National Communication (INC), Second National Communication (SNC), and Third National Communication (TNC) with updated estimates.

The INC reported emissions of 165 Gg CO2-eq in 1995, but the revised value decreased to 162 Gg CO2-eq. Similarly, the SNC reported 131 Gg CO2-eq for 2001, while the recalculated value declined to 106 Gg CO2- eq. For 2011, the TNC reported 380 Gg CO2-eq, but the revised estimate shows a significant decrease to 350 Gg CO2-eq.

The main reasons for these differences are updated methodologies. The recalculations use the improved emission factors provided in the IPCC 2006 guidelines, replacing those from the IPCC 1996 guidelines. Additionally, the INC and SNC relied on Global Warming Potential (GWP) factors from the Second Assessment Report (SAR), while the TNC used GWP factors from the Fourth Assessment Report (AR4). For these recalculations, GWP factors from the Fifth Assessment Report (AR5) were applied, along with updated activity data on production and product use. These updates provide a more accurate picture of emissions from the IPPU sector.

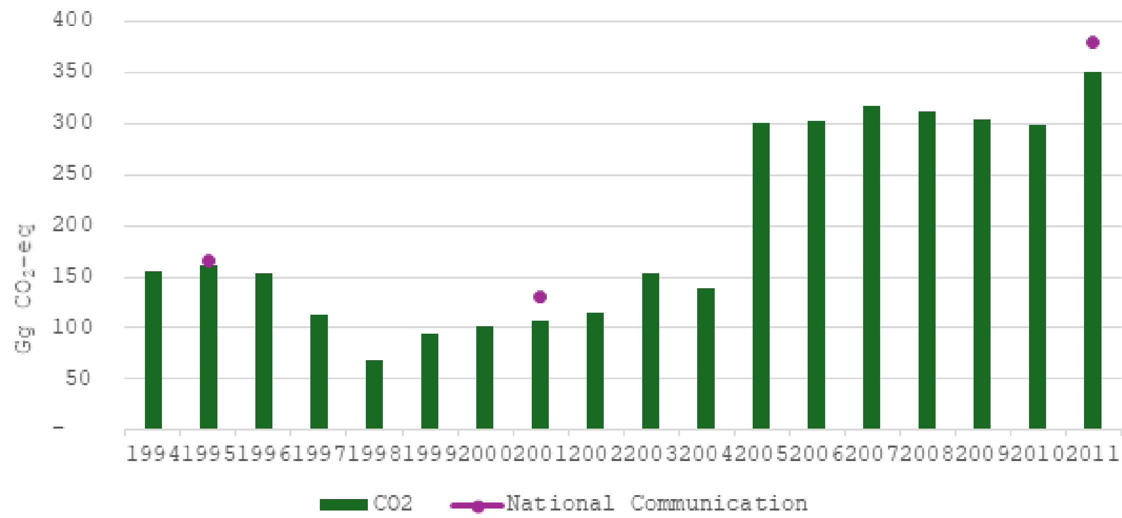

Figure 17: GHG emissions from IPPU sector during 1994-2011

Table 15: Recalculation of INC, SNC, and TNC GHG emissions

	INC (1995)	Revised INC	SNC (2001)	Revised SNC	TNC (2011)	Revised TNC
GgCO2-eq	165	162	131	106	380	350

2.10.6 Inventory development 2012-2022

Figure 16 provides calculation of the GHG inventory in the IPPU sector during 2012-2022. The GHG emissions in the IPPU sector are mainly carbon dioxide emissions from the cement industry during this period.

From 2012 to 2022, CO_2 emissions consistently dominated the emissions from the IPPU sector. The graph shows a steady increase in CO_2 emissions each year, reaching a sharp peak by 2022, where emissions equal nearly 4794.89 Gg CO_2-eq. This indicates an ongoing growth in industrial activities contributing to CO_2 emissions, particularly in the cement sector. The trend suggests that Nepal's industrial growth during this period has resulted in higher emissions, which reflects an increase in production capacities.

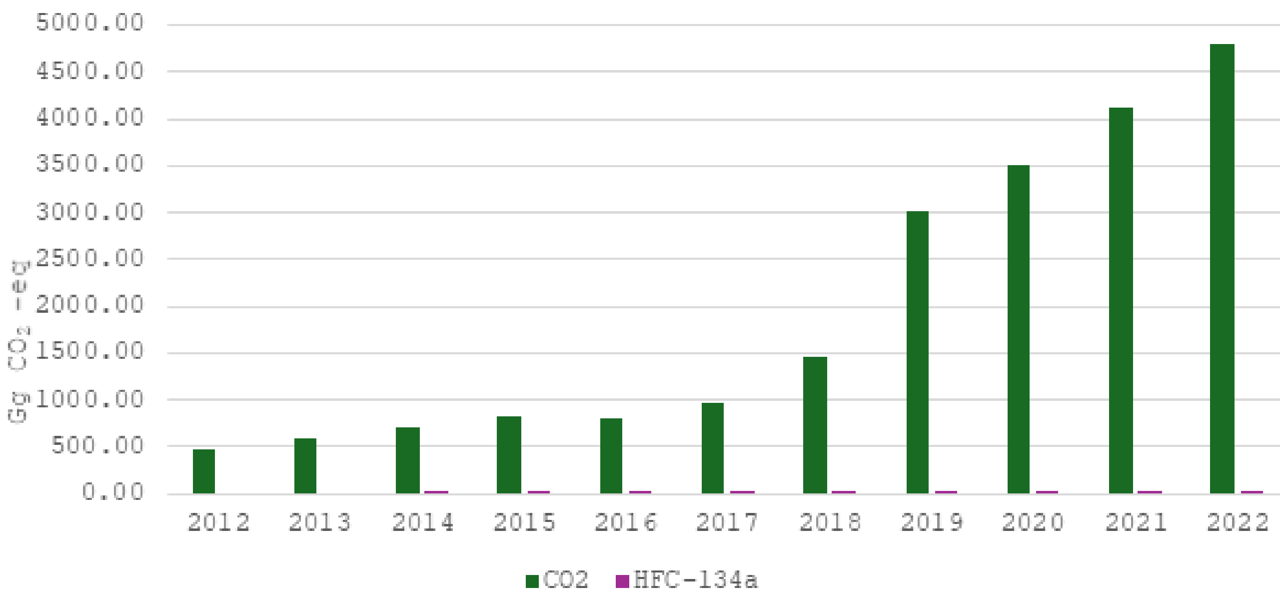

Figure 18: GHG emissions from IPPU sector during 2012-2022

2.10.7 Sectoral Emission in the year 2022

The data below shows the greenhouse gas emissions for 2022, focusing on CO2 and HFC-134a from industrial activities. Most CO2 emissions (4792.239 Gg) come from cement production, with smaller amounts from lubricants and paraffin wax. HFC-134a emissions (16.70 Gg) are entirely from refrigeration and air conditioning. This highlights cement production as a major CO2 source and refrigeration as the main HFC-134a contributor.

Table 16: GHG emission from IPPU in the year 2022

Inventory Year: 2022	**CO_2**	**HFC-134a**
Category	Gg CO2-eq	Gg CO2-eq
2 - Industrial Processes and Product Use	4794.891	16.70256
2.A - Mineral Industry	4792.239	
2.A.1 - Cement production	4792.239	
2.D - Non-Energy Products from Fuels and Solvent Use	2.652027	

2.D.1 - Lubricant Use	1.899627	
2.D.2 - Paraffin Wax Use	0.7524	
2.F - Product Uses as Substitutes for Ozone Depleting Substances		16.70256
2.F.1 - Refrigeration and Air Conditioning		16.70256
2.F.1.a - Refrigeration and Stationary Air Conditioning		16.70256

2.10.8 Non-GHG emissions in the year 2022

The 2022 inventory of non-GHG emissions highlights key industrial sources and their contributions: Cement Production (2A1) is the largest contributor to SO2 emissions at 2.91 Gg, while Food and Beverage Production (2H2) dominate NMVOC emissions at 1.48 Gg. Iron and Steel Production (2C1) contributes small amounts of SO2 (0.0285 Gg), NO2 (0.024 Gg), CO (0.0006 Gg), and NMVOC (0.019 Gg), and Pulp and Paper Production (2H1) adds minimally to NMVOC at 0.02 Gg. In total, SO2 emissions reach 2.9385 Gg, NO2 0.024 Gg, CO 0.0006 Gg, and NMVOC 1.519 Gg, with cement and food/beverage production being the most significant sources of SO2 and NMVOC, respectively. This inventory underscores the varying impacts of industrial activities on air quality.

Table 17: Non-GHG emissions in the year 2022

Inventory Year: 2022				
Category	**SO_2 (Gg)**	**NO_2 (Gg)**	**CO (Gg)**	**NMVOC (Gg)**
2A1 Cement Production	2.91			
2C1 Iron and Steel Production	0.0285	0.024	0.0006	0.019
2H1 Pulp and Paper Production				0.02
2H2 Food and Beverage Production				1.48
Total	**2.9385**	**0.024**	**0.0006**	**1.519**

2.10.9 Uncertainty assessment and time series consistency

The analysis focuses on a base year (2012) and a target year (2022) to examine changes in uncertainties over time and their influence on emission trends. The data is organized based on the 2006 IPCC Guidelines. Cement production exhibits the highest activity data uncertainty at 78.89%, while refrigeration and stationary air conditioning use have the lowest at 5%. Regarding emission factor uncertainty, paraffin wax has the highest at 100.12%, and refrigeration and stationary air conditioning use the lowest at 0%. The combined uncertainty ranges between 5% and 102%. The dataset also analyzes how uncertainties in individual categories affect the overall variance in emissions for the target year and their influence on national emission trends.

Table 18: Uncertainty in IPPU

2006 IPCC Categories	Gas	Base Year Emissions ($GgCO_2$-eq)	End Year Emissions ($GgCO_2$-eq)	Activity Data Uncertainty (%)	Emission Factor Uncertainty (%)	Combined Uncertainty (%)
Cement production	CO_2	470.77	4792.239	78.89	4.5	79.02
Lubricant Use	CO_2	4.24	1.89	20	50.09	53.93
Paraffin Wax Use	CO_2	2.14	0.75	20	100.12	102.09
Refrigeration and Stationary Air Conditioning	HFC-134a	0	16.70	5	0	5

2.10.10 Category-specific QA/QC and verifications

In the process of estimating greenhouse gas (GHG) emissions for the development of Nepal's national inventory, Quality Control (QC) and Quality Assurance (QA) procedures play a critical role in ensuring the accuracy, reliability, and transparency of the data and methodologies used. These procedures are implemented throughout the inventory compilation process to minimize errors, verify results, and ensure that the inventory reflects the national context correctly.

Quality Control (QC) Process: The QC process in the Industrial Processes and Product Use (IPPU) sector is essential during the estimation of GHG emissions and removals. QC checks are conducted at multiple stages of the inventory development process to minimize potential errors and ensure the selection of appropriate data, emission factors, and parameters. Key QC activities include:

Data Selection: Ensuring the correct and relevant data is chosen for the estimation of emissions in each sector. This includes validating the activity data and emission factors based on local conditions and international guidelines.

Emission Factor and Parameter Selection: Carefully choosing emission factors and parameters from recognized sources, such as the IPCC Emission Factor Database (EFDB), EMEP-EEA (2016) guidelines and other relevant technical guidelines, to ensure consistency and accuracy in emissions calculations.

Unit Conversion: Verifying that all data and parameters are correctly converted to consistent units, following international standards, to ensure compatibility and comparability across different datasets.

Methodological Tiers: Ensuring that the correct methodological tiers (Tier 1, 2, or 3) are selected based on the availability of data and the level of detail required for the national context. This ensures that the methods used to estimate emissions are both scientifically sound and suitable for Nepal's data availability.

Computation Files: The QC process includes reviewing and verifying the Excel files and data inputs in the IPCC Inventory Software used for calculations. This ensures that the files are properly structured and that the formulas are correctly applied.

Evaluation of Trends: Checking trends in data and results to identify any inconsistencies or outliers that may indicate errors in the data or calculation processes.

Documentation: Keeping comprehensive records of all QC procedures, including the selection of data, emission factors, and methodology, as well as any assumptions made during the calculation process. This documentation helps provide transparency and accountability in the inventory process.

The QC Checklist follows the recommended QC procedures outlined in Table 6.1, Chapter 6, Volume 1 of the 2006 IPCC Guidelines, which includes 12 QC activities, each with specific procedures to check and verify the accuracy of the data and calculations.

Quality Assurance (QA) Process: The QA process provides an additional layer of validation to ensure the accuracy and reliability of the national GHG inventory. QA procedures focus on the validation of all data sources, assumptions, and methodologies used in the estimation of GHG emissions in the IPPU sector. The goal is to confirm that the results represent the national context accurately and are free from systematic errors. The key QA activities include:

Validation of Data Sources: Ensuring that all data used for estimating GHG emissions, including activity data and emission factors, are obtained from reliable and up-to-date sources. This involves reviewing national and international databases, official reports, and statistical records to confirm the accuracy and relevance of the data.

Methodology Validation: Verifying that the methods used to compile the GHG inventory are appropriate for the national context of Nepal. This includes ensuring that the methodologies selected align with international guidelines, such as the 2006 IPCC Guidelines and the EMEP-EEA (2016) guidelines.

Cross-Checking Results: Using the calculations methods of MS Excel and LEAP to cross-check the emissions results calculated in IPCC Inventory Software v2.95. The results from the IPCC Inventory Software should match those obtained from both the Excel and LEAP national inventory calculation files if the emissions calculations are correct.

Trend Evaluation: Analyzing the trends in emissions data to ensure that the calculated emissions reflect the expected national trends. This includes checking for any significant deviations or discrepancies in emissions data over time.

The IPCC Inventory Software v2.95, Excel and LEAP files are used in parallel for calculating and validating emissions. The Excel and LEAP files are developed specifically for Nepal's national context and incorporate local data and factors. The IPCC Inventory Software v2.95 is then used to ensure that the calculations and results are consistent with international standards.

The QA and QC processes are integral parts of the GHG inventory development in Nepal. They help ensure that emissions data are accurate, reliable, and reflect the national context. The combination of the IPCC Inventory Software v2.95, Excel, and LEAP-based calculations provides a comprehensive approach to emissions estimation, with multiple layers of validation and verification. These rigorous procedures ensure that the final national GHG inventory is transparent, scientifically sound, and aligned with international reporting standards.

2.10.11 Category-specific planned improvements

Table 19: Planned improvements for the IPPU sector in Nepal

Category	Planned Improvement
Data Collection System	Establish centralized data repositories for all activity data.
	Standardize data collection protocols and formats.
Capacity Building	Conduct regular training workshops on IPCC guidelines, GHG inventory software, and data analysis.
	Develop a national and international expert network for methodological support.
Addressing Data Gaps and Uncertainty	Implement annual or biennial data collection cycles.
	Minimize interpolation by improving direct data collection processes.
	Perform uncertainty analysis regularly to address variability in datasets.
Coordination and Stakeholder Engagement	Strengthen inter-ministerial coordination for seamless data sharing and policy alignment.
	Engage industries through incentives, training, and feedback mechanisms.
Policy and Institutional Framework	Introduce legal mandates for regular reporting of activity data by industries.
	Establish a dedicated unit for inventory preparation, verification, and improvement.
Monitoring, Verification, and Quality Control	Implement third-party audits for independent verification of data accuracy.
	Develop and apply QA/QC protocols to ensure compliance with IPCC standards.
Research and Development	Collaborate with academic institutions to develop emission factors and refine methodologies.
	Use forecasting tools for future emission projections and policy development.
Transparency and Reporting	Publish inventory results in accessible, user-friendly formats.
	Align reporting formats with UNFCCC and IPCC guidelines for consistency and compliance.
Climate Finance Integration	Leverage international climate finance to fund system upgrades.
	Integrate inventory data with carbon market mechanisms to support climate finance goals.

2.11 Agriculture, Forestry, and Other Land Use

The overall greenhouse gas emissions from AFOLU sector for the year 2022 are presented in the Table 20 below. The net emission from AFOLU sector is 3571.787488 Gg CO2-eq and most of the emissions occurred from Livestock and Agriculture sector.

Table 20: Emissions from AFOLU sector in 2022

Categories	Net CO_2 emissions / removals			
	CO_2	CH_4	N_2O	Total
	Gg	Gg CO_2-eq	Gg CO_2-eq	Gg CO_2-eq
3 - Agriculture, Forestry, and Other Land Use	**(19916.207)**	**20527.305**	**2960.689**	**3571.787**
3.A - Livestock		18199.968	523.532	18723.500
3.A.1 - Enteric Fermentation		16686.635	-	16686.635
3.A.2 - Manure Management		1513.333	523.532	2036.865
3.B - Land	(20021.958)			(20021.958)
3.B.1 - Forest land	(18072.100)			(18072.100)
3.B.1.a - Forest land Remaining Forest land	(18072.100)			(18072.100)
3.B.1.b - Land Converted to Forest land	-			-
3.B.1.b.i - Cropland converted to Forest Land	-			-
3.B.1.b.ii - Grassland converted to Forest Land	-			-
3.B.1.b.iii - Wetlands converted to Forest Land	-			-
3.B.1.b.iv - Settlements converted to Forest Land	-			-
3.B.1.b.v - Other Land converted to Forest Land	-			-
3.B.2 - Cropland	6345.516			6345.516
3.B.2.a - Cropland Remaining Cropland	6345.516			6345.516
3.B.2.b - Land Converted to Cropland	-			-
3.B.2.b.i - Forest Land converted to	-			-

Cropland				
3.B.2.b.ii - Grassland converted to Cropland	-			-
3.B.2.b.iii - Wetlands converted to Cropland	-			-
3.B.2.b.iv - Settlements converted to Cropland	-			-
3.B.2.b.v - Other Land converted to Cropland	-			-
3.B.3 - Grassland	(38.794)			(38.794)
3.B.3.a - Grassland Remaining Grassland	(38.794)			(38.794)
3.B.3.b - Land Converted to Grassland	-			-
3.B.3.b.i - Forest Land converted to Grassland	-			-
3.B.3.b.ii - Cropland converted to Grassland	-			-
3.B.3.b.iii - Wetlands converted to Grassland	-			-
3.B.3.b.iv - Settlements converted to Grassland	-			-
3.B.3.b.v - Other Land converted to Grassland	-			-
3.B.4 - Wetlands	-			-
3.B.4.a - Wetlands Remaining Wetlands	-			-
3.B.4.a.i - Peat Extraction remaining Peat Extraction	-			-
3.B.4.a.ii - Flooded Land remaining Flooded Land	-			-
3.B.4.b - Land Converted to Wetlands	-			-
3.B.4.b.i - Land converted for Peat Extraction	-			-
3.B.4.b.ii - Land converted to Flooded Land	-			-
3.B.5 - Settlements	(8256.580)			(8256.580)

3.B.5.a - Settlements Remaining Settlements	(8256.580)			(8256.580)
3.B.5.b - Land Converted to Settlements	-			-
3.B.5.b.i - Forest Land converted to Settlements	-			-
3.B.5.b.ii - Cropland converted to Settlements	-			-
3.B.5.b.iii - Grassland converted to Settlements	-			-
3.B.5.b.iv - Wetlands converted to Settlements	-			-
3.B.5.b.v - Other Land converted to Settlements	-			-
3.B.6 - Other Land	-			-
3.B.6.a - Other land Remaining Other land	-			-
3.B.6.b - Land Converted to Other land	-			-
3.B.6.b.i - Forest Land converted to Other Land	-			-
3.B.6.b.ii - Cropland converted to Other Land	-			-
3.B.6.b.iii - Grassland converted to Other Land	-			-
3.B.6.b.iv - Wetlands converted to Other Land	-			-
3.B.6.b.v - Settlements converted to Other Land	-			-
3.C - Aggregate sources and non-CO_2 emissions sources on land	105.750	2327.337	2437.157	4870.245
3.C.1 - Burning	-	-	-	-
3.C.1.a - Burning in Forest Land	-	-	-	-
3.C.1.b - Burning in Cropland	-	-	-	-
3.C.1.c - Burning in Grassland	-	-	-	-
3.C.1.d - Burning in all other land uses	-	-	-	-

3.C.2 - Liming	0.530			0.530
3.C.3 - Urea application	105.220			105.220
3.C.4 - Direct N_2O Emissions from managed soils			1673.180	1673.180
3.C.5 - Indirect N_2O Emissions from managed soils			682.551	682.551
3.C.6 - Indirect N_2O Emissions from manure management			81.424	81.424
3.C.7 - Rice cultivation		2327.337		2327.337
3.C.14 - Other (please specify)	-	-	-	-

2.12 Livestock

The livestock sector includes emissions of greenhouse gas (GSG) arise from various sources. The major sources are from (1) Enteric fermentation: animals like cattle, buffalo, goats, sheep, pigs, horse and mule emit methane and carbon dioxide during digestion, primarily through burping (2) Manure: Solid waste, dung, slurry of biogas plants generates, both methane and nitrous oxide. Among the several emitters, livestock are the major source of greenhouse gas in agriculture farming system. Methane is one of the major gases which has a 28 times higher effect on global warming than carbon dioxide. In general, the livestock agricultural feed system contributes about 12 percent of all anthropogenic greenhouse gas emissions.

2.12.1 Description of Livestock Sector in Nepal

Livestock contributes both directly and indirectly to climate change through the emissions of GHGs. The livestock sector includes methane (CH4) from enteric fermentation and manure management, and direct N2O from manure management. Cattle are the most important livestock in Nepal which is integrated with crop agriculture for the livelihood of the small farmers. Methane emissions from manure management are reported to be usually smaller than those from enteric fermentation emissions. Considering the entire livestock commodity chain – from land use and feed production to livestock farming and waste management, to product processing and transportation – about 18% of total anthropogenic GHG emissions can be attributed to the livestock sector.

1. Enteric fermentation: Ruminants like cattle and sheep produce methane during digestion, primarily through burping. Ruminant animals, such as cattle, sheep, buffaloes, and goats, are unique due to their special digestive systems, which can convert plant materials that are indigestible by humans into nutritious food. In addition to food, these animals also produce hides and fibers that are utilized by humans. This same helpful digestive system, however, produces CH4, a potent GHG that can contribute to global climate change

2 Manure Management: Solid waste generates both methane and nitrous oxide, with emissions varying based on management systems. Manure management systems differ in different agro-ecological zones on Nepal. Livestock rearing in general, and the rearing of large ruminants in particular, is dependent upon the overall farming system of the area. The farming systems at different altitudes are dependent upon temperature, irrigation and other interrelated factors, and will vary. For the large ruminants, three management systems predominate in Nepal, and they are:

A) Transhumance management system

This system is adopted in the high mountain areas where herds of cattle and buffalo migrate from one place to another throughout the year and utilizes forage resources available from the alpine pastures during the monsoon season, and crop stubble of fallow land during the winter season. During the upward and downward migration, the undergrowth in the forest region is the major forage source. The large ruminant animals involved in the system are the yak, chauri and mountain native cattle, but in some areas of lower mountain, buffalo are also included in transhumance system. As the herd is in migration, the dungs are (a) Collected and pills outside the shed (80% of the manure during night in camp) and (b) Scattered on the pastureland (20% of the outputs).

B) Sedentary system of management

Ruminant livestock makes daily grazing in nearby community land, forest, and return to shed every evening. The main grazing areas during the summer are the scrubland and community grazing land around the village. The sedentary population consists of working oxen, dry buffaloes and a small number of exotic cattle breeds such as Holstein Frisian. This system prevails at the lower altitudes of the midhills (900–1000m asl) and utilizes all the available forage in and around the village. The grazing area is usually degraded, and gully formation and soil erosion are evident. Though the animals spend half their time grazing, most of the forage resource is based upon crop-products and tree fodder during winter, and grasses and weeds from crop land during the summer, which are offered during evening and morning hours.

As the herd is in Sedentary system of management, the dungs are (a) Collected and pills outside the shed (80% of the manure during night in camp) and (b) Scattered on the community grazing land (20% of the outputs).

C) Stall-fed system of management

This type of animal rearing is found mainly in the low to mid-hills (400–900m asl) and peri-urban areas with milking buffalo, and exotic or crossbred cattle and buffalo. It is governed both by the availability of community grazing land in the village. The system prevails in areas of intensive cultivation (three crops per year), where the availability of crop by-products is adequate to maintain the animals in winter. In addition to crop by-products, tree fodder, grasses and weeds collected from the farmland also constitute an important forage source. As the animals are completely stalled fed and remain inside, the manure deposition is under the shed. Every day, manure is collected and kept in pits up to 1 meter above the ground level. The Figure 18 below shows the emissions by livestock sector in Nepal considered in this inventory.

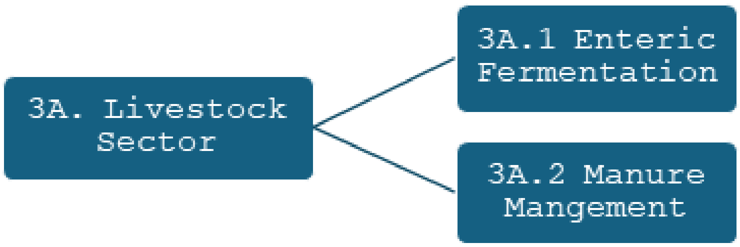

Figure 19: Categories included in Livestock Sector

2.12.2 Methodology

These emissions of greenhouse gas arise from various sources in livestock production, and these are as follows:

For this inventory, the emissions estimations from enteric fermentation and manure management system will be estimated using tier 1 method as per IPPC 2006 guideline.

For enteric fermentation the following equations will be used.

ANNUAL AVERAGE POPULATION

Where: AAP= annual average population

$AAP=Day_{alive*}$ *(NAPA/365)*

NAPA=number of animals produced annually Source: (IPCC, 2006)

The above presented equation is used for estimating annual average population for growing population (eg. Meat animals, such broiler etc.). For static animal population (eg. Dairy cows, buffalo) annual average population is obtained simply as livestock population from livestock inventory data. The emission is then further estimated using the equation below:

$$Emission= EF(T)*(N(T)/106)$$

Where:

Emission: methane emission from enteric fermentation, Gg CH_4 yr-1

EF(T): emission factor for the defined livestock population, kg CH_4 head-1 yr-1 N(T): number of head of livestock species/ category T in the country

T: species/category of livestock Then,

$$\text{Total } CH_4 \text{ Enteric} = \sum Ei$$

Where:

Total CH_4 Enteric: total methane emission from enteric fermentation, Gg CH_4 yr-, Ei=is the emission for the ith livestock categories and subcategories

Source: IPCC, 2006

For CH_4 from manure management the following equation will be used.

$$CH_{4\,Manure} = \sum \frac{(EF_{(T)} * N_{(T)}}{10^6}$$

Where:

CH_4 Manure = CH_4 emissions from manure management, for a defined population. Gg CH_4 yr-1 EF(T) = emission factor for the defined livestock population, kg CH_4 head-1 yr-1

N(T) = the number of head of livestock species/category T in the country T = species/category of livestock

Source: IPCC, 2006

The equation presented below will be used for estimating direct N2O from manure management.

DIRECT N_2O EMISSIONS FROM MANURE MANAGEMENT

$$N_2O_{D(mm)} = \left[\sum_{S}\left[\sum_{(T)}(N_{(T)} * Nex_{(T)} * MS_{(T,S)}\right] * EF_{3(S)}\right] * \frac{44}{28}$$

Where:

N2OD(mm) = direct N_2O emissions from manure management in the country, Kg N_2O

yr-1 N (T) = number of head of livestock species/category T in the country

Nex(T) = annual average N excretion for each livestock species/category T that is managed in manure management system S in the country, dimensionless

EF(T,S) = emission factor for direct N_2O emissions from manure management system S in the country, kg N_2O-N/kg N in manure management system S

S = manure management system T= Species/category of livestock

44/28 = conversion of (N2O-N) (mm) emissions to N2O(mm) emissions Source: IPCC, 2006

The Table 21 below presents the category and the method used for the inventory

Table 21: Livestock Sector category and method that will be used for GHG Inventory

Category	Gases	Method	Required Data	Data Source
3A.1 Enteric Fermentation	CH_4	T1	Livestock population head	• Ministryof Agricultureand Livestock Development • Department of Livestock Services, • Third National Communication • FAO Stat • National Statistics Office
3A.2 Manure Management	CH_4	T1	Livestock population head	• Ministryof Agricultureand Livestock Development • Department of Livestock Services, • Third National Communication • FAO Stat • National Statistics Office
	Direct N_2O	T1	Livestock population head	• Ministryof Agricultureand Livestock Development • Department of Livestock Services, • Third National Communication • FAO Stat • National Statistics Office

2.12.3 Activity data

The data collection for the livestock sector involves direct data requests from the Ministry of Agriculture and Livestock Development (MOALD), KII and collection of published data. The time series data on livestock population (MOALD, 2023) published by MOALD is used for livestock population. Similarly, the year- wise livestock population published by MOALD every year were also collected for livestock population, supplemented by national statistics, surveys and FAOSTAT. The activity data for emission inventory of livestock sector from 2012-2022 is presented in BTR1 Annex VII.I

2.12.4 Emission factors

The default emission factors provided by IPCC guidelines for Indian subcontinent are used for emission estimation of CH4 and N2O as presented in BTR1 Annex VII.III

2.12.5 Trend of Emission in Livestock Sector

The Figure 19 shows the trend of GHG emission from 1994-2022. The trend shows the increasing trend of GHG emissions. The CH4 emission from both enteric fermentation and manure management also shows the increasing trend. Similarly, the N2O emission also shows an increasing trend from 1994-2022. The data associated with emission trend for livestock sector is presented in BTR1 Annex VII.VIII

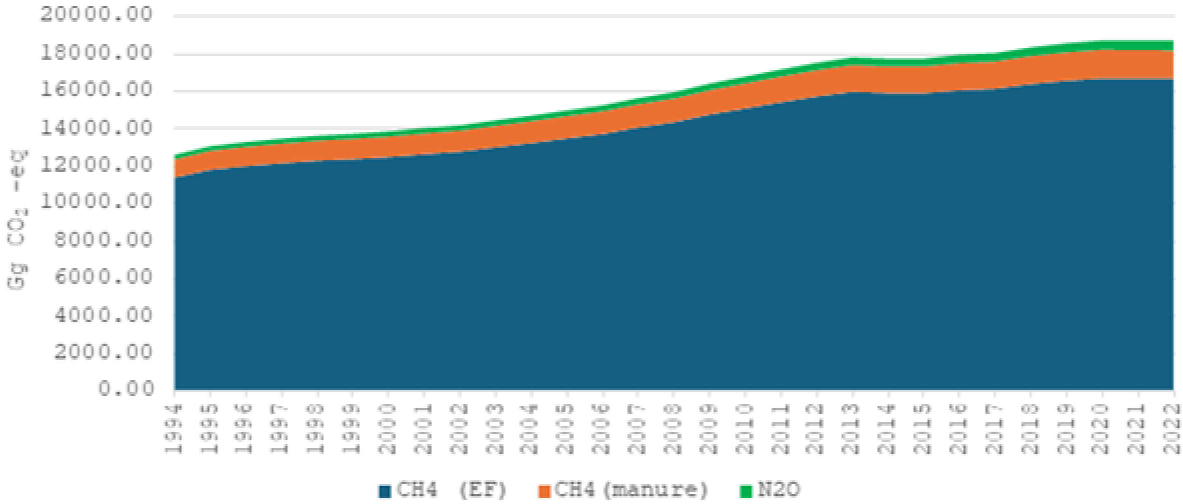

Figure 20: emission trend in livestock Sector

2.12.6 Recalculation of emissions 1994-2011

The Figure 20 presents the recalculation of GHG for livestock sector for years 1994 to 2011(BTR1 Annex VII.V) based on IPCC 2006 guidelines. The emission reported in Initial National Communication (INC), Second National Communication (SNC), and Third National Communication (TNC) are compared with the recalculated value. The dark black outlined bar indicates the GHG values in Gg CO2-eq as reported in the National Communication Report that are different from the recalculated emission due to the use of the improved emission factors provided in the IPCC 2006 guidelines in recalculation. Furthermore, while the INC and SNC use the global warming potential (GWP) factor from the Second Assessment Report (SAR) while the TNC uses the GWP factors from the Fourth Assessment Report (AR4) however GWP factors from the Fifth Assessment Report (AR5) were applied for recalculation.

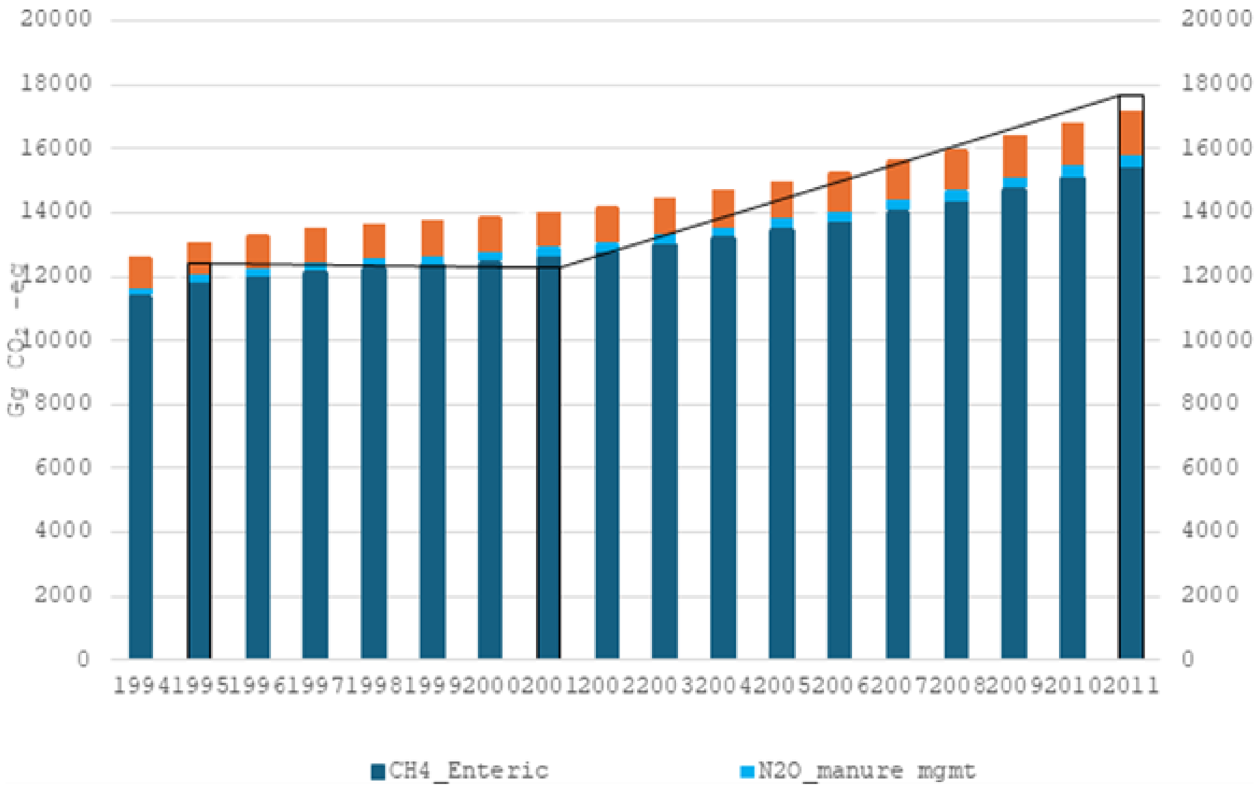

Figure 21: Recalculation of Livestock Sector for Year 1994-2011

2.12.7 Inventory development 2012-2022

The GHG inventory of the year 2012-2022 for livestock sector is presented in the Figure 21. The GHG inventory has been carried out using IPCC software. The graph shows a slightly increasing and decreasing and then again increasing trend reaching a sharp peak by 2022, where emissions exceed 18,700 Gg CO2-eq which is due to change in the population of livestock each year. The trend shows that emissions due to both enteric and manure management are increasing gradually and the emissions due to manure management are comparatively lower than enteric fermentation.

Furthermore, the graph shows that direct N2O has a lower contribution to total emission than methane. The manure management system such as dry lot, solid storage, anaerobic digestor and pasture/paddock were considered for this inventory development.

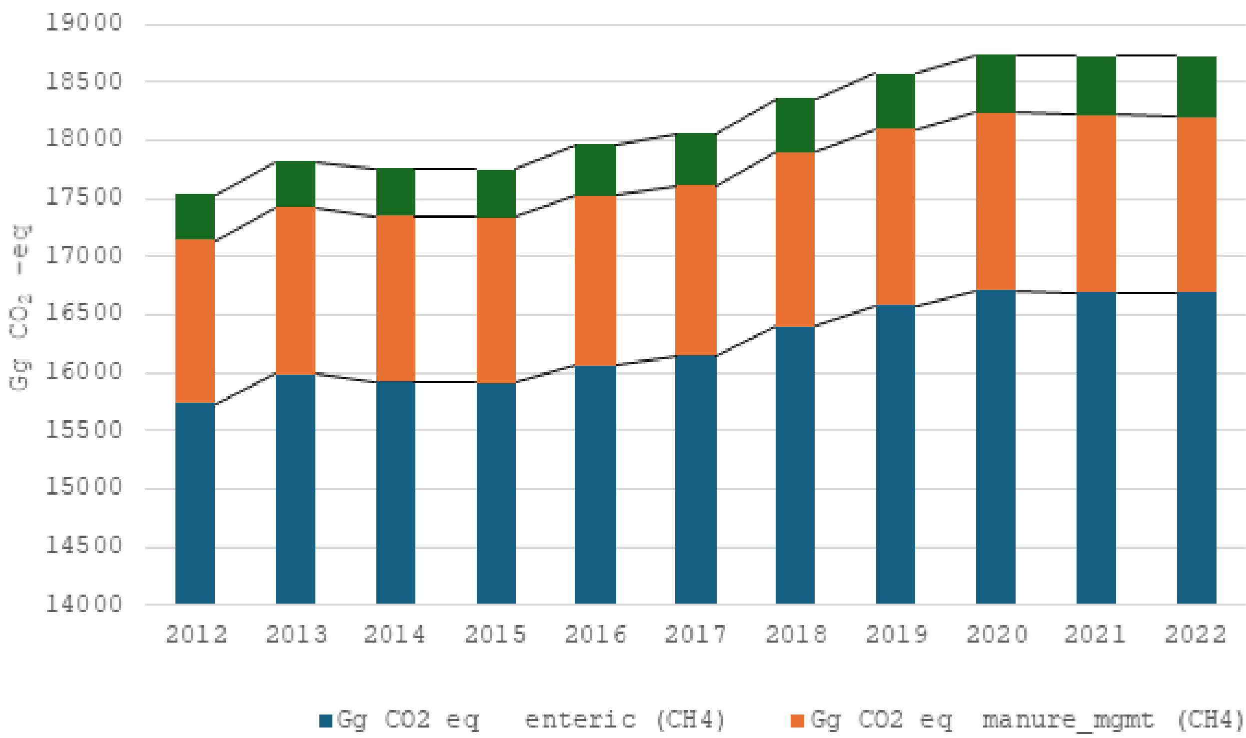

Figure 22: GHG Inventory of Livestock Sector for Year 2012-2022

Category-wise emission for year 2022

In the livestock sector, CH4 emission from enteric fermentation has a greater share i.e. 91.4% of total sectoral emission as presented in the Figure 22, followed by 8.3% CH4 emission from manure management and 0.3% N2O emission from manure management.

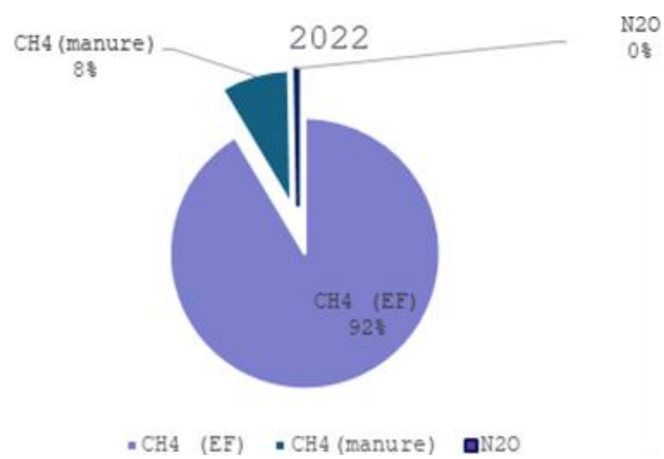

Figure 23: Total emission for the livestock sector for the year 2022

Table 22: GHG emissions from the livestock sector in 2022

Categories	Net CO_2 emissions/removals		
	CH_4	N_2O	Total
	Gg CO_2 -eq	Gg CO_2 -eq	Gg CO_2 -eq
3.A - Livestock	**18199.968**	**523.532**	**18723.500**
3.A.1 - Enteric Fermentation	16686.635		16686.635
3.A.1.a - Cattle	6665.993		
3.A.1.a.i - Dairy Cows	1986.251		
3.A.1.a.ii - Other Cattle	4679.742		
3.A.1.b - Buffalo	7904.713		
3.A.1.c - Sheep	107.968		
3.A.1.d - Goats	1958.698		
3.A.1.e - Camels	-		
3.A.1.f - Horses	5.541		
3.A.1.g - Mules and Asses	1.590		
3.A.1.h - Swine	42.129		
3.A.1.i - Poultry	-		
3.A.1.j - Other (please specify)	-		
3.A.2 - Manure Management	1513.333	523.532	2036.865
3.A.2.a - Cattle	517.876	31.592	
3.A.2.a.i - Dairy cows	171.229	1.682	
3.A.2.a.ii - Other cattle	346.648	29.911	
3.A.2.b - Buffalo	718.610	58.920	
3.A.2.c - Sheep	3.239	9.600	
3.A.2.d - Goats	66.594	393.303	
3.A.2.e - Camels	-	-	
3.A.2.f - Horses	0.505	0.823	
3.A.2.g - Mules and Asses	0.143	0.232	

3.A.2.h - Swine	168.518	12.167	
3.A.2.i - Poultry	37.749	15.191	
3.A.2.j - Other (please specify)	0.097	1.703	

2.12.8 Uncertainty assessment and time series consistency

The uncertainty analysis is done using IPCC software for base year (2012) and end year (2022). Since the nation lacks both disaggregated activity data and national EF (validated by government) as required by the 2006 IPCC guideline, the default emission factor is considered for this inventory resulting higher uncertainty associated. The uncertainty associated with the activity data for livestock sector is assumed to be ±20% (as per IPCC guideline). The uncertainty associated with the default excretion rate is assumed to be ± 50 (as per IPCC guideline). The uncertainty of default emission factors as per IPCC 2006 guideline are presented in the table below:

Table 23: Uncertainty in livestock sector

Category	Activity Data	Uncertainty associated with default emission factor/value	Combined Uncertainty for default emission factor/value
Enteric Fermentation (CH_4)	±20	±30- 50%	
Manure Management (CH4)	±20	±30	
N Excretion Rate (Default value)	-	±50	-70.71 to + 111.8
Manure Management System (N2O)	±20	-50% (lower value) to +100% (higher value)	

The uncertainties associated with each category are presented in BTR1 Annex IV. The combined uncertainty was calculated by applying the formula:

$$U=\sqrt{(U1)^2+(U2)^2}$$

2.12.9 Data Quality Assurance, QA, and Quality Control

The inventory is carried out considering the UNFCCC reporting principles, ensuring transparency, accuracy, clarity, completeness, and consistency (TACCC). Moreover, the following processes are used to ensure QA/ QC:

- Utilization of government-owned or government-published data and verified web-based sources only
- proper documentation of datasets

- Data from one source is cross-checked with other sources
- source references for all data sources

2.12.10 Category-specific planned improvements

Table 24: Category-specific planned improvements in livestock sector

Category	Challenges/Limitations	Necessity
Updated Data and Data Availability	- Lack of proper historical data for recalculation and trend analysis. - Limited centralized database for systematic updates.	- Accurate and updated data is essential for precise GHG estimation and tracking emission trends
Disaggregation Data Suitable for IPCC Guidelines	- Disaggregated data does not align with IPCC guidelines (e.g. fraction of manure management system, N excretion rate)	- Disaggregated data enables compliance with IPCC standards and improves sector-specific emission calculations.
Research to Establish National Emission Factors	- National emission is available for some livestock, however, not validated by the government - Validation and authenticity of available scientific data	- National emission factors improve accuracy as they reflect local conditions. - The available scientific data is to be validated by in-line agencies for their use and authenticity

2.13 Agriculture

The agriculture sector (here, excluding the enteric fermentation and direct emissions from manure management) is one of the major GHG emissions. According to the World Resources Institute Climate Analysis Indicators Tool (WRI CAIT), half (50.1%) of Nepal's 2014 GHG emissions were from the agriculture sector. Within the agriculture sector, 46% of emissions were from crop agriculture. In 2021, the agriculture sector produced 55.1% of Nepal's total GHG emissions (GCP, 2023), meaning that emissions from this sector represent a significant share of national emissions. This inventory analysis reveals that the key emission sources in this sector include methane emission from rice cultivation (3C7 as per IPCC 2006 guideline), direct (3C4) and indirect (3C5) N2O emissions from synthetic fertilizers, animal manure and urine and dung deposited to soils (croplands/PRP), CO2 emission from urea application (3C3), indirect N2O emission from manure management (3C6) and CO2 emission from liming (3C2), order placed based on their contribution.

2.13.1 Methodology

This inventory follows the methodologies as per IPCC 2006 guidelines. For the inventory of this section, Volume 4, Chapter 5: Cropland and Chapter 11: N2O emission from Managed Soils and CO2 emission from Lime and Urea Application were referred for calculation of CH4 emission from rice cultivation; CO2 emissions from urea and lime application; and direct and indirect N2O emission from managed soils, synthetic fertilizer, organic manure and urine and dung depositions to grazed lands and from manure management. Since data on crop residue burning, which contributes to CO2 emissions, and on cover crops and legumes that enrich soils with nitrogen is unavailable, as well as the lack of data on nitrogen addition through soil mineralization, these factors have not been included in the emission calculations. Figure 23 shows the categories and sub-categories included for the inventory while Table 24 presents the summary of categories and sub-categories included, type of gases emitted, methodology used and data sources for the calculation of GHG emissions. The equations used for the calculation of the GHG emission rates are stated in the later sections.

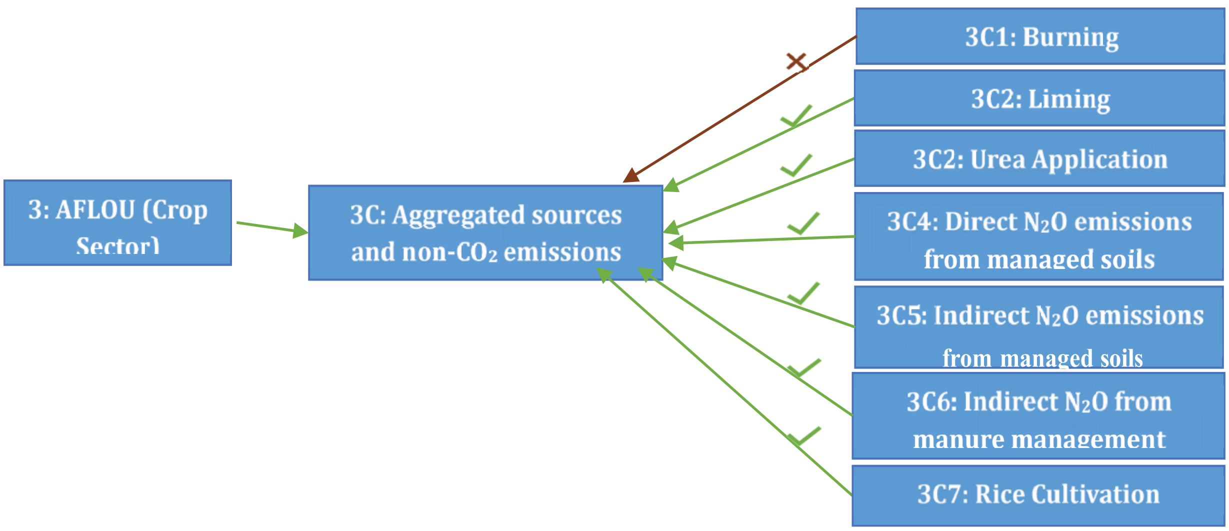

Figure 24: Categories included in the crop sector for Nepal's GHG Inventory

Table 25: Categories for GHG emission selected for GHG Inventory of Agriculture Sector along with Type of GHGs, Methods Applied and Data Sources

Category	**GHGs**	**Method**	**Required Data**	**Data sources**
Rice cultivation	CH_4	T1	Harvest area that is continuously flooded, single aerated, multiple aerated, regularly rainfed, and rainfed drought-prone; data on organic amendment rate of application, crop growth duration	Statistical Information on Nepalese Agriculture yearly book by the MoALD (the then MoAC). Irrigation and rainfed rice fields based on experts' judgment. Maintained consistency over time.
Urea application	N_2O	T1	The rate of urea applied in the rice field	Statistical Information on Nepalese Agriculture yearly book by the MoALD (the then MoAC).

Liming	CO_2	T1	Lime application rate and amount	Agriculture Input Company Ltd. Private sector contribution is based on expert judgment
Direct N_2O emission from managed soil	N_2O	T1	Use of synthetic fertilizer emitting N2O, organic manure applied to rice fields and other cropland or soils, urine and dung deposition in pasture, range, and paddock.	Livestock population head data from the Statistical Information on Nepalese Agriculture yearly book by the MoALD (the then MoAC). Other data is based on expert judgement.
Indirect N_2O emission from managed soil	N_2O	T1	Synthetic fertilizers emitting N are applied to rice fields and other soils, organic manure is applied to rice fields and other managed soils, and urine and dung are deposited on grazed lands.	DAP and Urea data from Statistical Information on Nepalese Agriculture, a yearly book by the MoALD (the then MoAC). Other data are based on Livestock population head and experts' judgment.
Indirect N_2O emission from manure management	N_2O	T1	Total livestock population and N excreted	Yearbook Statistical Information on Nepalese Agriculture (MoALD)

All the activity data used for the calculation of the emission from all the above-mentioned sources is in BTR1 Annex VIII.I. The livestock population data is the same as that used in Section 9.6.

Urea Application

The CO2 emissions from the area application were calculated using Equation 11.3 from the IPCC 2006 guidelines (Equation 9.7.1). The detailed calculations are provided in BTR1 Annex VIII.II. An emission factor of 0.2, as specified by the IPCC guidelines, was used for this analysis. It is assumed that the urea sales data corresponds to its application on croplands. Approximately 70% of the urea is estimated to be used in rice fields, as rice is the country's primary crop, with the remaining applied to other cro

$$CO_{2_{Urea}} = M_{urea} * EF_{Urea} * \frac{44}{12}$$

where,

CO_2 Emission = annual CO_2 emissions from urea application, tonnes per year M = annual amount of urea fertilization, tonnes of urea per year

EF = emission factor, tonne of C per tonne of urea

Lime Application

The carbon dioxide emissions from lime application in agricultural soils were calculated based on sales data provided by AICL. It is assumed that the private sectors contribute an additional 20% of lime sales, which are not officially recorded. However, AICL provided data for only four years, from 2019 to 2022. For earlier years, no data was available, so the inventory assumes a consistent application of 320.79 tonnes of lime annually from 1994 to 2019.

The CO2 emissions were calculated using Equation 9.7.2 from the IPCC 2006 Guidelines (Volume 4, Chapter 11, Equation 11.13). The inventory excludes dolomite due to a lack of data and assumes that 100% of the lime is limestone. Using an emission factor of 0.12 tonnes of carbon per tonne of limestone, the total annual emissions were calculated.

$$CO_{2_{liming}} = M_{limestone} * EF_{limestone} * \frac{44}{12}$$

where,

CO2 liming = annual C emissions from lime application, tonnes C yr-1

M = annual amount of calcic limestone (CaCO3) applied in tonnes per year

EF = emission factor, tonne of C per tonne of limestone

Rice cultivation:

Equations 5.1 and 5.2 of the IPCC 2006 guidelines were used to estimate methane emissions from rice cultivation and adjusted daily emission factors. Equation 9.7.3 and 9.7.4 show the equation used for methane emission calculation and for calculating the adjusted daily emission factor for rice cultivation.

$$CH_{4_{Rice}} = \left(EF_{ijk} * t_{ijk} * A_{ijk} * 10^{-6}\right)_{ijk}$$

Where:

CH4 Rice = annual methane emissions from rice cultivation, Gg CH4 yr-1 EFijk = a daily emission factor for i, j, and k conditions, kg CH4 ha-1 day-1 tijk = cultivation period of rice for i, j, and k conditions, day

Aijk = annual harvested area of rice for i, j, and k conditions, ha yr-1

i, j, k = represent different ecosystems, water regimes, type and amount of organic amendments, and other conditions under which CH4 emissions from rice may vary

For adjusted daily emission factor, the formula is in Equation 9.7.4, as follows

$$EF_i = EF_c * SF_w * SF_p * SF_o * SF_{sr}$$

Where:

EFi = adjusted daily emission factor for a particular harvested area

EFc = baseline emission factor for continuously flooded fields without organic amendments

SFw = scaling factor to account for the differences in water regime during the cultivation period (from Table 5.12)

SFp = scaling factor to account for the differences in water regime in the pre-season before the cultivation period (from Table 5.13)

SFo = scaling factor should vary for both type and amount of organic amendment applied (from Equation 5.3 and Table 5.14)

SFs,r = scaling factor for soil type, rice cultivar, etc., if available Source: IPCC 2006

The emission factors and assumption used for calculation are in Table 26 and Table 27.

Table 26: Emission factors, scaling factors and conversion factors used for CH4 emission calculation

SN	Category	Emission Factor (EF)		Scaling Factor (SF)		Conversion Factor (CF)	
		1996	2006	1996	2006	1996	2004
1	Baseline emission factor	10 (as of India)	1.3				
2	Continuously flooded harvest area			1	1		
3	Single aerated irrigated area			0.5	0.6		
4	Multiple aerated irrigated area			0.2	0.52		
5	Regularly rainfed area			NA	0.28		
6	Drought prone rainfed area			0.4	0.25		
7	Non flooded pre-season for more than 180 days				0.68		
8	Organic amendment for FYM application				1.15679 (for 2ton/ha of FYM)	2	0.14

Table 27: Assumption in calculating methane emission from rice cultivation

SN	Conditions
1	8% upland area

2	1994/95-1995/1996 = 50% irrigated area; 1996/1997-2009/10 = 60% irrigated area; 2010/11-2021/22 = 65% irrigated area
3	10% of irrigated areas are continuously flooded; 90% intermittently flooded
4	10% of irrigated area are single aerated
5	80% of the area are multiple aerated
6	No flood prone rainfed area harvested
7	No deep-water type of rice cultivated area
8	Out of total rainfed area, 50% are regular rainfed while other half is drought prone
9	Scaling factor for non-flooded pre-season of >180 days considered as mostly rice crops is followed by wheat/maize
10	FYM is applied to rice fields at 2 ton/ha
11	Growing period = 120 days
12	scaling factor for soil type, rice cultivar not available
13	Irrigated growing period 130; rainfed growing period 120 days

Direct N_2O Emission from Managed Soils

The inventory follows the formulas and equations outlined in Chapter 11 of the IPCC 2006 Guidelines. The inventory used formula modified from that of equation 11.1 as per the availability of data as stated in Equation 9.7.5

$$N_2O_{Direct}N = N_2O - N_{inputs} + N_2O - N_{PRP}$$

The N2O N that are added to the soils is calculated from the formulation in Equation 9.7.6.

$$N_2O - N_{inputs} = [\{(F_{SN} + F_{ON}) * EF_1\} + \{(F_{SN} + F_{ON}) * EF_{1FR}\}]$$

And, N2O N that are added to the pasture, range and paddock is calculated by using Equation 9.7.7

$$N_2O - N_{PRP} = [(F_{PRP\ CPP} * EF_{2PRP\ CPP}) + (F_{PRP\ SO} * EF_{2PRP\ SO})]$$

Where,

N2ODirect –N N per year = annual direct N2O–N emissions from managed soils, kg N2O–N per year

N2O–N inputs = annual direct N2O–N emissions from N inputs to managed soils, kg N2O–N yr-1

N2O–NPRP = annual direct N2O–N emissions from urine and dung inputs to grazed soils, kg N2O–N yr-1

FSN = annual amount of synthetic fertilizer N applied to soils, kg N yr-1

FON = annual amount of animal manure, compost, sewage sludge and other organic N additions applied to soils

FPRP = annual amount of urine and dung N deposited by grazing animals on pasture, range and paddock, kg N yr-1 (Note: the subscripts CPP and SO refer to Cattle, Poultry and Pigs, and Sheep and Other animals, respectively)

EF1 = emission factor for N2O emissions from N inputs, kg N2O–N (kg N input)-1(Table 11.1)

EF1FR is the emission factor for N2O emissions from N inputs to flooded rice, kg N2O–N (kg N input)-1

EF2PRP = emission factor for N2O emissions from urine and dung N deposited on pasture, range, and paddock by grazing animals, kg N2O–N (kg N input)-1

For the calculations, it is assumed that about 70% of the total urea and DAP sales are applied to rice fields, while the remaining 30% is used for other crops, including cereals and vegetables. Additionally, it is assumed that of the total nitrogen (N) available in organic manure for various uses, managed soils, fuel, and construction, 50% is used as fuel, 20% is applied to rice fields, and the rest is used on managed soils other than rice fields.

The total nitrogen available for these purposes is calculated by applying factors that account for losses from different manure management systems.

Although this inventory aims to include as many relevant factors as possible, some data gaps remain. Due to the lack of information on the annual amount of nitrogen mineralized in soils, soil carbon loss from organic matter due to land use or management changes, the annual area of managed or drained organic soils, and crop residues incorporated or burned, nitrogen additions and emissions from these factors are not included in the inventory.

Indirect N_2O emissions from Managed Soils

For indirect N_2O emissions from managed soils, two sources are considered: N_2O emissions from atmospheric deposition of nitrogen (N) volatilized from soils and N_2O emissions from nitrogen leaching and runoff.

It is assumed that 10% of the nitrogen applied through synthetic fertilizers and 20% of the nitrogen from organic manure, as well as urine and dung applied to pasture, range, and paddock (PRP), are volatilized. These volatilized fractions are then multiplied by an emission factor of 0.01 kg N_2O-N per kg of volatilized nitrogen to estimate N_2O emissions from atmospheric deposition.

For emissions from leaching and runoff, the total nitrogen applied to managed soils through synthetic fertilizers, organic manure, and urine and dung is multiplied by the fraction susceptible to leaching and runoff and by the emission factor of 0.0075 kg N_2O-N per kg of nitrogen lost through leaching or runoff.

Indirect N_2O emission from Manure Management

The indirect N2O emissions from the manure management are calculated for manure N lost due to volatilization of NH3 and Nox. The total N excretions from different livestock species are multiplied by their respective fractions for volatilization and by the emission factor for N2O emission. N loss due to leaching has not been included in the inventory.

2.13.2 GHG emissions from the Sector

Trend of GHG emission in the agriculture sector from 1994-2022 Emissions from the sector generally increased from 1994 to 2022, at a rate of 1.23% per year. Methane emissions from rice cultivation consistently contribute the largest share, followed by direct nitrous oxide (N_2O) emissions from managed soils. Indirect N_2O emissions from both managed soils and manure management show a gradual increase over the years, while carbon dioxide (CO_2) emissions from liming and urea application remain minimal. A more pronounced rise in emissions is observed from 2010 onward, indicating a growing impact of agricultural activities on greenhouse gas emissions. This trend highlights the need for climate-smart agricultural practices to mitigate emissions, particularly from rice cultivation and soil management. The graph (Figure 24) illustrates the trend in GHG emissions from agricultural activities over time, measured in gigagrams (Gg) of CO_2 equivalent.

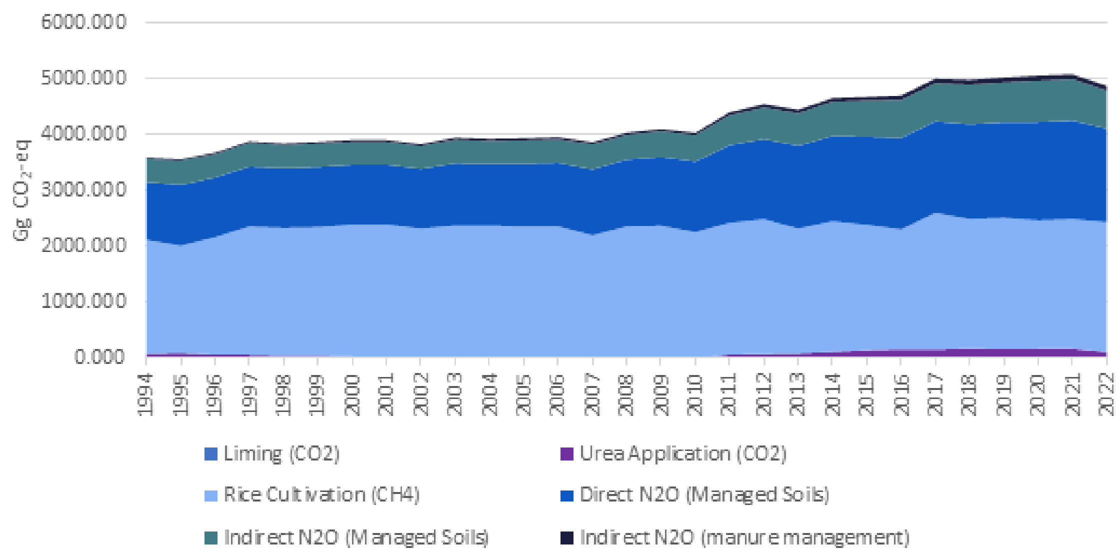

Figure 25: GHG emission trend in agriculture sector from year 1994-2022

In the year 2022, the total GHG emissions from the sector was 4870.25 Gg of CO2 equivalent. Of the total emission within the sector, the highest contribution was from rice cultivation (47.7%) followed by direct N2O emission from managed soils (34.36%), while about 18 % were contributed form other sources. Figure 25 shows the chart showing contribution of different sources for the year 2022.

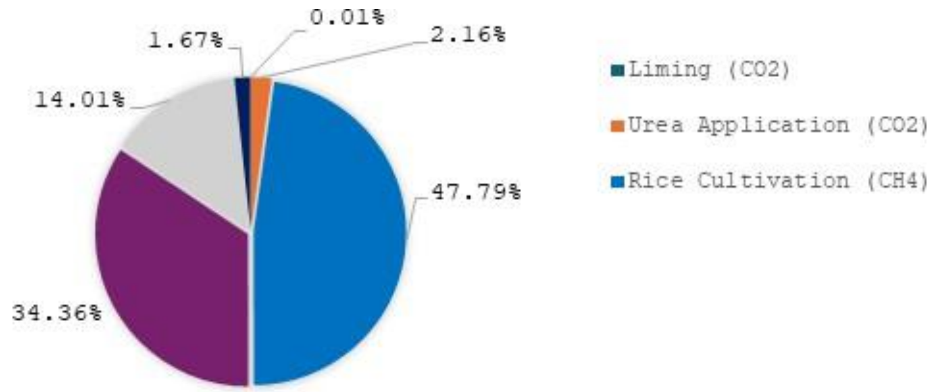

Figure 26: Contribution of different sources for year 2022

Recalculation of GHG emissions from 1994 to 2011 for crop sector.

The total emissions from the sector including all the emission sources were 3587.10 Gg CO2-eq for the year 1994 while for the year 2011 the emission rose to 4345.51 Gg CO2-eq. Over the period of 18 years emissions increased by 21.14% (with a p.a. increase rate at 1.175%). Within the sector, rice cultivation has significantly contributed to the emission over years. Figure 26 presents the emissions within the sector categorized under different sources. The emission calculated for different source categories is in BTR1 Annex VIII.V.

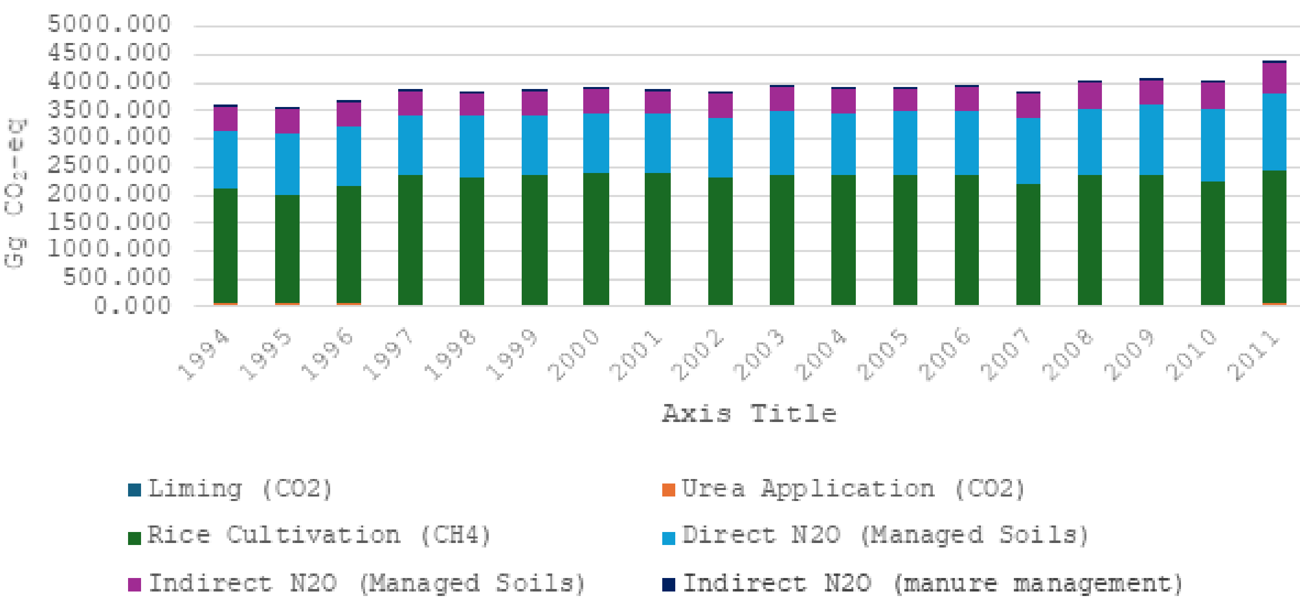

Figure 27: GHG emissions from the agriculture sector from year 1994-2011

Urea Application (3C3)

Figure 27 shows CO2 emissions from urea application over 18 years. A decline in urea applications occurred due to the reduction of government subsidies until 2009. However, with the development and endorsement of an operational modality for subsidy administration by MoAD and MoF, the subsidies were reintroduced, thereby leading to an increase in urea sales and application after 2010.

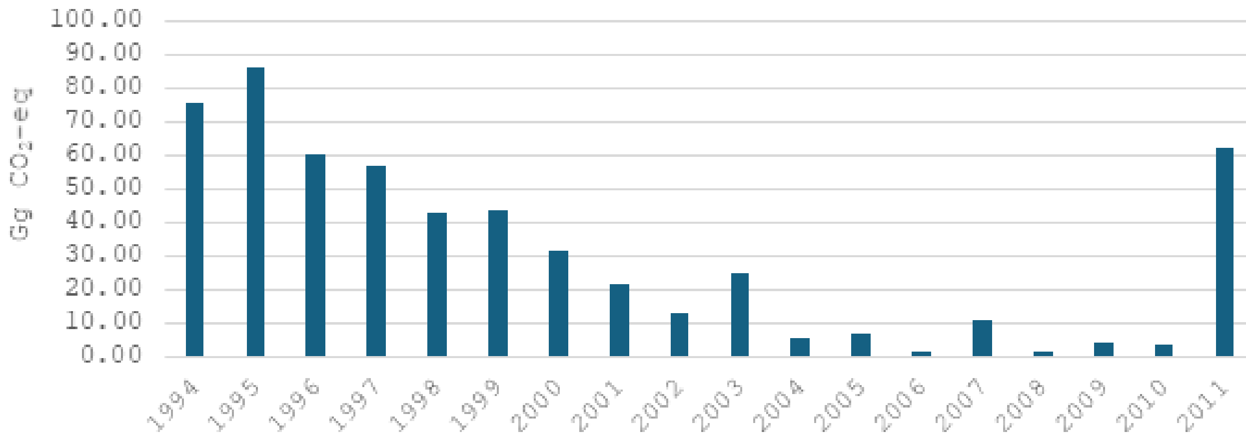

Figure 28: CO2 emissions from year 1994 to 2011 by urea application

Lime application

Due to the lack of sufficient data on lime application, expert judgment was used to assume that the amount of lime applied remained constant at 320.79 tonnes per year from 1994 to 2019. Based on this assumption, the annual CO2 emissions from lime application were calculated to be 141.15 tonnes per year.

Rice cultivation (3C7)

The activity data, which include time-series information on urea applied (in tonnes per year) from 1994 to 2011, are provided BTR1 Annex VIII.I and the year-wise calculated CH_4 emissions are included in BTR1 Annex VIII.V. Figure 28 illustrates methane emissions from rice cultivation over 18 years. The harvested area for rice has remained relatively constant over the years, resulting in a nearly stable emission trend.

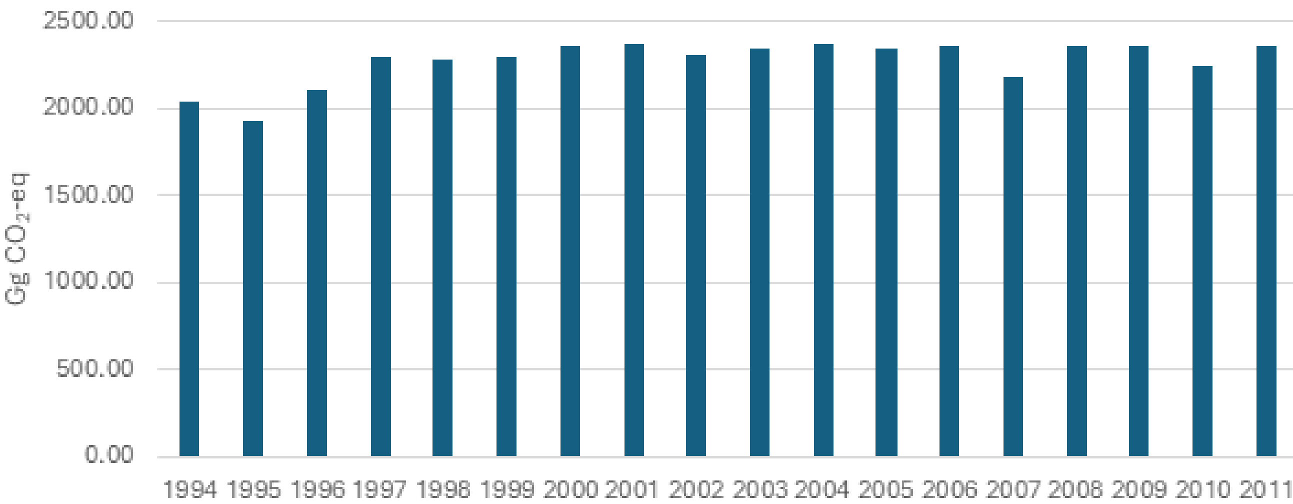

Figure 29: Methane emission from rice cultivation from the year 1994 to 2011

The comparisons from earlier inventories are presented in Table 28.

Table 28: Comparison of CH_4 emission calculation in different inventories over the years.

Categories	GHG Inventories			
	Current GHG emission (gGCH_4/ year) (in year 2022)	INC (July 2004)	SNC (in year 1994	TNC (in year 2011)
CH_4 emission (2011) (Gg)	84.19			159.00
CH_4 emission (2001) (Gg)	84.12		1.57	
CH_4 emission (1994/95) (Gg)	68.67	306		
% deviation from current emission		-345.61%	-98.35	
Remarks		EF, SF and CF and formula were different	EF, SF and CF and formula were different	Non flooded preseason >180 days (SF = 0.68 in current calculation but in TNC 1.22). SF for rainfed and irrigated condition also aggregated used while in current calculation disaggregated values for different areas and conditions used.

2.13.2.1.1.1 Direct and Indirect N2O Emissions from Managed Soils

For the calculation of direct N2O emission from managed soils and manure management, the methodologies and equations as stated in section 9.7.1 were applied. The direct N2O emissions from managed soils for the years 1994 and 2011 are calculated to be 1037.778 (Gg 3.916 N2O per year) and 1385.977 (5.230 Gg N2O) Gg CO2-eq per year, respectively. The indirect N2O emissions from atmospheric deposition from volatilization of N and from leaching and runoff from managed soils in 1994 and 2011 were calculated to be 411.920

(1.554 Gg N2O) and 541.265 (2.043 Gg of N2O) Gg CO2-eq per year, respectively. Similarly, the indirect N2O emission from volatilization of manure management for the years 1994 and 2011 were calculated to be 25.123 (0.095 Gg N2O) and 53.389 (0.201 Gg N2O) Gg CO2-eq per year, respectively. Figure 29 shows the graph for direct and indirect N2O emissions from managed soils and manure management. It is observed that the N2O emissions from these sources have been increasing over the years. BTR1 Annex VIII.V has the calculated indirect N2O emission for each year in gigagrams per year.

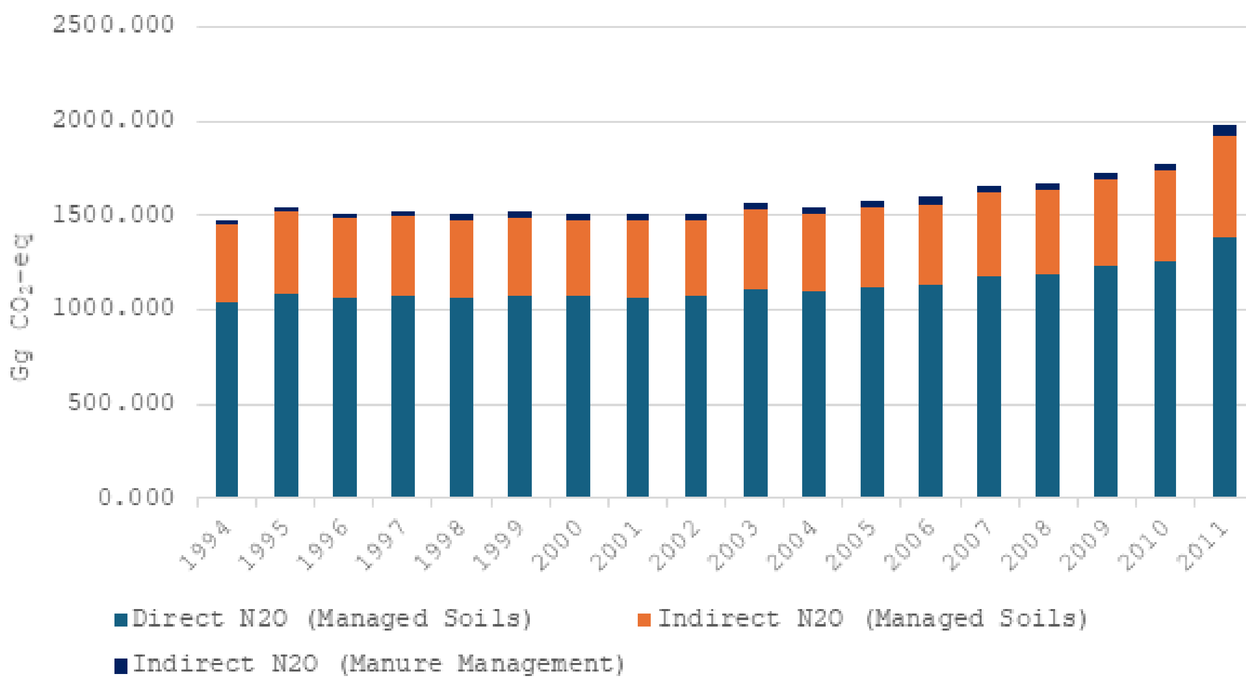

Figure 30: Direct and indirect N2O emission in managed soils

For the year 2011 of the total emission within the sector the highest contribution was from rice cultivation (53.59%) followed by direct N2O emission from managed soils (31.48%) while less than 15% were shared by other sources. Figure 30 shows the contribution of different sources within the sector for the year 2011.

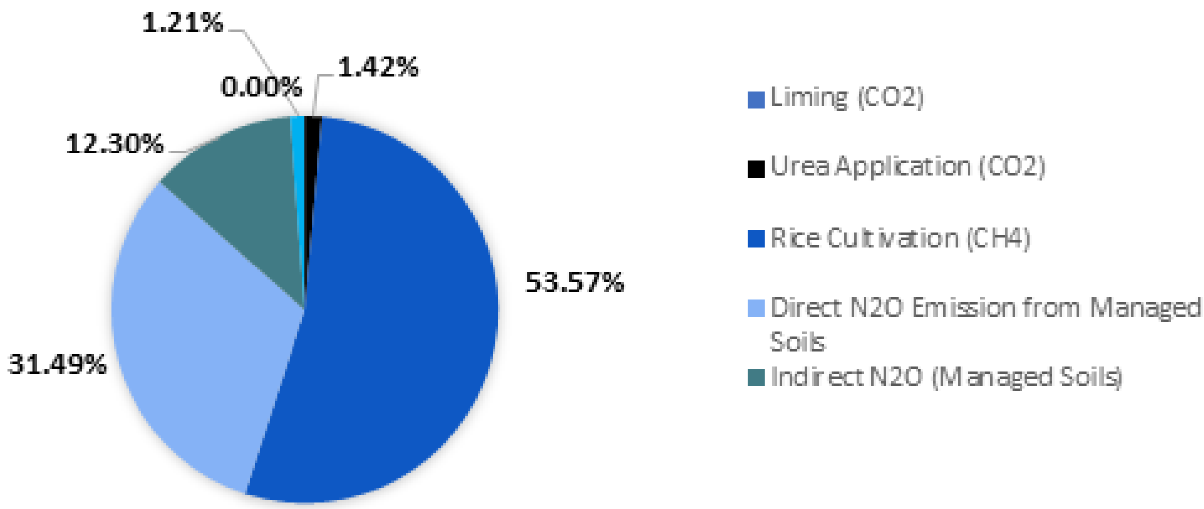

Figure 31: *Contribution of different sources in emissions within the sector for the year 202*

2.13.3 Inventory of GHG emissions from 2012 to 2022 from urea application

The calculation of CO2 emission from the urea application was done by applying the same method as for recalculation. The year-wise calculated CO2 emission is in BTR1 Annex VIII.V.. Figure 34 shows the CO2 emissions from urea application from 2012 to 2022. The graph shows an increasing trend of emissions over the years for the increase in application of urea fertilizers to the soils.

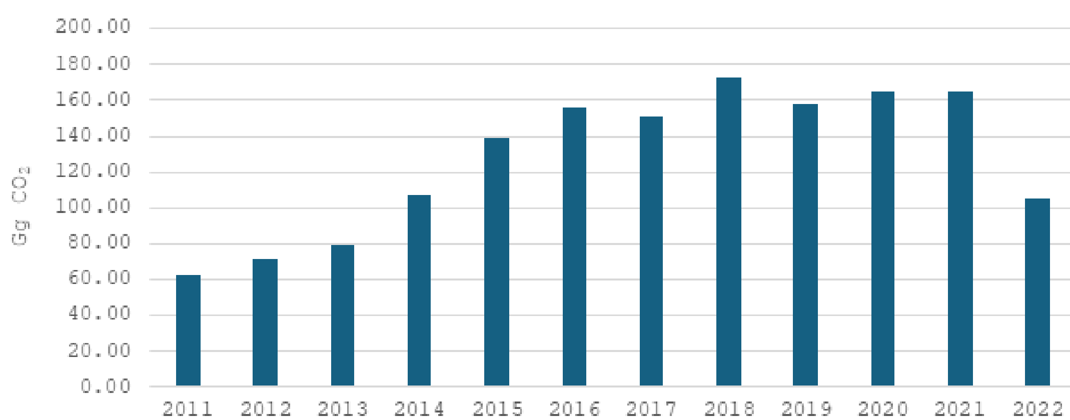

Figure 34: CO_2 emission from year 2012 to 2022 by urea application

Lime Application

The CO_2 emission due to application of lime in the agricultural soils in the year 2022 based on the data provided by AICL and assumptions made accounted to be 530.63 tonnes CO2 per year. Figure 35 presents the emission from liming from 2012 to 2022. The application of lime may be expected to increase over years as the soil is becoming more and more acidic, demanding more lime, thereby increasing the chances of contribution of liming in GHG emissions.

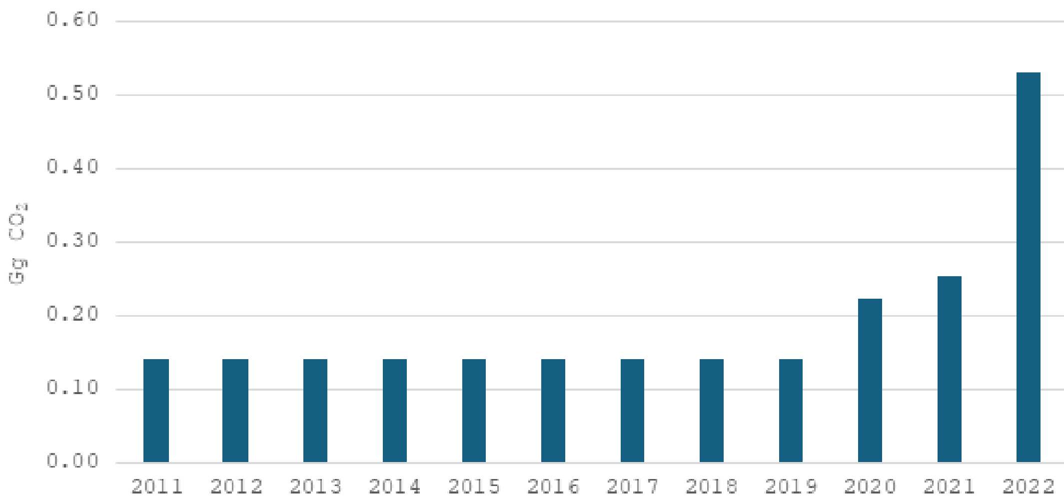

Figure 35: CO_2 emission from lime application from 2011-2022

Rice cultivation

The activity data (time series data on rice cultivation for these periods is in BTR1 Annex VIII.I. While year-wise calculated gigagrams of CH4 emission are in BTR1 Annex VIII.V. Figure 36 shows the CO2 emission from the area application from 2012 to 2022. The harvested rice has remained more or less constant, except in some years, due to delayed monsoon and other impacts of climate change, reducing the total harvested area.

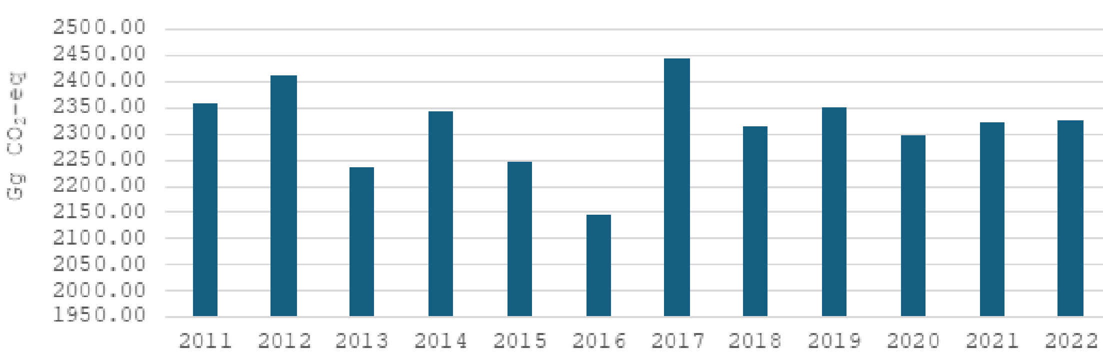

Figure 36: Methane emissions from rice cultivation from 2012-2022

Direct and indirect N2O emissions from Managed Soils

The direct and indirect N2O emissions for the year 2022 including emission from synthetic fertilizers, organic manures applied to managed soils and urine and dung deposited to pasture, range and paddock were calculated to be 1673.181 (6.314 Gg N2O) and 682.552 (2.576 Gg N2O) Gg CO2-eq per year, while the indirect N2O emission from manure management was 81.425 Gg CO2-eq (0.307 Gg N2O per year). The total N2O emission for the year 2022 is calculated as 2437.157 Gg CO2-eq, which is an increase of 18.12% compared to the year 2012. The direct and indirect N2O emission calculated for the years 2012 to 2022 is shown in Figure 31. BTR1 Annex VIII.V presents the year-wise calculation.

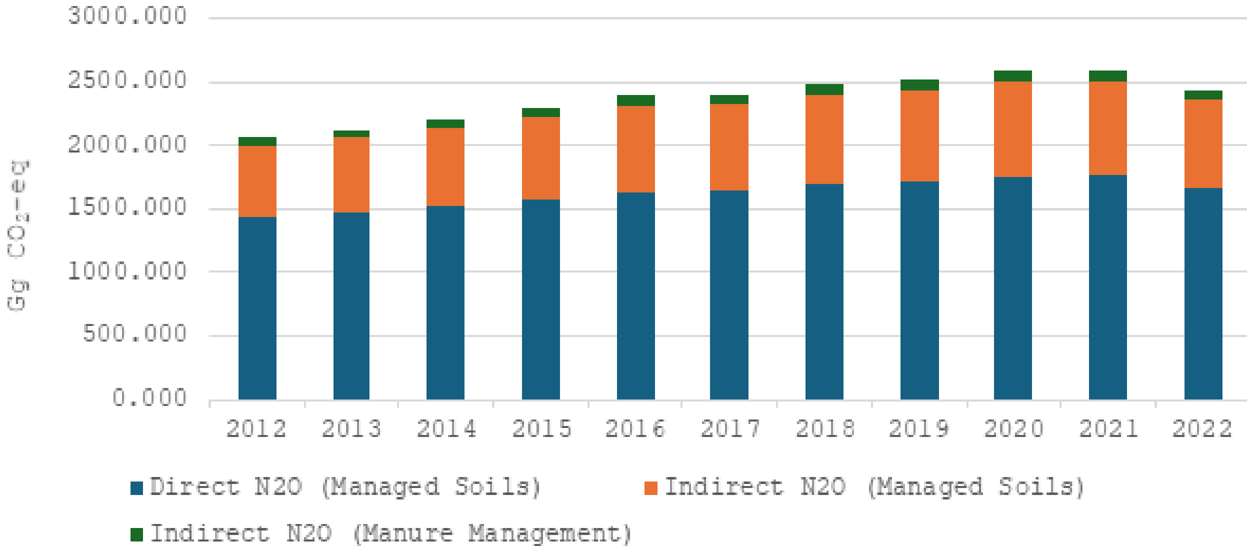

Figure 32: Direct and indirect N2O emission from year 2012-2022

Table 29: Net emissions / removals from agricultural sectors / 3C subsector

Categories	**Net emissions / removals**			
	CO_2	**CH_4**	**N_2O**	**Total**
	Gg	Gg CO_2-eq	Gg CO_2 -eq	Gg CO_2 -eq
3.C - Aggregate sources and non-CO_2 emissions sources on land	**105.751**	**2327.337**	**2437.157**	**4870.245**
3.C.2 - Liming	0.531			0.530627
3.C.3 - Urea application	105.220			105.2201
3.C.4 - Direct N_2O Emissions from managed soils			1673.181	1673.181
3.C.5 - Indirect N_2O Emissions from managed soils			682.552	682.552
3.C.6 - Indirect N_2O Emissions from manure management			81.425	81.425
3.C.7 - Rice cultivation		2327.337		2327.337

2.13.4 Uncertainty

The uncertainty for activity data related to the urea application and rice production area is estimated at 5%. The number of rice-growing days is assumed to range between 120 ± 5 days and 130 ± 10 days, while the proportion of irrigated and rainfed conditions may vary by ±5%. The combined impact of these variations, including changes in the harvested area under both irrigated and rainfed conditions and the number of growing days, results in an overall uncertainty of ±11.02%.

For the daily emission factor, the uncertainty ranges from -62.50% to +178.60% when considering the lowest and highest possible values for selected baseline emission factors, scaling factors, and conversion factors.

Although assumptions on private sector involvement in lime sales are made, the data may not fully represent all private sector contributions. Therefore, the uncertainty for lime application is assumed to be 20%.

The uncertainty for activity data for synthetic fertilizers (urea and DAP) and rice harvested area is ±5%, while the calculation of direct and indirect N2O emissions from animal manure application to managed soils has considered ±20% uncertainty for the livestock population head data. The uncertainties for emission factors for calculating CO2 emission from lime and urea application is -50%, total N excretion from livestock for calculating direct N2O emission ranges from -75% to 208.51%, emission factor for calculating direct N2O emissions from synthetic fertilizers and animal manure applied to rice and other croplands ranges from -100% to +223.61%, emission factor for calculating direct N2O emission from urine and dung deposition to PPR ranges from -95.52% to 223.61% and the uncertainties of emissions factors for calculating indirect N2O emission form atmospheric deposition from volatilization form managed soils ranges from -80% to +427.20 and for calculating indirect emission from leaching/runoff ranges from -74.75% to +286.74. The uncertainty for emission factors used for calculating indirect N2O emissions from manure management ranged from -80% to 400% while the uncertainty for the activity remains same as for livestock population data.

2.13.5 Inventory Improvement Plans

Currently there are several data gaps and other challenges hindering in the development of a robust inventory. The following improvement plans are recommended for the development of strong inventories in the upcoming years.

Sector	Activities	
Liming	• Maintaining records of lime sales from PS + AICL • Keeping track of the types of lime used, such as dolomite, limestone, and other sources. • Deriving specific EFs	• Collecting data on the amount of lime applied to different land use systems/cropland (area). • Gather information on the rate of lime application through regular agricultural surveys.

Urea Application	• Keeping track of urea sales from PS/ agrovets, + AICL. • Collecting data on urea applied to different land use categories and cropland types (areas),	• Determining the average rate of urea application through agricultural surveys. • Determining specific EFs
Direct N_2O Emissions from Managed Soils	• Keeping records of livestock numbers, including detailed categories and subcategories • Determining different types of livestock manure managements in various regions • Collecting data on the number of livestock manure/ organic manure applied to croplands/land types (area) • Continuously monitoring NH_4 and NO_3 in soils. • Gathering detailed data on crop residues burning/ incorporation, cover crops incorporation and legumes integration (by surveys, remote sensing)	• Improving maps and classifications of land use and soil types to better reflect managed soils. • Incorporating sensors, drones, and process-based models to simulate N_2O emissions and track soil nitrogen and moisture levels. • Accounting for seasonal or yearly changes in fertilizer use, rainfall, and cropping patterns. • Conducting field experiments to measure N_2O emissions under varying soil, crop, managements. • Developing region-specific or crop-specific emission factors.
Indirect N_2O emissions from managed soils	• Determining region-specific EFs based on local research and field studies. • Establishing monitoring systems for N volatilization, leaching, and runoff using lysimeters, water sampling, and air-quality measurements under diverse agro-climatic conditions.	• Transitioning to models that simulate N dynamics, incorporating high-resolution data on soil properties, rainfall, and management practices. • Investing in centralized databases to track variability of N inputs, crop management practices, and • environmental conditions.

Rice Cultivation	• Establish field monitoring systems using flux chambers and advanced sensors to measure CH_4 emissions across diverse rice-growing regions and management practices. Develop and apply EFs tailored to local conditions (e.g., water management, soil type, organic inputs)	◆ Disaggregating Activity Data – (irrigation regimes - continuous flooding, alternate wetting and drying; organic residue incorporation; cropping intensity)

2.14 Land Use, Land Use Change and Forestry

Nepal covers an area of 14,751,600 hectares, with approximately 46.1% of this land under forest cover. The Land Use, Land Use Change, and Forestry (LULUCF) sector is vital for the country's environmental sustainability and economic development. It plays a dual role by helping mitigate climate change through carbon sequestration while supporting livelihoods, preserving biodiversity, and regulating water resources. However, human activities such as deforestation, land degradation, and unsustainable agricultural and grazing practices pose significant challenges to this sector. These pressures contribute to environmental degradation, including increased greenhouse gas emissions and reduction in the capacity for carbon sequestration, threatening Nepal's overall ecological balance.

In response to these challenges, Nepal has developed a comprehensive framework of policies, strategies, and institutions at both the national and local levels, specifically aimed at addressing key areas within the Land Use, Land Use Change, and Forestry (LULUCF) sector. These frameworks demonstrate Nepal's commitment to mitigating climate risks while promoting a resilient, low-carbon economy.

This section focuses on the greenhouse gas (GHG) emissions (and removals) of CO2 occurring in managed ecosystems. It examines emissions from land (IPCC category 3.B) caused by activities such as deforestation, forest degradation, afforestation/reforestation, and the sustainable management of forests. Changes in land use for non-forest categories have also been considered. As a result, emissions from the land category have been analyzed across six land representations:

3.B.1 - Forestland

3.B.2 - Cropland

3.B.3 - Grassland

3.B.4 - Wetland

3.B.5 - Settlement

3.B.6 - Other Lands

This section has been prepared in accordance with decision 18/CMA.1, which outlines the Modalities, Procedures, and Guidelines (MPGs) for the transparency framework under Article 13 of the Paris Agreement. It includes comprehensive data collection, uncertainty assessments, key category analysis, methodological choices, recalculations, and processes for quality control and quality assurance.

This report covers only the CO2 emissions/removals based on the (a) Forest remaining forest and land use converted to the forest (b) Cropland remaining cropland and land converted to cropland (3) Grassland remaining grassland and land use converted to grassland and (4) settlement remaining settlements and land

use converted to settlements. Emissions/removals of CO2 were calculated for each of these categories. Figure 32 below illustrates the categories and subcategories applied during the inventory process, while Figure 33 shows the specific subcategories used in the IPCC software. The CO2 emissions/removals for this sector were estimated using the Tier 1 approach, with data sourced from the National Land Cover Monitoring System (NLCMS), as shown in Table 29.

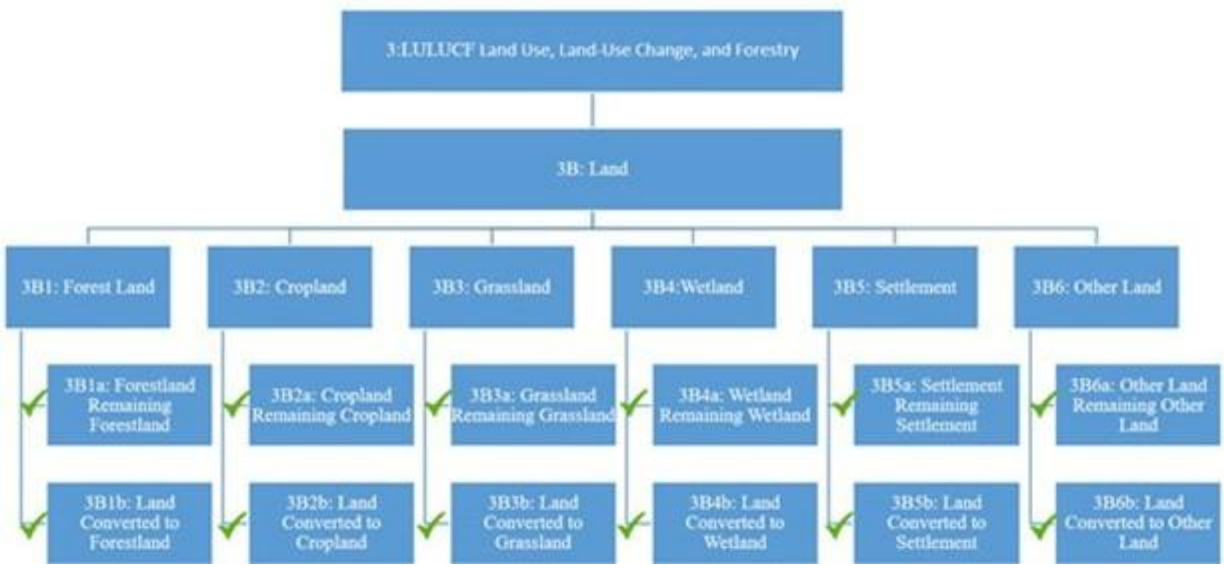

Figure 33: Included categories for the GHG inventory

2.14.1 Description of Land Use, Land Use Change and Forestry Sector in Nepal

The forestry and land-use sector play a critical role in Nepal's GHG inventory, contributing both emissions and significant carbon removals. Forests act as major carbon sinks, absorbing substantial amounts of CO2 through photosynthesis. However, deforestation, degradation, and land-use change released carbon as CO2, contributing to GHG emissions. As highlighted in IPCC reports, an estimated 23% of total anthropogenic GHG emissions (2007-2016) derive from agriculture, forestry and other land use (AFOLU) (IPCC 2019). This underscores the importance of effective forest management and conservation in mitigating these emissions. To comply with UNFCCC requirements and accurately report GHG inventories, including those from AFLOU, it is crucial to monitor forest cover, carbon stocks, and land-use changes. This section provides information on these sectors, following IPCC guidelines to ensure transparency, accuracy, and completeness.

The main datasets used in LULUCF include (a) land use representations for each sub-category and (b) a land use change matrix (representing transitions in land use) generated through national land cover monitoring systems. The land use maps from 2002 to 2022 were downloaded, and the change matrix was prepared using Python. The information derived from the land use data was verified through expert judgment. The data generation process involved a thorough QA/QC procedure, both internally and externally, and included documentation of the processes involved in generating the activity data. Table 30 shows the data sources used in this report.

Table 30: Data sources and GHGs calculated (National Land Cover Monitoring System)

Category	GHGs	Method
Forest Land	CO_2	T1
Cropland	CO_2	T1
Grassland	CO_2	T1
Wetland	CO_2	T1
Settlement	CO_2	T1
Other Land	CO_2	T1

vv3.9.2 Methodology

The methods and assumptions are used to categorize land use/land cover classes, generate activity data, and apply emission factors for the LULUCF sector. The inventory follows the 2006 IPCC guidelines, specifically in terms of data identification and selection, methodologies, and the use of emission factors. In cases where data were limited, expert judgment and underlying assumptions were applied consistently and transparently. Nepal has implemented a national land cover monitoring system, with land cover maps available from 2002 to 2022. The system classifies land into 11 classes, and importantly, the NLCMS report provides guidance on which classes can be merged and categorized under the IPCC land cover classes Table 31. The values generated for each land class in each year were processed using IPCC software to calculate the GHGI. Due to the unavailability of land use data for 2012 and issues with the 2008 land use map, linear interpolation was applied to fill the gaps. Emission estimates in this report were generated using Tier 1 method, depending on the availability of data.

Table 31: Land cover classes, definition and IPCC value (NLCMS report)

NLCMS land cover value	Main land cover class	Description	IPCC land cover class	IPCC value

4	Forest	Land spanning more than 0.5 ha with trees higher than 5 m and a canopy cover of more than 10%, or trees able to reach these thresholds in situ. It does not include land that is predominantly under agricultural or urban land use.	Forest land	1
11	Other Wooded land (OWL)	Land is not classified as forest spanning more than 0.5 ha, having at least 20 m width and a tree canopy cover of trees between 5% and 10%. The canopy cover of trees is less than 5% but the combined cover of shrubs, bushes and trees is more than 10%; including areas of shrubs and bushes where no trees are present.	Forest land	1
10	Grassland	Areas covered by herbaceous vegetation with cover ranging from Closed to Open (15–100%). This category includes rangeland and pasture that is not considered cropland.	Grassland	3
7	Cropland	This category includes arable and tillage land, and agroforestry systems where vegetation falls below the thresholds used for the forest land category, consistent with the selection of national definitions.	Cropland	2
6	Built-up area	Built-up areas refer to artificial structures such as towns, villages, industrial areas, airports, etc.	Settlement	5
1	Waterbody	Rivers are natural flowing water bodies and typically have elongated shapes. Lakes and ponds are perennial standing water bodies.	Wetland	4
5	Riverbed	A tract of land without vegetation surrounded by the waters of rivers, streams & lakes usually includes any accretion in a river course.	Wetland	4
8	Bare soil	A soil surface devoid of any plant material.	Other	6
9	Bare rock	Non-vegetated areas with a rock surface.	Other	6
3	Snow	This class describes perennial snow (persistence > 9 months per year).	Other	6
2	Glacier	Perennial ice in movement.	Other	6

Land representation approaches

Nepal used approach 1 for the land use representation, which enabled the tracking of land use changes within and between specific land use categories. Annual matrices were developed to document both land that remained unchanged and land that underwent conversion during the period from 2002 to 2022. This data was then utilized to create the land representation matrix BTR1 Annex IX.I for input into the IPCC software.

Information on approaches used for representing land areas and on land-use databases used for the inventory preparation

Nepal implemented approach 1 for land representation, assessing both net gains and losses in land use. This method tracked areas that remained within the same land use category and those that transitioned between categories. The representation incorporated top-level land use categories, further subdivided to address national circumstances critical for estimating emissions and removals, as outlined in the 2006 IPCC guidelines. These sub-categories were analyzed to ensure robustness in emissions and removal estimations, representing the various ecological regions of the country and ensuring comprehensive reporting. To input the data into the IPCC software, the entire country was treated as a single climate region (tropical montane) with one soil type of High Activity Clay Mineral Soil, as per Table 3.1 of the 2006 IPCC Guidelines.

Land representation data was generated annually for each sub-category, capturing both land that remained unchanged and land conversions throughout the reporting period. In the forestry sector, the primary sources of greenhouse gas (GHG) emissions—predominantly carbon dioxide (CO_2) arise from land transitions such as conversion to agriculture, grassland, or settlements. While CO_2 is the main GHG in this sector, other gases like methane (CH_4) and nitrous oxide (N_2O) can be emitted from biomass burning; and methane (CH_4).

2.14.2 Activity data

The data collection for the forestry sector involved the development of a land use change matrix utilizing land cover maps from Nepal's National Land Cover Monitoring System (NLCMS) (MoFE, 2024). The NLCMS provides comprehensive land cover information spanning from 2002 to 2022. However, a land cover map for the year 2012 was unavailable. To address this gap, linear interpolation was employed to estimate the land cover change matrix for the missing year, ensuring data continuity. Subsequently, information on forest land subcategories, including natural forests and plantation forests, was compiled. The State of Nepal's Forests Report (DFRS, 2015) served as a primary data source up to 2015, supplemented with additional records from relevant divisions and departments. Any missing years' data were interpolated to maintain consistency across the timeline.

Forest fire data was sourced from FAOSTAT (FAO, 2024), with relevant information for Nepal carefully extracted, categorized, and incorporated into the analysis. Data on forest growing stock were derived from successive forest resource inventories conducted in 1994 and 2010–2014, supplemented by secondary data from credible sources to ensure completeness and accuracy.

Emissions/removals of CO2 were calculated for each of these categories. Figure 33 shows the specific subcategories used in the IPCC software. The CO2 emissions/removals for this sector were estimated using the Tier 1 approach, with data sourced from the National Land Cover Monitoring System (NLCMS), as shown in Table 31.

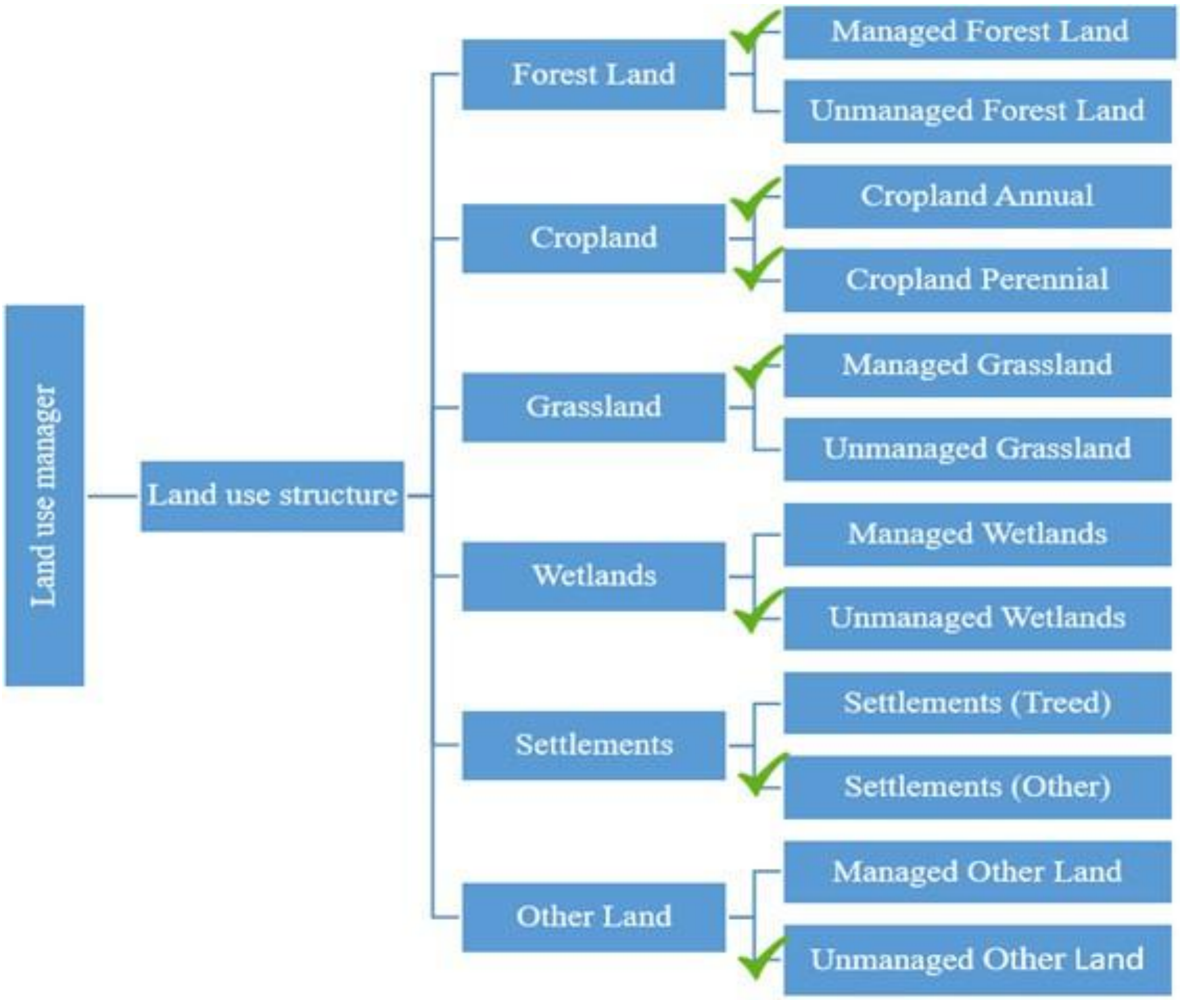

Figure 34: Categories and sub-categories applied in IPCC software

Description of flexibility applied

In the LULUCF sector, Nepal has applied several flexibility measures due to challenges related to data availability and the limitations of existing monitoring systems. These flexibility measures include the following:

- Land Use Change Matrix: The information used to construct the land use change matrix has been derived from the NLCMS. This system provides a comprehensive overview of land cover changes, although certain data gaps have necessitated the application of a supplementary method.

- Interpolation of Land Use Maps: There were issues identified with the 2008 land use map, leading to the need for linear interpolation to address these discrepancies. Additionally, for the year 2012, no land use map was available. As a result, linear interpolation was again applied to estimate land use changes for that year.
- Forest Data Limitations: Nepal faces significant data gaps in the forestry sector, including the absence of comprehensive data on forest fire areas. Due to the lack of this specific information, readily available data from the FAO Stat database was used as a substitute to estimate the areas affected by forest fires.
- General Database Challenges: The overall lack of a robust database in the forestry sector, combined with limitations in data collection and monitoring infrastructure, has necessitated the use of flexible approaches. This includes reliance on international datasets and interpolated estimates to ensure continued reporting in line with the UNFCCC requirements.

2.14.3 Emission Factor

The emission factor used for the GHG inventory for Land use and Forestry sector is presented in the BTR1 Annex IX. II. (BTR 1, Nepal)

2.14.4 GHG trends in this sector

GHG emissions and removals were reported from forestland, cropland, grassland, and settlements. Using Approach 1, emission data for wetlands and other land types were unavailable. The general trend for removals in the forestry sector has been increasing throughout the reporting period, which is linked to management practices and government priorities aimed at improving the country's forest cover. In contrast, emissions from cropland have been steadily increasing, while emissions from grassland have shown both increases in certain years and decreases in Figure 34. The analysis indicates that the forestry sector has been a net remover, with an estimated average removal of 13,889.7 Gg CO2-eq per year from 2002 to 2022. Similarly, emissions from cropland averaged an estimated 2,060.08 Gg CO2-eq over the same period. Interestingly, the settlement sector also showed removals, peaking in 2018, with an unrealistic trend observed in 2022. The grassland sector emitted an average of 2,467.57 Gg CO2-eq during this period, with only removal occurring in 2022.

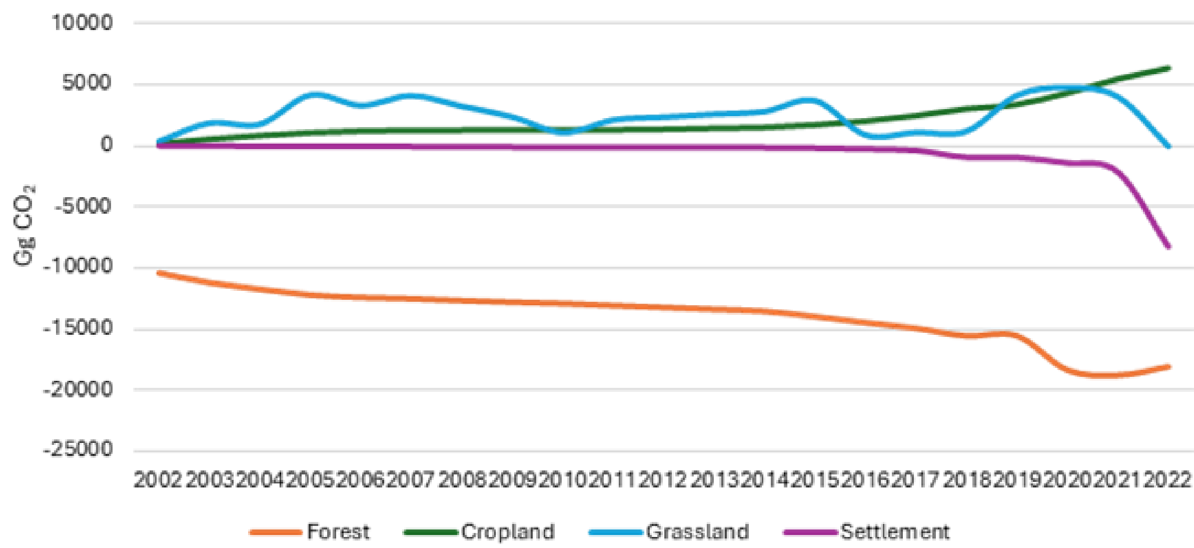

Figure 35: LULUCF sector emission trend

2.14.5 Recalculation from 1994-2011 for LULUCF

The national land cover map has been available since 2002 on the NLCMS website. Since recalculations are required back to 1994, a backward linear projection was applied for all land classes to estimate the data for earlier years. For forest fire emissions, the data were accessed directly from the FAO Stat database, which provides information starting from 1990.

The recalculation of LULUCF emissions and removals from 1994 to 2011 across four land use categories: Forest Land, Cropland, Grassland, and Settlement, is presented in Figure 35. The values represent emissions and removals, where negative values indicate carbon removals (i.e., carbon sequestration) and positive values represent emissions. For Forest Land, the consistently negative values from 1994 to 2001 (around -13063 Gg CO2) suggest a significant and stable level of carbon sequestration through forest growth or preservation. From 2002 onwards, the negative values decreased gradually, indicating that carbon sequestration in forests has been reduced, with emissions increasing slightly due to deforestation or forest degradation.

In Cropland, emissions start at zero and then gradually increase from 2002 onward, with the highest emissions in 2005, reflecting land-use changes and possible shifts in farming practices, such as intensification or land conversion. Grassland shows a similar trend, with emissions fluctuating over the years, peaking in 2005 at over 1073 Gg CO2, which may indicate changes in land management practices or land use conversions to other forms of land cover.

For Settlement, the values are consistently negative, indicating carbon removal (possibly through urban greening, afforestation, or the transformation of land into built-up areas), but the level of removal decreases over time, with a steady increase in the values becoming less negative. Overall, the recalculation reflects the changes in land use and land management practices over time, showing that forests and grasslands have been net carbon sinks in earlier years, with emissions rising in later years due to deforestation and land conversion for agriculture and settlement expansion.

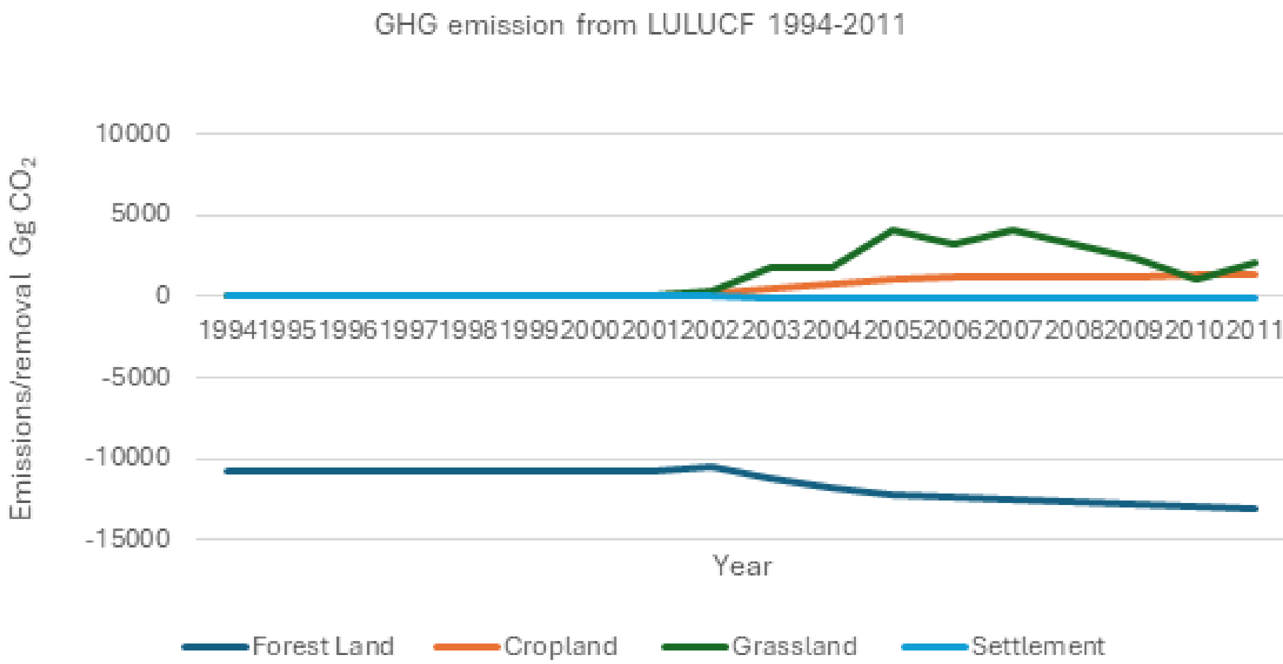

Figure 36: Recalculation of GHG emission/removal from 1994-2011 for LULUCF

The recalculation of emissions from 2001 to 2011 is compared with the Third National Communication (TNC), showing a noticeable difference. The only similarity between the two is the increasing trend in carbon sequestration from the forestry sector. In 2001, the sequestration in this recalculation is higher compared to the TNC, which reported a sequestration of -10,500 Gg. However, in 2011, the TNC reported a higher level of CO2 sequestration (-17,077.81 Gg) compared to this recalculation, which showed -13,063.10 Gg. The discrepancy in the rate of improvement between the TNC and this recalculation suggests that different methodologies or assumptions were used in data analysis. For non-forest sectors, emissions in 2011 were positive, indicating carbon release. TNC reported emissions of 35.39 Gg, while this report shows significantly higher emissions of 3,279.11 Gg. This contrast again highlights methodological differences, as the TNC accounts solely for non-forest land, whereas the report includes a broader range of land categories, such as cropland, grassland, settlements, wetlands, and others.

Table 32: Forest and Non-Forest GHG emissions and removal (Gg) (TNC vs. NIR, 2001–2011)

S.N		Year	Emissions (TNC)	Emissions (NIR)
1	Forest	2001	- 10500	-10791.4938
2		2003	-11800	-11201.0355
3		2005	-13200	-12194.2854

4		2007	-14500	-12512.9261
5		2009	-15700	-12801.0747
6		2011	-17077.81	-13063.0981
7	Non-forest	2011	35.39	3275.108

Forest Fire

For the recalculation of emissions due to forest fires, data for three greenhouse gases (GHGs) were considered. However, CO2 data is only available from 2000 onwards. Therefore, a combined CO2-eq for CH4 and N2O is presented in one Figure 36, while CO2 emissions are displayed separately in another Figure 31.

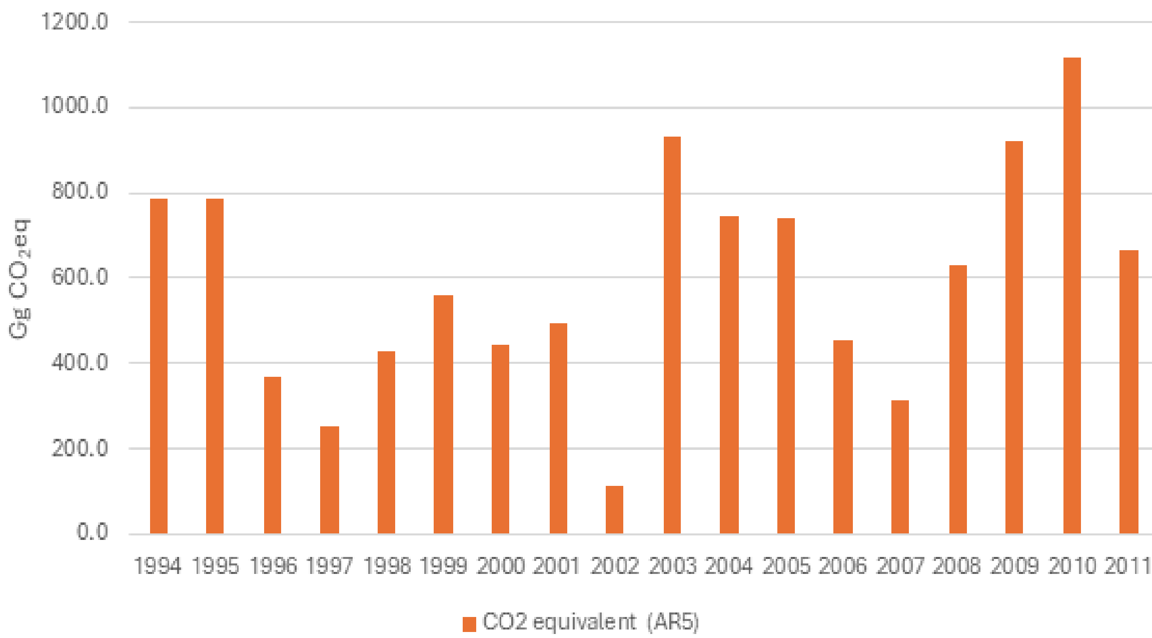

Figure 37: CO2 equivalent emissions (CH4 and N2O) from forest fires

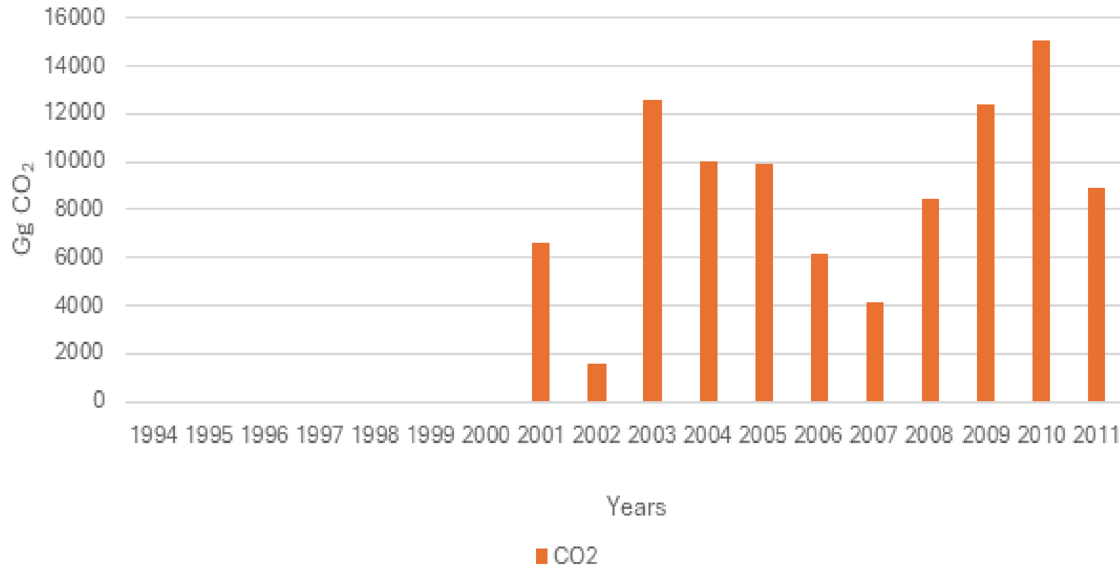

Figure 38: CO2 equivalent emissions from forest fires

CH4 and N2O emissions are recorded throughout the period, while CO2 emissions are available only from 2001 onward. Methane (CH4) emissions range from a high of 17.9 Gg in 2003 to a low of 2.2 Gg in 2002, showing variability across the years. Similarly, N2O emissions fluctuated between 2.0 Gg in 2010 and 0.2 Gg in multiple years, including 1997 and 2002. CO2 emissions, beginning in 2001, exhibit a general upward trend, peaking at 15,021.15 Gg in 2010, followed by a slight decrease to 8,913.85 Gg in 2011. This data highlights distinct emission patterns for each greenhouse gas, with CO2 increasing more after its initial recording in 2001, potentially indicating escalating forest fire impacts or improved recording mechanisms over time.

2.14.6 Inventory development 2012-2022 for LULUCF

2.14.6.1 Forest Land

Emissions in this category have been reported for stable land, forestland, remaining forestland, and for land converted to forestland from other classes. Overall, the forestland category shows an increasing trend in sequestration, measured in gigagrams of CO2 equivalent, rising from 13,220.32 Gg CO2-eq in 2012 to 18,072.10 Gg CO2-eq in 2022, as illustrated in Figure 38.

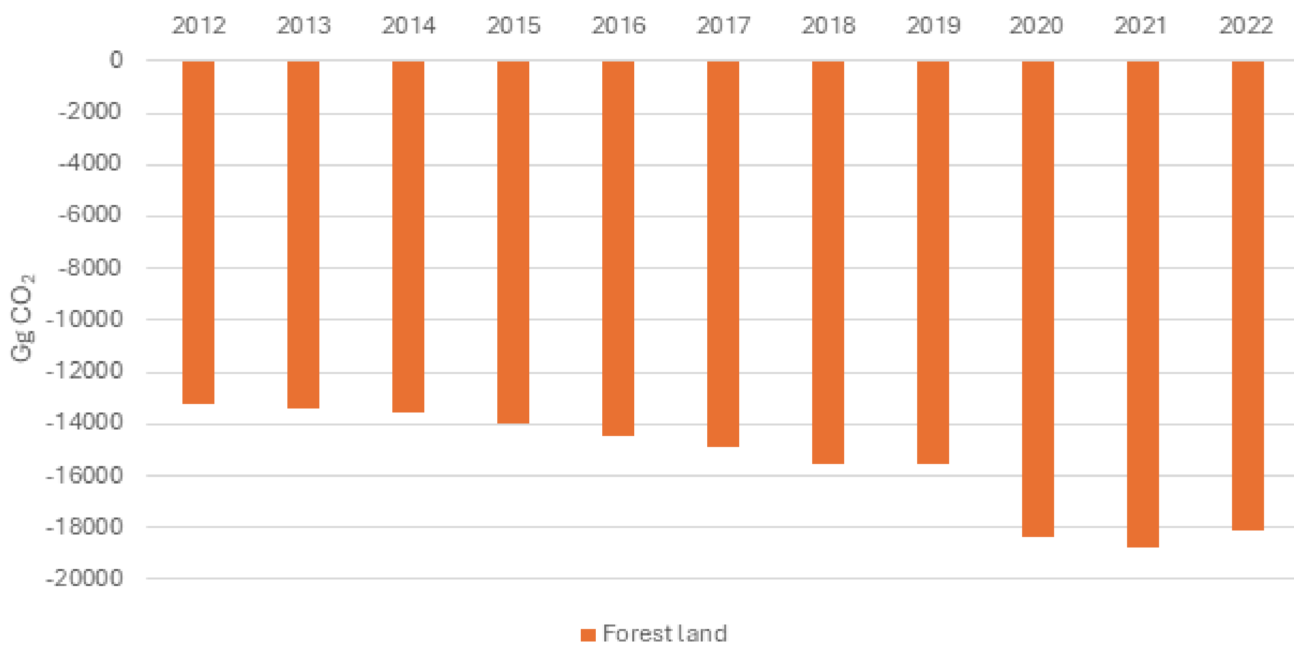

Figure 39: GHG sequestration from forest land

2.14.6.2 Cropland

Similar to the forest land, for this category cropland remaining cropland and other land converted to cropland is calculated. This category showed that emissions are in an increasing trend from 1346.68 Gg CO2-eq to 6345.51 Gg CO2-eq from 2012 to 2022 as shown in Figure 39.

2.14.6.3 Grassland

This category includes both remaining grasslands and other land converted to grassland. When comparing emissions from 2012 to 2022, there has been an overall increase, though emissions fluctuated from year to year. From 2012 to 2015, emissions rose steadily from 2,345.285 Gg CO2 to 3,698.237 Gg CO2. However, in 2016, emissions dropped to 871.491 Gg CO2, with a slight increase to 1,196.18 Gg CO2 in 2018. In 2019, emissions peaked at 4,127.99 Gg CO2, followed by a rise to 4,771.51 Gg CO2 in 2020. In 2021, emissions decreased to 4,005.21 Gg CO2. The inventory analysis from 2012 to 2021 shows the overall trend in GHG emissions, while for 2022, 38.8 Gg CO2 was sequestered, as illustrated in Figure 40.

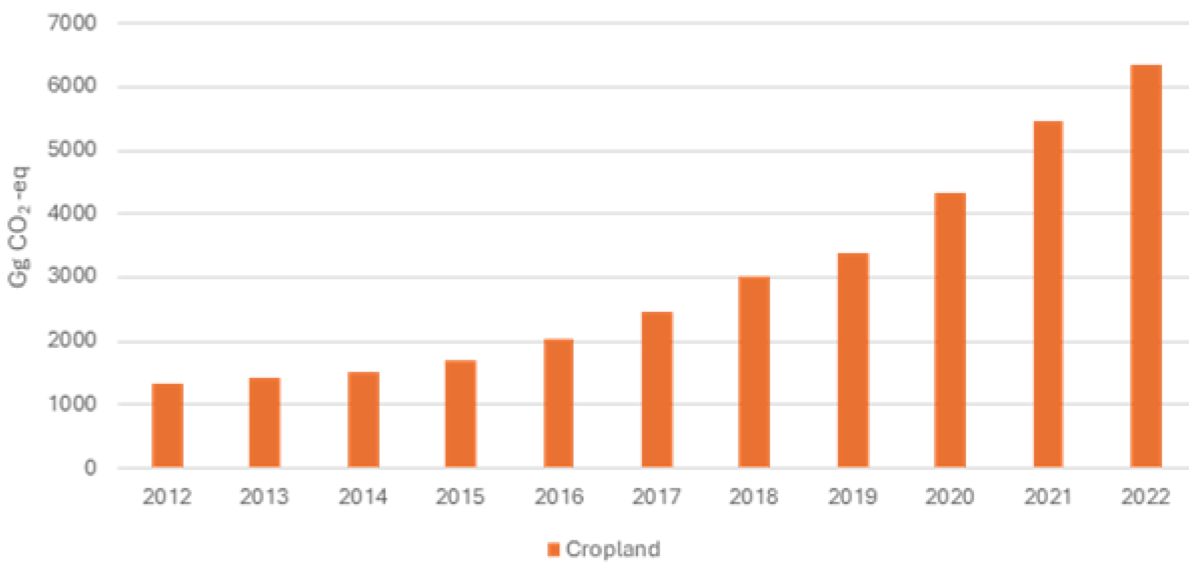

Figure 40: Emissions from Cropland

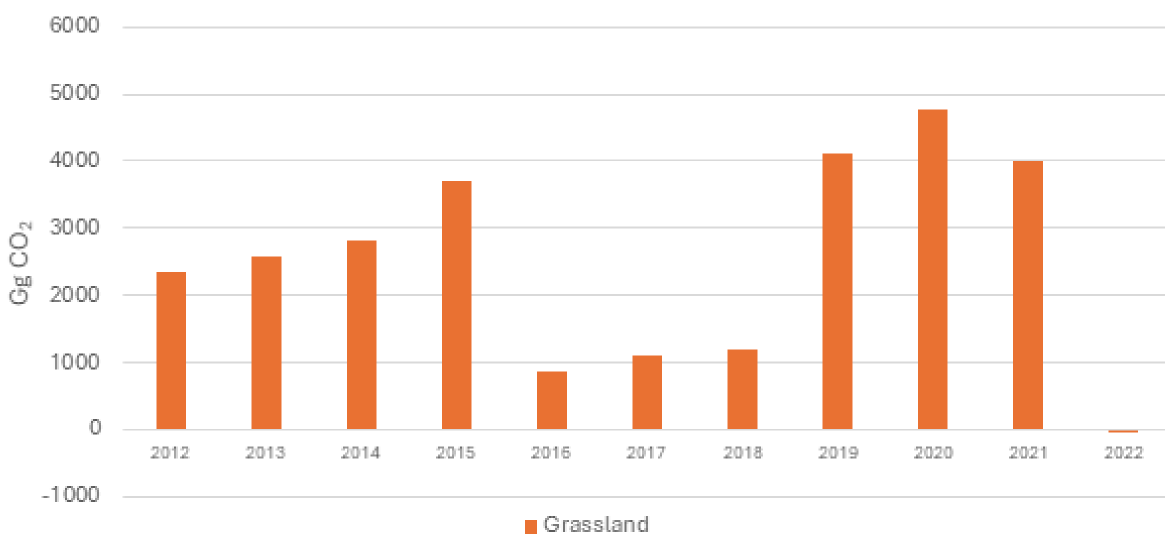

Figure 41: Emissions/Removals from grassland

2.14.6.4 Settlements

The analysis for settlements includes both remaining settlements and other land converted to settlements, calculated for each year from 2012 to 2022. The results revealed that settlements are acting as a sink for GHG emissions in the context of Nepal. The trend shows a steady increase, starting from 143.54 Gg CO2 in 2012 and rising to 8,256.5 Gg CO2 in 2022, as shown in Figure 41.

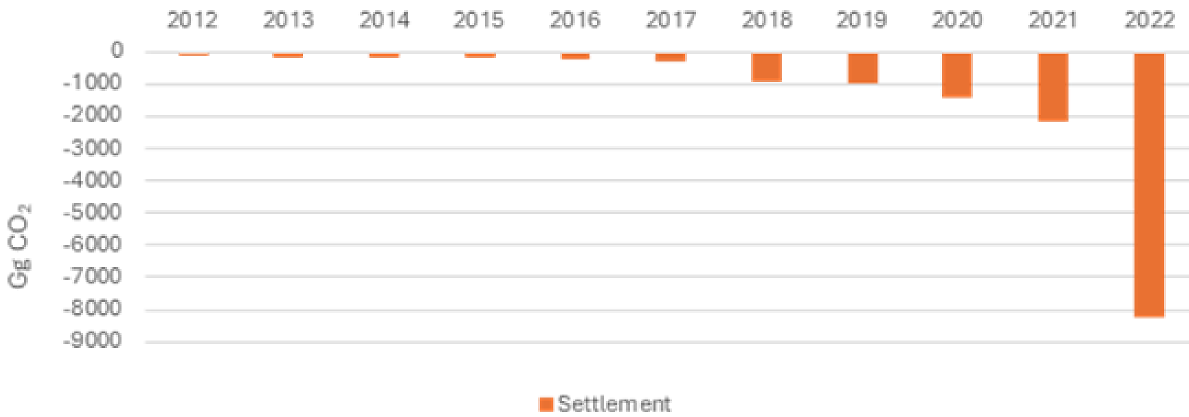

Figure 42: Emissions/Removal from settlement category

Table 33: Emission from Forestry and Land Use sector in 2022

Categories	**Net CO_2 emissions / removals**			
	CO_2	**CH_4**	**N_2O**	**Total**
	Gg	**Gg CO_2-eq**	**Gg CO_2-eq**	**Gg CO_2-eq**
3.B - Land	**-20021.958**			**-20021.958**
3.B.1 - Forest land	-18072.100			-18072.100
3.B.1.a - Forest land Remaining Forest land	-18072.100			-18072.100
3.B.1.b - Land Converted to Forest land	-			-
3.B.1.b.i - Cropland converted to Forest Land	-			-
3.B.1.b.ii - Grassland converted to Forest Land	-			-
3.B.1.b.iii - Wetlands converted to Forest Land	-			-
3.B.1.b.iv - Settlements converted to Forest Land	-			-
3.B.1.b.v - Other Land converted to Forest Land	-			-
3.B.2 - Cropland	6345.516			6345.516
3.B.2.a - Cropland Remaining Cropland	6345.516			6345.516
3.B.2.b - Land Converted to Cropland	-			-

3.B.2.b.i - Forest Land converted to Cropland	-			-
3.B.2.b.ii - Grassland converted to Cropland	-			-
3.B.2.b.iii - Wetlands converted to Cropland	-			-
3.B.2.b.iv - Settlements converted to Cropland	-			-
3.B.2.b.v - Other Land converted to Cropland	-			-
3.B.3 - Grassland	-38.794			-38.794
3.B.3.a - Grassland Remaining Grassland	-38.794			-38.794
3.B.3.b - Land Converted to Grassland	-			-
3.B.3.b.i - Forest Land converted to Grassland	-			-
3.B.3.b.ii - Cropland converted to Grassland	-			-
3.B.3.b.iii - Wetlands converted to Grassland	-			-
3.B.3.b.iv - Settlements converted to Grassland	-			-
3.B.3.b.v - Other Land converted to Grassland	-			-
3.B.4 - Wetlands	-			-
3.B.4.a - Wetlands Remaining Wetlands	-			-
3.B.4.a.i - Peat Extraction remaining Peat Extraction	-			-
3.B.4.a.ii - Flooded Land remaining Flooded Land	-			-
3.B.4.b - Land Converted to Wetlands	-			-
3.B.4.b.i - Land converted for Peat Extraction	-			-
3.B.4.b.ii - Land converted to Flooded Land	-			-
3.B.5 - Settlements	-8256.580			-8256.580

3.B.5.a - Settlements Remaining Settlements	-8256.580			-8256.580
3.B.5.b - Land Converted to Settlements	-			-
3.B.5.b.i - Forest Land converted to Settlements	-			-
3.B.5.b.ii - Cropland converted to Settlements	-			-
3.B.5.b.iii - Grassland converted to Settlements	-			-
3.B.5.b.iv - Wetlands converted to Settlements	-			-
3.B.5.b.v - Other Land converted to Settlements	-			-
3.B.6 - Other Land	-			-
3.B.6.a - Other land Remaining Other land	-			-
3.B.6.b - Land Converted to Other land	-			-
3.B.6.b.i - Forest Land converted to Other Land	-			-
3.B.6.b.ii - Cropland converted to Other Land	-			-
3.B.6.b.iii - Grassland converted to Other Land	-			-
3.B.6.b.iv - Wetlands converted to Other Land	-			-
3.B.6.b.v - Settlements converted to Other Land	-			-
3.C - Aggregate sources and non-CO_2 emissions sources on land	-			
3.C.1 - Burning	-	-	-	-
3.C.1.a - Burning in Forest Land	-	-	-	-
3.C.1.b - Burning in Cropland	-	-	-	-
3.C.1.c - Burning in Grassland	-	-	-	-
3.C.1.d - Burning in all other land uses	-	-	-	-

3.D - Other	-	-	-	-
3.D.1 - Harvested Wood Products	-	-	-	-
3.D.2 - Other (please specify)	-	-	-	-

2.14.7 Uncertainty assessment and time-series consistency

The uncertainty primarily arises from challenges related to data availability, quality, and the methodologies used. One key issue is the lack of comprehensive and consistent forest inventory data, particularly on forest fires, which has led to an increased level of uncertainty in emission and removal estimates. For some years, the use of interpolation methods, such as linear interpolation for the 2008 and 2012 land use maps, has been necessary to address data gaps, further contributing to uncertainty. Additionally, the application of default emission factors from international sources like the FAO introduces some level of uncertainty, as these may not fully capture the specific conditions in Nepal's forests and land use dynamics.

The uncertainty assessment for the LULUCF was carried out using the uncertainty values provided in the IPCC Guidelines, specifically in Volume 4, Chapter 4. This assessment covered Forest Remaining Forest, considering biomass, dead organic matter, and soil carbon for the years 2012 and 2022. The total uncertainty (U) was calculated by applying the formula:

This same approach was applied to the Cropland sector, using the relevant uncertainty values from Volume 4, Chapter 5 of the IPCC Guidelines. The assessment for Cropland Remaining Cropland also considered biomass, dead organic matter, and soil carbon for the years 2012 and 2022, and the total uncertainty for each year was determined using the same formula. Similarly, the uncertainty assessment for Grassland was conducted with reference to the uncertainty values in Volume 4, Chapter 6. This assessment covered Grassland Remaining Grassland, addressing biomass, dead organic matter, and soil carbon for the years 2012 and 2022. Again, the uncertainty for each year was calculated using the same formula. Lastly, for the Settlement sector, the uncertainty assessment followed the methodology outlined in Volume 4, Chapter 8

of the IPCC Guidelines, focusing on Settlement Remaining Settlement, and covering biomass, dead organic matter, and soil carbon for the years 2012 and 2022. The total uncertainty (U) for these years was also calculated using the same formula. The Table 34 presents the uncertainty values for both emission factors and activity data across different land use categories. For Forest Remaining Forest (FL), the uncertainty in emission factors is ±50, while activity data uncertainty is significantly higher at ±90. In the case of Cropland Remaining Cropland (CL), emission factor uncertainty is ±75, with activity data uncertainty at ±50.99. For Grassland Remaining Grassland (GL), the uncertainty in emission factors is relatively low at ±6, but activity data uncertainty is high at ±100. Lastly, for Settlement Remaining Settlement (SL), there is no uncertainty in emission factors (0), while activity data uncertainty is ±50. These values indicate that uncertainty levels vary considerably across land use categories, with activity data generally exhibiting higher uncertainty than emission factors.

Table 34: Uncertainty analysis for emission factor and activity data Uncertainty Analysis

	Emission Factor Uncertainty	Activity data Uncertainty
FL remaining FL	±50	±90
CL remaining CL	±75	±50.99
GL remaining GL	±6	±100
SL remaining SL	0	±50

To maintain time-series consistency, Nepal has made efforts to apply consistent methodologies and data sources across the reporting period from 2012 to 2022. However, due to data limitations, adjustments were necessary to ensure comparability over time. For example, linear interpolation was used for the years 2008 and 2012 in the absence of available land use maps, ensuring temporal continuity despite potential inaccuracies in these years. Efforts to apply consistent estimation methods, such as using default emission factors from the IPCC guidelines and relying on FAO data for forest fire areas, have been made, although variations in methods across years may occur as national capacities improve and data availability increases.

2.14.8 Category specific QA/QC and verification

The QA/QC procedures for data collection were carried out in accordance with the 2006 IPCC Guidelines for National Greenhouse Gas Inventories, ensuring both international comparability and consistency. To enhance accuracy and reliability, the sources of information were obtained from relevant government bodies and verified web-based sources. Data derived from the land use matrix was further validated through consultations with experts from the Forest Research Training Centre and the International Centre for Integrated Mountain Development (ICIMOD). To align with the IPCC guidelines, the land use change matrix was prepared using the IPCC land class values. During the data analysis process, several inconsistencies and inaccuracies were identified and addressed through discussions with officials from the Climate Change Management Division, leading to necessary adjustments. All datasets were securely stored, well-organized, and regularly backed up to prevent data loss. This report was prepared in accordance with the UNFCCC reporting principles, ensuring transparency, accuracy, clarity, completeness, and consistency.

2.14.9 Category-specific planned improvements

In the context of Nepal, several planned improvements can be undertaken to enhance emission estimates within the LULUCF sector, drawing on global best practices. Establishing a comprehensive data hub and sharing platform will improve access to activity data, emission factors (EFs), and research outputs, ensuring greater consistency and transparency. With increased ground-based research, Nepal can develop national- level emission factors, significantly enhancing the accuracy of its estimates. Conducting systematic reviews of research papers on carbon stocks, emission factors, and land-use dynamics will provide a robust scientific foundation for refining estimation methodologies. Nepal could also benefit from technical cooperation agreements or partnerships aimed at reducing uncertainties, acquiring high-quality data, and conducting targeted studies on previously estimated emissions, such as those from forest fires without land-use change and harvested wood products. Furthermore, reviewing and improving carbon stock data for native vegetation and better estimating emissions and removals from grasslands will ensure more comprehensive and accurate reporting. Expanding national studies and methodologies will help address existing gaps, improve classification systems, and strengthen Nepal's capacity to monitor and report on LULUCF-related emissions and removals more effectively.

2.15 Waste

The waste sector covers greenhouse gas (GHG) emissions occurring from solid waste disposal techniques, biological treatment/compost, incineration/open burning activities, and wastewater treatments (domestic and industrial).

2.15.1 Description of the waste sector in Nepal

Solid waste management has emerged as a critical concern, particularly in Nepal's urban areas. In many areas of Nepal, managing solid waste and wastewater treatment has been given a low priority due to the overwhelming demand for other public services. Due to poor management of waste, it results in serious environmental degradation and public health threats (Alam et al., 2007). Waste decomposition, incineration, open burning, and fugitive sources have grown to be a significant source of greenhouse gases (GHGs) and other harmful pollutant emissions (Das et al., 2018; Nagpure et al., 2015; Shrestha, 2018; Shrestha et al., 2013; TNC, 2017). A significant amount of CH4 is also released from the decomposition of waste, which has a high Global Warming Potential (GWP) to the environment (Das et al., 2018; Shrestha, 2018). The fugitive emissions from the waste sector (including wastewater treatment) are poorly characterized and underestimated sources of air pollution in developing countries (IPCC, 2006). The majority of fugitive emissions are minor, do not have immediate consequences, and are challenging to find. Fugitive emissions include a number of poorly known routes for the most potent and long-lived GHGs and ozone depleting compounds into Earth's atmosphere (Laconde et al., 2018). In particular, fugitive emissions frequently escape into the atmosphere without proper containment or control measures, making them a challenging target for environmental management.

Previous studies of Nepal (Das et al., 2018; Gautam, 2006; INC, 2004; Shrestha, 2018; SNC, 2014; TNC, 2021) present GHGs emission from waste sector. Those studies also highlight the need for more variables to reduce uncertainty associated with the findings. In light of those studies and in order to uphold the Government of Nepal's international commitments made thus far (such as the Paris Agreement, the NDC, and the UN Sustainable Development Goals), this study aimed for developing a database of greenhouse gases (GHGs) released by different waste categories such as disposal of solid waste, the biological treatment of solid waste, open burning and incineration, and the treatment and discharge of wastewater. New Version 2.95 – IPCC Inventory Software is used for baseline assessment of GHGs from waste sector from the years 1994-2022, whereas Low Emissions Analysis Platform (LEAP) computational tools is used for scenarios development and GHGs projections up-to 2050 considering the base year 2022.

Table 35: IPCC emission categories in waste sector relating to Nepal

Category code	Category Name	Remarks
4	Waste	
4 A	Solid Waste Disposal	

4 A 1	Managed Waste Disposal Sites	Only limited practices
4 A 2	Unmanaged Waste Disposal Sites	Prevails mainly in urban areas
4 A 3	Uncategorized Waste Disposal Sites	Where disposal sites are not categorized properly
4 B	Biological Treatment of Solid Waste	Only limited practices and without information.
4 C	Incineration and Open Burning of Waste	
4 C 1	Waste Incineration	Mainly in health care facilities (but uncontrolled incineration)
4 C 2	Open Burning of Waste	Very common
4 D	Waste Water Treatment and Discharge	
4 D 1	Domestic Wastewater Treatment and Discharge	Only limited information is available
4 D 2	Industrial Wastewater Treatment and Discharge	Only limited information is available
4 E	Other	Not estimated

No- Not considered

The following categories of emissions were estimated by Nepal's Third National Communications (TNC) for 2011: solid waste disposal, biological treatment of solid waste, open burning of waste, and wastewater treatment and discharge (both domestic and industrial wastewater). The GHG inventory was estimated by the TNC using the 2006 IPPC Guidelines. However, INC (2004) and SNC (2014) excluded emissions from biological treatment of solid waste, incineration, and open burning of waste, while TNC (2021) excluded emissions from incineration practices.

2.15.2 Methodology

The IPCC (2006) National GHG Inventory Guidelines are used to estimate Nepal's waste sector's emissions. According to the 2006 Guidelines, Tier 1 Approach uses default emissions factors from the IPCC based on global averages for waste activities. The procedures and information needed in the various waste industry subcategories are compiled in Table 36. Tier 1 technique is used for the waste sector for developing Nepal's National GHGs Inventory.

The accompanying activity data is multiplied by emissions variables, correction factors, and the applicable emission factors to estimate the GHG emissions for each waste source category. Emissions can be broken down by individual pollutants (CO_2, CH_4, N_2O) or combined into total CO_2 equivalent emissions, depending on reporting requirements. In addition to the annual reports of the various ministries of the Government of Nepal, the Central Bureau of Statistics (CBS) and National Statistics Office (NSO) documents, as well as relevant research organizations and publications, provide the activity data for the different waste sources. Solid waste disposal, biological treatment of solid waste, incineration and open burning of garbage, and wastewater treatment and discharge are among the data collected that measure the degree of activity for each specified waste source category.

Table 36: Waste emission category and method used reported in Third National Communication of Nepal

Category	Subcategory	Gases	Method	Required Data	Data sources and variables
4A. Solid Waste Disposal	A1. Solid Waste Disposal	CH_4, N_2O	T1	Waste Generation Rate, Amount and Methods of Waste Disposal, Urban Population	ADB (2013), CBS (1995, 2003, 2012, 2021, 2023); Das et al. (2018); IPCC (2006); 2006SWMRMC (2004/2008); SWMTSC (2015); Pathak and Pokhrel (2023)
4B. Biological Treatment of Solid Waste	4B1. Biological Treatment of Solid Waste	CH_4, N_2O	T1	Fraction of Waste Composed	ADB (2013); IPCC (2006); TNC (2021)
4C. Incineration and Open Burning	4C2. Open Burning	CO_2, CH_4, N_2O	T1	Amount and type of waste burned	Amount and type of waste burned
4D. Wastewater Treatment & Discharge	4D1. Domestic Wastewater	CH_4, N_2O	T1	Population Data, Wastewater generated and treated per year, Protein consumption, Type of wastewater treatment system in use	CBS (1995, 2003, 2012, 2021, 2023); Data sheets; INC (1994); SNC (2000); TNC (2011); MoAD (1994-2022); KII; Webpage
	4D2. Industrial Wastewater	CH_4, N_2O	T1	Industrial Production Data	DoI (1994-2014); INC (1994); SNC (2000); TNC (2011); MoAD (1994-2022); Data sheets; KII; Webpage

The global warming potentials (GWPs) values from the IPCC AR5 (temporal horizon 100 years) were used to make it easier to report GHG values aggregate, expressed as carbon dioxide equivalents (CO2-eq) BTR1 Annex I.I.

2.15.2.1 Solid waste disposal

The calculation of CH4 emissions for dumping/disposal sites is based on the IPCC, 2006/2019. The country- specific waste disposal parameters/variables are not available nationwide; therefore, Tier 1 method is used. The annual CH4 emissions from the disposal of solid waste are calculated using equation 1 (IPCC, 2006/2019). In an anaerobic setting, organic matter decomposes to produce CH4. A portion of the generated CH4 is either partially oxidized in the SWDS cover or recovered for energy or flaring. As a result, the amount of CH4 emitted from the SWDS will be less than the amount generated.

$$CH_4 Emissions = \left[\sum_x CH_4\ gennerated - R_T\right] * (1 - OX_T)$$

Where,

CH_4 Emissions = CH4 emitted in year T, Gg T = inventory year

x = waste category or type/material RT = recovered CH_4 in year T, Gg

OXT = oxidation factor in year T, (fraction) Biological treatment of solid waste

The CH emissions of biological treatment can be estimated using the default method from IPCC (2006/2009).

$$CH_4\ Emissions = \sum_i (M_i \times EF_i) \times 10_{-3} - R \qquad (2)$$

Where,

Mi = mass of organic waste treated by biological treatment type i, Gg EF = emission factor for treatment i, g CH_4/kg waste treated

i = composting or anaerobic digestion

R = total amount of CH_4 recovered in inventory year, Gg CH_4

The N_2O emissions of biological treatment can be estimated using the default method from IPCC (2006/2009).

$$N_2O\ Emissions = \sum_i (M_i \times EF\__i) \times 10_{-3} \qquad (3)$$

N_2O Emissions = total N_2O emissions in inventory year, Gg N_2O

Mi = mass of organic waste treated by biological treatment type i, Gg EF = emission factor for treatment i, g N_2O/kg waste treated

i = composting or anaerobic digestion Incineration and open burning of waste

Both country-specific waste burning parameters/variables and IPCC default values are used to estimate the quantity of incineration and open burning of waste as well as emissions (IPCC, 2006/2019). The total amount of clinical waste incineration was estimated, referring to the recent study (MoHP, 2024), which was further applied for emission estimation. The total amount of municipal solid waste open-burne $U = \sqrt{(U1^2 + U2^2)}$ ısing the default method from IPCC (2006/2019).

$$MSW_B = P * P_{frac} * MSW_P * B_{frac} * 365 * 10^{-6}$$

Where,

MSWB = Total amount of municipal solid waste open-burned, Gg/yr P = population (capita)

Pfrac = fraction of population burning waste, (fraction) MSWP = per capita waste generation, kg waste/capita/day

Bfrac = fraction of the waste amount that is burned relative to the total amount of waste treated, (fraction) 365 = number of days by year

10-6 = conversion factor from kilogram to gigagram

$$CO_2 \text{ Emissions} = MSW * \sum_j (WF_j * dm_j * CF_j * FCF_j * OF_j) * \frac{44}{12}$$

Where,

CO_2 Emissions = CO_2 emissions in inventory year, Gg/yr

MSW = total amount of municipal solid waste as wet weight incinerated or open-burned, Gg/yr

WFj = fraction of waste type/material of component j in the MSW (as wet weight incinerated or openburned) dmj = dry matter content in the component j of the MSW incinerated or open-burned, (fraction)

CFj = fraction of carbon in the dry matter (i.e., carbon content) of component j FCFj = fraction of fossil carbon in the total carbon component j

OFj = oxidation factor, (fraction)

44/12 = conversion factor from C to CO_2 with: ΣjWFj = 1

j = component of the MSW incinerated/open-burned such as paper/cardboard, textiles, food waste, wood, garden (yard) and park waste, disposable nappies, rubber and leather, plastics, metal, glass, other inert waste.

$$CH_4 \text{Emissions} = \sum_i (IW_i * EF_i) * 10^{-6}$$

Where:

CH_4 Emissions = CH_4 emissions in inventory year, Gg/yr

IWi = amount of solid waste of type i incinerated or open-burned, Gg/yr EFi = aggregate CH_4 emission factor, kg CH_4/Gg of waste

10-6 = conversion factor from kilogram to gigagram

i = category or type of waste incinerated/open-burned, specified as follows: MSW: municipal solid waste, ISW: industrial solid waste, HW: hazardous waste, CW: clinical waste, SS: sewage sludge, others (that must be specified)

$$N_2O\ Emissions = \sum_i (IW_i * EF_i) * 10^{-6}$$

Where,

N_2O Emissions = N_2O emissions in inventory year, Gg/yr

IWi = amount of incinerated/open-burned waste of type i , Gg/yr EFi = N_2O emission factor (kg N_2O/Gg of waste) for waste of type i 10-6 = conversion from kilogram to gigagram

i = category or type of waste incinerated/open-burned, specified as follows: MSW: municipal solid waste, ISW: industrial solid waste, HW: hazardous waste, CW: clinical waste, SS: sewage sludge, others (to be specified)

Waste water treatment and discharge Domestic wastewater treatment and discharge CH_4 emissions from domestic wastewater

Estimating emissions from domestic wastewater treatment requires the application of equation 8 (IPCC, 2006/2019).

$$\mathbf{CH_4\ Emissions_j = [(TOW_j - S_j) * EF_j - R_j]}$$

Where,

CH_4 Emissionsj = CH_4 emissions from treatment/discharge pathway or system, j, in inventory year, kg CH_4/ yr

TOWj = organics in wastewater of treatment/discharge pathway or system, j, in inventory year, kg BOD/yr.

Sj = organic component removed from wastewater (in the form of sludge) from treatment/discharge pathway or system, j, in inventory year, kg BOD/yr. For wastewater discharged to aquatic environments, there is no sludge removal (Sj = 0) and no CH_4 recovery (Rj = 0).

j = each treatment/discharge pathway or system

EFj = emission factor for treatment/discharge pathway or system, j, kg CH_4/kg BOD.

Rj = amount of CH_4 recovered or flared from treatment/discharge pathway or system, j, in inventory year, kg CH_4/yr. Default value is zero.

$$\mathbf{N_2O\ Plants_{DOM} = \left[\sum_{i,j} (U_i * T_{ij} * EF_j)\right] * TN_{DOM} * \frac{44}{28}}$$

Where,

N_2O Plants DOM = N_2O emissions from domestic wastewater treatment plants in inventory year, kg N_2O/yr

TNDOM = total nitrogen in domestic wastewater in inventory year, kg N/yr.

Ui = fraction of population in income group i in inventory year.

Tij = degree of utilisation of treatment/discharge pathway or system j, for each income group fraction i in the inventory year.

i = income group: rural, urban, high income and urban low income

j = each treatment/discharge pathway or system

EFj = emission factor for treatment/discharge pathway or system j, kg N_2O-N/kg N The factor 44/28 is for the conversion of kg N_2O-N into kg N_2O.

Industrial wastewater treatment and discharge CH_4 emissions from industrial wastewater

CH_4 emissions in the inventory year can be estimated using the default method from IPCC (2006/2019).

$$\mathbf{CH_4\ Emissions} = \sum_i [(\mathbf{TOW_i} - \mathbf{S_i}) * \mathbf{EF_i} - \mathbf{R_i}] * \mathbf{10^{-6}}$$

Where,

CH_4 Emissions = CH_4 emissions in inventory year, Gg CH_4/yr

TOWi = total organically degradable material in wastewater from industry i in inventory year, kg COD/yr i = industrial sector

Si = organic component removed from wastewater (in the form of sludge) in the inventory year, kg COD/yr

EFi = emission factor for industry i, kg CH_4/kg COD for treatment/discharge pathway or system(s) used in inventory year

If more than one treatment practice is used in an industry, this factor would need to be a weighted average.
Ri = amount of CH_4 recovered or flared in inventory year, kg CH_4/yr

10-6 = conversion of kg to Gg

$$\mathbf{N_2O\ Plants_{IND}} = \left[\sum_i (\mathbf{T_{ij}} * \mathbf{EF_j} * \mathbf{TN_{INDi}})\right] * \frac{\mathbf{44}}{\mathbf{28}}$$

Where,

N_2O PlantsIND = N_2O emissions from industrial wastewater treatment plants in the inventory year, kg N_2O/yr

TNINDi = total nitrogen in wastewater from industry i in inventory year, kg N/yr.

Tij = degree of utilization of treatment/discharge pathway or system j, for each industry i in the inventory year

i = industry

j = each treatment/discharge pathway or system

EFj = emission factor for treatment/discharge pathway or system j, kg N_2O-N/kg N. The factor 44/28 is for the conversion of kg N_2O-N into kg N_2O

2.15.3 Activity data

2.15.3.1 Solid waste disposal site

To estimate emission from solid waste disposal site, data sets like population of urban areas (per capita), municipal waste generation rate (MSWGR) (kg/person/yr), total landfilled/MSW disposed at SWDS (Gg), waste disposed at SWDS (%), organic waste composition (%), paper (%), rubber/leather (%), wood (%), plastic (%), textile (%) were obtained from various literature, as depicted below.

The urban population of the years 1991, 2001, 2011, and 2021 was obtained from CBS 1995, CBS 2003, CBS 2012, and CBS 2022, respectively. The compound annual growth rates (CAGR) were estimated based on the data, which were further applied in linear regression models to get data on the urban population from 1994 to 2022. The MSWGR for urban areas of Nepal was available only for the years 2003 (SWMRMC, 2004), 2007 (SWMRMC, 2008), and 2012 (ADB, 2013). As national context data of MSWGR was not available after 2013, we considered the average per capita of 21 municipalities of Kathmandu Valley. MSWGR for 2014 (SWMTSC, 2015), 2016 (Das et al., 2018), and 2021 (Pathak & Pokhrel, 2023) were based on KV. Due to the unavailability of urban MSWGR from 1994-2002, we assumed the same value of 2003 (SWMRMC, 2004). The MSWGR for the year 2004-2006 was based on the average value between (2004) and SWMRMC (2008), while 2008-2011 (average value from SWMRMC, 2008 and ADB, 2013); 2013 (average value from ADB, 2013 and SWMTSC, 2015); 2015 (average value from SWMTSC, 2015 and Das et al., 2018); and 2017-2020 (average value from Das et al., 2018, and Pathak and Pokhrel, 2023). The year 2022 was assumed to have the same value as that of 2021 (Pathak & Pokhrel, 2023). The MSWGR and the quantity of waste generated are presented in the BTR1 Annex X.II.

According to the ADB (2013), waste collection efficiency (WCE) or solid waste disposal for urban areas of Nepal is only reported for 2012. Due to the unavailability of the yearly-wise literature of this type for urban areas of Nepal, we have assumed the same value of ADB (2013) for the rest of the years. The value of organic waste for the years 2003, 2007, and 2012 for urban areas of Nepal was reported in the literature, SWMRMC (2004), SWMRMC (2008), and ADB (2013), respectively. SWMRMC (2004) and SWMRMC (2008) report waste composition for plastic, paper, metal, and glass in a single category. Considering this value and waste categorized data from ADB (2013), plastic and paper composition were estimated, while rubber/leather was assumed to be the same. From 1994 to 2002, the waste composition value for 2003 was considered. From the years 2004-2006, the average value was estimated, referring to SWMRMC (2004) and SWMRMC (2008). For the years 2008-2011, average values from SWMRMC (2008) and ADB (2013) were estimated. Due to the unavailability of waste composition data after 2012, the same value of ADB (2013) was considered. Waste disposal amount and composition of urban areas of Nepal are presented in the BTR1 Annex X.III

2.15.3.2 Biological treatment of solid waste

While Nepal has a large number of small-scale anaerobic digestion biogas plants, they do not handle solid waste. For this inventory, it is assumed same percentage of composting (i.e, 5%) with that of TNC (2021). Based on it and total organic waste generation, amount of compost from 1994-2022 was estimated BTR1 Annex X.IV.

2.15.3.3 Incineration and open burning of waste

Incineration

Nepal currently lacks suitable incinerators to handle solid garbage. Commonly, garbage is incinerated in built- in chambers. Therefore, this analysis considered uncontrolled waste incineration. Altogether 30 healthcare facilities (HCFs) (both specialized and teaching hospitals) have been considered for garbage incineration. The clinical waste burning of Tribhuvan University Teaching Hospital (TUTH) was estimated for the year 2022 referring to MoHP (2024), which was further converted to bed wise incineration from 1994-2022. The clinical waste burning for the remaining HCFs were calculated referring to bed wise incineration of TUTH and total number of beds of each HCF. The number of beds added in the respective years is also considered. The total amount of clinical waste incinerated is presented in the BTR1 Annex X.V.

Open burning of waste

The data sets like urban population, rural population, urban waste generation rate, rural waste generation rate, and solid waste composition from 1994-2022 have been considered from various literature. The national and urban population of the years 1991, 2001, 2011, and 2021 were obtained from CBS 1995, CBS 2003, CBS 2012, and CBS 2022 respectively. The CAGR was estimated based on those data, which were further applied in linear regression model to get data of national and urban population from 1994-2022. The rural population was estimated by subtracting urban population from national population. The value of urban MSWGR was considered from section SWDS. The MSWGR for semi-rural areas is available only for 2016

(SWMTSC, 2017). Therefore, we assumed it same for the rest of the years (1994-2022). After multiplying urban and rural waste generation rate with its population, total quantity of waste was estimated for Nepal. The composition wise waste quantity from 1994-2022 was obtained similar to section SWDS. The open waste burning parameters (Pfrac and Bfrac) were considered for Nepalese context (Das et al., 2018) to estimate composition wise mass of MSW open burnt BTR1 Annex X.VII.

2.15.3.4 Waste water treatment

Domestic wastewater treatment

In Nepal, there aren’t many domestic wastewater treatment facilities, and the majority of wastewater is untreated. This study compiled 12 wastewater treatment facilities, based on the availability of data sets and functioning status. The untreated and treated waste were further categorized. Total populations served in domestic water treatment was collected from the available literature, key informant interview and on-site visit, while national urban population from 1994-2022. The urban population for wastewater discharge or untreated was estimated considering total urban population and population of domestic wastewater treatments. The value of sludge removed (kg BOD), flaring (kg CH4), and energy use (kg CH4 Nitrogen in wastewater was not considered dvue to unavailability of data. Per capita protein consumption was obtained from MoAD (1994-2022). Rivers and constructed wetlands (horizontal sub-surface flow) are the types of domestic WWT plants. While various parameters like emission factors (kg CH4/kg BOD; N2O/person/ year; kg N2O-N/kg N; kg N2O/year), degradable organic component (g/cap/day), correction factor for BOD discharged in sewers, degree of utilization of WWT plants, methane production capacity, methane correction factor, fraction of nitrogen in protein, fraction of non-consumption protein, and fraction of industrial co- discharged protein were considered from IPCC (2006), as default values.

Industrial wastewater treatment

Only limited data exists for industrial waste treatment plants (IWWTP). The activity data of industrial production was collected from available literature (DoI, 1994-2014; INC, 1994; SNC, 2000; TNC, 2011; MoAD, 1994-2022). The waste category includes alcohol refining, beer & meat, dairy products, meat & poultry, organic chemicals, plastics & resins, pulp & paper, soap & detergent, starch production, and vegetables, fruit & juice, all in units of tonnes. Most of the data is available from 2001-2014, except for dairy and meat products. The untreated industrial wastewater or discharge from 2001-2014 was estimated referring to total industrial production and treated waste, while remaining years data was estimated based on linear regression model and annual growth rate depending upon the data structure. In this study, four IWWTPs have been taken into account for waste treatment considering its functionality, availability of data, KII and onsite visit. The daily flow rate of industrial wastewater by type (m3/day) was further calculated referring to IPCC (2006) and industrial productions by type. While various parameters like emission factors (kg CH4/ kg COD; kg N2O-N/kg N), wastewater generated (m3/t), chemical oxygen demand (kg COD/m3), methane production capacity (kg CH4/kg COD), methane correction factor (Frac), and total N concentration in industrial wastewater treated by constructed wetlands were considered from IPCC (2006), as default values. The quantity of treated industrial waste and untreated discharge is reflected in the BTR1 Annex X.X

2.15.4 Emission Factors

The default value of emission factors (EFs) for biological treatment of solid waste, waste water treatment, and MSW open burning/incineration have been considered from IPCC (1996/2006) as presented in BTR1 Annex X.XI.

2.15.5 Trend of GHG emissions by categories

The emissions from the waste sector between 1994 and 2022 show an upward trend. In the year 1994, the highest emissions were from wastewater treatment, followed by emissions from solid waste disposal, then emissions from open burning and biological treatment. The growing amount of solid waste being disposed of in Nepal is the cause of the rise in emissions from solid waste. According to Nepal's new constitution, 252 municipalities were added after 2015.

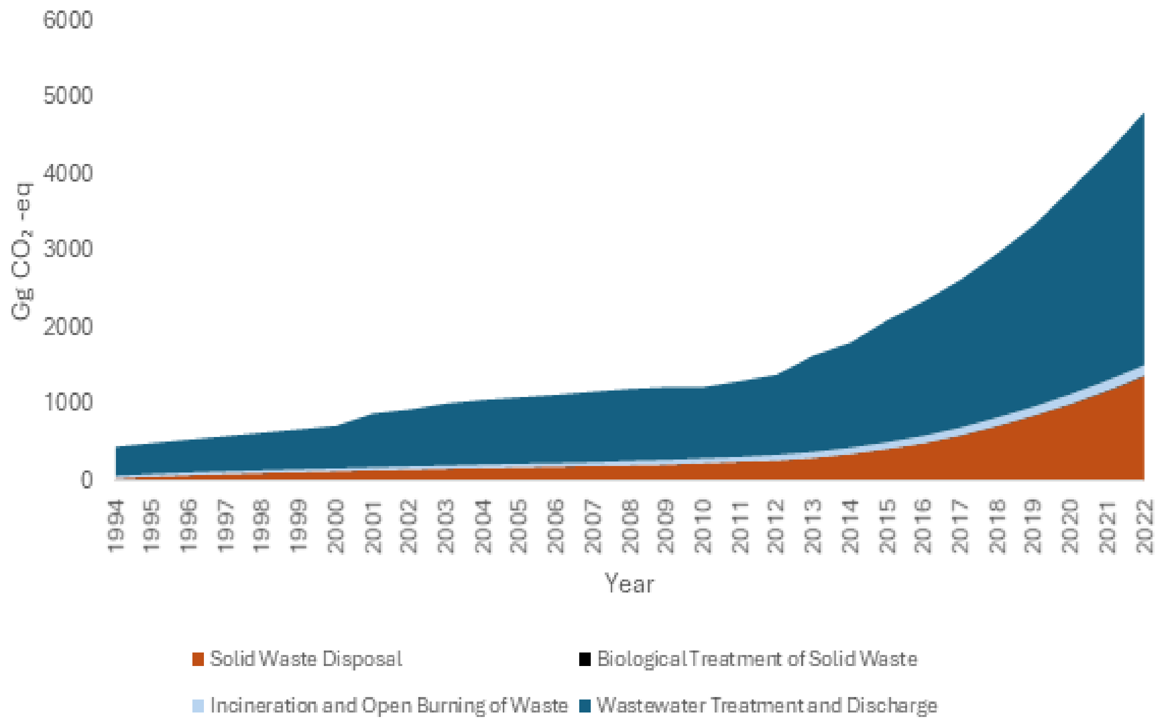

Figure 43: GHG emission trend by categories of waste sector from 1994-2022

2.15.6 Recalculation of emissions 1994-2011 for the waste sector

This study considers solid waste disposal based on waste collection efficiency, while INC and SNC have not reported the sources. Though TNC assumes waste collection efficiency similar to this study; however, the values are different. The choices of methods of this study (IPCC, 2006) using advanced software (version 2.93) with more variables compared to IPCC (1996) also have a profound impact on the findings. Likewise, INC and SNC have not accounted for open burning and biological treatment of waste, hence the values are not compared with recalculated values, while it is compared with TNC. Also, the open burning of waste for the year 2011 for TNC is just assumed (i.e., 10%), while the recalculated value is based on the activity data collected from various literature and estimations. Also, waste incineration is not covered in any communication reports. This is the reason for the significant difference between the recalculated value and TNC. The data before 1994 on wastewater treatment plants are not available officially. Therefore, we have excluded them in the recalculations, which could have caused a significant difference. The recalculation of emissions from the waste sector is presented in Figure 43.

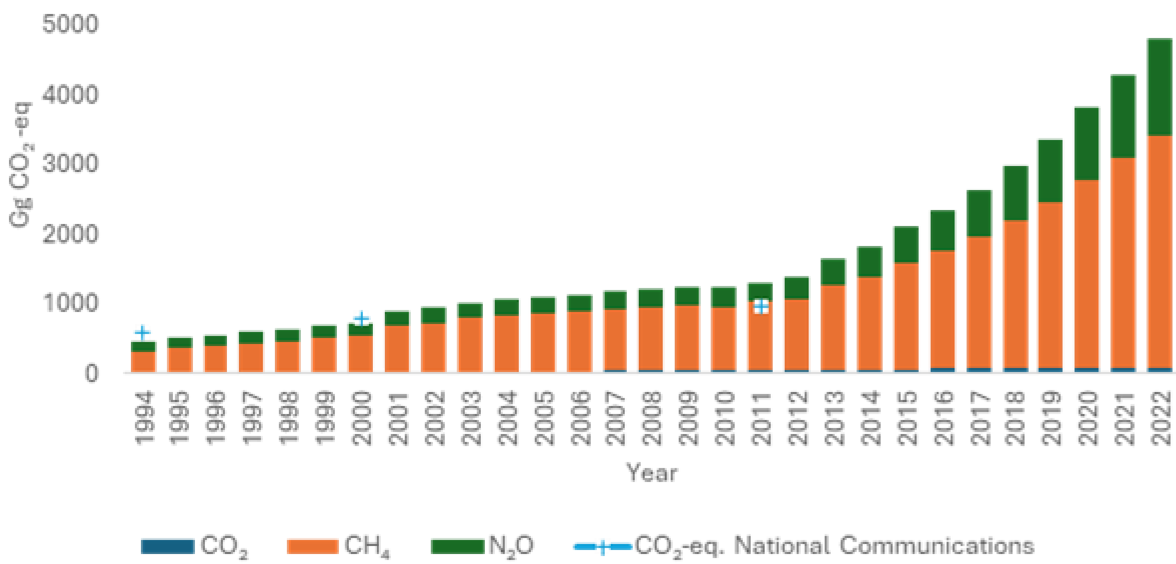

Figure 44: GHG emissions from the waste sector during 1994-2011

Table 37: Recalculation of INC GHG emissions in 1994

Categories			Emissions [Gg]				
	Revised CO_2	INC CO_2	Revised CH_4	INC CH_4	Revised N_2O	INC N_2O	Remarks
4.A - Solid Waste Disposal			1.10	9.33	0.0		This study considers Sisdole landfill site, which operated from 2005.
4.B - Biological Treatment of Solid Waste			0.03	N/A	0.001	N/A	
4.C - Incineration and Open Burning of Waste	16.3	N/A	0.51	N/A	0.006	N/A	
4.D - Wastewater Treatment and Discharge			9.04	1.14	0.48	1.10	

Table 38: Recalculation of SNC GHG emissions in 2000

Categories			Emissions [Gg]				
	Revised CO_2	INC CO_2	Revised CH_4	INC CH_4	Revised N_2O	INC N_2O	Remarks
4.A - Solid Waste Disposal			4.48	12.16			
4.B - Biological Treatment of Solid Waste			0.04	N/A	0.002	N/A	
4.C - Incineration and Open Burning of Waste	19.01	N/A	0.60	N/A	0.008	N/A	
4.D - Wastewater Treatment and Discharge			13.12	4.58	0.70	1.19	

Table 39: Recalculation of TNC GHG emissions in 2011

Categories			Emissions [Gg]				
	Revised CO_2	INC CO_2	Revised CH_4	INC CH_4	Revised N_2O	INC N_2O	Remarks
4.A - Solid Waste Disposal			8.83	10.46			
4.B - Biological Treatment of Solid Waste			0.06	0.10	0.003	0.01	
4.C - Incineration and Open Burning of Waste	35.63	2.36	0.80	0.34	0.01	0.01	
4.D - Wastewater Treatment and Discharge			25.34	11.45	1.06	1.20	

2.15.7 GHG Emissions Inventory of 2012-2022 for the waste sector

The GHG emissions from 2012 to 2022 are shown in Figure 44. In recent years, significant rises in disposal sites have resulted in CH4 accounting for the majority of GHG emissions (91.7%), followed by CO2 (4.3%), and N2O (4%).

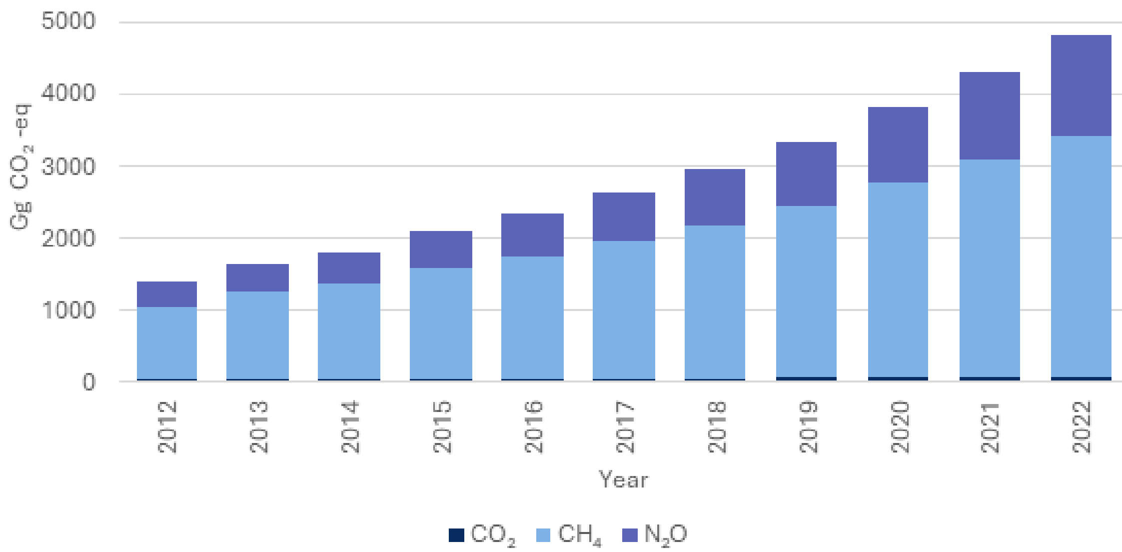

Figure 45: GHG emissions from the waste sector from 2012 – 2022

Table 40: Category and emissions from waste sector of Nepal

Categories	Net CO_2 emissions / removals			
	CO_2	CH_4	N_2O	Total
	Gg	Gg CO_2-eq	Gg CO_2-eq	Gg CO_2-eq
4 - Waste	**79.623**	**3340.697**	**1393.971**	**4814.291**
4.A - Solid Waste Disposal		1363.106		1363.106
4.A.1 - Managed Waste Disposal Sites		1.491		1.491
4.A.2 - Unmanaged Waste Disposal Sites		858.945		858.945
4.A.3 - Uncategorized Waste Disposal Sites		502.671		502.671
4.B - Biological Treatment of Solid Waste		8.964	4.878	13.843
Composting		8.964	4.878	13.842
Anaerobic digestion at biogas facilities				0
Other				0
4.C - Incineration and Open Burning of Waste	79.623	44.519	6.248	130.390

4.C.1 - Waste Incineration	0.566	0.002	0.015	0.583
4.C.2 - Open Burning of Waste	79.057	44.517	6.233	129.807
4.D - Wastewater Treatment and Discharge		1924.107	1382.845	3306.952
4.D.1 - Domestic Wastewater Treatment and Discharge		572.440	1382.844	1955.284
4.D.2 - Industrial Wastewater Treatment and Discharge		1351.667	0.001	1351.668
4.E - Other (please specify)	0	0	0	0

2.15.8 Uncertainty assessment and time series consistency

Table 41: Uncertainty in GHG Emissions of Waste Sector

2006 IPCC Categories	Gas	Base Year emissions or removals (Gg CO_2)	Year T emissions or removals (Gg CO_2)	Activity Data Uncertainty (%)	Emission Factor Uncertainty (%)	Combined Uncertainty (%)
4 - Waste						
4.A - Solid Waste Disposal	CH_4	262.96	1363.11	173.21	0.00	173.21
4.B - Biological Treatment of Solid Waste	CH_4	1.90	8.96	100.00	100.00	141.42
4.B - Biological Treatment of Solid Waste	N_2O	1.03	4.88	100.00	150.00	180.28
4.C - Incineration and Open Burning of Waste	CO_2	44.70	79.62	70.71	56.57	90.55
4.C - Incineration and Open Burning of Waste	CH_4	24.90	44.52	70.71	141.42	158.11
4.C - Incineration and Open Burning of Waste	N_2O	3.50	6.25	70.71	141.42	158.11
4.D - Wastewater Treatment and Discharge	CH_4	723.57	1924.11	147.65	60.00	159.37

4.D - Wastewater Treatment and Discharge	N_2O	324.48	1382.84	40.00	60.00	72.11
4.E - Other (please specify)	CO_2	0.00	0.00	0.00	0.00	0.00
4.E - Other (please specify)	CH_4	0.00	0.00	0.00	0.00	0.00
4.E - Other (please specify)	N_2O	0.00	0.00	0.00	0	0.00

2.15.9 Category-specific QA/QC and verifications

Tier 1 QA/QC procedures are implemented for the Category 4 Waste Sector. The QA/QC procedures followed the general principles and QA/QC plan guidelines. The verification process included the following for the waste sector, as recommended by the IPCC guidelines (IPCC, 2006).

1. Reviewing activity data for accuracy: Ensuring proper data entry and completeness.
2. Verifying emission factors: Ensuring they are up-to-date and relevant for the region.
3. Cross-checking data consistency: Ensuring calculations are consistent across time series.
4. Identifying and correcting discrepancies: Addressing gaps or inconsistencies in data and maintaining consistency in activity data and emission factors, applying necessary conversion factors when needed. Data and factors should align with similar system boundaries (IPCC, 2006).

Quality Assurance/Quality Control procedures are conducted as an element of good practice to improve the quality of national inventories at all stages of GHG inventory preparation. Quality control is followed by Tier 1 general procedures and is carried out by experts from the technical group responsible for GHG inventory preparation. Various ministries, agencies, organizations, and public-private companies, categorized by emission sources, contributed to the quality assessment of the national GHG inventory, even though they are not directly involved in its preparation. Quality control procedures were implemented at every stage of the GHG inventory preparation process. Any changes or corrections were recorded in the corresponding quality control table. The following quality control activities are performed:

- Checking received activity data for mechanical errors.
- Verifying the accuracy of entered data to identify mechanical errors.
- Validating calculations to address activity data gaps using mathematical methods.
- Ensuring proper entry of emission units, parameters, and conversion factors.
- Reviewing greenhouse gas emission calculations for accuracy.
- Confirming the consistency of input data and calculations across time series, particularly when methods, emission factors, or other parameters changed.
- Ensuring formulas and calculations were correctly entered in modified worksheets according to national conditions.

- Validating calculations is involved in the development of national factors.
- Reviewing emission source documentation, including assumptions, criteria for selecting calculation methods, activity data, emission factors, and other multipliers.
- Verifying all references related to data and factors.
- Conducting cross-checks of the data for consistency and accuracy (UNFCCC, 2024, Uzbekistan: National Inventory Report).

2.15.10 Category-specific planned improvements

Table 42: Challenges, Limitations, and Necessity for the Waste Sector

Category	Challenges/Limitations	Necessity
Updated Data and Data Availability	- Lack of consistent and historical data on waste generation, composition, and management. -There is no centralized database for systematic updates. -Insufficient data on wastewater treatment plants, including their emissions and operational efficiency.	Accurate and updated data is essential for estimating GHG emissions and tracking trends in waste management practices.
Research to Establish National Emission Factors	-Limited studies on waste-specific emission factors for Nepal. -Lack of validation for existing data.	National emission factors reflect local waste characteristics, improving accuracy in GHG inventories.
Subsector-Level Studies	-Detailed studies on emissions from specific waste streams (e.g., solid waste disposal, wastewater treatment) require resources and expertise.	Subsector-level studies provide a bottom-up approach, capturing variations in emissions and improving inventory accuracy.
Inter-Agency Collaboration	- Poor coordination among agencies managing waste data. - No standardized reporting framework or shared platform for data exchange.	Collaboration ensures consistent and high-quality data collection and sharing for GHG inventory preparation.
Capacity Building and Training	- Limited awareness of IPCC guidelines for waste sector reporting. Shortage of trained personnel ta collection and analysis.	Skilled professionals are essential for implementing standardized methodologies and enhancing the quality of GHG inventories.

Table 43: Recommendations and Agencies

Category	Actions	Agencies
Data Collection and Availability	-Create a centralized database to track wastegeneration and management. -Set clear reporting guidelines for municipalities and private waste handlers. -Ensure regular updates from all stakeholders.	MoFE, SWMTSC, Municipalities
Data Disaggregation Suitable for IPCC Guidelines	-Separate data by waste type (organic, plastic, etc.) and treatment method.	MoFE, SWMTSC, Municipalities
Research to Establish National Emission Factors	-Analyze the impact of treatment technologies on emissions. -Study waste composition and emissions under local conditions and update findings regularly.	NAST, Universities, SWMTSC
Subsector Studies	- Assign specific agencies to study emissions from solid waste, wastewater, and biogas. - Use findings to improve national GHG inventories.	MoFE, SWMTSC, Municipalities
Collaboration	- Share data through a unified platform. -Conduct joint research to reduce emissions.	MoFE, SWMTSC, Municipalities
Training and Capacity Building	-Provide training in international waste reporting guidelines. -Work with global experts for technical and financial support. -Train teams to implement and monitor waste technologies.	MoFE, SWMTSC, Donor Agencies

2.16 Scenario Analysis and projection till 2050

2.16.1 GHG emissions projection till 2050

This chapter gives the emission projection till the year 2050. For this purpose, a model with an accounting framework has been developed. The methodology follows a mixed model of trend and scenario-based analysis. While trend analysis primarily relies on historical data for activity and emissions, scenario analysis incorporates historical and current trends and the influence of external parameters that can govern activities. For example, economic and population growth rates are considered key drivers in the energy sector, influencing GHG emissions based on changes in these drivers. Additionally, forestry targets aimed at increasing forest areas affect FOLU emissions and removals, while strategies to introduce high-productivity cattle impact livestock emissions, and so on.

For emission projection, scenario analysis was conducted using LEAP (Low Emissions Analysis Platform) software, developed by the Stockholm Environment Institute. LEAP can integrate both energy and non- energy sectors within a single toolkit (Heaps, 2024). The framework for emission projection through scenario analysis using LEAP is illustrated in Figure 45.

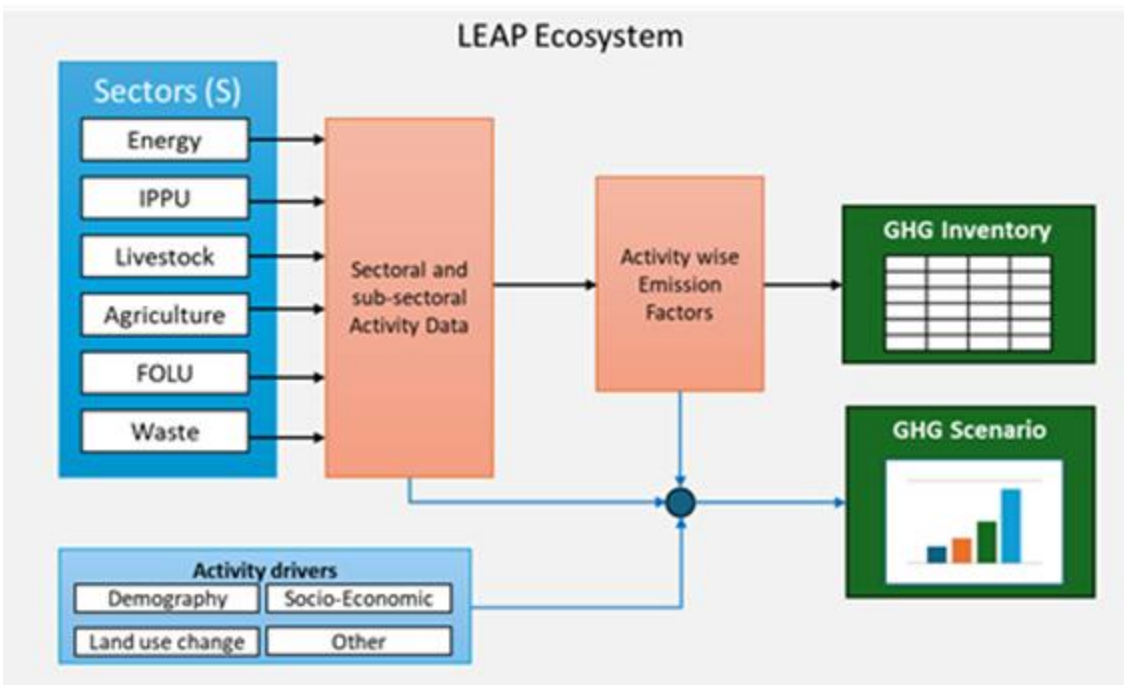

Figure 46: Overview of LEAP system for emission projection

2.16.2 Total GHG Emissions

The total GHG emissions, excluding LULUCF, are expected to grow at a rate of 3.3% starting from 2022, reaching 145,436 Gg CO2-eq by 2050. When LULUCF is included, emissions in 2050 are expected to be 125,454 Gg CO2-eq, mainly due to the high sequestration capacity of forest land. The emissions from the IPPU sector are growing the fastest, while emissions from livestock are growing the slowest. This suggests that industrialization is likely to have a greater impact on total emissions, while a shift away from agriculture may lead to lower emissions in that sector. However, it is important to analyze the social costs and benefits of each sector to ensure that the proper mitigation actions are taken without negatively affecting the country's economic output and well-being.

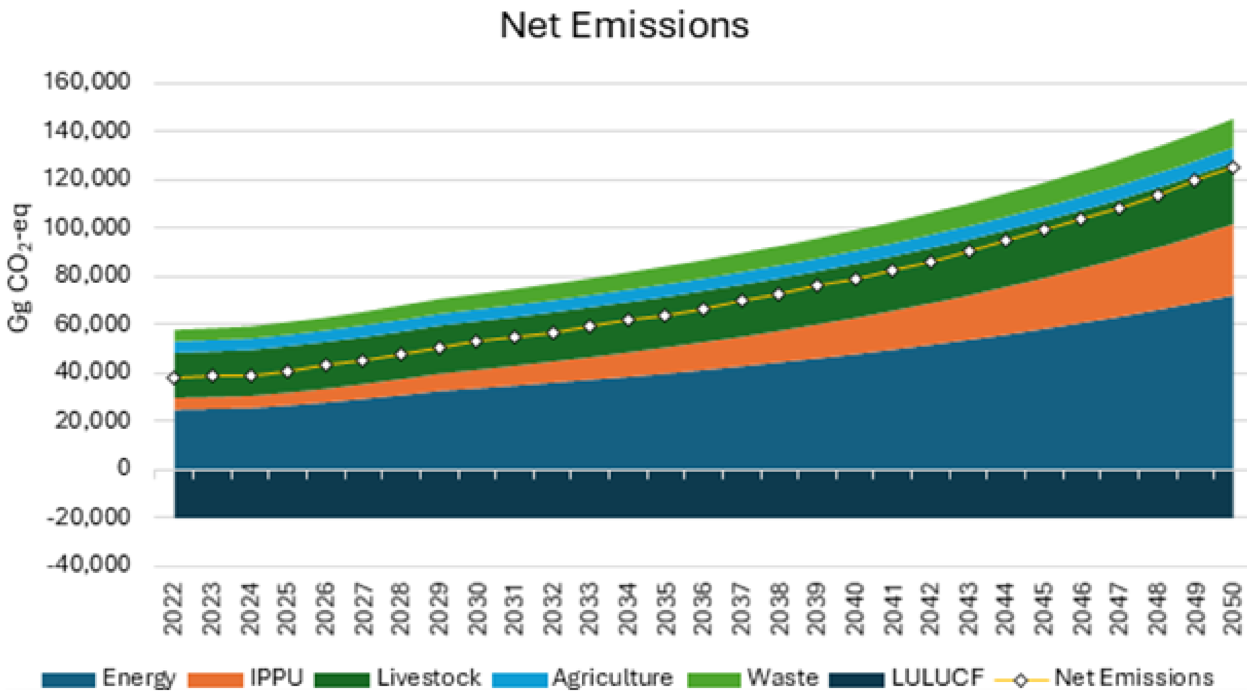

Figure 47: GHG emissions projection till 2050

Due to the different growth rates of each sector, the energy sector is expected to be the largest emitter by 2050, accounting for 50% of total national emissions (excluding LULUCF) (Figure 47). It will be followed by emissions from IPPU at 20% and from livestock at 18%. These results suggest that emission control strategies should prioritize the energy sector, as they can be more easily addressed through clean energy interventions. Emissions from other sectors are generally harder to reduce, but with the right strategies, they can either be reduced or managed through appropriate adaptation measures to minimize their impact.

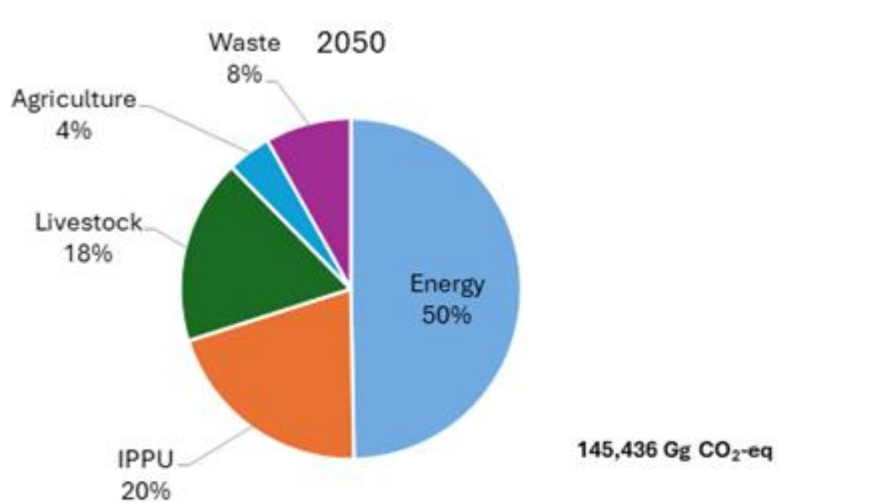

Figure 48 : Shares of sectoral emissions in 2050 (excluding LULUCF)

In terms of GHG types, while methane emissions remain constant, CO2 emissions are rising rapidly Figure 48. This indicates the cumulative impact of various factors, with the main factor being the change in emission sources. The slower growth in AFOLU activities, in contrast to the higher growth in fuel combustion, is the primary reason for this rise in CO2 emissions. As fuel combustion increases, it leads to a significant increase in CO2 emissions, while the relatively stable emissions from AFOLU activities, such as agriculture and land- use, contribute less to the overall increase.

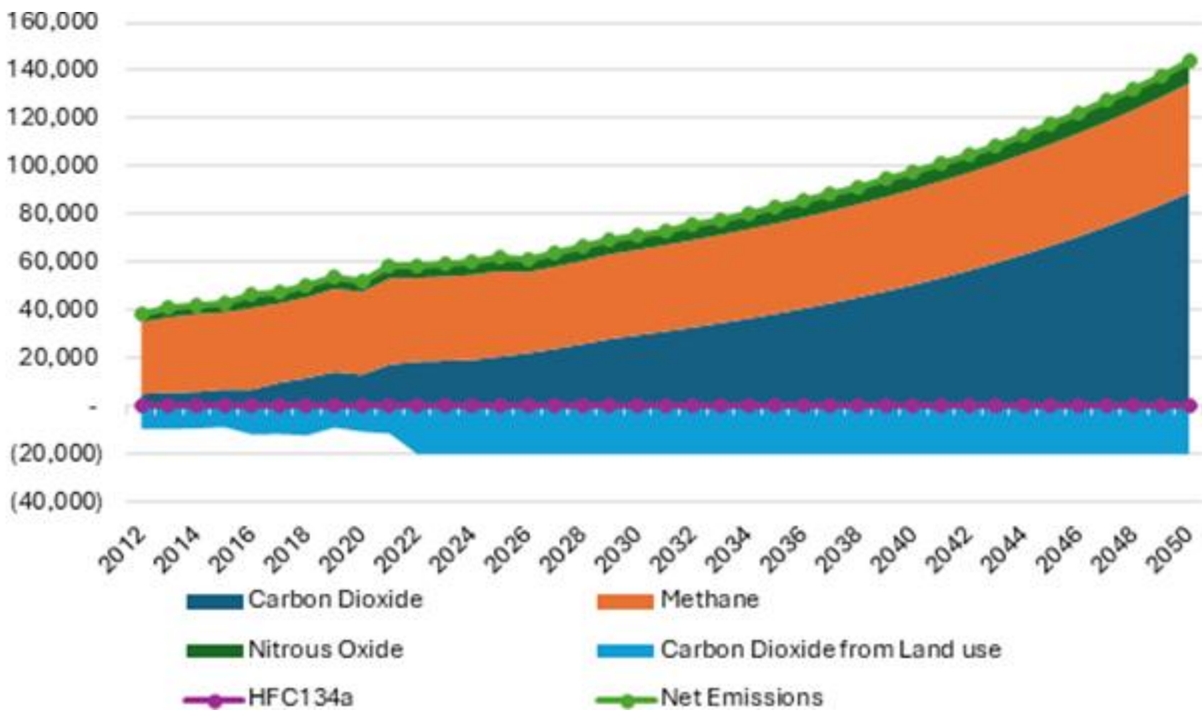

Figure 49: GHG emissions by gas type till 2050

2.16.3 Sectoral GHG emissions

2.16.3.1 Projection Energy Sector

In the energy sector, GHG emissions are predicted to rise by an average of 3.9% each year from 2022 to 2050 (Figure 49). The growth will be faster in the first five years, driven by higher economic activity between 2024 and 2029, which will increase energy consumption. The industrial sector will see the highest growth in emissions, at about 6.7%, followed by the commercial and service sectors. The industrial sector is expected to grow at higher levels with increasing development activities, mainly related to hydropower and road construction. The increased manufacturing activity also aids the commercial and service sectors, and hence their energy consumption and associated emissions. This suggests that efforts to reduce GHG emissions should focus on these sectors. In contrast, emissions from the residential sector will be lower, due to people moving to urban areas and using cleaner fuels. This emphasizes the need for clean fuel solutions in the industrial and commercial sectors. To reduce emissions, strategies like switching to mass transportation and electrification are suitable for Nepal. Over the past decade, emissions have increased rapidly, mainly due to growth in industrial and transportation activities. Therefore, mitigation efforts should concentrate on these sectors while ensuring that economic development is not hindered.

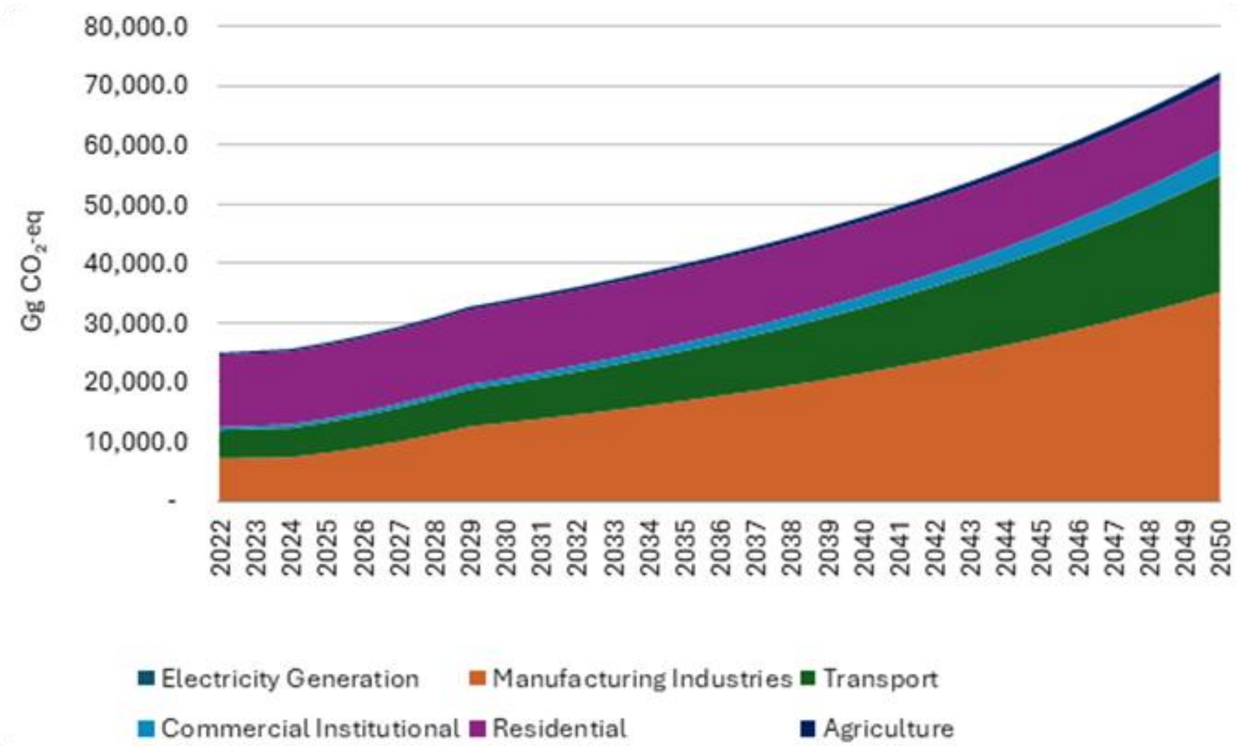

Figure 50: GHG emissions projection from the energy sector

2.16.3.2 IPPU Sector

Emissions from the IPPU sector grow significantly from 4811.59 Gg CO2-eq in 2022 to 29,603.80 Gg CO2-e in 2050. This sharp increase is driven primarily by the cement sector, which contributes over 99% of the emissions throughout the years. In 2022, cement emissions were 4792.239 Gg, and they are expected to rise steadily, reaching a substantial 29,574.02 Gg by 2050. This consistent growth reflects increasing industrial activity and demand for cement, likely driven by infrastructure and construction needs. Lubricant emissions, while much smaller, also show a gradual increase, starting at 1.90 Gg in 2022 and rising to 9.37 Gg by 2050. This growth suggests a steady expansion in industries reliant on lubricants, such as machinery and transportation. Similarly, paraffin emissions, the smallest contributor, grow from 0.75 Gg in 2022 to 3.71 Gg by 2050, indicating limited but consistent use in relevant applications. The upward trend across all activities highlights the importance of addressing emissions in this sector. Reducing emissions from cement production will be critical. Strategies could include using alternative materials, improving energy efficiency, and adopting carbon capture technologies.

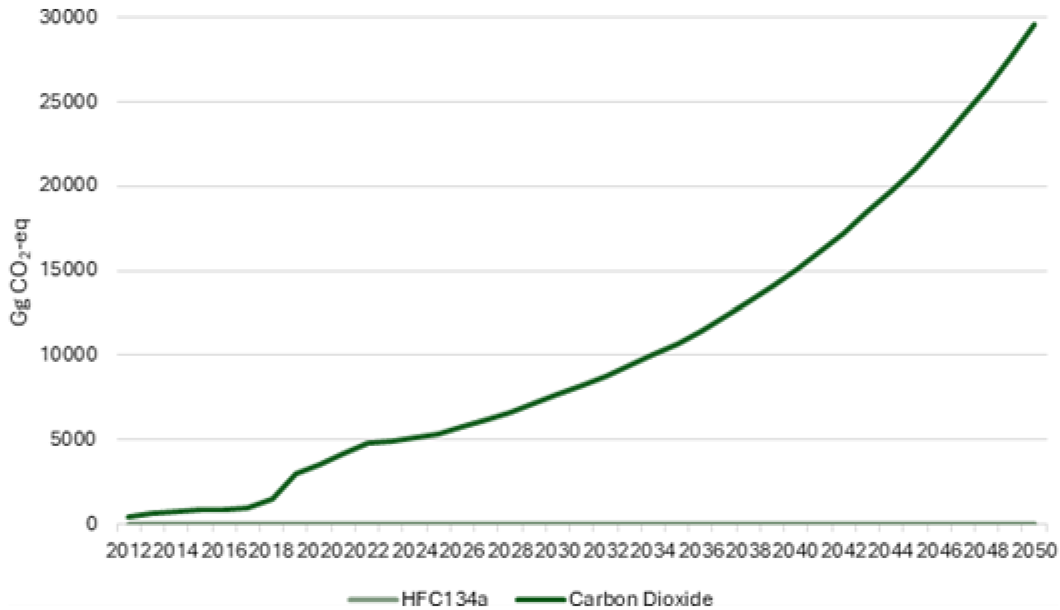

Figure 51: GHG emissions projection from IPPU sector

2.16.3.3 Agricultural and Livestock Agriculture

In the agriculture sector, the total GHG emission is expected to increase by around 1.06% every year from 2022 to 2050; the emission in 2050 will be 30% higher compared to the 2022 emission (4690.65 Gg CO2- eq). Methane emission from rice cultivation will rise at a rate of 0.072% per year, while the emission from direct N2O emission from organic manure, urine and dung deposition and synthetic fertilizer application is expected to rise at the rate of 1.86% each year until 2050. The right rate of emission (2.77% per year) is expected for indirect N2O emission from managed soils after 2022, while the indirect N2O emission from manure management will rise at a rate of 0.74% per year until 2050.

For an increased use of urea by 20% by 2050, the CO2 emission will rise at the rate of 0.58% with slightly higher growth rate in the starting years after 2022. For an increase by 20% in lime application compared to 2022, the CO2 emission from liming will increase from 0.78% over years till 2050. Figure 51 shows the category wise projection of emissions until 2050 in the agricultural sector.

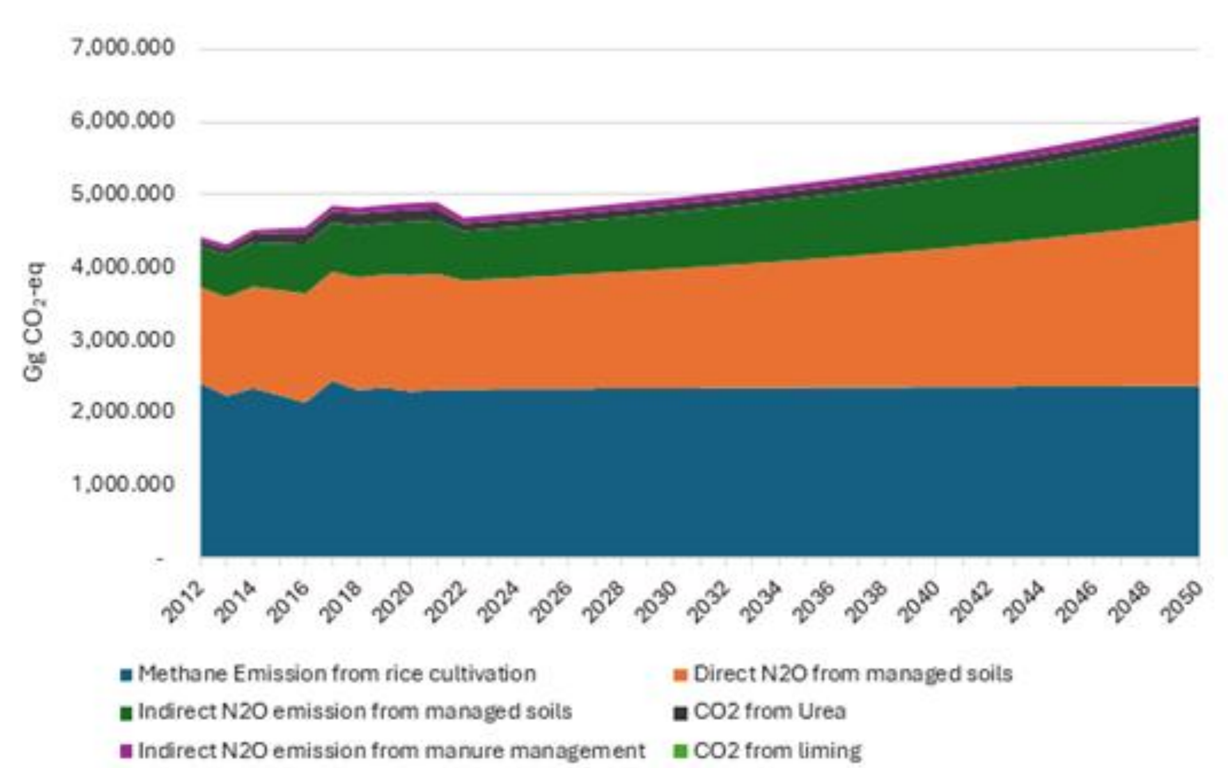

Figure 52: GHG emissions projection from agriculture

2.16.3.4 Livestock

The emission for the livestock sector tends to increase from 2022 to 2050, from 18723.50 Gg in 2022 CO_2 eq to 25,579.54 in 2050, which accounts for the rise of 36.62 % as presented in Figure 52. Methane emission is expected to increase from 18,199.97 Gg CO_2-eq in 2022 to 24,086.96 Gg CO_2-eq in 2050, which accounts for a 32.35% rise in methane emission in 2050. Similarly, the nitrous oxide also tends to increase from 523.53 Gg CO_2 -eq in 2022 to 1492.58 Gg CO_2-eq in 2050 which is 185.09% rise as presented in Figure 52.

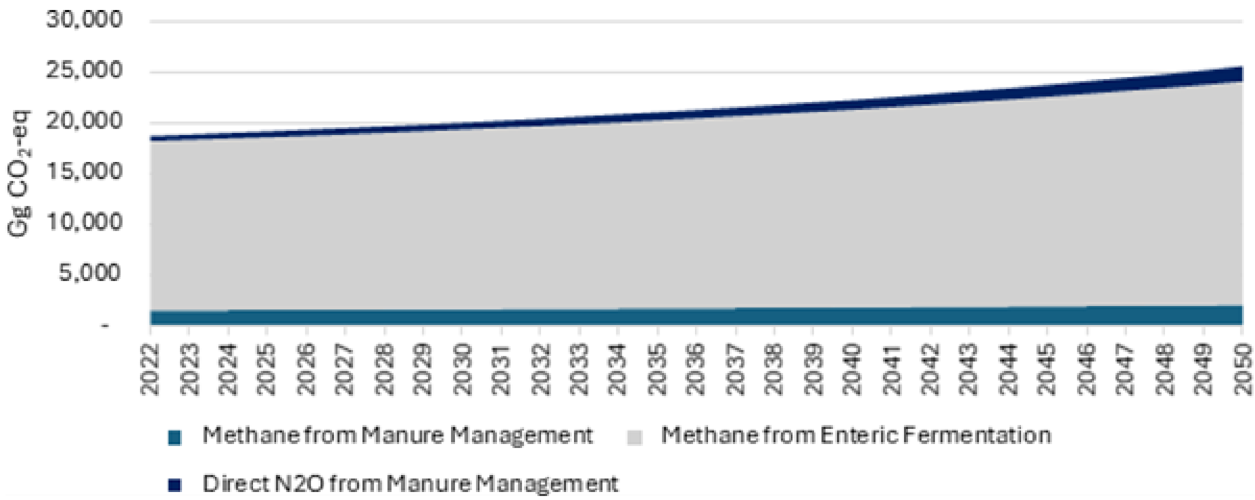

Figure 53: GHG emissions projection from livestock

2.16.3.5 LULUCF

The LULUCF emissions data from 2022 to 2050 shows consistent trends across categories, indicating that overall, the land use sector will remain a sink, due to the high area covered by forest. The total sink capacity will remain fairly constant at around 20,000 Gg CO2-eq. Cropland emissions remain stable at around 6.3–6.4 thousand Gg, while Grassland emissions are negligible. Settlements and Forest Land act as carbon sinks, with consistent sequestration of approximately 8,200 Gg and 1,800 Gg, respectively, throughout the period.

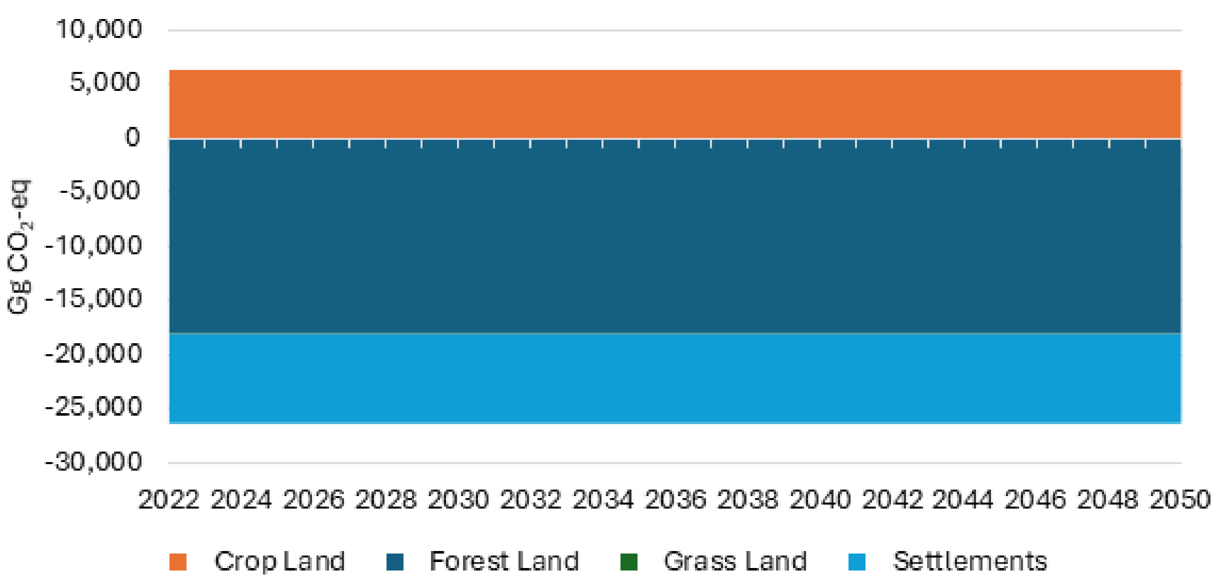

Figure 54: GHG emissions/removal projection from the land use sector

2.16.3.6 Waste

The waste sector's greenhouse gas (GHG) emissions are projected to rise significantly from 4,827.02 Gg CO_2-eq in 2022 to 11,859.60 Gg CO_2-eq in 2050, reflecting an average annual growth rate of approximately

3.3% per annum. Industrial wastewater treatment and discharge is the fastest-growing source, driven by expanding industrial activity. Domestic wastewater treatment and discharge grow steadily to 2,950 Gg CO_2-eq, at a moderate annual rate of around 1.5%, due to population growth and urbanization. Methane emissions from municipal solid waste in landfills increased to 2,047 Gg CO_2-eq, reflecting an annual growth of 1.5%, indicating continued reliance on landfilling. Emissions from incineration and open burning increase modestly to 165.9 Gg CO_2-eq, growing at 0.9% annually, while biological treatment of waste rises slightly to 20 Gg CO_2-eq, at an annual growth rate of 1.5%. These trends underscore the urgent need for effective waste management strategies, including methane capture, advanced treatment technologies, and waste minimization to curb emissions growth.

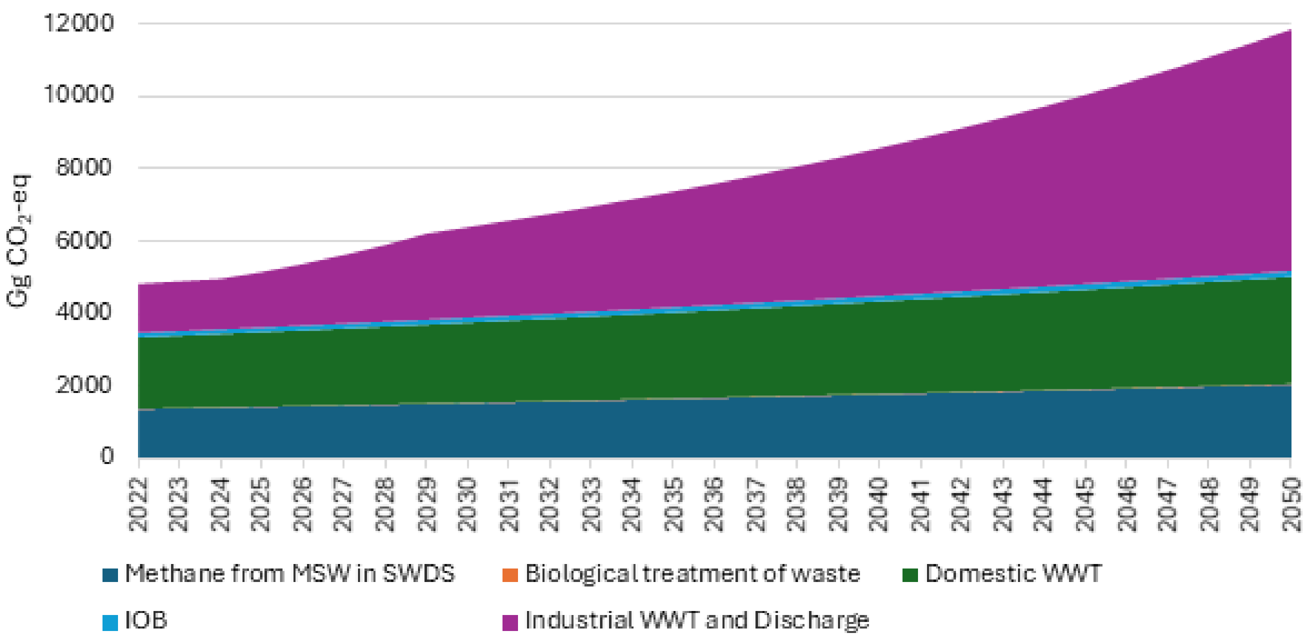

Figure 55: GHG emissions projection from the waste sector

2.17 Way forward – moving to higher tier

2.17.1 Way Forward for Next Tier Emission Inventory

In the current Greenhouse Gas (GHG) inventory study, the transition from Tier 1 to Tier 2 methodologies was not feasible for several logical and practical reasons:

- Data Gaps: A significant barrier was the lack of high-quality, granular, and specific data, such as detailed activity data, technologies, and localized emission factors. For several activities, the required detailed data was incomplete or inconsistent across the years. This lack of historical data made it impossible to consistently apply Tier 2 methodologies to estimate emissions accurately from 1994 onwards.
- Technical Complexity: Tier 2 methodologies are more complex and involve incorporating more specific emission factors, refined calculation methods, and a variety of additional parameters. Transitioning from the simpler Tier 1 methods to the more detailed Tier 2 approaches required significant adjustments to existing systems, which were technically challenging within the timeline of the current inventory. Furthermore, given the complexity of Tier 2 methodologies, there was potential for introducing uncertainties or errors in the results. Tier 1 methodologies, where the uncertainties are generally understood and more manageable, were thus advisable.
- Resource Constraints: Upgrading to Tier 2 requires considerable technical expertise and resources. The available human and financial resources were insufficient to support the extensive data collection, refinement, and methodology adaptation required for such a transition.
- Time Constraints: Since the inventory needed to cover emissions from 1994 onward, the time required to gather the data, apply Tier 2 methods, and ensure the accuracy of historical data would
- have significantly impacted the process. The need to meet the requirements made it impractical to complete the Tier 2 upgrade within the given timeframe.
- Nevertheless, it is now essential to move toward the higher-tier methodologies for given reasons:
- Enhanced Accuracy and Precision: Tier 2 offers more accurate and detailed emissions estimates by using specific local data. This leads to better-informed decision-making and climate change.
- Improved Transparency and Credibility: A Tier 2 inventory is more transparent and credible, as it relies on refined data and clear methodologies. This improves the inventory's acceptance in international reviews.
- Better Policy Design and Monitoring: With more precise emissions data, the country can implement targeted policies and track progress toward climate goals more effectively. It allows for a deeper understanding of sectoral contributions to emissions.

Given is the recommended conceptual framework for the steps for transitioning from Tier 1 to Tier 2:

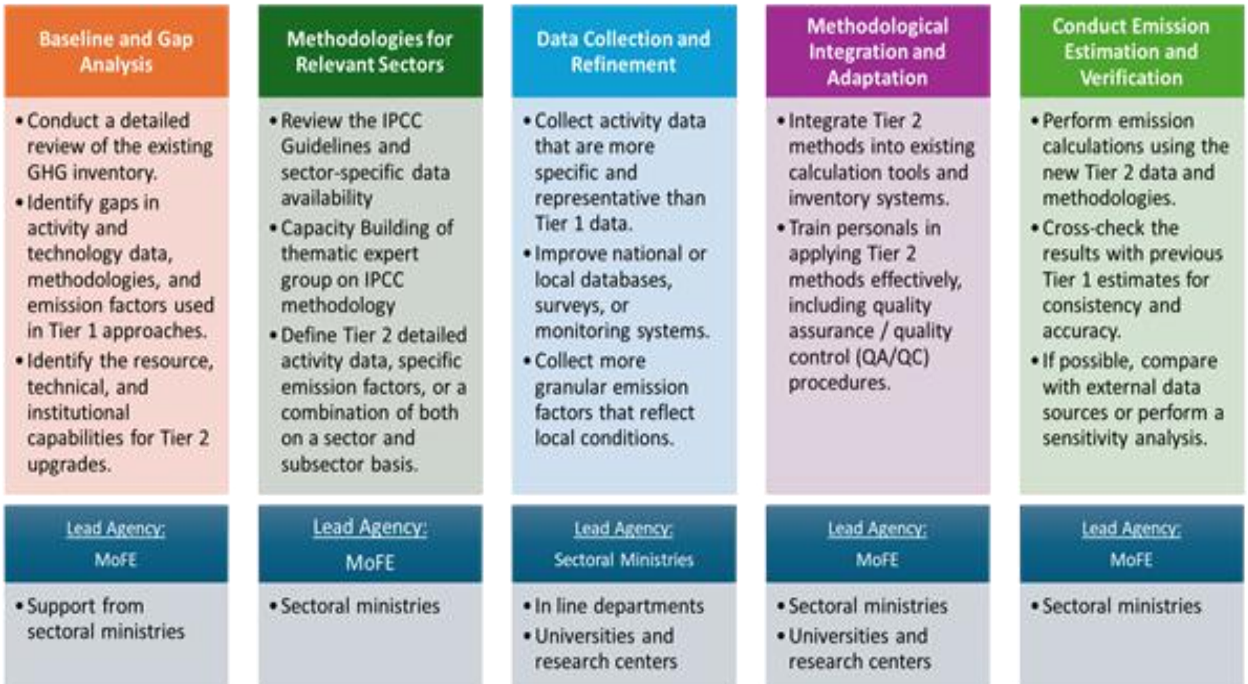

Figure 56: Conceptual framework for the steps for transitioning from Tier 1 to Tier 2

In order to effectively address climate change and meet national and international climate commitments, it is underlined that a comprehensive framework should be established, complemented by a robust Monitoring, Reporting, and Verification (MRV) system. This framework is expected to provide guidelines and standardized methodologies for sectoral agencies, responsible for key economic sectors such as energy, transportation, agriculture, and industry, to systematically collect, analyze, and report emissions data.

By equipping sectoral agencies with the necessary tools and processes, this approach will enable them to gather appropriate and high-quality data, conduct thorough analyses to identify emission trends and mitigation opportunities, and contribute to the accurate estimation of national emissions. Such a system will not only enhance the transparency and reliability of emissions data but also empower sectoral agencies to take ownership of their emissions management, ultimately supporting informed decision-making, effective policy implementation, and progress tracking toward national climate goals.

This integrated framework, combined with a rigorous MRV system, is essential for building a cohesive and actionable strategy to reduce greenhouse gas emissions and achieve sustainable development objectives. Since the end of 2024, Nepal has begun implementing the CBIT project, which aims to support capacity building and establish an operational MRV system. This system will play a crucial role in preparing subsequent GHG inventories and meeting Nepal's other reporting requirements.

3 Mitigation Actions and Outcomes

3.1 Introduction

Nepal envisions achieving socio-economic prosperity by building a climate-resilient society. It is formulating a long-term strategy with an aim to achieve net-zero greenhouse gas emission by 2050.This chapter provides a detailed and representative description of the mitigation measures on climate change. The data for this assessment were obtained from the National GHG Inventory 2011 and its projections to 2050. Based on the projections, mitigation options for different sectors, including energy, IPPU, AFOLU, and waste are proposed. The most promising mitigation options in each of the sectors are identified and multi-criteria analysis (MCA) carried out to ascertain the validity of the options. Then, a national action plan has been proposed.

For MCA, eight criteria were identified through literature review and expert consultations (Table 44). The experts were asked to rank and give the score for the four sectors (Figure 56). Based on criteria and the scores, mitigation options were analyzed through Analytical Hierarchy Process (AHP).

Table 44: Criteria for ranking the mitigation options

S.N.	Criteria
1	Availability (whether the technology is available)
2	Sustainability of the option
3	Emission reduction potential
4	Affordability (mitigation cost and financing requirement of the option)
5	Level of co-benefits.
6	Adoptability (technical difficulty and ease of implementation)
7	Acceptability (societal and cultural behavior)
8	Accessibility (including accessibility of the technology)

The figure shows that emission reduction potential and affordability are highly ranked, while acceptability is the least prioritized in most of the sectors. The availability of the technology for implementation received highest priority in Energy and AFOLU sectors. Similarly, emission reduction potential got the highest priority for IPPU. Other criteria received intermediate priorities.

It is essential to note that the availability of technology and other accessories is challenging for Nepal. Similarly, societal and cultural behavior greatly influences the choice of the options, influencing acceptability (IPCC, 2015). Even if acceptability is prioritized the least, it is the critical factor in implementing mitigation options.

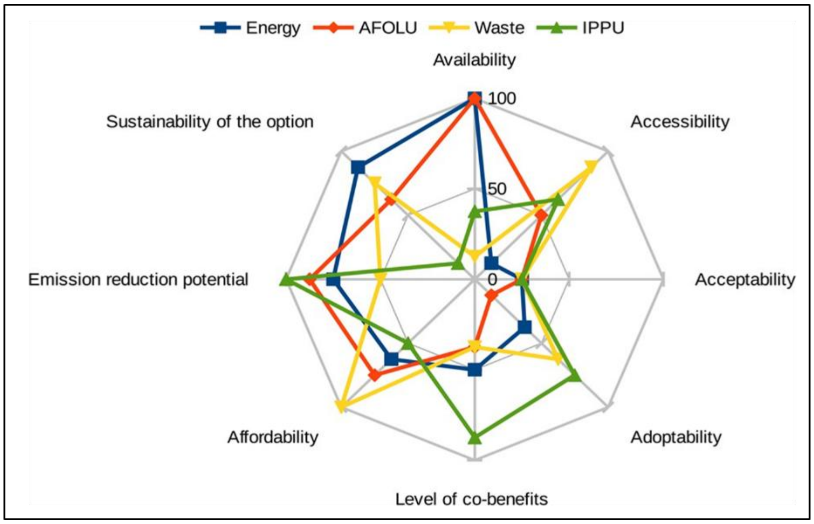

Figure 57: Ranking of criteria in four sectors

3.2 Sectoral Mitigation Policies

The following paragraphs present mitigation policies and efforts adopted in the four sectors – energy, AFOLU, IPPU and waste.

3.2.1 Energy Sector

While Nepal's energy consumption is growing, it is dominated by biomass (wood, agriculture residues and dung) use. Biomass accounts for 77% of the energy consumption; petroleum accounts for 11%; and coal 4%. While 78% of Nepal's population has access to electricity, its contribution to energy use is very limited. Major policies in the energy sector include those concerned with renewable energy; cleaner transport; and cleaner and efficient cooking (Table 45)

Table 45: Mitigation policies in energy sector

Policy	Description or Priorities
A. Renewable Energy	
National Climate Change Policy (2019)	• Prioritizes hydropower for low carbon energy. • Emphasizes diversification of energy sources.
Rural Energy Policy (2016)	• Provisions for subsidies and mobilize capital from financial institutions. • Recognizes solar home systems as the main electrification option for many rural households where grid and micro-hydro are not options.

Renewable Energy Subsidy Policy (2016-2030)	• Determines subsidy criteria. • Equally emphasizes credit (at least 30% for projects) and subsidy up to 80% for certain technologies.

Policy	Description or Priorities
National Renewable Energy Framework (2017)	• Allows non-governmental sectors to deliver renewable energy services. • Coordinates stakeholders, mobilizes finance and tracks results from RE initiatives
National Energy Strategy for Nepal (2013-2030)	• Aims to increase energy supply, energy efficiency and domestic clean energy development. • Develop hydropower for multiple purposes and as the lead energy source and build mini-grids in remote areas. • Promote renewable and energy efficient technology. • Explore solar and wind energy potentials. • Promote private investment in hydropower offering loans and subsidies
Nepal's Energy Sector Vision 2050	• Meet national energy demand relying less on petroleum • Prioritizes hydropower and other renewable energy.
White Paper: Current Status and future course of Energy, Hydropower and Irrigation Sector (2018)	• Establish a national carbon market for renewable energy. • Pursue solar and wind energy led irrigation and drinking water projects.
Nepal Electricity Regulatory Commission Bill	• Facilitate electricity production, transmission, distribution, trading and management in a transparent way.
16th National Plan (2024-2029)	• Promote clean energy by increasing investment in renewable energy, encouraging electric vehicles, electric stoves, and reducing reliance on imported fossil fuels like LPG. • Implement green financing mechanisms (e.g.,

	green bonds, concessional loans) and provide incentives for energy efficiency in residential and industrial sectors.
B. Cleaner Transport	
National Urban Development Strategy (2017)	• Reduce emissions by improving public transportation • Upgrade provincial road connections • Improve overall connectivity infrastructure and standards.
National Sustainable Transport Strategy (2015-2040)	• Promote the electrification of public transportation • Calls for electric vehicle options in priority tourist destinations.

Policy	Description or Priorities
Environment-Friendly Vehicle and Transport Policy (2014)	• manufacture environment friendly vehicles. • Promote private sector investment in construction and management of EV parking stations and service centers.
National Energy Strategy (2013)	• Promote new transport technology like fuel blending, electric and hybrid vehicles.
Bank Monetary Policy (2017)	• Provides greater loan-to-value ratio for personal electric vehicles (up to 80% versus 65% for fossil fuel vehicles).
National Environmental Policy (2019)	• Reduce air pollution.
15th National Plan (2019-2024)	• Promote electric vehicles.
C. Cleaner and More Efficient Cooking	
Biomass Strategy (2017)	• Replace LPG and kerosene with biomass in cooking. • Improve biomass technology such as ICS, briquettes, biogas plants • Make biodiesel and bioethanol price-competitive through tax exemptions, subsidies and credit facilities. • Preference to locally produced bio-products.

National Energy Strategy of Nepal (2013)	• Promote technologies that improve efficiency of biomass cookstoves. • Promote emerging biomass energy technologies like briquettes, gasifiers, cogeneration and liquid biofuels.
Nepal Environmental Policy (2019)	• Reduce air pollution.
15th National Plan (2019-2024)	• Increase the shares of renewable and alternative energy technology to reduce dependency on fuels such as LPG.

3.2.2 AFOLU Sector

AFOLU is the largest GHG emitting sector. Nepal has adopted a range of policies and measures for mitigation from the AFOLU sector (Table 46).

Table 46: Mitigation Policies in AFOLU sector.

Policy	Description or Priorities
A. Forestry and Other Land Use	
National Climate Change Policy 2019	• Increase forest carbon sequestration through sustainable forest management. • Mobilize global financial resources through REDD+, Clean Development Mechanism, Green Climate Fund, Global Environment Facility etc.
16th National Plan (2024-2029)	• Focus on sustainable forest management by controlling deforestation, forest fires, and illegal activities, while increasing forest carbon stocks and productivity through community and private sector engagement. • Promote ecosystem-based adaptation, conservation of biodiversity and wetlands, and use of degraded/public lands for agroforestry, linking forest resources with carbon sequestration and green enterprise development.
National Environmental Policy (2019)	• Tree planting along roads and open spaces.
Forest Policy 2018	• Achieve prosperity through sustainable management of forests, biodiversity and watershed. • Increase carbon stocks for climate change mitigation and generating funds through REDD+.

Agroforestry Policy 2076 BS	• Increase productivity on non-timber forest products under agroforestry and facilitate harvest, transport and sale. • Achieve agricultural commercialization and reduce pressures on forests and biodiversity, maintaining soil quality and protecting the climate.
Land Use Policy 2069 BS	• Maintain forest cover and protected areas, rehabilitate degraded forests and land, and promote green and open urban spaces. • Allocate grazing lands in mountainous areas. • Requires that forest land conversion will need permission from relevant departments.
Rangeland Policy 2068 BS	• Reduce pressures in rangelands from grazing. • Manage rangelands for climate change mitigation, biodiversity conservation and food security.
Forest Sector Strategy	• Seeks to achieve prosperity through sustainable management of forests, biodiversity and watershed. • Recognizes climate change mitigation and resilience as one of the eight pillars of the strategy.
National REDD+ Strategy 2018	• Reduce emissions and enhance carbon stocks by preserving existing forests, rehabilitating degraded ones, increasing reforestation and afforestation efforts, controlling forest fires and sustainably managing forest. • Promote indigenous species; forest-dependent stakeholder engagement; integrated forest, biodiversity and watershed conservation; ecosystem-based adaptation; and participatory ecotourism. • Enhance institutions, policies, management regimes and stakeholder capacity, capability and inclusivity.

Policy	**Description or Priorities**
Nature Conservation National Strategic Framework for Sustainable Development (2015-2030)	• Integrate nature conservation in sectoral development and planning.
B. Agriculture	
National Climate Change Policy 2076	• Promote low carbon and energy efficient technologies in agriculture and animal husbandry.

16th National Plan (2024-2029)	• Promote climate-smart agriculture by encouraging the use of indigenous crops, organic fertilizers, and environmentally friendly pest management to enhance resilience and reduce emissions. • Implement targeted programs for marginalized and vulnerable farming communities, focusing on green enterprises like herbal cultivation and riverbank farming to support adaptation and livelihoods.
National Environmental Policy (2019)	• Expand climate smart agriculture and technology interventions in rural areas.
Agricultural Policy 2061	• Increase food security and rural development. • Preserve environment, natural resources and biodiversity. • Prioritize the development of commercialized agriculture.
Agricultural Mechanization Promotion Policy, 2071	• Increase investment in modern infrastructure and machinery. • Adopt environmentally friendly agriculture machinery.
Irrigation Policy 2070	• Develop reliable, sustainable and environmentally friendly irrigation systems. • Mainstream climate change adaptation and mitigation in irrigation strategies and programs.
Fertilizer Policy 2058	• Meet the demands for chemical fertilizer in agriculture. • Develop integrated nutrient management system.
Agriculture Development Strategy (2015-2035)	• Reduce food insecurity, rural poverty and strengthen the economy.
Nepal's Energy Sector Vision (2050)	• Achieve electrification of water pumping technology. • Achieve electrification of farm machinery.

3.2.3 IPPU Sector

IPPU sector emits the lowest GHG amongst the four sectors. Table 47 presents policies and measures for climate change mitigation in the IPPU sector.

Table 47: Policies and mitigation measures in IPPU sector

Policy	Description or Priorities
National Climate Change Policy 2076	• Adopt sustainable and low carbon industrial technology. • Develop and adopt mitigation standards after identifying key drivers of industrial sector emission.

16th National Plan (2024-2029)	• Enforce emission standards in all industrial sectors and promote clean, energy-efficient, and low-carbon industrial technologies. • Encourage the use of environment-friendly construction materials, reduce reliance on imported building materials, and promote industrial compliance with environmental regulations. •
Industrial Policy 2011 AD	• Increase industrial output in a sustainable manner.
Nepal's Energy Sector Vision 2050 AD	• Electrification of commercial sector
Nature Conservation Framework for Sustainable Development	• Integrate nature conservation in sectoral development planning and implementation. • Link nature conservation with industrial development and promote green industries.

3.2.4 Waste Sector

Nepal has adopted a range of policies and measures to mitigate GHG emissions from waste sector (Table 48).

Table 48: Policies and Mitigation Measures in Waste Sector

Policy/Law	Description or Priorities
Solid Waste Management Act (2011)	• Holds waste producers responsible for managing harmful waste. • Empowers local governments to lease land for landfills and to charge fee for waste management. • Allows the private sector in waste management through a transparent bid process.
Climate Change Policy (2019)	• Encourages source segregation of waste and management of harmful and hazardous waste. • Promotes the use of biodegradable waste for energy production.
National Environmental Policy (2019)	• Promote energy production from waste
16th National Plan (2024- 2029)	• Strengthen waste management through public-private partnerships, promote recycling, reduce landfill use, and prohibit dumping in water bodies or open burning. • Implement extended producer responsibility, impose landfill and plastic taxes, and promote the use of organic fertilizers to reduce chemical inputs and emissions.

3.3 Sectoral Mitigation Options and plan

3.3.1 Energy Sector mitigation option

The multi-criteria analysis (MCA)result on mitigation options in energy sector is shown in Table 49. It shows that solar PV systems got the highest rank in energy production followed by roof- top PV systems, solar thermal systems, biogas plants, and wind farming. These options have easy-to-use technologies and received the high priorities. But primary biodiesels, ethanol biodiesel and biodiesel got the low priority.

For energy efficiency, the use of induction lighting and cooking, energy efficient brick kilns, LED lighting got higher priority. Lower priority on improved cookstoves (ICS) can be attributed to rapid urbanization, as urban households use less of ICS. Nevertheless, the use of ICS in rural areas has great potential to mitigate GHG emissions.

In residential sector, electric cooking, advanced lighting systems that include day-lighting and daylight harvesting options got higher priorities. They can ease livelihood of the people and help mitigate GHG emissions. Similarly, in transportation sector, clean energy-based railways, ropeways and cable cars are prioritized over FCV/FCEV and series-hybrid vehicles. However, feasibility studies are need prior to using these options in large scale.

Policy-based climate change mitigation options were also identified for the energy sector. Emission control measures in vehicles got the highest rank followed by energy-saving policies, industrial plant efficiency, mass-transit transport, and eco-driving. For this, users should be encouraged to switch the transport options through tax or other incentive measures. Similarly, cycling is the cleanest means of transportation and reduces the GHG emission. Nepal needs to adopt cycle city policy. For this, Nepal should develop cycle lanes in both old and new roads. It must be further emphasized that the implementation and enforcement of policies related to the control of vehicular emission need greater attention.

Table 49: Mitigation Options on Energy Sector

Rank	Energy Production	Energy Efficiency	Residential	Transportation	Policy-based Options in Energy Sector
1	Solar PV Systems	Induction lighting and cooking	Electric cooking	Electric railways	Introducing emission control measures in vehicles
2	Roof-top PV systems	Energy-efficient	Advanced lighting systems	Electric ropeways and cable	Formulating and implementing energy-saving
		brick kilns	that include day-lighting and daylight harvesting	cars	policies
3	Solar Thermal systems	LED lighting	Building insulation materials	Plug-in hybrid electric vehicle (PHEV)	Increasing industrial plant efficiency
4	Biogas plants	Energy-efficient boilers	Passive house standard	Power-split or series-parallel hybrid vehicles	Developing mass-transit transport systems
5	Wind farming	Energy-efficient furnaces	Advances in digital building automation and control systems	Fuel cell vehicle (FCV) or fuel cell electric vehicle (FCEV)	Promoting eco-driving that consists of vehicle operation that minimizes energy consumption
6	Community biogas plants	Improved Water Mills (IWM)	Electric heating	Series-hybrid vehicles	Promoting cogeneration in industries (both heat (steam) and power)
7	Biomass briquettes	Metal-type (ICS)			Better traffic management, intelligent transport systems, and improved road maintenance
8	Small, Micro and	Mud-type (ICS)			Net metering, smart meters and grids as a means of
	Pico hydropower plants				reducing peak demand and accommodating intermittent renewable electricity sources
9	Primary biofuels				Promoting waste-to-energy technologies

10	Ethanol biofuel				Energy auditing to reduce the amount of energy input into the system (building, process, etc.) without negatively affecting the outputs
11	Biodiesel				Promoting and regulating vehicle maintenance

3.3.2 Energy Sector Mitigation Plan

Mitigation action plan for energy sector is presented in Table 50. Renewable and alternative sources have to be promoted in the sector. With good sunshine hours, the installation of solar PV systems, rooftop PV systems and solar thermal systems can be a good option for Nepal. Similarly, biogas production needs to be promoted as energy sources in rural households. Wind energy could also be one of good sources of energy production.

To achieve energy efficiency, induction lighting and cooking have to be promoted. Emissions from brick kilns are significant and hence energy efficient brick kilns, including zigzag brick firing, need to be installed. Energy efficient broilers and furnaces in the industries and powerhouses also help reducing emissions. The promotion of LED bulbs on subsidy basis could enhance the efficiency in lighting. This is consistent with the campaign of 'Bright Nepal, Prosperous Nepal' adopted by the government from FY 2014/15. The installation of solar and micro-hydro for electric cooking, and advanced systems (day-lighting and day-light harvesting) are being promoted in rural households, while in urban areas, hydro energy sources are being promoted.

For transportation sector, the switch to mass transit and promotion of electric railways, ropeways and cable cars are a part of immediate actions. The government has provisioned subsides for the purchase of battery used in electric vehicles. The government has already banned vehicles with age above 20 years and is going to Euro 4 standards. These policies reduce GHGs emissions. Moreover, switch to energy-efficient and new/clean energy vehicles through incentives is an immediate action.

For industrial sector, replacement of fossil fuels by hydro-electricity and other clean energy sources is required. Relocation of enterprises to industrial-business zones and business parks is also required as a long-term action. Promotion of green enterprise and energy efficiency in manufacturing enterprises may also be required.

Table 50: Mitigation action plan for energy sector

Mitigation Option	**Action**	**Timeline**	**Responsibility**
Solar PV Systems	Policies and financial support for solar tech promotion and installation	Short to long term	Provincial government
Rooftop PV Systems	Research, policies, and financial support for promotion	Long term	Local government
Solar Thermal Systems	Support for solar thermal energy and heat pumps in residential buildings	Immediate to short term	Central government

Biogas Plants	Financial support for promotion and installation	Immediate	Local government
Wind Farming	Research, policies, and financial support for wind energy	Short to long term	Local and provincial government
Community Biogas Plants	Community empowerment	Long term	Local government
Biomass Briquettes	Feasibility studies for bio-briquetting	Immediate	Provincial government
Small/Micro/Pico Hydropower	Promotion of small hydropower at community level	Immediate	Local government
Primary Biofuels	Promotion and efficiency tests	Short to long term	Central government
Ethanol Biofuel	Technology intervention	Long term	Central government
Biodiesel	Research and policy support	Short to long term	Central government
Induction Lighting and Cooking	Subsidies and reliable electricity supply	Immediate	All governments
Energy-Efficient Brick Kilns	Scale-up of technology adoption	Immediate	Local government
LED Lighting	Awareness and cost-efficiency programs	Immediate to short term	Central government
Energy-Efficient Boilers	Policy formulation and access to technology	Long term	Provincial government
Energy-Efficient Furnaces	Policy formulation and access to technology	Short to long term	Provincial government
Improved Water Mills (IWM)	Subsidy-based deployment in rural settings	Immediate	Local government
Metal-type Improved Cooking Stoves (ICS)	Training and capacity building for firewood-dependent areas	Immediate to short term	Local government

Mud-type Improved Cooking Stoves (ICS)	Training and capacity building	Short to long term	Central government
Electric Cooking	Promote energy-efficient housing construction	Long term	Central government
Daylighting and Insulation Systems	Apply energy-efficient building regulations and insulation	Short to long term	Central government
Passive House Standard	Promote renovation of residential buildings	Long term	Central government
Digital Building Control Systems	Advance building automation systems	Long term	Central government
Electric Heating	Subsidies and reliable electricity supply	Short term	Provincial government
Electric Railways	Introduce EVs and reshape public transport system	Long term	Central government
Electric Ropeways and Cable Cars	Private sector-friendly policies and investment	Short to long term	Provincial government
Plug-in Hybrid Electric Vehicles (PHEVs)	Incentives for energy-efficient and alternative fuel vehicles	Short to long term	Central government
Vehicle Emission Control	Energy-saving policies and maintenance enforcement	Immediate to short term	All governments
Industrial Plant Efficiency	Promote cogeneration and energy audits	Immediate to long term	All governments
Transport System Efficiency	Mass transit, traffic management, eco-driving	Short to long term	All governments
Smart Grids and Net Metering	Manage peak demand and integrate renewables	Short to long term	Central government
Waste-to-Energy Technologies	Promotion and implementation	Short to long term	Central government
Market-Based Instruments	GHG/energy taxes, cap-and-trade, and renewable subsidies	Short to long term	Central government

Regulatory Measures	Implement performance and emission standards	Immediate to short term	All governments

3.3.3 IPPU Sector Mitation options

Cleaner production, use of alternative raw materials and retrofitting of infrastructure received the highest priorities in IPPU sector, whereas improvement of energy efficiency, replacing high carbon fuels by low carbon fuels, and use of blended cements were prioritized in cement industry (Table 51).

Table 51: Ranking of mitigation options in IPPU, including cement industry

Rank	IPPU	Cement
1	Cleaner production	Improvement of the energy efficiency
2	Alternative raw materials	Replacing high carbon fuels by low carbon fuels
3	Retrofitting	Blended cement
4	Electricity for energy in industries	Shifting to a more energy efficient process
5	Resource/mass efficiency	Alternative bricks
6	Energy recovery from sludge and waste	Removal of CO_2 from flue gases
7		Application of alternative cements (e.g., Mineral polymers)
8		Applying lower clinker/cement ratio (increasing the ratio additives/cement): blended cements

3.3.4 IPPU Sector Mitigation Plan

The trend of IPPU sector is difficult to ascertain. The most dominant category in IPPU is cement production, which is the major source of GHG emissions due to energy consumption and its clinker making process. Table 52 presents the mitigation action plans for IPPU sector.

Table 52: Mitigation action plans for IPPU sector

Mitigation Options	Actions	Key Technologies	Timeline	Responsibility
Cleaner	Replacing fossil fuel-	Wind mill, Photo voltaic systems,	Long term	Central
production	based sources of energy by cleaner sources of energy like electricity (hydro, wind, solar etc.)	applying lower clinker/cement ratio (increasing the ratio additives/cement): blended cements, Research, development, and commercial demonstration of		Government and Provincial government

		new technologies and processes		
Alternative	Substituting fossil fuels	Application of alternative	Short to	Central
raw materials	(mixing ethanol in fuels, biodiesel)	cements (mineral polymers)	medi um term	Government and Provincial government
Retrofittin g	Blended cement		Immedia te	Local Government authorities
Electricity for	Adoption of energy	Energy efficient electric motors,	Short to	Provincial
energy in	efficient lightings	pumps, fans, compressors, and	medium	Government
industries		boilers and use of LED, CFL fluorescent lamps, Tax incentives for energy efficiency, fuel switching, Emission and efficiency standards	term	
Resource/ mass	Controlling the Cogeneratio n in	Shifting to a more energy efficient process [e.g., from (semi) wet to	Short to medi um	Industrialists
efficiency	industries (both heat (steam) and power, electricity leakages, Energy-saving policies, Metallic Cook Stove (MCS), Smoke hood, use	(semi) dry process], Replacement of high carbon fuels by low carbon fuels	term	
	of alternative bricks			
Energy	Removal of CO_2 from the		Immedia te	Local
recovery from sludge and waste	flue gases		to short term	Government authorities

Cleaner production includes changes in technology, processes, resources or practices to reduce waste, minimize environmental damage, use resources more efficiently and increase business profitability, ultimately increasing the efficiency of production processes. Some of its techniques include changes in technology, changes in input materials, changes in operating practices, changes in product design, changes in waste use, changes in maintenance, and changes in packaging.

Electricity for energy in industries. Hydroelectricity is the dominant source of energy in industries in spite of enough potential of other cleaner sources of energy like solar energy. Adoptions of energy efficient lightings in industries can also abate excessive consumption of electricity.

Resource/mass efficiency. There is a huge potential of energy conservation in residential cooking, industrial thermal application and commercial enterprises. It also supports foreign currency savings and energy security. Options include the replacement of diesel-powered electricity generation, cogeneration in industries (both heat and steam), control of electricity leakages, the use of metallic cook stoves, smoke hoods, use of alternative bricks, as well as tax incentives for energy efficient goods and the introduction of emission and efficiency standards.

3.3.5 Mitigation Options for AFOLU Sector

Table 53 identifies and ranks mitigation options for four categories in the AFOLU sector – agriculture, forestry, livestock and land-use. It shows, for example, that *agriculture conservation practices* got the highest priority. Research has shown that conservation agriculture has the potential to reduce the emissions (Sapkota et al., 2014; Aryal et al., 2015). *Adoption of climate-smart technologies* could also mitigate the GHG emissions. Therefore, the government should promote climate friendly agriculture technologies.

Table 53: Ranking of mitigation options for AFOLU sector

Rank	Agriculture	Forestry	Livestock	Land-use
1	Agriculture conservation practices	Reducing deforestation	Animal fertility	Grazing lands, plants and animal management
2	Adoption of climate-smart technologies	Afforestation	Enhancing animal productivity	Grazing land fire management
3	Organic farming	Community-based forestry	Rotational grazing	Promotion of protected areas
4	Crop water Management	Agroforestry	Manure management	Control of forest fire
5	Efficient and/or renewable energy in irrigation, food storage and processing	Alternative Energy, Improved Stoves, Private forestry	Stall feeding combined with biogas plant	

6	Development of adaptive varieties	Urban forestry
7	Vertical farming	Enhancing management of forest resources
8	Agroforestry	

Similarly, *reducing deforestation* and *afforestation* and reforestation are important mitigation options in forestry. Management of animal fertility and enhancement of animal productivity got the highest priorities in livestock sub-sector. Similarly, management of plants and animals in grazing lands and management of fire in grazing lands got the highest priority in land use sub-sector.

3.3.6 AFOLU Sector Mitigation Plan

Table 54 presents the action plans for AFOLU sector. This will be followed by a brief discussion of main options.

Table 54: Mitigation action Plan for AFOLU Sector

Mitigation Options	Actions	Timeline	Responsibility
Agriculture conservation practices	Mulching, crop residue management, crop rotation by legumes, cover cropping, intercropping, mixed cropping (leguminous species and mustard), crop intensification, farming with perennials	Immediate	Local Government authorities
	Minimize N loss from fields, stables and manure storage	Short to medium term	Local Government authorities
	Minimize field crop drying	Immediate and continuing	Local Government authorities
	Increase efficient nitrogen utilization	Short to medium term	Local Government authorities

	optimizing crop rotations		
	Use crop rotations with a low energy requirement (perennial, N fixing, durable or grazed crops)	Immediate	Local Government authorities
	Encourage capturing and reuse of rain water	Immediate	Local Government authorities
	Reduce pumped irrigation	Immediate	Local Government authorities
	Employ biodiesel and fuel-efficient farm equipment	Medium to Long Term	Local Government authorities
Adoption of climate smart technologies	Dissemination of knowledge and technology of solar based irrigation, drip irrigation, sprinkler irrigation and provision of incentives	Short to medium term	Ministry of Agricultural and Livestock Development
	Formation of a clear organic agriculture development policy	Long Term	Ministry of Agricultural and Livestock Development
	Implementation of organic standards and certification programs	Long Term	Ministry of Agricultural and Livestock Development
	Strengthening human resource capacity for organic farming	Long Term	Ministry of Agricultural and Livestock Development
	Promote Integrated Pest Management	Immediate	Ministry of Agricultural and

			Livestock Development
	Dissemination and awareness of System of Rice Intensification (SRI) with Alternate Wetting and Drying (AWD)	Immediate	Local Government authorities
Crop water Management	Give priority to maintenance actions and operation of installed drainage infrastructure, adoption of water efficient irrigation (e.g., ridge and furrow planting)	Short to medium term	Local Government authorities
Drainage management		Immediate and continuing	Local Government authorities
Use of efficient and/or renewable energy in irrigation, food storage and processing	Provide incentives for using energy efficient techniques in agriculture	Short Term	Local Government authorities
Development of adaptive varieties	Vitalize NARC and its field stations for research, knowledge management and training on climate change	Short to medium term	Local Government authorities
	Adoption of drought resistance and high yielding varieties	Short to medium term	Local Government authorities
	Enhance skill of researchers for conducting research on climate change	Immediate and continuing	Local Government authorities
Vertical farming	Protection of urban and peri-urban	Immediate and continuing	Local Government authorities

	agricultural zones for enhanced local food production		
Avoid biomass burning	Conversion of biomass to compost	Immediate	Local Government authorities
Tillage management	Reduced tillage/minimum tillage, zero tillage, no tillage	Immediate	Local Government authorities
Reducing deforestation	Adopt effective forest management techniques or processes	Medium to Long Term	Local Government authorities
Afforestation	Plantation in urban areas	Immediate and continuing	Local Government authorities
	Afforestation in denuded or degraded lands	Immediate and continuing	Local Government authorities
	Conduct forest restoration programs	Immediate and continuing	Local Government authorities
Community-based forestry	Promote collaborative, community and leasehold forestry	Short to medium term	Local Government authorities
Agroforestry	Productive trees plantation in and around crop fields and pastures	Immediate and continuing	Local Government authorities
Urban forestry	Use flood zones productively to mitigate flood risks	Short to medium term	Local Government authorities
	Integrate gardening and small-scale farming in planning by including green space to facilitate	Short to medium term	Local Government authorities

	urban agriculture and reduce food miles		
Grazing lands, plants and animal management	Give priority to the expansion and consolidation of the Program for the Conservation and Protection of Grazing lands	Long Term	Province level ministry
Grazing land-fire management	Give priority to the protection and consolidation of the Program for Conservation and Protection of Grazing lands	Long Term	Province level ministry
Promotion of protected area	Designate areas for new development in clusters adjacent to existing development; avoid policies that enable sprawl	Long Term	Province level ministry
	Give priority to the protection and consolidation of the Program for the Conservation and Protection of Green Space	Long Term	Province level ministry
Control of forest fire	Protection and consolidation of the Program for the Conservation and Protection of Grazing lands from Forest Fire	Immediate and continuing	Province level ministry
	Enhance human resources capacity for control of forest fire	Immediate and continuing	Province level ministry
Animal fertility	Choice of breed and mating strategies,	Long Term	Local Government authorities

	early puberty attainment and seasonality, enhanced fecundity, nutritional flushing, periparturient care and health, early weaning, reduction of stressors, assisted reproductive technologies		
Enhancing animal productivity	Improvements in animal genetics, improving animal health and mortality	Long Term	Province level ministry
Manure management	Diet manipulation, manure storage and separation, composting, manure application	Long Term	Local Government authorities
Stall feeding combined with biogas plant		Long Term	Local Government authorities

Agriculture

The agriculture sector of Nepal accounts for around three quarters of employment and one quarter of the country's gross domestic product (MoAD, 2015). In this sector, conservation practices should be modified, and farmers should adopt climate smart technologies like use rain water and use solar energy for pumping water for irrigation, practice organic farming and vertical farming, produce adaptive varieties, mix forestry with agriculture and minimize tillage.

Grazing lands in Nepal are prone to overgrazing and fire so they should be well managed. It is also necessary to increase in fertility and productivity of animals, manage manures, and mix stall-feeding with biogas plant should be practiced.

Agriculture conservation practices: Conservation practices in agriculture constitute the most important option to mitigate agricultural GHG emission. The government should promote mulching, crop residue management, crop rotation, cover cropping, inter-cropping, mixed cropping (leguminous species and mustard), crop intensification, farming with perennials, minimizing nitrogen loss from fields, stables and manure storage by covering the manure with an impermeable sheets, minimize field crop drying, Increase efficient nitrogen utilization-optimizing crop rotations, use crop rotations with a low energy requirement (perennial, N fixing, durable or grazed crops) are few ways that save large amount of CH_4 gas and carbon emissions.

Adoption of climate smart technologies: Climate smart technologies like solar based irrigation, drip irrigation, sprinkler irrigation, capturing and re-use of rain water, use of fossil fuel-efficient farm equipment should be adopted. These practices should also be made part of the 'Prime Minister Agriculture Modernization Project (PMAMP) seeks to develop agriculture as profitable by enhancing the competitiveness of agriculture commodities. Further promotion is also required for solar powered water pumps low-Cost Drip and Micro-Sprinkle Irrigation Technologies, rainwater harvesting. At the same time, knowledge and technology of climate smart technologies should be spread far and wide in the country.

Organic farming: Organic farming should be practiced as a complementary approach. Trainings should be provided to farmers and technicians alike. Clear policy, standards and certification programs for organic agriculture should be developed and implemented.

Crop water Management: Rice is the most important crop and is likely to emit larger amounts of CH_4 in the future. Dissemination and awareness of System of Rice Intensification (SRI) with Alternate Wetting and Drying (AWD), maintaining the installed drainage infrastructure, adoption of water efficient irrigation (e.g., ridge and furrow planting) should be practiced.

Use of efficient and/or renewable energy (such as solar/wind) in irrigation, food storage and processing): The amount of energy used in agriculture is huge since it is used in various forms in numbers of steps. So, efficient and /or renewable energy (derived from wind, water or solar energy) should be used for various agricultural processes. The government should also provide incentives for farmers who use energy efficient techniques.

Development of adaptive varieties (Drought resistance and high yielding varieties): Local varieties are treated as varieties with resistance with various stresses to heat, drought, insects and diseases. Comprehensive breeding strategy to produce seeds with such characteristics along with high yielding capacity will help to tackle the various environmental stresses. NARC and its field stations should be activated more, more researches should be conducted. Farmers should be trained about cropping such species. Farmers should also adopt stress tolerant and high yielding varieties. Skills of researchers should also be enhanced for producing more stress tolerant and high yielding varieties.

Vertical (Roof top) farming: Roof top farming is one of the ways in which urban population can make their resource consumption sustainable. It is possible to produce variety of fruit, grain and vegetable crops on rooftops. Three types of green roofs are: (i) Agricultural green roofs or direct-producing green roofs on which crops are directly grown in (shallow) beds in a soil-based growing medium that is possibly placed on top of a waterproof membrane or additional layers such as a root barrier, drainage layer and an irrigation system, (ii) Rooftop container gardens or modular green roofs that involve the growing of vegetables, herbs, fruits and flowers in pots, buckets, containers, bottles or raised beds which contain a soil-based growing medium, and (iii) Rooftop hydroponic systems which involve growing plants using water-based nutrient solutions in place of soil. These roofs along with urban and peri-urban agricultural zones can be good medium for enhanced local food production.

Agro-forestry: Agro-forestry is more profitable than forestry alone under some circumstances, and has added benefits for farmers and environment (Amatya, 1999). There is ample scope for introducing agro-forestry in Nepal's community forests as well.

Avoid biomass burning: Farmers burn biomass to reduce the labor costs of preparing their fields for the next crop, but in the process producing smoke, black carbon and GHGs (Pant, 2014). The conversion of biomass to compost should be practiced.

Tillage management: Tillage is a fundamental practice in agricultural management, aimed at creating suitable conditions for the germination of the seeds and the growth of the plant. The mechanical processes increase the porosity of the soil and improve soil structure, with general positive effects, among the others in terms of weed control, water conservation and soil nutrient mineralization, however tillage can possess negative effects like soil erosion, nutrients loss, fuel/energy consumption, and GHG emissions. In particular, tillage causes a loss of soil carbon and therefore CO_2 in the atmosphere (Adrian, 2017). Hence, tillage should be either prohibited or minimized to the extent possible.

Forest

The GoN has been promoting programs related to afforestation, community-based forestry, agro-forestry, private forestry and horticulture as well. A new REDD+ program in Nepal is poised to protect about 2.4 million hectares of forests between 2019-2024 with the approval of Nepal's Emissions Reduction Program Document (ERPD) without conditions at the 18th meeting of the FCPF Carbon Fund. The performance-based Emissions Reduction (ER) Program covers 13 contiguous districts of Nepal's Terai Arc Landscape (TAL) with the potential to recover up to US$45 million in lieu of 9 million tons of CO_2e sequestered over a six-year period ending 2024.

Reducing deforestation: Different Forest management approaches and expansion of forestry administration have not been fully successful in halting or reversing the deforestation trends in the country. Hence, effective forest management techniques or processes should be carried out; afforestation programs especially in denuded or degraded lands and forest restoration programs should be conducted.

Community-based forestry: Approximately 40% of the total forests come under community forestry. In addition to Community Forests, other community-based forestry like collaborative and leasehold forestry must be promoted to increase the green zones in the country. Private forestry, urban forestry, horticulture promotion programs should be introduced and managed effectively.

Land Use

Grazing lands, plants and animals and fire management: Rangelands are the basis for the livelihoods of local communities. Grazing lands are part and parcel of ecosystem; therefore, programs related to protection of grazing lands from encroachment, over-grazing, and fire should be conducted.

Promotion of protected area: Protected areas of the lowlands and highlands of Nepal comprise huge areas of grasslands, so they should be conserved. Also, local governments should avoid policies that enable sprawling development.

Livestock

Choice of breed and improvement in mating strategies, attention to early puberty attainment and seasonality, enhanced fecundity, nutritional flushing, enhanced peri-parturient care and health, early weaning, reduction of stressors, assisted reproductive technologies should help to reduce emission of GHGs from livestock.

Manure management: Diet manipulation, manure storage and separation, composting of animal waste and manure application in fields also help to cut off GHGs emission. In addition, the combination of stall feeding with biogas plant is also beneficial to reduce GHG emission.

3.3.7 Mitigation Options for Waste Sector

The mitigation options for waste sector of Nepal are identified and prioritized in Table 55. Open burning of waste is the major source of GHG emission in the country. Thus, the *reducing/controlling open burning of waste* received the highest priority, followed by *reducing landfilling*. On the other hand, use of advanced technologies, like incineration and industrial co-combustion and landfill gas recovery got the lowest priority. However, these options are also important in mitigating the GHG emissions in the sector (Bogner et al., 2008).

Table 55: Ranking of mitigation options for Waste Sector

S.N.	Mitigation Options
	Reduce/control open burning of waste
	Reduce land-filling
	Engineered and non-engineered wastewater management
	Post-consumer recycling
	Composting
	Anaerobic digestion
	Waste technologies (incineration and industrial co- combustion)
	Landfill gas recovery

3.3.8 Waste Sector Mitigation Plan

Open burning of solid waste, unscientific land filling, inefficient waste water treatment and inadequate post-consumer recycling and insufficient composting lead to emission of GHGs from Nepal's waste sector. To reduce emissions from waste, an action plan is prepared and presented in Table 56.

Table 56: Mitigation action plans for waste sector

Mitigation Options	Actions	Timeline	Responsibility
Reduce/control open burning of waste	Education focusing on disastrous effect of burning waste and high cost for government and individual to treat illness	Immediate	Local Government
	Waste to energy technologies including plasma arc technology, refuse derived fuels (RDF) and solid refuse fuel (SRF)	Short to long term	Provincial Authorities
	Expansion of recycling infrastructures and facilities; Single and dual stream recycling plants are recommended technologies	Long term	Local Government
	Composting of degradable waste that are burned	Immediate	Local Government
	Improved collection to reduce residential waste burning and improved dumpsites to reduce open burning at dumpsites; Scientific land filling technologies are recommended	Short to long term	Local Government
Engineered and non-engineered wastewater management	Construction of smaller wastewater treatment plants with reduced nutrient loads and proportionally lower GHG emissions; Improved engineering technologies are recommended	Medium to long term	Provincial Authorities
	Low-water-use toilets and ecological sanitation approaches (including ecological toilets) where nutrients are safely recycled into productive agriculture and environment	Short to long term	Local Government
	Recycling of bio solids; the organic byproduct of the treatment process for agricultural and forestry uses; Sludge recycling technologies are recommended	Long term	Provincial Authorities
	Providing opportunities to reuse highly-treated water from the plants; Engineered wastewater treatment plants are recommended technologies	Long term	Local Government
Post-consumer recycling	Legislative promotion and imposition, research on appropriate technologies for recycling	Immediate	Provincial Government

	Preparation of a complete recovery and recycling plan, assessment of markets for recyclables	Immediate to short term	Local Government
	Establishment of recycling plants for end-of-life tires and batteries; Heavy metal (e.g., Lead, Pb) recycling technologies are recommended	Short to long term	Provincial Authorities
Composting	Promotion of vermin-composting	Immediate	Local Government
Anaerobic digestion	Promotion of anaerobic digestion technologies that capture CH4 from manure which might otherwise be released into the atmosphere as a potent GHG	Short to long term	Local Government
Landfill gas recovery	Shifting from conventional to engineered landfill gas recovery system (Controlled landfill bioreactor, permeable layers to improve LFG recovery, use of subsurface gas probes, methods to overcome water-logging that can impede gas extraction); Engineered landfill gas recovery systems are recommended technologies	Long term	Provincial Authorities

3.4 Mitigation Targets and progress so far

Nepal's first Biennial Transparency Report (BTR), submitted in 2025, provides a comprehensive overview of the country's climate mitigation efforts and progress. The report outlines the national greenhouse gas (GHG) inventory, highlighting key sectors such as energy, forestry, agriculture, transport, and waste. It also identifies the challenges Nepal faces in implementing mitigation measures, including limited financial resources, technical capacity, and gaps in data collection. The BTR reflects Nepal's commitment to transparency, accountability, and adherence to the Paris Agreement's Enhanced Transparency Framework.

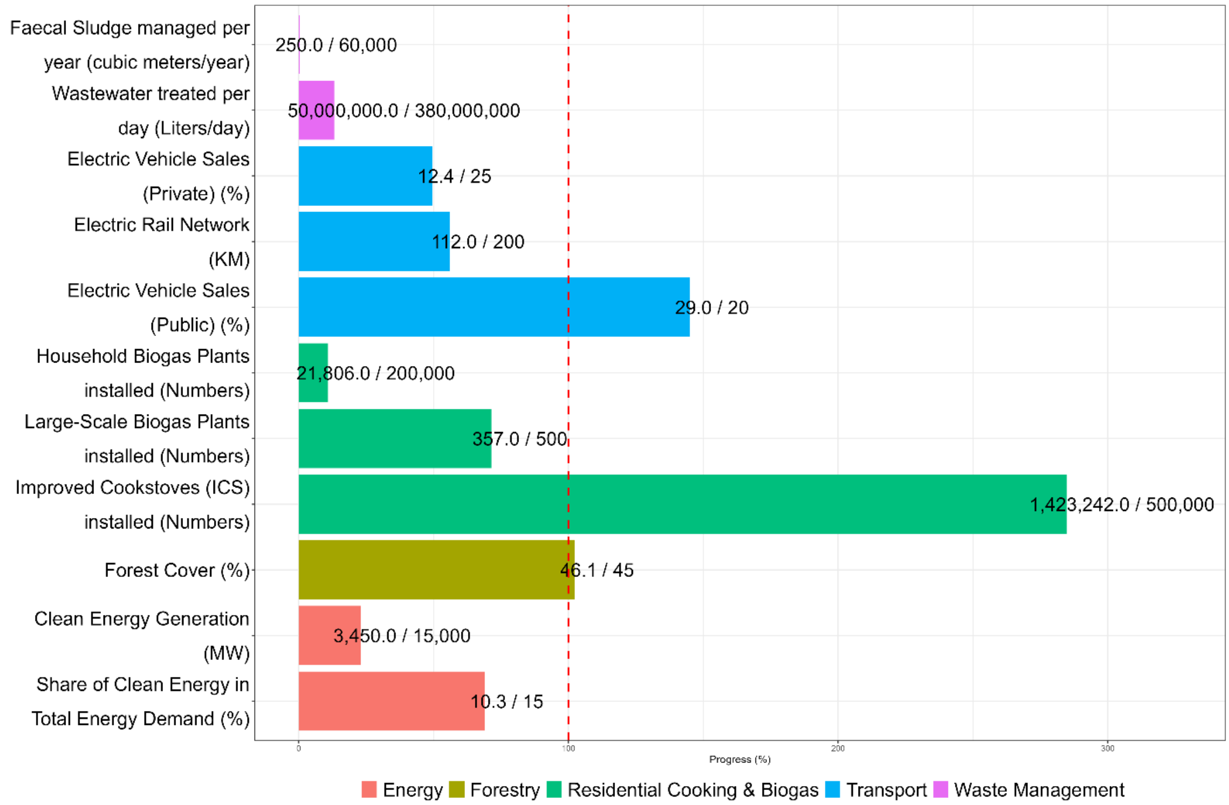

Figure 58: Progress / Mitigation outcomes of second Nationally Determined Contribution of Nepal. Red dotted line indicated the target of NDC 2.0, the numbers in all bars represent the achieved target and target separated by "/".

The report emphasizes Nepal's mitigation targets, which are aligned with its Nationally Determined Contributions (NDCs). These targets focus on reducing GHG emissions through the promotion of renewable energy, energy efficiency improvements, sustainable forest management, expansion of community forestry, adoption of climate-smart agriculture, and better waste management practices. The overall aim is to reduce emissions while enhancing carbon sinks and promoting sustainable development across sectors.

In terms of outcomes, Nepal has made progress in several areas despite existing challenges. Renewable energy capacity, particularly hydropower, has increased, and initiatives to improve energy efficiency are underway. Community forestry programs and reforestation efforts have strengthened carbon sequestration, while sustainable agricultural practices and improved waste management have contributed to emission reductions. Overall, the BTR indicates measurable progress toward mitigation goals, though it also underscores the need for continued support, capacity building, and enhanced data systems to fully achieve Nepal's climate targets. The sectoral information are as follows with comparative progress is shown in Table 57 and Figure

3.4.1 Energy Sector

Targets in Second NDC

Nepal committed to expand clean energy generation from 1,400 MW in 2020 to 15,000 MW by 2030, with 5,000 MW as an unconditional target. By 2030, 90 percent of private passenger vehicles and 60 percent of public four-wheelers should be electric. The country also aims to develop 200 km of electric rail network and ensure 25 percent of households use electric stoves as their primary cooking method.

Mitigation Progress

By 2025, installed clean energy capacity reached 3,450 MW, about 23 percent of the 2030 goal. Electric mobility is advancing quickly: EV imports accounted for 12.38 percent of private passenger vehicles, 46 percent of two-wheelers, and 29 percent of public four-wheelers, already surpassing the 2025 target for public transport. Rail development has reached 112 km, though much of it is diesel-electric. Progress in electric cooking adoption is less clear due to limited tracking data. Overall, EV adoption is strong, but clean energy expansion is lagging.

3.4.2 AFOLU Sector

Targets in Second NDC

Nepal aims to maintain 45 percent forest cover, increase soil organic matter in agricultural land to 3.95 percent, expand mulberry and fruit orchards to 6,000 hectares, establish 500,000 improved cattle sheds, and develop 100 organic fertilizer production plants by 2030.

Mitigation Progress

Forest cover stood at 46.08 percent by 2025, surpassing the 2030 goal. Forests remain a major carbon sink, removing more than 20,000 Gg CO_2 in 2022. However, emissions from agriculture persist, particularly from livestock enteric fermentation (16,687 Gg CO_2-eq in 2022) and rice cultivation. While forestry targets are being met, agricultural methane and nitrous oxide emissions remain a challenge.

3.4.3 IPPU Sector

Targets in Second NDC

While Nepal's NDC does not set strict quantitative targets for IPPU, it calls for promoting cleaner industrial technologies, including efficient brick kilns, cleaner fuels, emission guidelines, and potential adoption of carbon capture technologies.

Mitigation Progress

By 2022, IPPU emissions had grown to 4,812 Gg CO_2-eq, with cement production alone accounting for 4,792 Gg. This sector has become the fastest-growing source of emissions due to industrial expansion. The shift to cleaner processes is yet to be widely adopted, meaning mitigation progress is limited.

3.4.4 Waste Sector

Targets in Second NDC

By 2025, Nepal aimed to treat 380 million liters of wastewater per day and manage 60,000 cubic meters of faecal sludge annually. The sector also targets broader adoption of composting, anaerobic digestion, recycling, and engineered landfill gas recovery systems.

Mitigation Progress

By 2025, only about 50 million liters per day of wastewater was being treated, representing just 13 percent of the target. Fecal sludge management reached only 250 m^3 per year. Total waste sector emissions rose to 4,814 Gg CO_2-eq in 2022, mainly from wastewater discharge and solid waste disposal. The sector is far behind its mitigation targets, with technologies still at a very early stage.

Table 57: Overall comparison of sectoral mitigation outcomes

Sector	Key 2030 NDC Targets	Progress by 2025	Mitigation Outcome
Energy	15,000 MW clean energy; 90% private EV sales; 60% public EV sales; 200 km rail; 25% households with electric stoves	3,450 MW achieved; EV imports growing; 112 km rail (diesel-electric); e-stoves under-tracked	Ahead in EV adoption, lagging in clean power expansion
AFOLU	45% forest cover; 3.95% soil organic matter; 6,000 ha orchards; 500k cattle sheds; 100 organic fertilizer plants	46.08% forest cover achieved; forests strong carbon sink; agriculture emissions persist	Strong forestry mitigation, but agriculture emissions remain high
IPPU	Cleaner industrial processes and guidelines, carbon capture potential	4,812 Gg CO_2-eq in 2022, cement production dominant	Emissions growing fast, mitigation still weak
Waste	380M liters/day wastewater treatment; 60,000 m^3 sludge management by 2025	50M liters/day treated; 250 m^3 sludge; 4,814 Gg emissions in 2022	Well behind targets, mitigation limited

4 Domestic Monitoring, Reporting and Verification

4.1 Introduction

As part of the UNFCCC, the Climate Change Management Division, Ministry of Forests and Environment, prepared and submitted the National GHG inventories, National Communications reports, and other reporting requirements. Nepal has committed to reducing greenhouse gas (GHG) emissions and increasing resilience under the Paris Agreement. Although Nepal doesn't have a dedicated MRV system to report, Nepal is reporting through official mandates of the respective organizations. To comply with the transparency provision under the Paris Agreement, Nepal is preparing Nepal's MRV Framework under the CBIT project.

Nepal's MRV system tracks GHG emissions using IPCC guidelines. Emissions estimates are derived from sectoral activity data collected across federal, provincial, and local levels.

Adaptation monitoring is guided by indicators identified in the National Adaptation Plan (NAP), focusing on outcomes related to policy implementation, infrastructure development, and community resilience. Key mechanisms include Local Adaptation Plans for Action (LAPAs), community-based reporting systems, and the Climate Change Data Management and Reporting Centre, which collectively ensure inclusive and effective adaptation tracking.

Climate finance monitoring captures both public and private climate-related expenditures using tools such as the Climate Change Budget Code (CCBC), Climate Change Financing Framework (CCFF), and the Medium-Term Expenditure Framework (MTEF). It also includes data on technology transfer and capacity-building activities, supporting enhanced transparency and evidence-based decision-making.

4.2 Overview of Nepal's Institutional Arrangements

The Ministry of Forests and Environment is a national focal point for the UNFCCC and plays a central role in reporting. The Environment Protection and Climate Change Management National Council (EPCCMNC) provides policy direction, and the Inter-Ministerial Climate Change Coordination Committee (IMCCCC) acts as the MRV steering committee. Additionally, a range of institutions are involved in climate governance and data management in Nepal. The following section shows the key institutions and their mandate.

Table 58: Institutional Mandate of Selected Institution

Institution	Mandate
Ministry of Forests and Environment (MoFE)	Within MoFE, the CCMD performs functions, among others, related to the development of GHG inventories, adaptation communications, climate finance tracking, and report submission to the UNFCCC; however, its legal designation as the national MRV authority is not formalized in law.

National Planning Commission (NPC)	The NPC oversees national development planning, M&E systems, and policy coherence, and plays a central role in data integration and project monitoring. While NPC is pivotal for integrating climate MRV into national development frameworks, its role in climate-specific reporting is not clearly defined.
Line Ministries	Various line ministries have sectoral responsibilities that intersect with climate MRV: **Ministry of Energy, Water Resources and Irrigation (MoEWRI)**: Collects data on water resources and energy generation and utilization. **Ministry of Agriculture and Livestock Development (MoALD)**: Oversees agriculture and livestock development programs and projects and their reporting. **Ministry of Industry, Commerce and Supplies (MoICS)**: Manages industrial data; the Department of Industry (DoI) collects data on enterprises and has been developing an integrated industrial data portal. **Ministry of Water Supply (MoWS)**: Maintains data on water and sanitation in the N-WASH portal. **Ministry of Federal Affairs and General Administration (MoFAGA)**: Coordinates with local governments but does not have a formal mandate for climate MRV functions. However, this ministry can play a coordination role in standardizing local-level data collection and integrating emissions data into the national MRV framework. **Ministry of Urban Development (MoUD):** Oversees urban infrastructure and municipal services, but it lacks a system for tracking emissions and integrating data into climate MRV frameworks. **Ministry of Health and Population (MoHP):** Oversees public health services and medical waste management through health facilities. **Ministry of Physical Infrastructure and Transport (MoPIT)**: Manages transport data and vehicle records but does not track GHG emissions or fuel use.

Provincial Ministries	Provincial ministries are custodians of different datasets at the provincial level, expected to act as a bridge between the federal and local governments in climate governance and data management. While structures like the Provincial Climate Change Coordination Committees (PCCCC) exist, their specific roles in MRV are not defined, and implementation remains limited due to unclear mandates and inadequate institutional arrangements. Once legally empowered, provincial sectoral ministries are expected to play a key role in MRV by collecting, reporting, and coordinating climate-related data within their respective domains.
Local Governments (Municipalities)	Local governments are legally responsible for undertaking many environmental-related activities, including waste management; however, they lack clearly defined MRV roles and the necessary capacity to manage and collect data.

The proposed system is designed to operate through both lateral and vertical institutional arrangements to ensure a systematic and reliable flow of data for Nepal's domestic Measurement, Reporting, and Verification (MRV) system. Figure 59 illustrates the institutional framework that underpins this arrangement. At the sectoral level, individual ministries, along with their line departments, affiliated agencies, provincial governments, and local bodies, are responsible for the generation and primary management of sector-specific data. These data streams converge at the national level, where the Ministry of Forests and Environment (MoFE), acting as the national focal point to the United Nations Framework Convention on Climate Change (UNFCCC), compiles, integrates, and processes the information. This process is undertaken in close collaboration with the National Statistical Office to ensure methodological consistency, data quality, and compliance with international reporting standards.

To strengthen this institutional mechanism, Nepal is implementing the Capacity-Building Initiative for Transparency (CBIT), a global program that supports the enhancement of transparency-related capacities among government officials and institutions. Within the framework of the CBIT project, Nepal is conducting an in-depth study to design and operationalize an integrated, web-based automatic data management platform. The vision for this platform, as depicted in Figure 59, is to establish a seamless system in which climate-related data are collected, verified, and transmitted in an automated manner from grassroots institutions through provincial structures to the central administration. Once centralized, MoFE will oversee data validation and analysis before submitting the official climate change reports to the UNFCCC.

This integrated approach is expected to improve accuracy, timeliness, and transparency in climate data management, while also reducing redundancy and strengthening coordination across institutions. Ultimately, the system aims to enhance Nepal's capacity to meet its international reporting obligations, support evidence-based policymaking, and foster accountability in the implementation of climate change mitigation and adaptation actions.

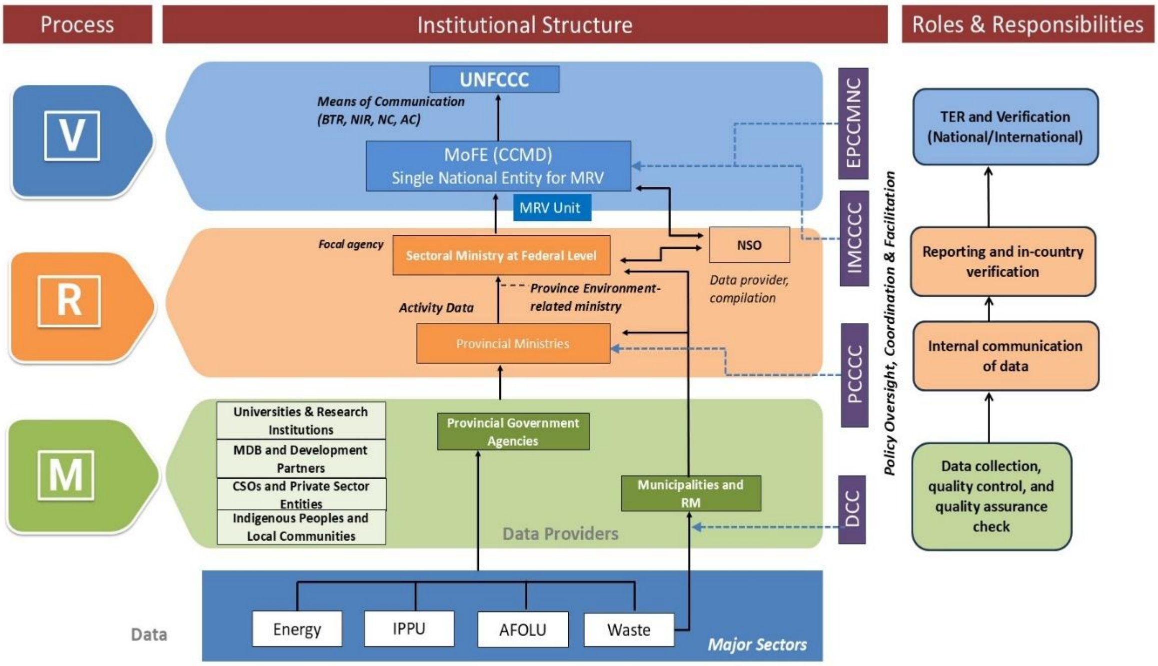

Figure 59: Proposed Institutional Structure for Climate Change Reporting

4.3 Roles and Responsibilities of Government Entities

The table below presents the roles and responsibilities of the governmental entities for MRV.

Stakeholder Category	Stakeholder Name	Sector	Roles and Responsibilities
Government Ministries	MoFE	FOLU	1. Act as the focal and lead ministry for MRV 2. Provide sectoral policy and regulatory oversight to enforce MRV in fulfilling national and international climate commitments.
	MoICS	Energy, IPPU, AFOLU, Waste	1. Provide sectoral policy and regulatory oversight to enforce MRV.
	MoALD/DoLMA	Agriculture and Livestock Development	1. Provide sectoral policy and regulatory oversight to enforce MRV.
	MoFAGA	Waste	1. Provide sectoral policy and regulatory oversight to enforce MRV.
	MOF	Energy, IPPU, AFOLU, Waste	1. Provide financial policy and regulatory oversight

			to climate change finance.

4.4 Complementary role of non-governmental actors in strengthening the MRV Process

A range of stakeholders contributed to the MRV process. Depending on the stakeholder groups, they have contributed technically by providing data collection and management. Their roles are identified as below:

- **Private Sector:** Industries, energy producers, and waste management companies serve as both data providers and implementation partners in mitigation activities. Sectoral associations such as the Federation of Nepalese Chambers of Commerce and Industry (FNCCI), Confederation of Nepalese Industries (CNI), and Independent Power Producers' Association Nepal (IPPAN) play a key role in mobilizing private sector engagement.
- **Academic and Research Institutions:** Universities, policy research institutes, and think tanks contribute to the development of methodologies, quality assurance and control (QA/QC), capacity building, and the generation of new data and scientific knowledge to strengthen the MRV system.
- **Civil Society & Indigenous Peoples/Local Communities (IPLCs):** Support participatory data collection, community-based monitoring, and inclusion of vulnerable groups.
- **International Development Partners:** Development agencies and international organizations provide critical financial, technical, and capacity-building support. Many also require transparent and credible MRV systems as a prerequisite for climate finance and project implementation.

4.5 Transitioning to the Enhanced Transparency Framework

Nepal, as a party to UNFCCC, has submitted three National Communication reports as Initial Communication Report, Second National Report, and Third National Communication Report in 2004, 2014, and 2021, respectively. As a party to the Paris Agreement, Nepal prepared and submitted its first Biennial Transparency Report in 2025. Nepal is working to finalize its MRV Framework to facilitate the reporting mechanism under the Paris Agreement. Nepal's MRV framework is being upgraded to align with ETF requirements under the Paris Agreement:

- **Biennial Transparency Reports (BTRs):** Nepal is now required to submit its Biennial Transparency Reports (BTRs). Nepal submitted its first BTR in 2025, marking the transition to ETF.
- **Digital Integration:** Development of a centralized digital MRV database and standardized reporting templates for federal, provincial, and local levels.

- **Verification:** Independent verification systems and third-party audits will ensure data quality and credibility.
- **Phased Implementation:**
    - *Short-term (1–2 years):* Establish MRV unit, pilot projects, legal frameworks.
    - *Medium-term (2–4 years):* Expand MRV coverage to all sectors, roll out data-sharing agreements, strengthen provincial roles.
    - *Long-term (5+ years):* Fully institutionalize MRV, integrate into national planning and budgeting, and align with evolving ETF requirements.

5 Finance, Technology and Capacity Building Needs and Support Received

5.1 Overview

The section of constraints, gaps, and proposed solutions and need for financial/technical/capacity building support provides updated information required from non-BTR1 Annex I countries in accordance with decision 2/CP.17, BTR1 Annex III. It includes a detailed description of constraints and gaps along with related solutions, as well as the financial, technical, and capacity needs of Nepal, highlighting the level of support received to facilitate the preparation and submission of the Biennial Update Report (BUR). The content presented covers the period from 2012 to 2024.

The chapter identifies constraints and gaps in the preparation of Nepal's GHG inventory, assesses vulnerabilities, and examines mitigation and adaptation actions taken. These gaps and constraints are identified through a literature review (MoFE 2021a, MoFE 2021b) and a comprehensive survey designed to collect primary data. The aim is to identify barriers and gaps, formulate recommendations, and propose feasible solutions. Mitigation gaps and adaptation actions are presented sector-wise, while general constraints that cut across all sectors are discussed separately. These constraints are categorized based on economic, social, technical, and political dimensions.

In addition to literature review, the information presented in this chapter is gathered through a participatory consultation process involving key stakeholders, including federal and provincial government agencies, academic institutions, and civil society organizations. This collaborative approach ensures that the chapter reflects diverse perspectives and accurately addresses Nepal's climate-related challenges and proposed solution to respond those constraints.

5.2 Constraints, Gaps and Proposed Solutions

5.2.1 GHG Inventory Preparation

Preparation of the GHG inventory is a critical component of Nepal's climate change mitigation strategies. However, Nepal lacks a formalized system for inventory preparation, which hinders its ability to estimate accurate GHG emissions across sectors. In particular, the absence of sector-specific data and emission factors creates significant challenges in estimating GHG emissions in key areas such as agriculture, energy, transport, and forestry. A coordinated, national-level framework under a supervisory body is essential to ensure each sector contributes to accurate and comprehensive GHG emissions accounting.

Constraints and gaps in GHG inventory preparation include insufficient credible data on fossil fuel use and inefficient agricultural practices like open crop residue burning, which are prominent in rural Nepal. Additionally, Nepal faces a shortage of skilled professionals and technical capacity to follow IPCC guidelines for inventory preparation. Limited financial resources, inadequate country-specific emission factors (Tier 2 and 3), and weak coordination between federal, provincial, and local bodies further exacerbate these issues. Proposed solutions include conducting sectoral surveys, building technical capacity, enhancing access to advanced inventory tools, and creating mandates for consistent emission reporting. These initiatives are imperative for ensuring an effective and credible GHG inventory process in Nepal.

Table 59: Gaps, Constraints, and Proposed Solutions in Nepal's GHG Inventory Preparation

Gaps/Constraints	Proposed Solutions
Lack of reliable and consistent data on key sources, e.g., methane emissions from agriculture or municipal solid waste (MoFE, 2022).	Establish mechanisms mandating institutions to record, maintain, and submit emissions data periodically under an umbrella organization.
Limited availability of country-specific GHG emission factors (Tier 2 and 3), particularly for agriculture, land use, and forestry (UNFCCC, 2023).	Conduct detailed sectoral surveys, e.g., methane measurements in paddy fields and emissions from animal husbandry, to collect data and develop national emission factors.
Insufficient skilled human resources to prepare the GHG inventory following IPCC guidelines (ADB, 2021).	Introduce training programs and workshops for relevant government officials and experts to enhance their capacity in GHG inventory preparation.
Inadequate financial and technical resources for collecting and processing climate-related data (World Bank, 2022).	Secure financial resources through accessible international climate funds, such as the GCF, and allocate them for climate data infrastructure and GHG inventory efforts.
Weak intergovernmental coordination among federal, provincial, and local agencies, leading to duplication and inefficiency (MoFE, 2022).	Strengthen interagency coordination by establishing formalized communication pathways between the Ministry of Forest and Environment and provincial/local governments.
Limited accessibility to technical tools and technologies for GHG data collection and analysis (UNFCCC, 2023).	Improve access to advanced technology for emissions monitoring and inventory preparation through partnerships with international organizations like UNEP and IPCC support.
Absence of mandatory provisions for regular inventory updates across sectors (MoFE, 2023).	Amend rules of business to make periodic inventory updates obligatory for federal, provincial, and local government entities.

5.2.2 Vulnerability Assessment

Vulnerability assessment is a critical step in the adaptation planning process to address climate change impacts in Nepal. It evaluates the susceptibility of various sectors, systems, and communities to the adverse effects of climate change. The assessment often focuses on high-risk ecosystems, species, or sectors, aiding policymakers in prioritizing adaptation measures. However, in Nepal, the concept of vulnerability assessment is underdeveloped due to the lack of technical capacity, insufficient funding, and minimal integration of climate-related modeling and tools into decision-making processes. Strengthening this area is pivotal for reducing risks and building resilience in climate-sensitive sectors such as agriculture, water, forestry, and biodiversity.

The primary constraints and gaps in vulnerability assessments include the non-mandatory nature of these evaluations in planning, insufficient technical resources, and inadequate real-time data and climate modeling capabilities. Additionally, poor inter-agency collaboration and limited research and development activities hinder comprehensive vulnerability analyses in Nepal. Table 59 below highlights these challenges, along with potential solutions to support evidence-based assessments. Key recommendations include enhancing technical and human resources, establishing dedicated research centers, promoting R&D, and introducing financial and institutional mechanisms to integrate vulnerability assessments into the national planning framework.

Table 60: Vulnerability Assessment – Constraints, Gaps, and Proposed Solutions in Nepal

Constraints & Gaps	Proposed Solutions
Vulnerability assessments are not mandatory and are poorly integrated into local and federal planning processes.	Make vulnerability assessments a mandatory component of climate-related planning and sectoral development strategies under the Ministry of Forests and Environment.
Lack of measuring tools, real-time climate data, and observational data, e.g., streamflow variability and extreme event frequency (MoFE, 2023).	Develop a comprehensive climate data observatory system that integrates river flow monitoring and extreme weather tracking in collaboration with the Department of Hydrology.
Insufficient funding and underutilization of skilled professionals in existing organizations (ADB, 2021).	Allocate national budget resources and access international funding, e.g., Green Climate Fund (GCF), for vulnerability-related projects and technical training programs.
Inadequate expertise in climate modeling, satellite imagery analysis, and high-resolution forecasting techniques (World Bank, 2022).	Conduct capacity-building programs at provincial and local levels for technical modeling and invest in hiring experts to support advanced climate tools.
Limited focus on R&D activities, including disaster risk reduction and early warning systems (UNFCCC, 2023).	Promote interdisciplinary R&D through collaboration with local universities and international partners to create locally tailored adaptation and mitigation solutions.
Poor inter-agency coordination between federal, provincial, and local bodies such as meteorology and disaster management authorities.	Establish regular communication channels, and introduce integrated policies to align the goals of diverse agencies for efficient climate change response.
Lack of technical resources for sector-specific vulnerability assessments, e.g., for water and energy sectors.	Establish provincial research and climate action centers with technical expertise to monitor sectoral impacts and devise mitigation strategies.
Climate change could affect enterprises, human health, infrastructure, and	Energy efficient technology and switching towards this

transportation systems, as well as energy, food, and water supplies forced switching to more carbon emission	

5.2.3 Adaptation Actions

Nepal's vulnerability to climate change is particularly acute in key thematic sectors: agriculture, water resources, forestry, energy, and urban infrastructure. Agriculture, which employs over 65% of the population and contributes approximately 25.8% to GDP (CBS, 2023), faces recurring droughts, erratic rainfall, and extreme weather, threatening food security. To overcome challenges, Nepal must foster institutional collaboration, strengthen research and development, and enhance local capacity. Agriculture policies should emphasize resilient farming practices, while sustainable watershed management and rainwater harvesting systems can ensure the availability of water resources. Moreover, Nepal's ambitious hydropower plans require robust climate risk assessments. By investing in sustainable forestry management and promoting community-based approaches, Nepal can mitigate the adverse effects on biodiversity and livelihoods dependent on forests. Climate-resilient infrastructure and green urban planning strategies should also address vulnerabilities in urban systems. Table 60 details constraints and potential solutions for these thematic sectors.

Table 61: Adaptation Actions Across Thematic Sectors – Constraints, Gaps, and Proposed Solutions

Thematic Area	Constraints & Gaps	Proposed Solutions
Agriculture	Lack of timely dissemination of weather forecasts and climate-related advisory to farmers.	Establish localized weather and climate advisory systems through mobile and digital platforms; enhance access to climate-smart agriculture resources (FAO, 2023).
	Limited availability of drought-resistant crops and seeds in rural regions.	Increase R&D funding for developing and distributing climate-resilient seed varieties via decentralized agricultural extension centers.
	Declining crop, fisheries and livestock production Impact on subsistence farming, which is more vulnerable to erratic monsoon rains and floods	Direct costs from the effects of climate change on crop production, livestock production, and risks of natural hazards. Indirect costs from the effects of climate change on socioeconomic conditions and lost opportunities for their advancement of the living conditions.
	Decline in the production of winter and spring crops because of temperature and precipitation anomalies	Cost of crop to keep themselves away fromor minimize the negative effects of the climate change.

	Decline in rice and wheat yields, with serious implication on food security for a large section of the population, particularly in the western region Loss of local and traditional cro p varieties, leading to negative impacts on food and nutrition security	
	Increased run-off variability Increased sediment loading	Replicable, adaptable, efficient and accessible international climate finance, affordable and appropriate technology and capacity building support needed
	Poor irrigation infrastructure and lack of affordable technologies.	Promote community-managed drip and sprinkler irrigation systems with government subsidies; establish cooperative models for affordable irrigation access.
Water Resources	Insufficient watershed management and low adoption of rainwater harvesting techniques.	Develop and scale up community-based watershed programs; incorporate rainwater harvesting systems in public and private construction standards (UNDP, 2023).
	Increased risk of GLOF Increased evaporation	Replicable, adaptable, efficient and accessible international climate finance, affordable and appropriate technology and capacity building support needed
	There are serious concerns that increased climate variability in combination with increased population density and inadequate sanitation could augment the occurrence of diseases in Nepal	Replicable, adaptable, efficient and accessible international climate finance, affordable and appropriate technology and capacity building support needed
	Inadequate institutional frameworks to govern groundwater management and resolve transboundary water issues.	Strengthen transboundary water cooperation mechanisms and adopt regulatory frameworks for groundwater monitoring and management (MoFE, 2023).
	Lack of technical capacity to integrate hydrological climate models into policymaking.	Build technical capacity in hydrological modeling using training programs with international organizations like ICIMOD and regional knowledge-sharing platforms (ICIMOD, 2023).
Forestry	Limited capacity in forest fire management and biodiversity conservation under changing climatic conditions.	Equip forest user groups with modern firefighting tools and techniques; implement biodiversity-focused

		conservation strategies (FECOFUN, 2023).
	Climate change is a global phenomenon and not a single sector is aloof from its severe impacts; however, the degree of impact is not proportionally distributed across all the sectors including forest and biodiversity	Replicable, adaptable, efficient and accessible international climate finance, affordable and appropriate technology and capacity building support needed
	Limited availability and accessibility of funding for SFM and restoring degraded forests Limited success in maintaining or restoring forest for SFM in Nepal's context, Opportunities for financing, technology transfer, and capacity building to increase the forestry for prosperity	
	Weak incentives for communities participating in afforestation and reforestation programs.	Provide subsidies, eco-tourism benefits, and carbon credit payments to incentivize afforestation and reforestation initiatives (REDD+ Nepal, 2023).
	Poor integration of forest ecosystem services into broader adaptation and development programs.	Include forest ecosystem valuation metrics in provincial and federal development projects to ensure climate-smart planning.
Urban Infrastructure	Outdated urban drainage systems incapable of handling climate-induced extreme rainfall events.	Allocate budgets for upgrading urban stormwater systems; introduce innovative designs integrating permeable pavements and green roofs (Kathmandu Metropolitan City, 2023).
	Increasing Vehicle, Road congestion and bottlenecks on the existing roads in major hubs such as Kathmandu causing more carbon emission	Switching to energy efficient system
	Lack of policy to promote energy-efficient and climate-resilient building designs.	Establish building codes mandating the adoption of climate-resilient structures and incentivize the use of energy-efficient technologies in housing (MoUD, 2023).
Energy	High vulnerability of hydropower systems to glacial floods, droughts, and sedimentation.	Conduct climate risk assessments for hydropower installations and integrate adaptive design principles; increase investment in sedimentation management research (NEA, 2023).
	Implement environment friendly, clean energy and green development concept for climate change mitigation	Reduce the impacts of climate change as per the Paris

		Agreement and build adaptive capacity
	Climate change is likely to result in increased damage to buildings, energy services, telecommunications, transport structures and water service.	Replicable, adaptable, efficient and accessible international climate finance, affordable and appropriate technology and capacity building support needed
	Climatic variability and associated hydrological variability are likely to result in high vulnerability for the overall energy system, and cause high economic impacts.	
	Changing climatic conditions may affect the operational plan of existing hydropower system, which are built based on historical records of climate patterns, and therefore, impacts on energy supply	
	Inadequate grid infrastructure for distributing energy during disasters.	Expand micro-grid systems and off-grid energy solutions in remote disaster-prone areas to ensure resilience.
	Dependency on traditional biomass fuels in rural areas leads to increased carbon emissions and deforestation.	Promote alternative energy solutions like biogas and solar systems with financial and technical support programs targeting rural households (AEPC, 2023).
Cross cutting	Climate change could affect human health, infrastructure, and transportation systems, as well as energy, food, and water supplies. This may slow down economic development and poverty reduction, and make it harder to achieve the Sustainable Development Goals. Hence, the technology should contribute towards reducing the impacts on the society and thus promote job opportunities, urban and rural development, healthy living condition, and reduce risks associated with disasters.	Replicable, adaptable, efficient and accessible international climate finance, affordable and appropriate technology and capacity building support needed
	Greater risk of injury, disease and death, owing to more intense heat waves, cold waves and forest fires Increased risk of undernutrition, resulting from diminished food production in resource- poor regions More negative health consequences from lost work capacity and reduced labour productivity in vulnerable populations Increased risk of vector-borne, waterborne and foodborne diseases, especially in mountain areas, and leading to perennial occurrence in the lowlands Increase in cardiorespiratory diseases, owing to higher ambient air pollution and haze in urban areas, resulting from climate change Increase in mental health problems, owing to extreme climatic events such as droughts, floods and landslides	Replicable, adaptable, efficient and accessible international climate finance, affordable and appropriate technology and capacity building support needed

	Modest reductions in cold-related mortality and morbidity in the highlands, owing to fewer cold extremes Increased morbidity and mortality related to cold waves in the southern Tarai lowlands Reduced disease-transmission capacity of vector insects in the Tarai, owing to higher temperatures exceeding their thermal thresholds.	
Others	Big discrepancy between disbursed resource and committed resource	
	Inadequate/Limited access to finance and technical assistance: The access to finance and technical assistance for communities, organizations, and government bodies still inadequate	

5.2.4 Mitigation Actions in Key Sectors for Nepal

Effective mitigation actions are critical for reducing greenhouse gas (GHG) emissions in Nepal, particularly in energy, agriculture, transport, and urban infrastructure. The energy sector, which primarily depends on hydropower, has immense potential for renewable energy (RE) development, such as solar and wind power, but faces challenges related to high initial costs and limited local manufacturing. Similarly, the agricultural sector is one of the largest contributors to methane emissions due to traditional rice farming and livestock management practices, necessitating a shift to climate-smart agriculture. In transport, GHG emissions are escalating as vehicle numbers increase without a parallel development of sustainable transport systems like electric vehicles (EVs) and efficient mass transit systems. Urban areas suffer from high emissions due to the absence of proper waste management and outdated urban planning practices.

To address these gaps, Nepal must prioritize localized RE technology manufacturing, institutional capacity building, and sustainable development frameworks in its mitigation agenda. Promoting electric public transport, indigenizing solar and biogas production systems, and enhancing policy enforcement for emission reductions in agriculture and waste management are essential. The establishment of state-of-the-art research facilities, consistent R&D funding, and increased public-private partnerships can drive innovations in emission reduction. Nepal's forthcoming mitigation policies under its updated Nationally Determined Contributions (NDCs) could pave the way for a low-carbon future across key sectors. Table 61 highlights sector-specific constraints, gaps, and proposed solutions.

Table 62: Mitigation Actions Across Thematic Sectors – Constraints, Gaps, and Proposed Solutions

Thematic Area	Constraints & Gaps	Proposed Solutions
Energy	High capital costs for installing solar panels, wind turbines, and micro-hydropower systems in rural areas.	Incentivize domestic manufacturing of renewable energy technologies; establish subsidies and low-interest financing schemes (AEPC, 2023).

	Inadequate testing facilities and regulations for RE technology standards, leading to substandard products in the market.	Set up national testing laboratories and formulate quality assurance frameworks in collaboration with international organizations (ICIMOD, 2023).
	Limited grid infrastructure for integrating distributed RE sources into the national grid.	Expand decentralized micro-grid systems for rural electrification, complemented by policies to incentivize hybrid grid integration.
Transport	Lack of electric vehicle (EV) charging infrastructure and high cost of hybrid and electric vehicles.	Promote public-private partnerships for establishing EV charging stations and provide tax incentives for EV adoption (MoPIT, 2023).
	High dependency on fossil-fuel-based public transport systems.	Develop Bus Rapid Transit (BRT) systems and upgrade urban transport systems to EV or hybrid technologies (ADB Nepal, 2023).
	Lack of comprehensive transport policy focused on emission reduction.	Formulate a detailed sustainable transportation policy incorporating funding mechanisms for EVs and BRT systems.
Agriculture	Traditional farming methods leading to significant methane emissions.	Promote climate-smart agriculture practices such as alternate wetting and drying (AWD) in rice farming (FAO Nepal, 2023).
	High capital costs and limited availability of certified seeds and fertilizers for sustainable farming.	Develop R&D collaborations for producing cost-effective certified seeds locally; implement subsidy programs for fertilizers.
	Lack of infrastructure for scientific livestock management to reduce methane emissions.	Establish model livestock farms with integrated waste and emission management systems.
Urban Infrastructure	Inefficient waste management practices leading to methane and CO_2 emissions.	Develop comprehensive waste-to-energy systems for

		urban centers (e.g., biogas plants) and introduce urban composting initiatives.
	Outdated urban designs and lack of energy-efficient housing models.	Introduce green building codes mandating energy-efficient design and construction materials (MoUD, 2023).
	Poor drainage and sanitation systems causing emissions and affecting air quality.	Allocate budgets to upgrade urban sanitation and drainage infrastructure to climate-resilient standards.
Forestry	High deforestation rates due to unregulated land use change and traditional biomass use for energy.	Strengthen forest protection policies through incentivized community forestry programs and promote alternative clean energy sources (REDD+ Nepal, 2023).
	Limited funding for reforestation and forest conservation projects.	Secure international funding mechanisms like REDD+ and Green Climate Fund to support reforestation and carbon sequestration programs.
	Climate change has increased vulnerability on forests and biodiversity as well. Increased variability and timing of precipitation, and rise in temperature have profound impact on the entire forest ecosystem. Change in flowering and fruiting season, reduced availability of NTFPs, less grass and forest fire are already evident in many parts of the country.	
	Lack of technical capacity for forest carbon monitoring and assessment.	Build capacity in forest carbon measurement techniques with partnerships between academic institutions and government agencies.

5.3 Support Needed and Received

To address climate change challenges effectively, Nepal has sought and received various forms of technical and financial support in four key thematic areas: GHG inventory preparation, vulnerability assessment, mitigation actions, and adaptation actions. Realizing the need for robust GHG inventories, Nepal has invested in capacity-building programs focusing on IPCC guidelines and setting up an institutional framework to strengthen data collection processes. Although progress has been made, additional technical support, such as advanced monitoring tools and a centralized data management system, remains crucial. Vulnerability assessments have been enhanced through collaborations with agencies to develop climate-resilient strategies for agriculture, forestry, and water resource management, yet more comprehensive risk assessment frameworks and automatic weather stations are required.

Mitigation actions have benefitted from partnerships focusing on the promotion of renewable energy technologies, including mini-grid systems, biogas plants, and solar irrigation. However, scaling up clean energy initiatives requires technical advisory services and localized production facilities for renewable energy equipment. Adaptation actions have received financial aid for climate-smart agriculture projects and community-based initiatives. Yet, the expansion of sustainable practices like drought-tolerant crop varieties and integrated watershed management calls for greater technical resources and enhanced farmer training programs. Nepal's journey toward climate resilience continues to necessitate sustained global collaboration and investments.

Table 63: Technical Support Needed and Actually Received in Nepal's Context

Sector	Support Required	Support Received	Additional Support Required
GHG Inventory Preparation	- Training on IPCC 2006 guidelines for national GHG inventory. - Establishment of sector-specific emission databases. - Procurement of advanced data collection equipment.	- Training programs organized with ICIMOD and UNEP. - Partial data centralization at the Ministry of Forests and Environment.	- Advanced data validation tools. - Upgrading the existing emission monitoring infrastructure. - Hiring skilled experts.
Vulnerability Assessment	- Installation of automatic weather stations (AWS). - Development of real-time disaster monitoring systems. - Capacity building for multi-sectoral risk assessments.	- Assistance from USAID and WWF to install limited AWS. - Pilot studies on flood and landslide risk mapping.	- Comprehensive climate risk frameworks. - Increased AWS coverage for real-time monitoring in remote areas. - Satellite data integration.
Mitigation Actions	- Localized production units for renewable energy technologies. - Development of	- Implementation of micro-hydro and biogas initiatives with UNDP collaboration. - Expansion of	- Technical expertise for hybrid/electric vehicle promotion. - National grid enhancement for RE

	urban public transport plans. - Dissemination of solar and biogas technologies.	renewable energy access under AEPC.	integration. - Promotion of urban tree planting.
Adaptation Actions	- Drought-tolerant seed varieties. - Farmer training on climate-smart practices. - Development of integrated water resource management projects.	- Introduction of climate-resilient crops in select regions with FAO support. - Pilot water harvesting systems in Terai region.	- Scale-up of crop diversification programs. - Creation of dedicated community adaptation centers. - Advanced forecasting models for agriculture.

5.4 Financial Support in Nepal's Context

Nepal has been actively seeking financial support to combat climate change impacts, primarily through international sources such as the Green Climate Fund (GCF), the Global Environment Facility (GEF), and bilateral funding agencies. Financial investments have been made for mitigation projects, including renewable energy expansion, afforestation programs, and low-carbon development strategies. However, gaps remain in accessing adequate resources for feasibility studies, capacity building, and infrastructure for GHG inventory preparation. Nepal has successfully allocated international funding to pilot projects on solar irrigation systems and clean energy technologies, yet additional resources are needed to scale these solutions to a national level.

Adaptation efforts have been supported by UNDP, the Climate Investment Funds (CIF), and other global mechanisms to enhance climate resilience in agriculture, forestry, and water management. Projects such as drought-tolerant crop development, watershed management, and community-based adaptation initiatives have been implemented. Nevertheless, funding gaps persist in key areas, including resilient infrastructure development, enhanced monitoring systems, and expanding farmer training programs to promote sustainable practices across agroecological zones. The future requires a more robust financial commitment from international and local partners to meet Nepal's Nationally Determined Contributions (NDCs) and Sustainable Development Goals (SDGs).

Table 64: Financial Support Needed and Received in Nepal's Context

Sector	Support Required	Support Received	Additional Support Required
GHG Inventory Preparation	- Funds for setting up fully equipped GHG inventory centers. - Capacity-building programs for data analysis and reporting.	- Financial assistance from UNEP and ICIMOD for training programs. - Partial funding for institutional frameworks.	- Continued training for technical staff. - Equipment for reliable and accurate data collection.

	- Procurement of monitoring equipment.		- Resources for QA/QC systems.
Vulnerability Assessment	- Financing for automatic weather stations and disaster surveillance systems. - Funded risk assessment studies for vulnerable communities.	- Limited support for automatic weather stations from WWF and USAID. - Pilot studies on disaster-prone areas.	- Nationwide deployment of AWS and early warning systems. - Funding for detailed sectoral vulnerability mapping.
Mitigation Actions	- International funding for renewable energy projects (e.g., GCF, CIF). - Investment in feasibility studies and promotion of low-carbon technologies.	- Projects funded by AEPC for solar energy, biogas, and micro-hydro expansion. - GCF-supported pilot renewable energy initiatives.	- Grants for scaling renewable energy systems. - Financial incentives for sustainable transportation. - Development of mitigation manuals.
Adaptation Actions	- Resources for drought-tolerant crops, water-efficient farming techniques, and agroforestry projects. - Funds for farmer training programs.	- Financial assistance from GEF and UNDP for climate-resilient farming practices and community adaptation programs.	- Expanded adaptation funding for remote communities. - Investment in infrastructure to withstand climate events. - Establishment of long-term resilience projects.

5.5 Capacity Building Support in Nepal’s Context

Nepal's efforts to tackle climate change have emphasized the need for capacity building across various sectors, including GHG inventory preparation, vulnerability assessments, mitigation strategies, and adaptation actions. Trainings on the 2006 IPCC Guidelines, supported by the International Centre for Integrated Mountain Development (ICIMOD) and UNEP, have enhanced expertise in data collection and emissions reporting. However, there remains a critical need to expand these efforts to provincial and local government levels, enabling decentralized, comprehensive, and reliable inventory compilation.

Adaptation-focused capacity building in Nepal has primarily been supported through projects facilitated by GEF and UNDP, including farmer training programs for drought-tolerant crop adoption and water-efficient irrigation practices. Despite these gains, significant gaps persist in developing sector-specific skills, especially for livestock health, agroforestry, and disaster-resilient infrastructure. Strengthening institutional frameworks and enhancing technical competencies for regional staff will ensure effective implementation of Nepal’s National Adaptation Plan (NAP) and compliance with Sustainable Development Goals (SDGs).

Table 65: Capacity Building Support Needed and Received in Nepal's Context

Sector	Support Required	Support Received	Additional Support Required
GHG Inventory Preparation	- Advanced training programs on GHG data collection, QA/QC protocols, and reporting standards. - National training on IPCC 2006 Guidelines. - Development of provincial data hubs.	- ICIMOD-supported regional training programs on GHG inventory preparation. - UNEP assistance in framework setup.	- Expansion of trainings to local levels. - Robust methodological enhancements for sub-sector inventory integration.
Vulnerability Assessment	- Capacity building for setting up satellite-based vulnerability mapping and disaster warning systems. - Training in delineation of climate-sensitive zones.	- GCF-supported vulnerability assessments in priority regions. - Training for localized risk mapping by MoFE.	- Advanced skill-building workshops for early warning systems. - Expansion of remote-sensing technologies for wider coverage.
Mitigation Actions	- Specialized training in renewable energy technologies. - Knowledge-sharing workshops for low-carbon farming solutions. - Practical training in emission reduction interventions.	- Training on solar water pumping and renewable energy development supported by AEPC. - GEF initiatives for clean agriculture tech.	- Certifications for climate-smart agriculture practitioners. - Inclusion of private-sector expertise in training programs.
Adaptation Actions	- Trainings for adoption of agroecological practices, including drought-tolerant crops and permanent raised beds. - Community-level training in disaster resilience.	- Farmer training programs supported by UNDP for climate-resilient practices. - GEF-supported adaptation initiatives.	- Technical support for community-based adaptation interventions. - Establishment of local adaptation training centers.

5.6 Financial and technological Support received

Nepal's first Biennial Transparency Report (BTR), submitted in 2025, underscores the nation's commitment to transparent climate action and adherence to the Paris Agreement. A pivotal aspect of this commitment has been the financial and technical support received from the international community, developed countries, and the United Nations Framework Convention on Climate Change (UNFCCC). This support has been instrumental in enabling Nepal to enhance its climate reporting capabilities and implement effective mitigation strategies.

5.6.1 Financial and Technical Support from the International Community and Developed Countries

Nepal has benefited from various climate finance mechanisms aimed at assisting developing countries in their climate action endeavors. The Global Environment Facility (GEF), through its Capacity-Building Initiative for Transparency (CBIT), has provided significant funding to Nepal. The CBIT project, with a total budget of USD 2.84 million, includes USD 1.65 million from the GEF, complemented by in-kind contributions from the Ministry of Forests and Environment (MoFE) and WWF Nepal. The project's goal is to strengthen Nepal's institutional capacity to meet the Enhanced Transparency Framework (ETF) requirements of the Paris Agreement, thereby enhancing the country's ability to track and report progress on its Nationally Determined Contributions (NDCs).

In addition to the CBIT project, Nepal has received financial support (~ 0.6 million USD) from the GEF through the United Nations Environment Program (UNEP) for the preparation of its BTR and Biennial Update Report (BUR). This support, provided as a top-up to the ongoing BUR project, enables Nepal to complete both reports concurrently, ensuring comprehensive and timely submission to the UNFCCC. The GEF's financial assistance is part of its broader efforts to support developing countries in fulfilling their reporting obligations under the Paris Agreement.

5.6.2 Technical Support Facilitated by the UNFCCC

The UNFCCC has played a crucial role in facilitating technical support to Nepal, enabling the country to enhance its capacity to address climate change. Through various programs and initiatives, the UNFCCC has provided Nepal with the necessary tools and expertise to strengthen its climate policies and actions. This technical support encompasses areas such as climate data collection and analysis, monitoring and evaluation of climate projects, and capacity building for stakeholders involved in climate action.

Furthermore, the UNFCCC has supported Nepal in aligning its climate strategies with international standards and frameworks. This alignment ensures that Nepal's climate actions are consistent with global efforts to mitigate and adapt to climate change, thereby enhancing the effectiveness and impact of the support received.

Conclusively, the financial and technical support from the international community, developed countries, and the UNFCCC has been vital in enabling Nepal to advance its climate action agenda. These contributions have not only facilitated the preparation of the BTR and BUR but have also strengthened Nepal's institutional capacity to address climate change effectively. As Nepal continues its journey towards sustainable development and climate resilience, sustained and enhanced support from the international community will be essential to meet the challenges posed by climate change and to achieve the targets set in its NDCs.

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