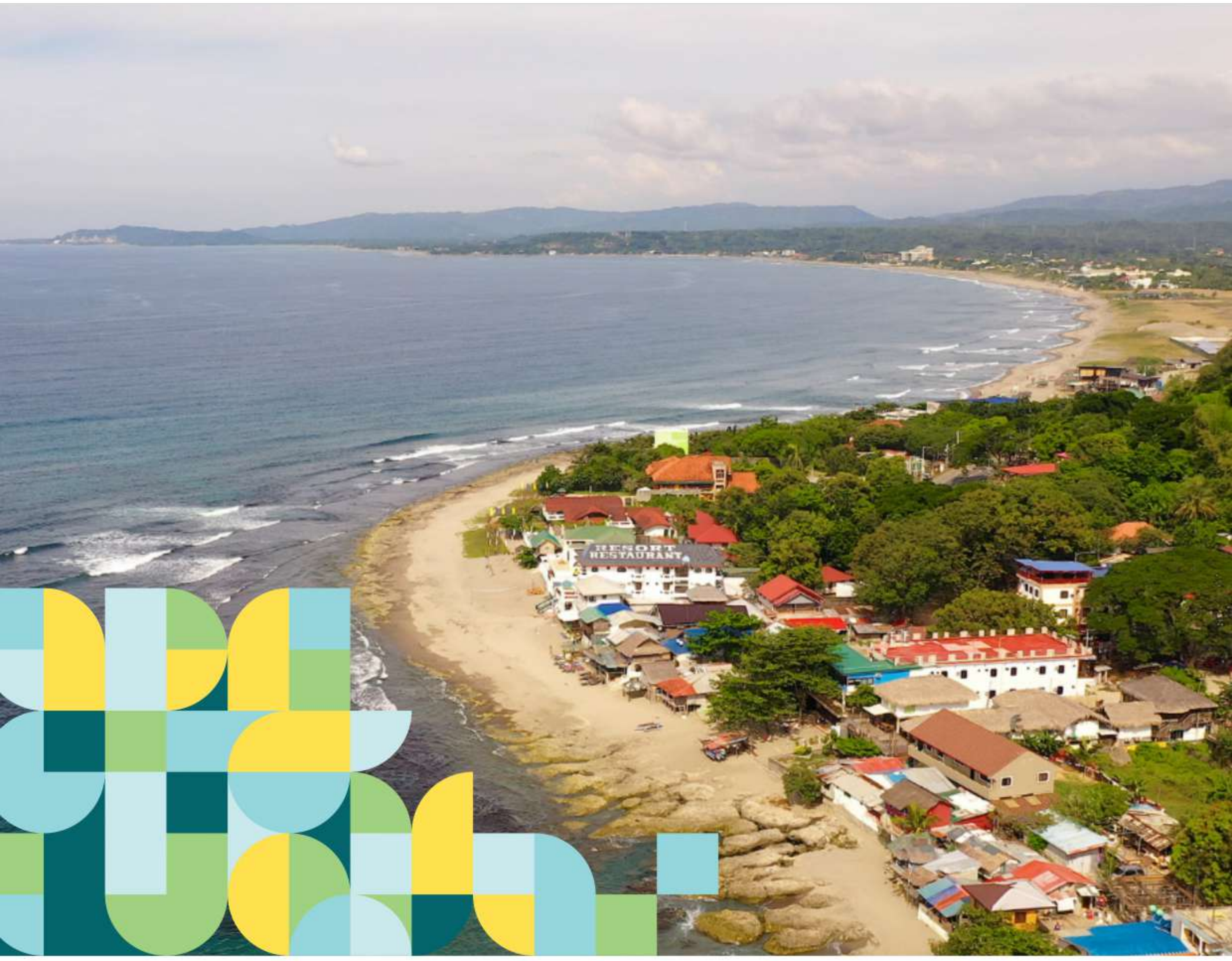
La Union Province Community-Level GHG Emissions Inventory 2023 Report



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Acronyms

A&D	Alienable and Disposable
AEUR	Annual Energy Utilization Report
AFOLU	Agriculture, forestry, and other land use
AR6	Sixth Assessment Report
BOD	Biochemical oxygen demand
CCC	Climate Change Commission
CH4	Methane
CO2	Carbon dioxide
CPH	Census of Population and Housing
DENR	Department of Environment and Natural Resources
DOC	Degradable organic carbon
DOCf	Degradable organic carbon that degrades
DOE	Department of Energy
DOE-EUMB	Department of Energy - Energy Utilization and Management Bureau
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GWP	Global warming potential
HA	Hectares
HVAC	Heating, ventilation, and air conditioning
IPCC	Intergovernmental Panel on Climate Change
LGU	Local Government Unit
LPG	Liquefied petroleum gas
LUECO	La Union Electric Company, Inc.
LUELCO	La Union Electric Cooperative, Inc.
N2O	Nitrous oxide
NDC	Nationally Determined Contribution
PDPFP	Provincial Development and Physical Framework Plan
SWMO	Solid Waste Management Office
tCO2e	Tonnes of carbon dioxide equivalent

Background

The Intergovernmental Panel on Climate Change's (IPCC) Sixth Assessment Report (AR6) predicts that global warming will likely reach 1.5°C between 2030 and 2040 if the current rate of increase continues. Human-induced global warming is currently rising by about 0.2°C per decade due to past and present emissions. This trajectory is expected to bring significant and lasting changes to the climate system, posing severe risks and impacts to people, economies, and ecosystems worldwide. These risks encompass threats to unique ecological and human systems, extreme weather events, disproportionate impacts on vulnerable groups, extensive financial damage and environmental degradation, and large-scale singular events. The severity and occurrence of these risks depend on the rate and magnitude of warming, geographic location, development levels, vulnerability, and the effectiveness of mitigation and adaptation strategies.

The IPCC stresses the importance of achieving and maintaining net-zero global anthropogenic carbon dioxide emissions to delay further global warming. Limiting global warming to 1.5°C requires adhering to a carbon budget which, from 2020 is estimated at 500 $GtCO2$ for a 50% probability of success. This goal demands accelerating ambitious, multi-level, and cross-sectoral climate actions involving rapid and extensive transitions in energy, land use, urban infrastructure (including transportation and buildings), and industrial systems.

Despite considering the current nationally determined contributions (NDCs) submitted by States under the Paris Agreement, the IPCC finds these efforts insufficient to limit warming to 1.5°C. Consequently, there is an urgent call for more ambitious and radical global commitments and actions, emphasizing the vital role of local and sub-national governments. Urban systems are key to achieving significant emissions reductions and climate resilience. This requires inclusive, integrated, and long-term planning of physical, natural, and social infrastructure to facilitate effective urban transitions.

Local Governments in Climate Action

Local governments play a pivotal role in climate action by implementing policies and initiatives that directly impact their communities. They are at the forefront of addressing climate change through urban planning, transportation management, waste management, and the promotion of renewable energy and energy efficiency. Local governments can enact building codes that require energy-efficient designs, establish public transit systems to reduce carbon emissions, and create green spaces that enhance biodiversity and mitigate urban heat islands. By engaging with local businesses, institutions, civil society, and residents, they can foster a culture of sustainability and resilience, ensuring that climate action is integrated into everyday life.

Moreover, local governments serve as critical links between national policies and grassroots initiatives. They can tailor climate strategies to their unique geographic and socio-economic contexts, ensuring that actions are effective and equitable. Through partnerships with national governments as well as international organizations, local authorities can leverage additional resources and expertise. This multi-level collaboration is essential for achieving comprehensive climate goals. Local governments also play a crucial role in raising public awareness and driving community engagement, the essential components for the success of any climate action plan.

In the Philippines, the Climate Change Act of 2009 (Republic Act 9729) which is the country's policy foundation for climate action recognizes the role of local government units (LGUs) as "the frontline agencies in the formulation, planning and implementation of climate change action plans in their respective areas, consistent with the provisions of the Local Government Code, the National Framework Strategy on Climate Action, and the National Climate Change Action Plan." Provincial governments shall provide technical assistance, enforcement and information management in support of municipal and city climate change action plans thus necessitating an inter-LGU collaboration in climate action. One fundamental step in climate change action plan formulation is to perform GHG inventories to have the necessary baseline data to inform climate mitigation strategies to reduce a locality's GHG emissions and enhance its carbon sinks. In support of this, the Philippine Climate Change Commission (CCC) with support from the USAID has developed the Community-Level GHG Inventory User Manual and the Community-Level GHG Quantification Spreadsheet to aid LGUs in establishing their baseline emissions data. Meanwhile, the Global Protocol for Community-Scale Greenhouse Gas Inventories (GPC) developed by the C40 Climate Leadership Group, ICLEI-Local Governments for Sustainability, and World Resources Institute (WRI) offers local and subnational governments a robust, transparent, and globally accepted framework to consistently identify, calculate, and report on GHG emissions. The GPC also served as a primary reference in the development of the guidebooks and tools by the CCC. To this end, a combination of global frameworks and methodologies as well as locally available tools has been adopted in this report to ensure that the resulting community-level GHG emissions inventory can showcase compliance with both global and local reporting requirements and standards.

Objectives

The La Union Province GHG Inventory Report was formulated to fulfill the following objectives:

- Quantify and document the GHG emissions from various sectors/sources within the province, such as energy, transportation, waste, agriculture to create a comprehensive emissions profile;
- Establish a baseline emissions data to serve as reference point for measuring future emission reductions and tracking progress over time;
- Identify the major sources of GHG emissions within the province to target for mitigation efforts;
- Ensure reporting compliance to key national government agencies;
- Provide transparent and verifiable data to stakeholders, including government agencies, businesses, and the public;
- Support the development and evaluation of informed and effective climate policies by providing solid evidence; and
- Raise public awareness about the sources and impacts of GHG emissions within the province thus opening opportunities to engage with community stakeholders to foster collaborations for climate action.

La Union Province Profile

Image from Wikimedia Commons

Geographical Location and Physical Features

La Union is a province located in the Southwestern part of Ilocos Region on the island of Luzon. It is situated 273 kms north of Manila and 57 kms northwest of Baguio City. The province is bordered by Ilocos Sur to the north, Benguet to the east, Pangasinan to the south, and West Philippine Sea to the west. La Union stretches across 1,497 square kilometers (or 578 square miles). This land area makes up roughly 11.6% of the entire Ilocos Region. Moreover, under its jurisdiction is one city and 19 municipalities which is equivalent to 16.39 % of the region, and 576 barangays accounting 17.76 % of the region's total.

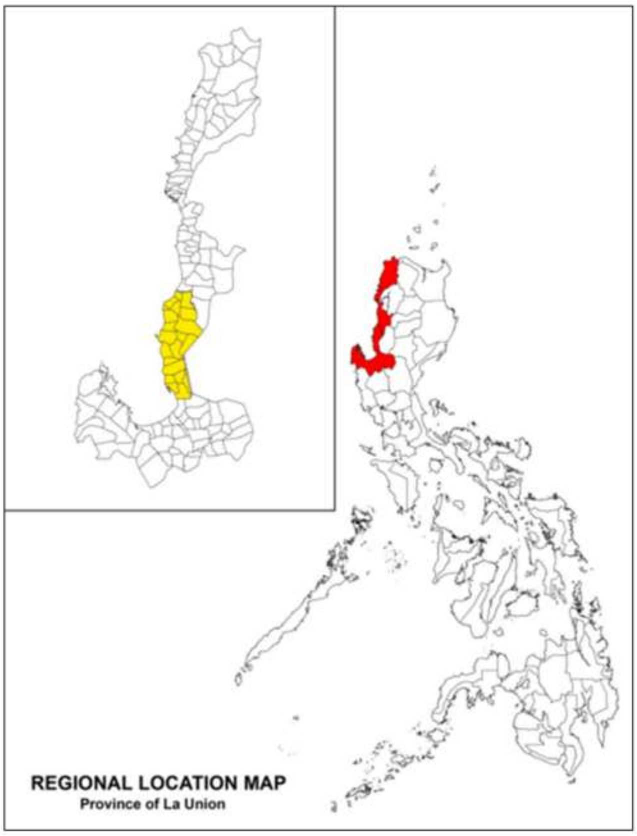


Figure 1. *Regional Location Map*

La Union, characterized predominantly by its hilly terrain, possesses abundant surface and groundwater resources suitable for agriculture and domestic use. According to its Provincial Development & Physical Framework Plan (PDPFP), the province has a total of 45, 790.5 hectares municipal waters available for marine fishery production with a coast of 114, 702 linear meters lie on the coastline from Rosario to Bangar. La Union is also delineated into five (5) major basins, including the expansive Amburayan River basin, which extends along the boundaries of La Union and Ilocos Sur. Other significant basins include those of the Aringay, Baroro, Naguilian, and Bued Rivers.

Furthermore, the province is divided into two (2) congressional districts. The District I, which covers 70,069 hectares, accounting for 46.93% of the province's total area and 5.46%of the region's area, San Gabriel holds the largest share with 10.38%(15,500 hectares), followed by San Fernando City with 10,688 hectares, while Luna has the smallest area at approximately 3.0%. Meanwhile, District II encompasses 79,240 hectares, comprising 53.07% of the province's area and 6.17%of the region's area, with Bagulin occupying the largest area at 14,762 hectares, followed by Aringay with 12,207 hectares, and Sto. Tomas with the least at 3,242 hectares. The province includes the second smallest number of municipalities and barangays in the region, with jurisdiction over one city and 19 municipalities, representing 16.39% of the region, and 576 barangays, which account for 17.76% of the region's total.

The province consists of two distinct seasons: the wet season, characterized by abundant rainfall from the southwest monsoon, and the dry season, marked by significantly lower rainfall due to the northeast monsoon passing over the Cordillera Mountains.

Land Use and Land Use Classification

As shown in Table 1, the existing predominant utilization of land area of the province is for agricultural activities. Agricultural areas encompass 54,701 hectares, comprising 36.64% of the total land area. These areas are mainly on the western side, including broad alluvial plains, valleys, and hills. In contrast, the eastern part, which includes the municipalities of Bagulin, Naguilian, and Rosario, features rice terraces. Irrigated rice lands are prevalent in low-lying areas such as Bangar, Balaoan, Agoo, and Rosario, whereas non-irrigated rice lands are found in flat alluvial plains, valleys, and river terrains across various municipalities.

On the other hand, the grassland and shrubland areas cover 22,834 hectares, constituting 15.59% of the total land area. These areas, dominated by cogon grass and various shrub species, are mostly located on sedimentary hills and mountains, particularly those with moderate to very steep slopes. Forest and wooded areas occupy 46,598 hectares, representing 31.21% of the total land area. These areas are characterized by diverse forest species, primarily located in the highest portions of mountain ranges near the boundary with Ilocos Sur and Benguet province.

Table 1. *Existing land use distribution of La Union*

Land Use	Area (Hectares)
Agricultural Areas	54,701
Forest/Wooded Areas	46,249
Grass/Shrubland Areas	22,834
Built-up Areas	15,555
Other Areas	9,621

Source: *La Union's PDPFP*

La Union has two major land use classifications namely alienable and disposable (A&D) lands and the public forestlands. A & D lands cover 120,307 hectares, constituting 80.58% of the total land area, while public forestlands occupy 19.43%. Balaoan, Bangar, and Luna are entirely classified as A & D lands. In District I, San Gabriel boasts the largest A & D land area with 10,938 hectares, whereas San Juan has the smallest at 3,788 hectares. Among the municipalities in District I, San Gabriel also holds the highest proportion of public forestlands at 43.5%. In District II, Naguilian features the largest A & D land area with 8,116 hectares, while Burgos has the smallest at 2,553 hectares. Bagulin has the largest share of public forestlands in District II, comprising 76.29% or 11,262 hectares, followed by Aringay with 8,288 hectares.

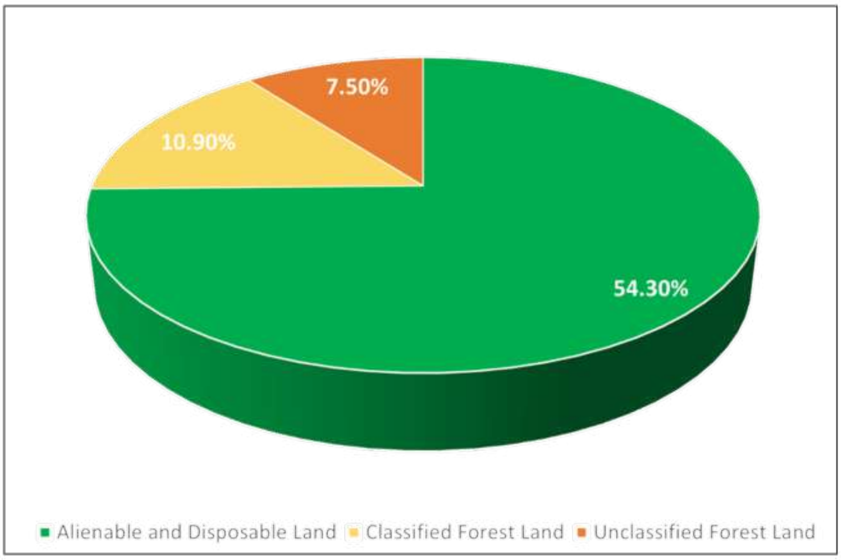


Figure 2. *Status of Land Classification*

Population

La Union, a province with land area of 1,499.28 square kilometers or 578.88 square miles. According to the 2020 Census of Population and Housing (CPH), La Union had a total population of 822,352, with a household population of 99.8% or 820, 343 persons. Its population is 15.51% of the total population of the Ilocos Region, 1.32% of the overall population of the Luzon Island group, or 0.75% of the entire population of the Philippines.

Table 2. *2015 Population, 2020 Population, Annual Population Growth Rate (2015-2020) and Population Density*

Municipality	2015 Population	2020 Population	Annual Population Growth Rate (2015-2020)	Density (2020) km^2
Agoo	63,692	66,028	0.76%	1,250
Aringay	47,458	50,380	1.27%	596
Bacnotan	42,078	44,388	1.13%	568
Bagulin	13,456	14,428	1.48%	134
Balaoan	39,188	40,339	0.61%	587
Bangar	35,947	38,041	1.20%	1,018
Bauang	75,032	78,449	0.94%	1,072
Burgos	8,067	9,006	2.35%	127
Caba	22,039	23,119	1.01%	499
Luna	35,802	37,318	0.88%	870
Naguilian	54,221	52,189	-0.80%	499
Pugo	19,690	19,337	-0.38%	308
Rosario	55,458	60,278	1.77%	815
San Fernado	121,812	125,640	0.65%	1,223
San Gabriel	18,172	18,943	0.88%	146
San Juan	37,188	40,507	1.82%	709
Santo Tomas	39,092	40,846	0.93%	638
Santol	12,476	14,166	2.71%	151
Sudipen	17,056	17,187	0.16%	176
Tubao	28,729	31,763	2.14%	626

Economy

As of 2022, La Union ranked second in the Ilocos region's Gross Regional Domestic Product, contributing 118.60 billion pesos or 18.1%. Its economy grew by 7.7%, achieving a Gross Domestic Product (GDP) of PHP 118.60 billion at constant 2018 prices. The per capita GDP also saw a notable increase of 6.8% in 2022. The province's economic profile demonstrates a dynamic and diverse economy, driven by a robust mix of agriculture, manufacturing, and unique local industries. Its ability to leverage its diverse resources and strategic initiatives underlines its economic resilience and growth potential.

In 2014, the province had 8,476 establishments. The province's manufacturing sector includes significant entities such as HOLCIM Cement Factory in Bacnotan, Coca-Cola and Pepsi Cola Plants, and various tobacco redrying and flue-curing plants. Additionally, La Union hosts a steel corporation, an ice plant, agricultural product suppliers, and fuel depots for major companies like Pilipinas Shell, Petron, and Caltex.

Agriculture remains a vital component of La Union's economy. In 2015, the province produced 12,381 metric tons of rice, generating PHP 1.827 billion, and 1,238 metric tons of corn, generating PHP 229.7 million. High-value crops yielded 4,378 metric tons, resulting in PHP 4.693 billion, and the fisheries sector produced 18,087.53 metric tons, generating PHP 1.684 billion.

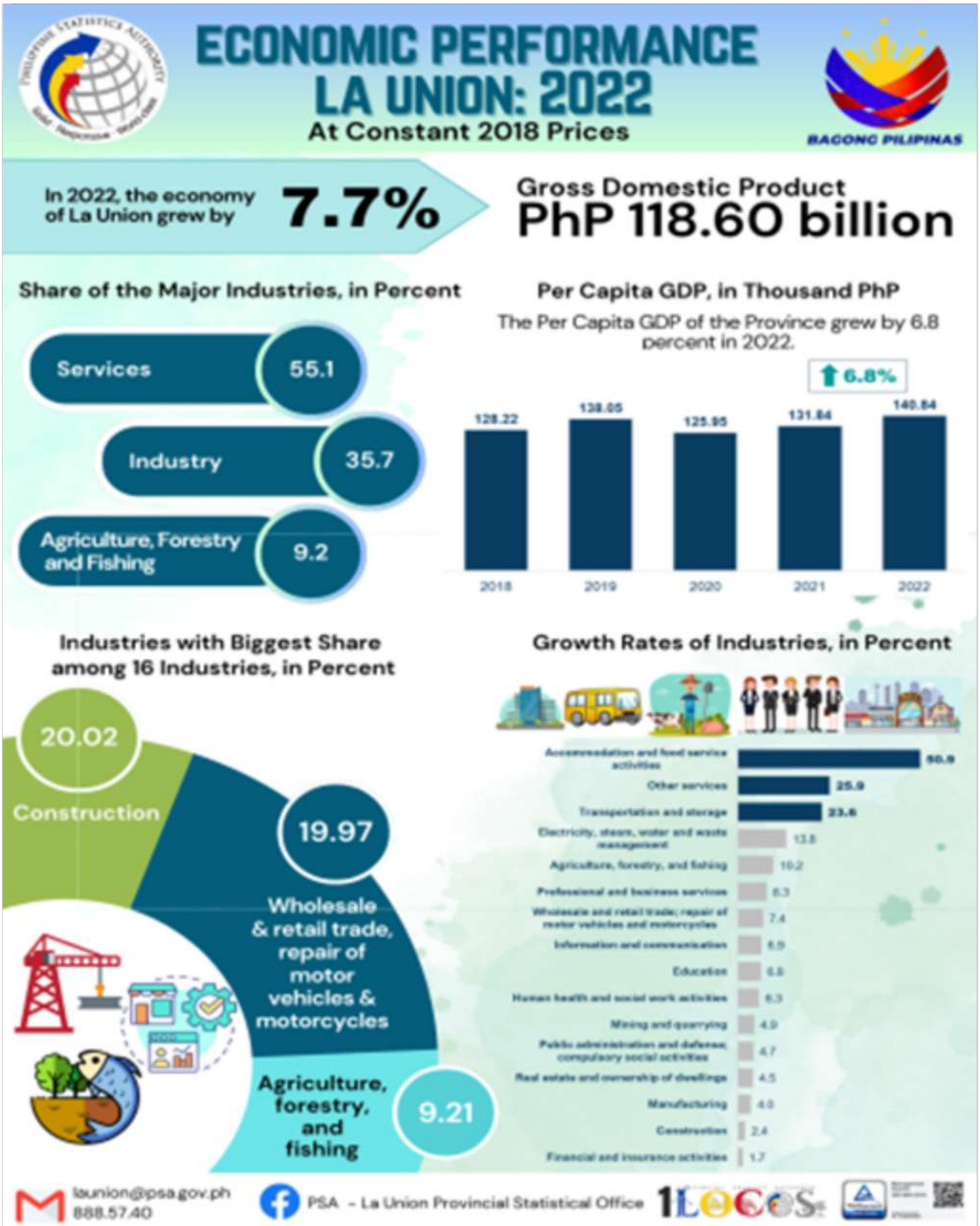


Figure 3. *Economic Performance of La Union*

Inventory Boundaries

This section details the scope and limitations of the inventory report according to the following inventory boundary parameters: geographic boundary, base year, GHGs, GHG emission sources, scopes.

Geographic boundary. The official administrative boundary of La Union Province has been adopted in this inventory report. This includes the one (1) city and nineteen (19) municipalities that comprise the province.

Base year. The year 2023 has been selected as the base year for this inventory report. It is the most recent normal year of the province as of the inventory formulation.

GHGs. The GHGs covered in this inventory report are carbon dioxide (CO2), methane (CH4), nitrous oxide (N2O).

Global Warming Potential (GWP). The GWP values used in the calculation of the emissions is from the IPCC 5th Assessment Report.

GHG emission sectors/sources. The GHG emission sources in this inventory report include stationary energy, on-road transportation, solid waste, wastewater, livestock production, rice production, industrial processes, and forest removals.

Scopes. Scope 1 (territorial) and Scope 2 (purchased electricity) emissions were accounted for in this inventory.

Image from Wikimedia Commons

GHG Inventory Results

This section presents La Union Province's estimated community-level GHG emissions, discussing in turn:

- Stationary energy
- On-road transportation
- Solid waste
- Wastewater
- Industrial processes
- Livestock management
- Rice production
- Forest removals

Each GHG emission source/sector will present the activity data, emission factor and emissions calculation methodologies used as well as the estimated GHG emissions expressed in tonnes of CO_2 equivalent (tCO_2e).

Stationary Energy

Stationary energy sources are energy systems that are fixed in place and GHG emissions are caused by fuel combustion as well as fugitive emissions released in the process of generating, delivering, and consuming useful forms of energy such as electricity. These sources are one of the largest contributors to a city's GHG emissions. This inventory report shall present two subsets of stationary energy – stationary fuel use and electricity consumption.

Stationary Fuel Use

Activities considered under stationary fuel use include fuel consumption for cooking, lighting, heating, and cooling by households and commercial and industrial establishments. This can also include fuel consumption of machinery and generator sets.

Activity Data

There was no municipal-level and provincial-level data obtained during the data collection activities due to the absence of survey activities. The individual LGUs may not have performed survey activities due to lack of financial resources and personnel dedicated for the conduct of this inventory. Therefore, regional-level (Region 1) data was requested from the Department of Energy – Energy Utilization and Management Bureau (DOE-EUMB). The DOE-EUMB provided the total energy consumption of designated establishments in Region 1. As provided under the Energy Efficiency and Conservation Act (RA 11285), private entities are classified as designated establishments depending on their annual electricity consumption. Likewise, they have mandatory obligations including submission of Annual Energy Utilization Report (AEUR) to the DOE. Population data was used to downscale regional to provincial stationary fuel consumption using the formula below.

Provincial fuel use = (Region 1 fuel use ÷ Region 1 population) x La Union Province population

Where:

- Region 1 fuel use refers to the total energy consumption per fuel type by designated establishments in Region 1, according to the data provided by DOE-EUMB

- Region 1 population refers to the projected population of Region 1 – 5,438,928.26 - based on the data by the Philippine Statistics Authority (2020)

- La Union Province Population refers to the projected population of the province – 846,396 - based on the data by the Provincial Government (2024) accessible via https://launion.gov.ph/quick-facts/.

Table 3: *Stationary fuel use of industrial and commercial sector of La Union Province, 2023*

Fuel Type	Fuel Use (Industrial)	Fuel Use (Commercial)	Unit
Diesel	498,826.29	23,870.59	liters
Liquefied petroleum gas (LPG)	183,114.98	-	liters
Residual fuel oil	2,305,103.03	-	

Meanwhile, the residential fuel use data was also obtained from the Philippine Energy Situationer 2022 by the DOE. The national-level data was downscaled using population as scaling factor using the formula below. It is assumed that the same degree of fuel use might be similar for 2023.

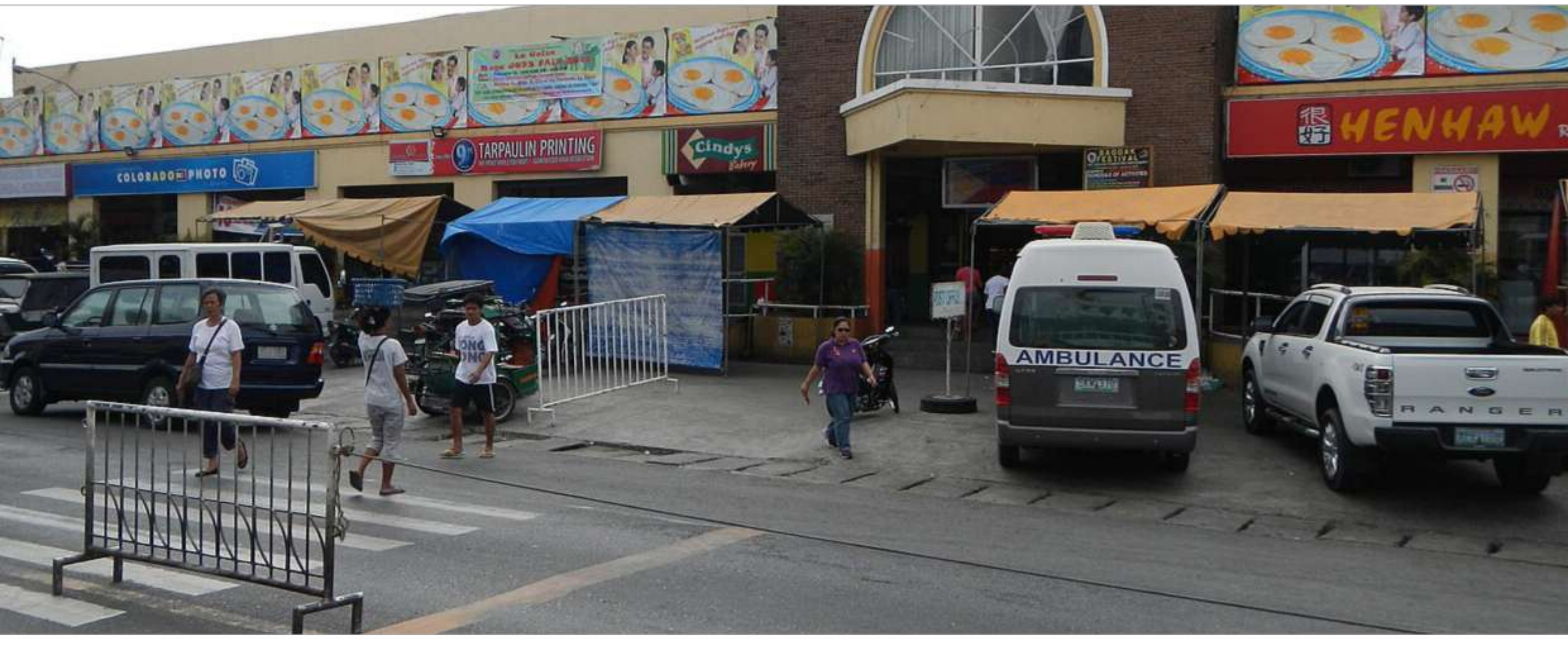
Provincial fuel use = (National fuel use ÷ National population) x La Union Province population

Where:

- National fuel use refers to the stationary fuel use of the residential sector, according to the data from the Philippine Energy Situationer (DOE, 2022)
- National population refers to the projected population of the Philippines – 11,683,844.34 - based on the data by the Philippine Statistics Authority (2020)
- La Union Province Population refers to the projected population of the province – 846,396 - based on the data by the Provincial Government (2024) accessible via https://launion.gov.ph/quick-facts/.

Table 4. *Stationary fuel use of residential sector of La Union Province, 2023*

Fuel Type	Residential	Unit
Kerosene	341,032.49	kilogram
Liquefied petroleum gas (LPG)	9,852,049.76	kilogram
Charcoal	10,049,090.76	kilogram
Fuelwood	31,602,344.23	kilogram



Emission Factors

Table 5 shows the emission factors used in the computation of GHG emissions from stationary fuel use of the activities mentioned above.

Table 5. *Emission factors for stationary fuel use*

Fuel Type	Emission Factors			Unit
	CO_2	CH_4	N_2O	
Blended Diesel Industrial (Philippines)	2.66E+00	1.09E-04	2.18E-05	Kg/l
Blended Diesel Residential/ Commercial (Philippines)	2.66E+00	4.00E-04	2.18E-05	Kg/l
Charcoal (Biomass, International)	3.30E+00	5.90E-03	2.95E-05	Kg/kg
Kerosene (International)	2.52E+00	3.50E-04	2.10E-05	Kg/l
Propane or Liquefied Petroleum Gases (International)	2.98E-03	2.37E-07	4.73E-09	Kg/kg
Residual Fuel Oil (International)	2.94E+00	3.80E-04	2.28E-05	Kg/l
Wood or Wood Waste (Biomass, International)	1.75E+00	4.68E-03	6.24E-05	Kg/kg

Source: *WRI/WBCSD GHG Protocol Emission Factors From Cross-Sector Tools (Excel Workbook). Version 1.3, August 2012. Tables 1-3. - IPCC 2006 Guidelines for National Greenhouse Gas Inventories, http://www.ipcc-nggip.iges.or.jp/public/2006gl/vol2.html; IPCC 2006 Guidelines for National GHG Inventories, Volume 2, Chapter 1, http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/2_Volume2/V2_1_Ch1_Introduction.pdf*

Calculation Results

Table 6 shows the total estimated GHG emissions from stationary fuel use in La Union Province which amounted to 132,807.329 tCO2e. This is mostly due to residential consumption which makes up 72.07% of the total emissions from stationary fuel use compared to just 28.05% for commercial and industrial consumption combined.

Wood or wood waste accounted for the highest emissions with 45.09% of the total emissions in the stationary fuel use source. The significant amount of carbon stored in wood and wood waste, when burned, releases a substantial amount of CO_2. Therefore, the high use of this biomass fuel contributes to its elevated emission levels. This might be attributed to the use of wood for traditional cooking by households due to its availability and low cost. This might also be attributed to agricultural waste burning in the province. Charcoal yielded the second highest emissions with 26.31% of the total emissions in the stationary fuel use source. Like wood, charcoal combustion releases much CO_2 and other GHGs. Charcoal is also commonly used for cooking by many households and restaurants due to its affordability and ease of use.

Meanwhile, the propane or liquefied petroleum gases (LPG) yielded the lowest GHG emissions with only 0.03% of the total emissions in the stationary fuel source. Propane and LPG have lower carbon content compared to other fossil fuels, resulting in lower CO_2 emissions per unit of energy produced, despite the remarkably high usage of this fuel among households and industries in the province. They are also more efficient in combustion. LPG is widely used for cooking among households due to its cleaner combustion compared to wood or charcoal. These might also be used in restaurants and small businesses for heating and cooking. Blended diesel for residential and commercial as well as industrial sectors also yielded lower emissions with a share of 0.05% and 22.75% of the total emissions in the stationary fuel source, respectively. The lower emissions from blended diesel can be attributed to its lower consumption volume and possibly higher efficiency in smaller-scale applications. The use of blended diesel might be for backup power supply by generator sets, used in smaller industrial applications that require less fuel compared to large industrial operations, and/or used in tractors and other agricultural equipment.

Table 6. *Total estimated GHG emissions of stationary fuel use, 2023*

Fuel Type	Estimated GHG Emissions			Total GHG Emissions	Unit
	tonnes CO2	tonnes CH4	tonnes N2O		
Industrial					
Blended Diesel Industrial (Philippines)	1,325.88	0.05	109.00	30,212.40	tCO2e
Propane or Liquefied Petroleum Gases (International)	0.55	0.00	0.00	0.55	tCO2e
Residual Fuel Oil (International)	6,775.49	0.88	0.05	6,813.90	tCO2e
			Total	37,026.85	tCO2e
Commercial					
Blended Diesel Residential/ Commercial (Philippines)	63.45	0.01	0.00	63.86	tCO2e
			Total	63.86	tCO2e
Residential					
Kerosene (International)	859.19	0.12	0.01	864.42	tCO2e
Propane or Liquefied Petroleum Gases (International)	29.40	0.00	0.00	29.48	tCO2e
Charcoal (Biomass, International)	33,202.20	59.30	0.30	34,941.04	tCO2e
Wood or Wood Waste (Biomass, International)	55,215.62	148.00	1.97	59,881.67	tCO2e
			Total	95,716.61	tCO2e
			Total Estimated GHG Emissions	132,807.32	tCO2e

Electricity Consumption

GHG emissions from electricity consumption are classified as indirect or Scope 2 emissions. La Union Province's electricity is distributed by La Union Electric Cooperative, Inc. (LUELCO) and La Union Electric Company, Inc. (LUECO).

Activity Data

Provincial-level data on electricity consumption was obtained from both LUELCO and LUECO. The activity data are presented per LGU and customer type – residential, commercial, industrial, and institutional – in the table below. The institutional category covers electricity use from public buildings, streetlights, water systems, and hospitals.

Table 7. *Electricity consumption of La Union Province, 2023*

No.	City/ Municipality	Electricity Consumption in kWh			
		Residential	Commercial	Industrial	Institutional
1	Agoo	22.258.144,36	8.828.799,19	6.576.481,04	3.431.411,10
2	Aringay	13.503.618,13	3.413.124,12	541.180,50	1.203.877,39
3	Bacnotan	16.894.885,13	3.074.961,80	1.084.150,20	2.726.931,36
4	Bagulin	1.212.455,37	224.404,29	22.156,00	189.422,03
5	Balaoan	11.561.741,75	1.725.398,72	81.559,60	1.520.233,36
6	Bangar	10.685.893,55	1.900.787,86	45.342,00	1.060.807,34
7	Bauang	33.937.684,99	17.204.115,80	298.634,00	1.271.317,90
8	Burgos	1.292.331,44	145.814,80	-	212.335,90
9	Caba	6.759.753,81	1.300.992,70	43.104,00	700.449,10
10	Luna	10.535.827,40	1.390.560,13	102.975,00	854.698,90
11	Naguilian	15.193.593,43	2.970.365,16	472.384,10	1.928.342,89
12	Pugo	5.676.984,40	1.473.215,70	-	449.529,82
13	Rosario	13.769.938,25	6.223.404,26	15.854.860,16	1.645.038,78
14	San Fernando	80.352.993,02	63.558.280,80	23.006.927,00	11.933.845,20
15	San Gabriel	2.376.187,85	648.277,50	-	283.304,07
16	San Juan	19.876.015,17	12.740.615,60	1.413.300,00	935.587,69
17	Sto Tomas	11.953.615,60	2.603.129,25	109.845,40	620.392,60
18	Santol	1.881.754,04	150.613,24		377.998,67
19	Sudipen	3.747.327,54	639.283,70	149.491,80	482.953,93
20	Tubao	7.585.777,59	1.847.090,74	1.038.165,00	945.531,50
	Total	**291.056.522,82**	**132.063.235,36**	**50.840.555,80**	**32.774.009,53**

Emission Factors

The Philippine default values for emission factors in estimating emissions for electricity consumption were used. The default values entail GHG intensity for electricity-specific consumption which includes transmission and distribution losses and excludes heat generation.

Table 8. *Emission Factors for Residential, Commercial & Industrial Electricity Consumption*

Country/Regional Grid	GHG Emission Factor in tCO2/MWh
	CO2
Philippines	0.609

Source: *Department of Energy. National Grid Emission Factor for 2019-2021. Access via https://doe.gov.ph/sites/default/files/pdf/announcements/2019-2021-National-Grid-Emission-Factor.pdf*

Calculation Results

The estimated GHG emissions of electricity consumption is 351,420.25 tCO2e. More than half of these emissions (57%) are from the residential sector. This was followed by the commercial and industrial sector as well as the institutional sector with 36% and 6% of the total emissions of power use respectively.

The residential sector has a total GHG emissions of 201,847.70 tCO2e. Most of the emissions are from the San Fernando City (28%) and Bauang (12%) which are the two most populous LGUs in the province. As such, they lead to increased electricity consumption for residential activities such as lighting, cooling, and use of electrical appliances.

The commercial and industrial sectors have a total estimated GHG emissions of 126,843.78 tCO2e. Most of the emissions come from San Fernando City (47%) which is the province's capital and where commercial establishments of varying scales aggregate. This is followed by Rosario and Bauang with emissions share of 12% and 10% respectively. Continuous operation of commercial establishments such as malls, shops, and restaurants require significant electricity for lighting, refrigeration, and air conditioning. Office buildings could also generate high electricity usage due to lighting, computers, and HVAC systems. Conversely, Bagulin, Burgos, and San Gabriel yielded the least emissions. This is possibly due to fewer commercial and industrial establishments or lower energy demands from existing businesses.

The institutional sector has a total estimated GHG emissions of 22,728.78 tCO2e. Most of the emissions come from San Fernando City (36%). As the seat of capital of the province, most of the government offices and services can be found in San Fernando City. Interestingly, Agoo (10%) comes second as the LGU with the highest emissions in power use in the institutional sector. These LGUs could be housing many institutional facilities such as schools, hospitals, and government buildings, which consume significant electricity for various functions. For example, educational institutions might have significant power use due to lighting, laboratory equipment, and HVAC systems while healthcare services like hospitals and clinics require continuous operation of medical equipment, lighting, and climate control. On the other hand, Bagulin, Burgos, Pugo, and San Gabriel had the least emissions share. This might be due to fewer institutional buildings and lower operational hours or energy-efficient practices.

Table 9. *Total estimated GHG emissions of electricity consumption of residential sector, commercial and industrial, and institutional sectors, 2023*

City/Municipality	Estimated GHG Emissions in tCO2e		
	Residential	Commercial & Industrial	Institutional
Agoo	15.436,02	10.683,56	2.379,68
Aringay	9.364,76	2.742,31	834,89
Bacnotan	11.716,60	2.884,34	1.891,13
Bagulin	840,84	170,99	131,36
Balaoan	8.018,07	1.253,13	1.054,28
Bangar	7.410,67	1.349,64	735,67
Bauang	23.535,78	12.138,16	881,66
Burgos	896,23	101,12	147,25
Caba	4.687,89	932,13	485,76
Luna	7.306,60	1.035,77	592,73
Naguilian	10.536,76	2.387,55	1.337,31
Pugo	3.936,99	1.021,68	311,75
Rosario	9.549,45	15.311,28	1.140,83
San Fernando	55.724,80	60.032,97	8.276,12
San Gabriel	1.647,89	449,58	196,47
San Juan	13.784,02	9.815,74	648,83
Sto Tomas	8.289,83	1.881,45	430,24
Santol	1.305,00	104,45	262,14
Sudipen	2.598,77	547,02	334,93
Tubao	5.260,74	2.000,92	655,73
Total	201.847,70	126.843,78	22.728,78

On-road Transportation

On-road vehicles move people and goods on public roads, thoroughfares, or highways. These vehicles include buses, cars, trucks, motorcycles, etc. Most vehicles burn liquid or gaseous fuel in internal combustion engines and in turn, produce CO_2. Electric or hybrid vehicles charge their units in their own spaces or in designated communal charging stations and therefore consumer electricity and are therefore not included here.

Activity Data

The methodologies for estimating transport emissions can be broadly categorized into two approaches – top-down and bottom-up. Top-down approaches start with fuel consumption as proxy for travel behavior. Meanwhile, bottom-up approaches begin with detailed activity data and rely on ASIF framework for determining total emissions. The ASIF framework relates travel activity, the mode share, energy intensity of each mode, fuel, and vehicle type, and carbon content of each fuel to total emissions.

Due to challenges in data availability, the top-down approach is recommended for this inventory report. Municipal- and provincial-level data were not obtained. Therefore, the on-road transport fuel consumption data was also obtained from the Philippine Energy Situationer 2022 by the DOE. The national-level data was downscaled using population as scaling factor using the formula below. It is assumed that the same degree of fuel use might be similar for 2023.

Provincial fuel use = (National fuel use ÷ National population) x La Union Province population

Where:

- National fuel use refers to the on-road transportation fuel use, according to the data from the Philippine Energy Situationer (DOE, 2022)
- National population refers to the projected population of the Philippines – 11,683,844.34 - based on the data by the Philippine Statistics Authority (2020)
- La Union Province Population refers to the projected population of the province – 846,396 - based on the data by the Provincial Government[i] (2024).

To convert the fuel consumption from kilograms to liters, the following formula was used.

Amount of fuel in liters = Amount of fuel in kilograms ÷ Fuel density

Where:

- Amount of fuel in kilograms refers to the on-road transportation fuel consumption data derived from the Philippine Energy Situationer (DOE, 2022)
- Fuel density was assumed to be as in Table 10.

Table 10. *Fuel density per fuel type*

Fuel Type	Fuel Density (kg/l)	Source
Gasoline	0.75	EUBIA access via https://www.eubia.org/cms/wiki-biomass/biofuels/bioethanol/
Diesel	0.83	Guo et al. 2016 access via https://www.researchgate.net/figure/Density-of-biodiesel-diesel-fuel-blends_fig1_307547973
Bioethanol	0.81	EUBIA access via https://www.eubia.org/cms/wiki-biomass/biofuels/bioethanol/
Biodiesel	0.88	Guo et al. 2016 access via https://www.researchgate.net/figure/Density-of-biodiesel-diesel-fuel-blends_fig1_307547973

Table 11. *On-road transportation fuel use of La Union Province, 2023*

Fuel Type	Fuel Consumption	Unit
Gasoline	28,447.793.68	liters
Diesel	34,872,618.47	liters
Bioethanol	2,498,404.03	liters
Biodiesel	733,598.78	liters

Emission Factor

Table 12 shows the emission factors used in the computation of GHG emissions from on-road transportation fuel use.

Table 12. *Emission factors per fuel type for on-road transportation*

Fuel Type	Fuel Consumption	Unit
Gasoline/Petrol	2,27	Kg/l
On-Road Diesel Fuel	2,68	Kg/l
E85 Ethanol/Gasoline	1,47	Kg/l
100% Biodiesel	2,50	Kg/l

Source: *CO2 emission factors derived from WRI/WBCSD GHG Protocol Emission Factors from Cross-Sector Tools. Table 10 'CO2 Emission Factors by Fuel', Version 1.3. August, 2012. See tab entitled "Transport Fuel Use".*

Calculation Results

The total estimated GHG emissions for on-road transportation is 158,176 tCO2e. Diesel fuel yielded the highest emissions share likely due to it having the highest consumption among all the fuel types. Moreover, diesel fuel has a high carbon content, leading to substantial CO2 emissions per unit of fuel burned. Diesel engines emit significant amounts of CO2, especially from heavy-duty vehicles like trucks and buses that consume large quantities of diesel. Gasoline has yielded the second highest emissions share, likely due to it having the second highest amount of consumption among all the fuel types. Gasoline has a lower carbon content than diesel fuel, which means it produces less CO2 per liter when burned. Furthermore, gasoline is primarily used in lighter vehicles such as cars and motorcycles, which are more common. This widespread use across many smaller vehicles results in lower total emissions per vehicle compared to the fewer but heavier vehicles like trucks and buses that predominantly use diesel.

__Table 13.__ Total estimated GHG emissions of on-road transportation fuel use, 2023

Fuel Type	Total GHG Emissions	Unit
Gasoline/Petrol	64,620.50	tCO2e
On-Road Diesel Fuel	93,330.60	tCO2e
E85 Ethanol/Gasoline	224.90	tCO2e
100% Biodiesel	0.00	tCO2e
Total	**158,176.00**	**tCO2e**

The waste sector is an important GHG emission sector because of its direct relevance to the lives of citizens through waste generation and disposal. The LGUs, through their dedicated Solid Waste Management Office (SWMO), is mandated to provide appropriate waste collection and disposal services as well as to implement policies and programs to improve the overall waste management in the city.

Waste disposal and treatment produces GHG emissions (CH_4 and N_2O) through aerobic and anaerobic decomposition or incineration. There are two major sub-sectors measured when estimating GHG emissions in this sector – solid waste and wastewater.

Solid Waste

Municipal solid waste generated within the city is collected by the SWMOs. The wastes collected are characterized by the following composition: food waste, garden waste, paper and cardboard, textiles, disposal diapers, rubber, plastics, glass, among others. These collected wastes are disposed to the landfills located within the province's boundaries.

Activity Data

According to the data of the La Union Province 10-Year Solid Waste Management Plan CY 2024-2033, the average daily per capita waste generation in the country is 0.36 kg. Assuming that the projected population of the 20 LGUs of La Union Province is 846,396, the estimated annual waste generation of the province is 110,598.56 tonnes.

0.1307 tonnes x 846,396 = 110,598.56 tonnes

Where:

- 0.1307 tonnes refers to the average solid waste generation per capita per year
- 846,396 refers to the projected 2023 population of La Union Province

According to La Union Province 10-Year Solid Waste Management Plan CY 2024-2033, 74.83% of solid waste generated are diverted from the landfills, hence, about 25.17% of the solid wastes are picked up by collected for disposal to the landfill sites within the province's boundaries. Therefore, the estimated solid waste disposed to landfills is 27,782.36 tonnes per year.

Emission Factors

To arrive at the methane emissions generated from solid waste disposal to landfill of the province, the degradable organic carbon (DOC) of the solid waste shall be first determined. The DOC can be determined from the composition of solid waste being disposed. Due to the absence of actual breakdown of solid waste composition of La Union Province, the default values for Southeast Asia by the IPCC were used instead.

Table 14. *Degradable organic carbon (DOC) in tonnes*

Waste Type	Waste Composition % - default IPCC values for Southeast Asia may be changed to custom values	Waste Amount (tonnes)	Degradable Organic Carbon (DOC, %) - default IPCC values may be changed to custom DOCs	Degradable Organic Carbon (DOC, tonnes)
Paper/ Cardboard	12,90%	3,583.92	40,00%	1,433.57
Textiles	2,70%	750.12	24,00%	180.03
Food Waste	43,00%	11,946.41	15,00%	1,791.96
Wood	9,90%	2,750.45	43,00%	1,182.70
Garden/Park	0,00%	-	20,00%	-
Nappies/Diapers	0,00%	-	24,00%	-
Sewage/Sludge	0,00%	-	5,00%	-
Rubber/Leather	0,90%	250.04	39,00%	97.52
All other, Inerts (Plastics, Metals, Glass, Ash, and all inter material with a DOC = 0)	30,10%	8,362.49	0,00%	-
			Total (DOC, tonnes)	4,685.77

The next step is to determine the DOC that degrades (DOCf) that is generated. This is determined by multiplying the DOC by the percentage of DOCf with 60% as the default value and by the impact of waste site with 100% as DOCf formation default value. Therefore, the DOCf generated 2,670.89 tonnes of carbon.

Table 15. *DOC that degrades*

DOC that Degrades (DOCf)	**% DOC that degrades - default**	60.00%
	Type of Landfill Site	Managed - anaerobic
	Impact of waste site - % DOCf formation default value	95.%
	DOCf generated (tonnes C)	**2,670.89**

Calculation Results

After determining the DOCf, the next step is to determine the methane generated. This is achieved by multiplying the DOCf by the % DOCf that is methane which is 50% as the default value and by the carbon to methane conversion rate of 1.33. This yields methane generation of 1,776.14 tonnes of CH4. To convert this into its CO2 equivalent, we multiply the methane generated by GWP value of methane which is 28. Therefore, the estimated GHG emissions for solid waste disposal to the landfills is 49,731.98 tCO2e.

Table 16. Total estimated GHG emissions of solid waste disposal to landfill, 2023

Methane Generated	**% DOCf that is Methane - default**	50.00%
	C to CH4 conversion factor	1.33
	CH4 Generated (tonnes)	1,776.14
Global Warming Potential		28
Total GHG Emissions	**tCO2e**	49,731.98

Food waste, paper/cardboard, and wood have significant amounts of DOC which breaks down anaerobically in landfills to produce methane, a potent GHG. Food waste may have come from excess food purchased and not consumed by households, restaurants, and markets. Losses during harvest and post-harvest handling also contribute to food waste. Extensive use of paper and cardboard for packaging in commercial and retail sectors may also contribute to the methane emissions associated with paper/cardboard. Additionally, there might also be a high volume of paper waste generated in offices and institutions. Wood disposal may have come from construction sites and demolition activities as well as disposal of old or broken wood furniture and household items.

Wastewater

This section examines the GHG emissions generated from the treatment and management of domestic wastewater. This section provides data on CH4 emissions from various residential wastewater treatment processes.

Activity Data

Based on the data of the Environmental Health and Sanitation Report of the Provincial Health Office (2023), it is assumed that 89.49% of the total household population[1] of the 20 LGUs which is equivalent to 217,528, has access to septic tanks as their wastewater management system.

Emission Factor

The following default values were used to estimate CH4 emissions of the province's domestic wastewater sector.

Table 17. Wastewater IPCC default values

		Uncollected	Collected	Units	Reference Source
IPCC Defaults	Per capita BOD generation	40,00	40,00	gBOD/ person/ day	IPCC default, Asia. Source: IPCC 2006 guidelines vol. 5, chapter 6, table 6.4 page6.14
	Correction factor for industrial BOD dischargers in sewers	1,00	1,25	index	IPCC default. Source IPCC 2006 guidelines vol. 5, chapter 6, page 6.14
	Sludge removal (S)	0,00	0,00	%	IPCC default. Source IPCC 2006 guidelines vol. 5, chapter 6, page 6.9
	Methane recovery (R)	0,00	0,00	%	IPCC default. Source IPCC 2006 guidelines vol. 5, chapter 6, page 6.9

[1] It is assumed that an average household has four (4) residents.

Table 18. *Wastewater default values*

		Uncollected	Collected	Units	Reference Source
Factors used in Calculation (Default or LGU-Specific Factors) - user may input custom (e.g. LGU-specific) factors	Per capita BOD generation (per day)	40,00	40,00	gBOD/ person/ day	to use LGU, regional or country specific data if available ,
	Per capita BOD generation (per year)	14,60	14,60	kgBOD/ person/ year	to use LGU, regional or country specific data if available ,
	Correction factor for industrial BOD dischargers in sewers	1,00	1,25	index	to use LGU, regional or country specific data if available ,

Calculation Results

To determine the CH4 emissions from the use of septic tanks as residential wastewater management system, the estimated TOW producing CH4 is first determined. The estimated TOW producing CH4 is multiplied with the CH4 emission factor to arrive at the CH4 created. The CH4 recovered, if applicable, is subtracted from CH4 created to arrive at the CH4 emitted. The total estimated emissions of the use of septic tanks as residential wastewater management system is 26,677.63 tCO2e. The detailed calculation is outlined in the table below. Municipalities with a higher population density typically generate more wastewater. This leads to higher levels of Biochemical Oxygen Demand (BOD) in the wastewater, resulting in increased CH4 emissions from septic tanks. The absence of sludge removal or methane recovery exacerbates the emissions.

Table 19. *Total estimated GHG emissions of wastewater management system, 2023*

Population	217,528
Estimated TOW residential (kgBOD/year) Population x Per capita BOD generation (per day) x Per capita BOD generation (per year)	3,175,908.80
Sludge removed (S) (kgBOD/year) Estimated TOW residential x % Sludge removed	0.00
% Sludge removed (kgBOD/year)	0.00
Estimated TOW producing CH4 (kgBOD/year) Estimated TOW residential - Sludge removed (S)	3,175,908.802
Emission factor (kgCH4/kgBOD)	0.30
CH4 created (kgCH4) Estimated TOW producing CH4 x Emission factor	952,772.64
CH4 recovered (kgCH4) CH4 created x % CH4 recovered	0
CH4 emitted (kgCH4) CH4 created - CH4 recovered	952,772.64
GWP CH4	28
CH4 emitted (kgCO2e) CH4 emitted x GWP	26,677,633.92
CH4 emitted (tCO2e) CH4 emitted (kgCO2e) / 1000	26,677.63

Industrial Processes

Industrial processes are significant sources of GHG emissions, arising from both the combustion of fossil fuels for energy and specific chemical reactions inherent in industrial activities. Unlike energy-related emissions, which primarily result from fuel combustion, emissions from industrial processes are often the by-products of physical or chemical transformations. Key sectors contributing to these emissions include cement production, steel manufacturing, chemical production, and mining, where materials such as limestone, iron, and chemicals are processed or refined. The nature and scale of these emissions vary depending on the type of industry, the technologies used, and the materials processed.

A cement production company is the sole high-emitting industry in La Union Province; therefore, this shall be the focus of this section.

Activity Data

There is only one high-emitting industry in the province, which is a mineral industry, particularly, cement production. Holcim, the only cement production company operating in La Union, provided their activity data on the total production of cement (portland and blended) in 2023.

Table 20. *Total cement production, 2023*

Operation	Quantity	Unit
Cement production - Portland	121.326,04	tonnes
Cement production - Blended	824.205,05	tonnes

Emission Factor

The following emission factors were used to estimate the GHG emissions of cement production in the province.

Table 21. *Emission factors per cement production operation*

Operation	CO2 Emission Factor	Unit
Cement production - Portland	2.00	tCO2/tonnes
Cement production - Blended	2.00	tCO2/tonnes

Calculated Emissions

Blended cement production is the largest source of CO2 emissions. This is because blended cement production requires a significant amount of raw materials like limestone, which release CO2 when processed. The significantly higher emissions from blended cement production indicate that this is the dominant type of cement being produced in the province. This could be due to its widespread use in construction projects and its perceived durability. Portland cement production is another significant source of emissions, although lower than blended cement. This process involves calcination, where limestone is heated to release CO2, contributing to substantial emissions. While Portland cement production also contributes significant emissions, it is lower compared to blended cement. This is due to the smaller scale of production.

Table 22. *Total estimated GHG emissions of industrial processes, 2023*

Operation	Estimated GHG Emissions	Unit
Cement production - Portland	242.652,08	tCO2e
Cement production - Blended	1.648.410,10	tCO2e
Total	1.891.062,18	tCO2e

Agriculture, Forestry, and Other Land Use

The AFOLU sector produces GHG emissions and removals through a variety of pathways, including land-use changes that alter the composition of vegetation and soil, management of forests and other lands, methane produced in the digestive processes of livestock, and nutrient management for agricultural purposes.

Rice Production

Rice production is a significant source of methane emissions. The anaerobic conditions in flooded rice paddies create an environment conducive to methane-producing bacteria. These emissions are influenced by water management, organic soil amendments, and rice varieties used.

Activity Data

The activity data for rice production was obtained from the Provincial Agriculture Office. The rice production data was disaggregated into dry season, irrigated; wet season, irrigated; and wet season, rainfed. It is also assumed that the average number of days for rice production for each season and irrigation type are as follows: 110 days for dry season (irrigated), 110 days for wet season (irrigated), and 100 days for wet season (rainfed).

Image from Wikimedia Commons

Table 23. Rice production of La Union Province, 2023

No.	City/Municipality	Dry Season, Irrigated	Wet Season, Irrigated	Wet Season, Rainfed	Unit
1	Agoo	1.169,00	1.140,00	347,00	ha
2	Aringay	470,00	764,00	646,00	ha
3	Bacnotan	383,00	1.004,00	879,00	ha
4	Bagulin	93,00	200,00	546,00	ha
5	Balaoan	585,00	1.455,00	417,00	ha
6	Bangar	1.144,00	1.565,00	351,00	ha
7	Bauang	109,00	495,00	1.592,00	ha
8	Burgos	357,00	364,00	405,00	ha
9	Caba	192,00	283,00	868,00	ha
10	Luna	1.241,00	1.645,00	165,00	ha
11	Naguilian	423,00	1.200,00	990,00	ha
12	Pugo	387,00	614,00	146,00	ha
13	Rosario	1.151,00	1.104,00	934,00	ha
14	San Fernando	75,00	475,00	1.313,00	ha
15	San Gabriel	560,00	624,00	444,00	ha
16	San Juan	738,00	1.101,00	1.131,00	ha
17	Sto Tomas	266,00	683,00	394,00	ha
18	Santol	120,00	236,00	801,00	ha
19	Sudipen	117,00	649,00	775,00	ha
20	Tubao	334,00	838,00	292,00	ha

Emission Factor

The emission factors used for rice production in terms of dry season (irrigated), wet season (irrigated), and wet season (rainfed) are outlined in the table below. These emission factors were obtained from the 2020 National GHG Inventory.

Table 24. Emission Factors for Rice Production

Rice production	CH4 Emission Factor	Unit
Dry season, irrigated	1,05	kgCH4/hectare/day
Wet season, irrigated	2,97	kgCH4/hectare/day
Wet season, rainfed	1,23	kgCH4/hectare/day

Calculation Results

The total estimated emissions for dry season (irrigated) are 29,147.16 tCO2e, wet season (irrigated) is 150,377.40 tCO2e, and wet season (rainfed) is 46,273.58 tCO2e. A breakdown of these emissions per LGU is outlined in the table below. Municipalities such as Agoo, Naguilian, Rosario, and San Juan are on the higher end of GHG emissions, particularly in the wet season (irrigated) category. This might be because the use of irrigation in the wet season leads to higher methane emissions from anaerobic conditions in the rice paddies. Meanwhile, municipalities such as Bagulin, Burgos, and Caba are on the lower end of GHG emissions. This is likely due to lower intensity of rice farming or better water management practices that limit methane production.

Table 25. *Total estimated GHG emissions of rice production, 2023*

City/Municipality	GHG Emissions			Unit
	Dry Season, Irrigated	Wet Season, Irrigated	Wet Season, Rainfed	
Agoo	3.436,86	10.428,26	1.195,07	tCO2e
Aringay	1.381,80	6.988,77	2.224,82	tCO2e
Bacnotan	1.126,02	9.184,19	3.027,28	tCO2e
Bagulin	273,42	1.829,52	1.880,42	tCO2e
Balaoan	1.719,90	13.309,76	1.436,15	tCO2e
Bangar	3.363,36	14.315,99	1.208,84	tCO2e
Bauang	320,46	4.528,06	5.482,85	tCO2e
Burgos	1.049,58	3.329,73	1.394,82	tCO2e
Caba	564,48	2.588,77	2.989,39	tCO2e
Luna	3.648,54	15.047,80	568,26	tCO2e
Naguilian	1.243,62	10.977,12	3.409,56	tCO2e
Pugo	1.137,78	5.616,63	502,82	tCO2e
Rosario	3.383,94	10.098,95	3.216,70	tCO2e
San Fernando	220,50	4.345,11	4.521,97	tCO2e
San Gabriel	1.646,40	5.708,10	1.529,14	tCO2e
San Juan	2.169,72	10.071,51	3.895,16	tCO2e
Sto Tomas	782,04	6.247,81	1.356,94	tCO2e
Santol	352,80	2.158,83	2.758,64	tCO2e
Sudipen	343,98	5.936,79	2.669,10	tCO2e
Tubao	981,96	7.665,69	1.005,65	tCO2e
Total	29.147,16	150.377,40	46.273,58	tCO2e

Livestock Management

Livestock, especially ruminants like cows and sheep, produce methane through enteric fermentation, a digestive process that releases this potent GHG. Additionally, manure management practices can emit methane and nitrous oxide, another powerful GHG.

Activity Data

The activity data on the total number of live heads of cattle, swine, goat, and poultry were obtained from the Provincial Agriculture Office.

Table 26. Livestock heads of La Union Province, 2023

No.	City/Municipality	Cattle	Swine	Goat	Poultry
1	Agoo	1.074,00	3.637,00	2.722,00	128.393,00
2	Aringay	3.580,00	4.273,00	10.845,00	74.620,00
3	Bacnotan	3.817,00	4.765,00	7.946,00	77.303,00
4	Bagulin	1.189,00	4.073,00	2.663,00	74.929,00
5	Balaoan	2.058,00	2.955,00	3.498,00	75.598,00
6	Bangar	1.950,00	3.274,00	3.957,00	29.176,00
7	Bauang	3.768,00	4.842,00	6.638,00	122.954,00
8	Burgos	1.082,00	2.104,00	2.543,00	33.867,00
9	Caba	1.972,00	3.096,00	2.896,00	68.307,00
10	Luna	2.990,00	3.060,00	8.528,00	109.549,00
11	Naguilian	4.165,00	5.117,00	8.846,00	100.292,00
12	Pugo	1.355,00	3.288,00	3.577,00	58.004,00
13	Rosario	2.258,00	4.370,00	7.382,00	136.805,00
14	San Fernando	2.777,00	3.206,00	7.406,00	73.450,00
15	San Gabriel	1.606,00	3.904,00	3.967,00	56.317,00
16	San Juan	2.656,00	4.799,00	5.088,00	48.088,00
17	Sto Tomas	1.644,00	3.680,00	3.292,00	104.938,00
18	Santol	1.686,00	4.015,00	3.413,00	33.907,00
19	Sudipen	1.123,00	2.189,00	2.494,00	82.444,00
20	Tubao	2.951,00	3.097,00	6.724,00	270.186,00

Emission Factors

The emission factors used for cattle, swine, goat, and poultry are outlined in the table below.

Table 27. Emission Factors for Livestock Management

Livestock	CH4 Emission Factor	N2O Emission Factor	Unit
Cattle	46	1,47	kgGHG/head
Swine	8	0,76	kgGHG/head
Goat	5,22	0,35	kgGHG/head
Poultry	0,02	0,03	kgGHG/head

Calculation Results

The total estimated GHG emissions for cattle is 76,665.71 tCO2e, swine emissions is 31,370.70 tCO2e, goats are 24,948.18 tCO2e, and poultry are 14,970.17 tCO2e. The municipalities of Naguilian, Bacnotan, and Bauang yielded high emissions due to the large population of cattle and swine, which are major contributors to GHG emissions due to enteric fermentation and manure management. In large-scale cattle farming, cattle produce significant methane emissions through enteric fermentation, a digestive process that generates methane as a by-product. Feeding livestock with low-quality feed that is less digestible increases enteric fermentation emissions. Large quantities of manure from cattle also contribute to methane and nitrous oxide emissions when stored or managed improperly. In terms of swine production, swine manure management practices, particularly in large-scale operations, result in substantial methane and nitrous oxide emissions. High volume of swine in certain municipalities lead to increased emissions from manure and feed production. On the other hand, municipalities such as Burgos and Bagulin yielded lower emissions due to smaller populations of cattle and swine. Smaller-scale operations with fewer animals result in lower overall emissions. It is also likely that the manure of these livestock is composted. Proper composting of manure reduces methane emissions compared to uncontrolled anaerobic decomposition.

Table 28. *Total estimated GHG emissions of livestock management, 2023*

City/ Municipality	GHG Emissions				Unit
	Cattle	Swine	Goat	Poultry	
Agoo	1.801,69	1.547,18	650,31	1.092,62	tCO2e
Aringay	6.005,63	1.817,73	2.590,98	635,02	tCO2e
Bacnotan	6.403,21	2.027,03	1.898,38	657,85	tCO2e
Bagulin	1.994,61	1.732,65	636,22	637,65	tCO2e
Balaoan	3.452,40	1.257,06	835,71	643,34	tCO2e
Bangar	3.271,22	1.392,76	945,37	248,29	tCO2e
Bauang	6.321,01	2.059,79	1.585,88	1.046,34	tCO2e
Burgos	1.815,11	895,04	607,55	288,21	tCO2e
Caba	3.308,13	1.317,04	691,88	581,29	tCO2e
Luna	5.015,87	1.301,72	2.037,42	932,26	tCO2e
Naguilian	6.987,00	2.176,77	2.113,40	853,48	tCO2e
Pugo	2.273,08	1.398,72	854,58	493,61	tCO2e
Rosario	3.787,91	1.859,00	1.763,63	1.164,21	tCO2e
San Fernando	4.658,56	1.363,83	1.769,37	625,06	tCO2e
San Gabriel	2.694,15	1.660,76	947,76	479,26	tCO2e
San Juan	4.455,57	2.041,49	1.215,57	409,23	tCO2e
Sto Tomas	2.757,89	1.565,47	786,49	893,02	tCO2e
Santol	2.828,35	1.707,98	815,40	288,55	tCO2e
Sudipen	1.883,89	931,20	595,84	701,60	tCO2e
Tubao	4.950,45	1.317,46	1.606,43	2.299,28	tCO2e
Total	76.665,71	31.370,70	24.948,18	14.970,17	tCO2e

Forest Emissions Removal

Forest emissions removal provides an analysis of the role forests play in mitigating GHG emissions. This section details the quantifiable amount of CO2 removed from the atmosphere through forest activities, including afforestation, reforestation, and forest management practices. By highlighting the carbon sequestration capabilities of provincial forests, this section underscores the importance of maintaining and enhancing forest cover as a vital component of the province's overall strategy to achieve net-zero emissions.

Activity Data

Aringay, Bagulin, Bauang, Burgos, Naguilian, Rosario, and Tubao provided data about the area of the remaining forest cover in their respective municipalities as outlined in the table below.

Table 29. *Remaining forest cover and land use change of La Union Province, 2023*

LGU	Removal Type	Removal Source	Area	Unit
Aringay	Land use change	Barren to forestland	622,10	hectares
Aringay	Remaining forestland	Grassland	2.057,80	hectares
Aringay	Remaining forestland	Protection Forest/Old Growth/Mossy/Pine/ Submarginal Mangrove	100,70	hectares
Aringay	Land use change	Cropland to forestland	2.471,32	hectares
Bagulin	Remaining forestland	Protection Forest/Old Growth/Mossy/Pine/ Submarginal Mangrove	4.463,77	hectares
Bauang	Remaining forestland	Protection Forest/Old Growth/Mossy/Pine/ Submarginal Mangrove	113,09	hectares
Bauang	Remaining forestland	Grassland	15,95	hectares
Bauang	Remaining forestland	Secondary growth	633,73	hectares
Bauang	Remaining forestland	Brushland	2.603,66	hectares
Burgos	Remaining forestland	Protection Forest/Old Growth/Mossy/Pine/ Submarginal Mangrove	488,81	hectares
Burgos	Remaining forestland	Secondary growth	265,89	hectares
Burgos	Remaining forestland	Brushland	474,49	hectares
Naguilian	Remaining forestland	Protection Forest/Old Growth/Mossy/Pine/ Submarginal Mangrove	90,63	hectares
Naguilian	Remaining forestland	Protection Forest/Old Growth/Mossy/Pine/ Submarginal Mangrove	620,45	hectares
Naguilian	Remaining forestland	Secondary growth	711,08	hectares
Rosario	Remaining forestland	Protection Forest/Old Growth/Mossy/Pine/ Submarginal Mangrove	786	hectares
Rosario	Land use change	Barren to forestland	110	hectares
Tubao	Remaining forestland	Protection Forest/Old Growth/Mossy/Pine/ Submarginal Mangrove	2.740	hectares
Tubao	Remaining forestland	Grassland	398	hectares

Additionally, according to the data by the Provincial Environment and Natural Resources Office, there is approximately 4,799.51 hectares of land area planted with trees by various LGUs and people's organizations through the National Greening Program (NGP) of the DENR.

Table 30. *Total area covered by the National Greening Program, 2023*

LGU	Removal Type	Removal Source	Area	Unit
Agoo	Land use change	Barren to forestland	462,47	ha
Aringay	Land use change	Barren to forestland	526,00	ha
Bagulin	Land use change	Barren to forestland	760,00	ha
Bangar	Land use change	Barren to forestland	2,00	ha
Bauang	Land use change	Barren to forestland	7,55	ha
Burgos	Land use change	Barren to forestland	124,00	ha
Caba	Land use change	Barren to forestland	111,00	ha
Naguilian	Land use change	Barren to forestland	277,50	ha
Pugo	Land use change	Barren to forestland	45,00	ha
Rosario	Land use change	Barren to forestland	117,01	ha
San Fernando City	Land use change	Barren to forestland	201,00	ha
San Gabriel	Land use change	Barren to forestland	492,78	ha
San Juan	Land use change	Barren to forestland	111,79	ha
Sto Tomas	Land use change	Barren to forestland	172,00	ha
Santol	Land use change	Barren to forestland	570,00	ha
Sudipen	Land use change	Barren to forestland	721,41	ha
Tubao	Land use change	Barren to forestland	98,00	ha

Emission Factors

The emission factors for protection forest, tree plantation, and land use change from barren to forestland is outlined in the table below.

Table 31. *Forest emissions removal factors*

Removal Source	CO2 Removal Factor	Unit
Barren to forestland	14,03	tCO2/hectare
Grassland	3,26	tCO2/hectare
Protection Forest/Old Growth/Mossy/Pine/ Submarginal mangrove	3,44	tCO2/hectare
Cropland to forestland	14,03	tCO2/hectare
Secondary growth	10,49	tCO2/hectare
Brushland	15,61	tCO2/hectare

Calculation of Results

The total carbon sequestration capacity of the three LGUs is 202,643.24 tCO2e. Most of the carbon sequestration capacities (69% or 150,295.91 tCO2e) come from the forest cover of various LGUs. Aringay, Bauang, and Burgos are the municipalities with notable carbon sequestration capacity. This might be due to extensive forest areas including protection forests, secondary growth, and brushland. Meanwhile, the National Greening Program contributes to an estimated 31% or 67,337.13 tCO2e of the total carbon sequestration capacity potential. It is worth noting that the NGP data covers the years between 2011 to 2022, therefore, the planted trees have varying growths and sequestration capacity potential as of writing. It is also assumed that these trees were planted in barren lands.

Table 32. *Total carbon sequestration capacity of various LGUs, 2023*

LGU	Removal Type	Removal Source	Annual Total Removal	Unit
Aringay	Land use change	Barren to forestland	8728,06	tCO2e
Aringay	Remaining forestland	Grassland	6.708,43	tCO2e
Aringay	Remaining forestland	Protection Forest/Old Growth/ Mossy/Pine/Submarginal Mangrove	346,41	tCO2e
Aringay	Land use change	Cropland to forestland	34.672,62	tCO2e
Bagulin	Remaining forestland	Protection Forest/Old Growth/ Mossy/Pine/Submarginal Mangrove	15.355,36	tCO2e
Bauang	Remaining forestland	Protection Forest/Old Growth/ Mossy/Pine/Submarginal Mangrove	389,0296	tCO2e
Bauang	Remaining forestland	Grassland	51,997	tCO2e
Bauang	Remaining forestland	Secondary growth	6.647,83	tCO2e
Bauang	Remaining forestland	Brushland	40.643,13	tCO2e
Burgos	Remaining forestland	Protection Forest/Old Growth/ Mossy/Pine/Submarginal Mangrove	1681,5064	tCO2e
Burgos	Remaining forestland	Secondary growth	2789,1861	tCO2e
Burgos	Remaining forestland	Brushland	7406,7889	tCO2e
Naguilian	Remaining forestland	Protection Forest/Old Growth/ Mossy/Pine/Submarginal Mangrove	311,7672	tCO2e
Naguilian	Remaining forestland	Protection Forest/Old Growth/ Mossy/Pine/Submarginal Mangrove	2134,348	tCO2e
Naguilian	Remaining forestland	Secondary growth	7459,2292	tCO2e
Rosario	Remaining forestland	Protection Forest/Old Growth/ Mossy/Pine/Submarginal Mangrove	2703,84	tCO2e
Rosario	Land use change	Barren to forestland	1543,3	tCO2e
Tubao	Remaining forestland	Protection Forest/Old Growth/ Mossy/Pine/Submarginal Mangrove	9.426	tCO2e
Tubao	Remaining forestland	Grassland	1297,48	tCO2e
		Total	150.295,91	tCO2e

Table 33. *Total carbon sequestration capacities of the National Greening Program, 2023*

LGU	Removal Type	Removal Source	Annual Total Removal	Unit
Agoo	Land use change	Barren to forestland	6.488,45	tCO2e
Aringay	Land use change	Barren to forestland	7.379,78	tCO2e
Bagulin	Land use change	Barren to forestland	10.662,80	tCO2e
Bangar	Land use change	Barren to forestland	28,06	tCO2e
Bauang	Land use change	Barren to forestland	105,93	tCO2e
Burgos	Land use change	Barren to forestland	1.739,72	tCO2e
Caba	Land use change	Barren to forestland	1.557,33	tCO2e
Naguilian	Land use change	Barren to forestland	3.893,33	tCO2e
Pugo	Land use change	Barren to forestland	631,35	tCO2e
Rosario	Land use change	Barren to forestland	1.641,65	tCO2e
San Fernando City	Land use change	Barren to forestland	2.820,03	tCO2e
San Gabriel	Land use change	Barren to forestland	6.913,70	tCO2e
San Juan	Land use change	Barren to forestland	1.568,41	tCO2e
Sto Tomas	Land use change	Barren to forestland	2.413,16	tCO2e
Santol	Land use change	Barren to forestland	7.997,10	tCO2e
Sudipen	Land use change	Barren to forestland	10.121,38	tCO2e
Tubao	Land use change	Barren to forestland	1.374,94	tCO2e
		Total	67.337,13	tCO2e

Total GHG emissions of La Union Province

Image from Wikimedia Commons

La Union Province's estimated overall emission for Scopes 1 and 2 covering 20 LGUs is 2,765,995.23 tCO2e. Very evidently, the highest emissions source is from industrial processes, particularly the cement production by Holcim. Cement production releases significant CO2 during the calcination process, where limestone is broken down, and from the combustion of fossil fuels used in industrial operations. This sector's emissions dominate due to the carbon-intensive nature of industrial activities. Additionally, the province's total emissions are heavily influenced by its agricultural activities, residential energy use, and transportation sector.

The province's primary economic activity includes agriculture, specifically rice production. This sector is the largest contributor to GHG emissions – 225,798.14 tCO2e – due to methane emissions from flooded rice paddies, which create anaerobic conditions leading to significant methane production – a potent GHG. High emissions from residential electricity use (201,847.70 tCO2e) suggest substantial reliance on non-renewable energy sources. The tropical climate necessitates higher use of electricity for cooling, which contributes significantly to overall emissions. The high emissions from transportation (158,176.00 tCO2e) can be attributed to the dependency on road transport for both personal and commercial activities, essential in a region focused on tourism. This sector is also indicative of insufficient transportation infrastructure, leading to higher individual motorized vehicle use and emissions. Livestock management is another significant agricultural activity contributing to GHG emissions – 147,954.76 tCO2e. Methane from enteric fermentation in ruminants and manure management practices contribute heavily to emissions in this sector.

Emissions from electricity use of commercial activities contribute 126,843.78 tCO2e. Like electricity use of residential sector, a significant portion might be coming from cooling powered by non-renewable energy sources. The residential stationary fuel sector also showed significant emissions – 95,716.61 tCO2e – possibly due to traditional fuels for cooking and heating. The reliance on biomass or fossil fuels can significantly impact emission levels in residential areas. Emissions from landfill disposal are also notable with 49,731.98 tCO2e, highlighting issues in waste management practices. Methane emissions from decomposing organic waste in landfills contribute significantly to the province's overall emissions. Wastewater treatment and discharge yielded emissions of 26,677.63 tCO2e. Wastewater treatment contributes to emissions through the release of methane. The current treatment methods and infrastructure likely contribute to the relatively high emission levels.

Lastly, the sectors with the lowest emissions are industrial stationary fuel use and commercial stationary fuel use. The lower emissions from industrial fuel use – 37,026.85 tCO2e – can be attributed to either a limited industrial base or the presence of more energy efficient technologies. It aligns with the province's focus on agriculture and tourism rather than heavy industry. The relatively low emissions in commercial stationary fuel use – 63.86 tCO2e – similarly suggest limited industrial activities or efficient energy practices in the commercial sector. This may also reflect a smaller scale of commercial enterprises in comparison to the dominant agricultural and tourism sectors. The negative emissions from sinks – 217,633.04 tCO2e indicate significant carbon sequestration activities, such as reforestation or conservation efforts, which help mitigate the overall GHG emissions.

Table 34. *Total estimated GHG emissions of La Union Province, 2023*

Source/Sector	Total GHG Emissions	Unit
Scope 1 Emissions		
Residential stationary fuel use	95.716,61	tCO2e
Commercial stationary fuel use	63,86	tCO2e
Industrial stationary fuel use	37.026,85	tCO2e
Mobile combustion	158.176,00	tCO2e
Solid waste - landfill disposal (ICLEI method)	49.731,98	tCO2e
Wastewater treatment and discharge	26.677,63	tCO2e
Rice production	225.798,14	tCO2e
Livestock management	147.954,76	tCO2e
Industrial processes	1.891.062,18	tCO2e
Scope 1 Emissions and Removal		
Removal from sink	217.633,04	tCO2e
Scope 2 Emissions		
Electricity at residential sites	201.847,70	tCO2e
Electricity at commercial sites	126.843,78	tCO2e
Electricity at institutional sites	22.728,78	tCO2e
Total Net GHG Emissions	2.765.995,23	tCO2e

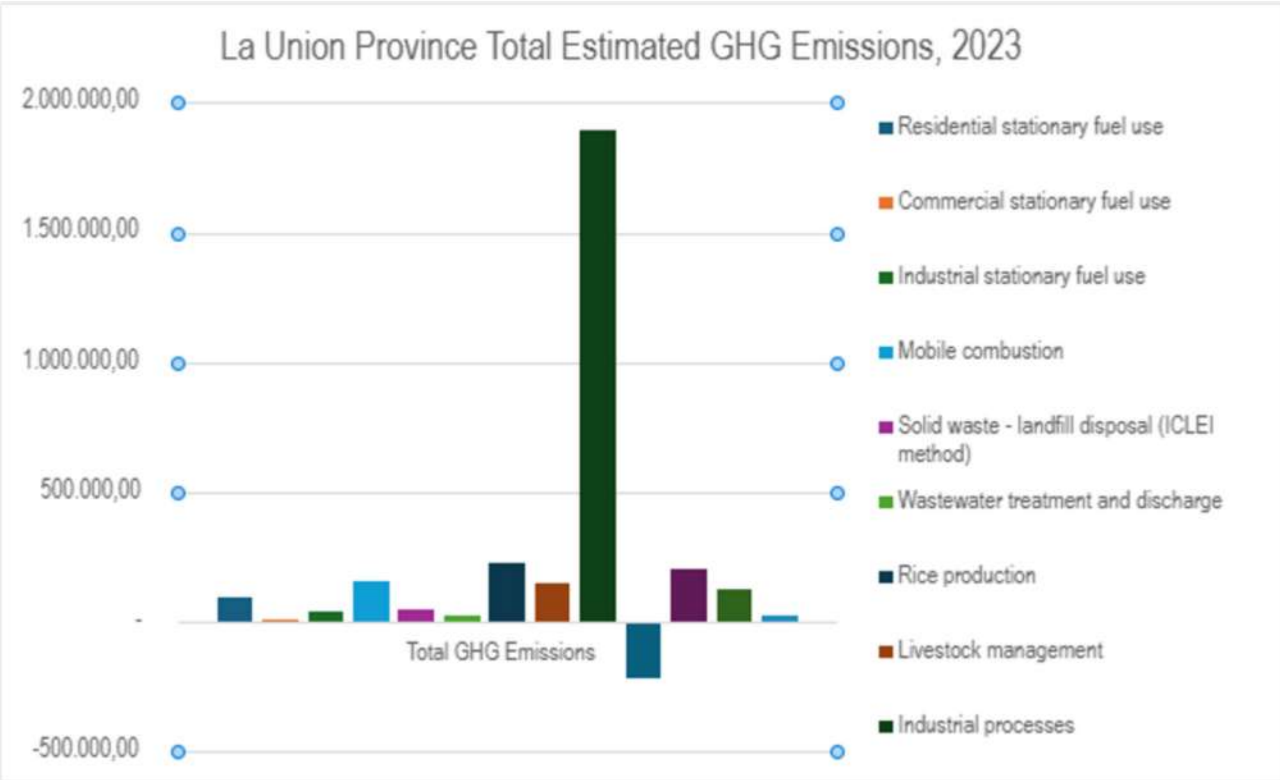


Figure 4. *Total estimated GHG emissions of La Union Province, 2023*

La Union Province Community-Level GHG Emissions Inventory 2023 Report

Image from Wikimedia Commons

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