CEADs

CEADs aims to establish an open, transparent verifable and free carbon accounting database for China andother developing countries and regions, The development of accurate and reliable emission inventories is theoasis and prerequisite for the imn ementation of emission reduction poices nventory comni ing reauiresgreat groundwork. We sincerely invite all interested researchers and students to join the CEADs team toearn from each other and develop together, so as to add to the global carbon accounting research work.

CEADs Carbon Emission Accounts & Datasets 中国碳核算数据库

Annual Report 2025 for CO_2 Emission Accounts of Global Emerging Economies

Compiled and published by Dabo Guan and the Research Team for Carbon Emission Accounts and Datasets (CEADs)

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Carbon Emission
Accounts & Datasets
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Annual Report 2025 for

CO_2 Emission

Accounts of Global Emerging Economies

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Dabo Guan and the Research Team for Carbon Emission Accounts and Datasets (CEADs)

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Foreword

Climate change sits at the intersection of environmental sustainability and socioeconomic development. Driven by the accumulation of greenhouse gases—chiefly carbon dioxide—it is accelerating global warming and amplifying the frequency and severity of climate extremes, with impacts on ecosystems and human systems. In this context, the development of robust and transparent carbon accounting systems is vital to enabling credible, science-based climate governance.

Models supporting energy planning, emissions forecasting, and climate policy design have become essential instruments in shaping both national and global climate responses. Yet, the reliability of these models is intrinsically linked to the consistency, and comprehensiveness of the underlying emissions data. In many cases, particularly in emerging economies, persistent data gaps and uncertainties limit the ability of these models to capture the full complexity of real-world dynamics—particularly with regard to regional disparities, developmental needs, and emission trajectories.

Emerging economies—particularly those along the Belt and Road—are experiencing industrialization and urbanization, driving substantial increases in energy demand and carbon emissions. These countries are integral to the global emissions and are simultaneously among the most vulnerable to the adverse effects of climate change. Supporting equitable development while enabling a just and feasible low-carbon transition is essential to advancing global climate targets.

The sustained efforts of the Carbon Emission Accounts and Datasets (CEADs) team merit special recognition. CEADs updates harmonized and transparent energy and emissions datasets for emerging economies every year. They provide essential inputs for models, supporting more realistic and differentiated assessments of country-level decarbonization pathways.

The database and accompanying report constitute a vital global public good—closing key gaps in carbon accounting, particularly within emerging economies, and furnishing a rigorous empirical foundation for data-driven modeling and policy formulation. As the global transitions from ambition to targeted implementation, such efforts are indispensable to ensuring that climate action is credible, inclusive, and results-oriented.

Richard Catlow

Fellow of the Royal Society

Executive Summary

As the impacts of climate change become increasingly evident and the urgency for global action continues to rise, countries have set diversified emission reduction targets, seeking to limit the increase in global average temperature to no more than 2℃ above pre-industrial levels and endeavoring to limit temperature rise to no more than 1.5℃. The goal is to achieve a global average of 2℃/1.5℃ by 2015. However, the current emission reductions from autonomous contribution targets set by countries still fall short of what is needed to achieve the global 2℃/1.5℃ target. In this context, advancing the transition to a low-carbon economy is a shared responsibility and mission across countries. Thus, we are releasing this report with the aim of providing the latest data and relevant in-depth analysis on the energy structure and carbon emissions characteristics of emerging economies. This is to support policymakers, researchers, and the general public in understanding the new dynamics and trends of carbon emissions in emerging economies, enabling better planning and decision-making.

The Report for CO_2 Emission Accounts of Global Emerging Economies has been published for five consecutive years as an important reference on energy consumption and CO_2 emissions in emerging economies, providing strong data support and guidance for their low-carbon transition. In the new report, the Carbon Emission Accounts and Datasets (CEADs) continue to monitor the developments in energy consumption and carbon emissions in emerging economies, expanding the scope of data and refining emission accounting methods to provide more robust data base for their future low-carbon development. Building upon the previous year's efforts, we continue to update the CO_2 emission inventories of emerging economies, offering the detailed analysis for changes of CO_2 emissions in emerging economies across Asia, Africa, Latin America and the Caribbean, and Oceania. Every emerging economy covers information, such as primary energy consumption, characteristics of fossil fuel emissions, and sectoral emission contribution. The number of emerging economy countries is 70, with the time series data updated until 2022. With ongoing updates, our goal is to continually improve the report's accuracy and make a meaningful contribution to global climate change mitigation efforts.

The CEADs research team is committed to developing a multi-scale, uniform, full-caliber, transparent, verifiable, long-time series, spatially precise CO_2 emissions accounting list for more than 150 developing countries worldwide. It also aims to continuously improve the timeliness of data from these countries. Towards these goals, CEADs continue to expand the number of CO_2 emissions inventories of emerging economies using data crowdfunding to improve the reliability and robustness of data.

This report was jointly prepared by scholars from Tsinghua University, Tianjin University, Shandong University, Renmin University of China, The University of Hong Kong, University College London, the University of Birmingham, Beijing Forestry University and other research institutions around the world. We are especially grateful to CEADs' Scientific Steering Committee for its guidance and assistance. We would also like to express our gratitude to the Department of International Cooperation of the Ministry of Science and Technology for their support of the "China-Europe Science and Technology Cooperation on Climate Change and Sustainable Development under the Carbon Neutrality Target" project; and to the National Natural Science Foundation of China for their sponsorship of this report. We also appreciate the support provided by the Administrative Center for China's Agenda 21 in the preparation of this report. If there are any inaccuracies in this report, readers are invited to criticize and correct them.

Carbon Emission Accounts and Datasets

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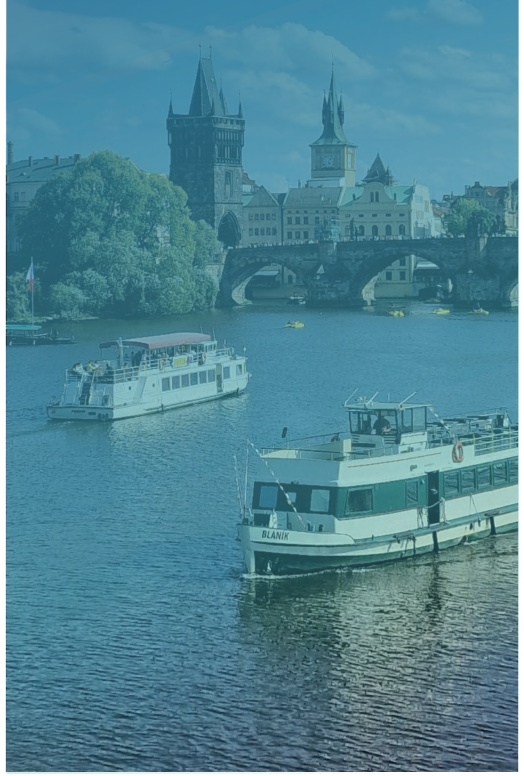


INTRODUCTION

Background

Greenhouse gas emissions caused by human activities are a central driver of global warming. CO_2, as the main greenhouse gas, accounts for 72% of total greenhouse gas emissions [1]. In recent years, several developed nations have reached carbon peaks, causing emerging economies to progressively emerge as the primary contributors to the surge in CO_2 emissions. China, in particular, has emerged as a major emitter of CO_2, surpassing the United States around 2006. From 2013 onward, China has experienced a rapid surge in CO_2 emissions, with expectations that its peak will be reached prior to 2030[2]. India, another crucial emerging economy, though experiencing a later uptick in CO_2 emissions than China, could potentially become the next "CO_2 emission giant." Notably, since 2010, the robust economic expansion of various other emerging economies worldwide has exerted a substantial impact on global CO_2 emissions. Furthermore, recent shifts in the global industrial landscape have seen the transfer of labor-intensive industries to these emerging economies, coupled with shifts in lifestyles leading to elevated energy demand and consumption[3-5]. Consequently, these economies have emerged as key contributors to the future escalation of global CO_2 emissions. However, the limited historical CO_2 emissions of individual emerging economies, excluding China and India, have resulted in diminished focus on their carbon accounting research and emission mitigation strategies. While a few emerging economies have initiated energy transition and emission reduction strategies to combat climate change and fulfill the objective of limiting global warming to below 1.5°C by the century's end[6], many such economies' pathways for emissions reduction in response to climate change remain unclear. Scholars have scrutinized decarbonization technologies and the integration of renewable energy into these economies [7, 8], along with the correlation between economic development and CO_2 emissions[9]. Yet, the absence of a comprehensive, detailed, and standardized CO_2 emission inventory has impeded effective climate action planning within emerging economies. In light of this, furnishing a precise and reliable CO_2 emission inventory stands to elucidate emissions sources within these economies and subsequently guide the formulation of effective climate change mitigation policies.

According to the Emissions Database for Global Atmospheric Research (EDGAR) report, greenhouse gas emissions have exhibited an upward trajectory since the early 21st century, predominantly due to amplified CO_2 emissions from China and other emerging economies. Reports from the Intergovernmental Panel on Climate Change (IPCC), the United Nations Environment Programme's (UNEP) emissions gap report, and the International Energy Agency's (IEA) energy outlook releases have all underscored the urgency of addressing climate change and the impending dangers it poses. India, as the world's third-largest emitter of CO_2, put forth a proposition for carbon neutrality by 2070 during the 26th Conference of the Parties to the United Nations Framework Convention on Climate Change (COP26), positioning itself to take a leading role in global emission reduction endeavors. However, the scope and adaptability of climate change mitigation actions still differ across nations. Hence, there's a pressing need to expedite carbon accounting efforts in emerging economies and hasten the creation and execution of targeted CO_2 reduction policies within these economies. This report is designed to further accelerate the carbon accounting process in emerging economies, offering comparable and verifiable CO_2 emission data while enhancing assessments of emission reduction potential and policy efficacy.

The CO_2 Emissions in Emerging Economies 2025 report shows a strong rebound in fossil energy-related carbon emissions in some countries fueled by rising energy demand in the post-epidemic period (2021-2022). Fossil energy-related carbon emissions in 2022 rise by 5.2%, 4.8%, 7.3%, 15.5%, and 5.1% from 2021 in India, Israel, Peru, Zambia, and Algeria, respectively, while emissions climb for the second year in a row in countries such as Bolivia, Guyana, Madagascar, Rwanda, and Niger. Fossil energy-related carbon emissions in Armenia, Laos, Burundi, and Mauritania, on the other hand, show a continuous increase in 2020–2022. Armenia, Togo, and Mauritania, which have experienced rapid industrialization in recent years, have seen their carbon emissions from fossil energy consumption for electricity production increase from 1.2 Mt, 0.07 Mt, and 0.3 Mt in 2010 to 1.9 Mt, 0.4 Mt, and 1.3 Mt in 2022, respectively. In addition, countries such as Turkey, Paraguay, Uganda, and South Africa show a decrease in fossil energy-related carbon emissions in 2022 compared with 2021.

All references to carbon emissions in this report refer to CO_2 emissions.

Data challenge

Carbon accounting systems in emerging economies are less detailed and consistent than those used by developed countries. Emerging economies struggle with limited databases encompassing energy consumption, emission factors, and economic activities, resulting in incomplete statistical systems that hinder the accurate calculation of CO_2 emission inventories. Presently, sources like the International Energy Agency (IEA), the Global Carbon Budget (GCB), the European Environment Agency's Global Atmospheric Emissions Database (EDGAR), the US Energy Information Administration (EIA), and British Petroleum (BP) furnish CO_2 emission data for various countries. However, these institutions predominantly focus on delivering emission data for developed nations and major emerging economies (such as China and India), while neglecting the emission dynamics of less developed countries. Constructing CO_2 emission databases for emerging economies is fraught with challenges:

To begin with, acquiring data proves challenging. In contrast to the attention garnered by China, India, and other prominent emerging economies, certain small island nations and least developed countries lack comprehensive CO_2 accounting systems, causing them to be overlooked. In the International Energy Agency (IEA) and other international agencies like the US Energy Information Administration (EIA), these countries, such as Liberia in Africa, are often lumped into "Other" or "Other regions in Africa," which curtails the thorough assessment of CO_2 emission trends within these emerging economies, impeding the identification of causes and suitable emission reduction pathways.

Secondly, data timeliness is inadequate. Due to variations in economic development levels and technological advancements across emerging economies, data on energy consumption and economic activities tend to lag, obstructing policy formulation and evaluation of policy impact. The timely and effective monitoring of CO_2 emissions within emerging economies holds immense importance.

Thirdly, the data are not comparable enough. Developed economies establish international organizations (e.g., the Organization for Economic Cooperation and Development, OECD) to standardize data disclosure and sharing, a feat challenging for emerging economies due to divergent statistical standards, accounting scopes, energy classifications, and industrial divisions. Poor specific-country CO_2 emission comparisons can impact attribution analyses and subsequently hinder discussions and equitable distribution of emission reduction responsibilities.

Fourthly, the data lack precision. In developed countries, carbon emission data are categorized by energy type and industry in some detail. In emerging economies, energy types are limited to coal, oil, natural gas and other categories; and industrial sources, to agriculture, transportation, civil and other relatively broad categories. Yet given the rapid industrialization in emerging economies, carbon emissions tend to be heterogeneous across industry sectors, which also face different challenges in CO_2 emission reduction and climate change response. All that points to a need for in-depth discussion based on refined carbon emission data on energy types and industry sources. Finally, in terms of scale, most existing emissions data for emerging economies are available only at the national level. The lack of regional emissions accounting makes it difficult to reflect the heterogeneity of carbon emissions within countries and among their regions, which also limits the formulation of regional emission reduction policies.

There is therefore a need to enrich national data for emerging economies such as small island states with studies specifically focused on shifts in their carbon emissions. Time series should be updated to improve the timeliness of the data. Emission inventories should follow a unified caliber and format, and multi-scale emissions should be compared and differentiated to better provide data support for the formulation and implementation of emission reduction policies.

Scientific contribution

The China-based international expert group Carbon Emission Accounts and Datasets (CEADs: https://ceads.net) has gathered scholars and specialists from China, the United Kingdom, the United States and other countries to conduct carbon emission accounting and application work on a global scale. CEADs provides transparent, verifiable, free and public data of carbon emissions and socioeconomic. Recognizing the problems emerging economies may have in producing emission inventories, CEADs is dedicated to establishing a unified, transparent and scientific accounting system for compiling them. Via data crowdsourcing, CEADs is also dedicated to building relevant databases for emerging economies to help in their analysis of current carbon emission conditions, and to explore decarbonization and emission-reduction pathways.

This report collects data on energy activities and emission factors officially released by emerging economies, and calculates the CO_2 emissions generated by energy consumption at the national level, according to the IPCC's accounting method. CEADs has compiled inventories of CO_2 emissions from 70 emerging economies for the period 2010-2022 across 8 energy types and 47 sectors (covered in this report, Table 1.1). Biomass is the main primary energy source in the civil sector in emerging economies; and in Southeast Asian and African countries particularly, emissions from biomass consumption play an important role in energy structure and in the analysis of emission characteristics overall. Thus, this report investigates whether emissions from biomass consumption should be included in national or regional carbon emission accounting systems. Finally, because differences in, say, data source or energy type are a major cause of disparities in data reported by various institutions, CEADs compared its inventory with those from a number of other bodies to validate its rationality and reliability.

CEADs' research team provides independent CO_2 emissions accounting for emerging economies, and the latest official energy, economic and other data released by them. CEADs continues to use the data crowdfunding method for this year's report, which covers CO_2 emissions data for 70 emerging economies. The research team has extended the time series of data from 2021 to 2022. In addition, the update of this report pays special attention to sectoral optimization. In the new version of the report, the Carbon Emission Accounts and Datasets (CEADs) continues to focus on the energy consumption and CO_2 emission characteristics of emerging economies and explores in-depth the emission accounting methodology by integrating the data of the production activities of the high-emission sectors such as industry, construction, and transportation, etc., and the precise sectoral allocation standards, focusing on the fine-tuned reconstruction of the multi-sectoral carbon emission data system, and optimizing the completeness and consistency of the carbon emission inventory at the sectoral level. It has optimized the completeness and consistency of the carbon emission inventory at the sectoral level and further strengthened the accuracy and reliability of carbon emission accounting in key sectors, with a view to providing a more solid data basis for the future low-carbon development of emerging economies.

In future reports, the number of emerging economies will be further expanded and the time range of emission inventories updated to ensure the timeliness of the data, while the plant-level carbon emission data under preparation will be used for cross-validation to improve accuracy and robustness. It should be noted that this report only covers CO_2 emissions related to energy consumption in emerging economies; it does not yet consider CO_2 emissions from industrial processes.

Table 1.1 Countries covered in the CO_2 Emissions from Emerging Economies Report 2025

Asia

Country	Location	Development stage	Time series
Myanmar	Southeast Asia	developing economies	2010-2022
Kyrgyzstan	Central Asia	transition economies	2010-2022
Pakistan	South Asia	developing economies	2010-2022
Cambodia	Southeast Asia	developing economies	2010-2022
India	South Asia	developing economies	2010-2022
Laos	Southeast Asia	least developed countries	2010-2022
Philippines	Southeast Asia	developing economies	2010-2022
Sri Lanka	South Asia	developing economies	2010-2022
Iran	South Asia	developing economies	2010-2022
Jordan	West Asia	developing economies	2010-2022
Indonesia	Southeast Asia	developing economies	2010-2022
Mongolia	East Asia	landlocked developing countries	2010-2022
Armenia	West Asia	transition economies, landlocked developing	2010-2022
Thailand	Southeast Asia	developing economies	2010-2022
Turkey	West Asia	developing economies	2010-2022
Kazakhstan	Central Asia	transition economies, landlocked developing	2010-2022
Malaysia	Southeast Asia	developing economies	2010-2022
China	East Asia	developing economies	2010-2022
Brunei	Southeast Asia	developing economies	2010-2022
Israel	West Asia	developing economies	2010-2022

Africa

Country	Location	Development stage	Time series
Burundi	East Africa	least developed countries, landlocked developing countries	2010-2022
Madagascar	East Africa	least developed countries	2010-2022
Niger	West Africa	least developed countries, landlocked developing countries	2010-2022
Liberia	West Africa	least developed countries	2010-2022
Rwanda	East Africa	least developed countries, landlocked developing countries	2010-2022
Uganda	East Africa	least developed countries, landlocked developing countries	2010-2022

Country	Location	Development stage	Time series
Ethiopia	East Africa	landlocked developing countries	2010-2022
Togo	West Africa	developing economies	2010-2022
Zambia	East Africa	small island developing states	2010-2022
Tanzania	East Africa	landlocked developing countries	2010-2022
Guinea	West Africa	developing economies	2010-2022
Zimbabwe	West Africa	small island developing states	2010-2022
Mauritania	West Africa	developing economies	2010-2022
Nigeria	West Africa	developing economies	2010-2022
Kenya	East Africa	developing economies	2010-2022
Ghana	West Africa	small island developing states	2010-2022
Djibouti	East Africa	small island developing states	2010-2022
Algeria	North Africa	small island developing states	2010-2022
Morocco	North Africa	developing economies	2010-2022
Tunisia	North Africa	developing economies	2010-2022
Egypt	North Africa	small island developing states	2010-2022
South Africa	South Africa	developing economies	2010-2022
Botswana	South Africa	developing economies	2010-2022
Mauritius	East Africa	small island developing states	2010-2022

Latin America and the Caribbean

Country	Location	Development stage	Time series
Venezuela	South America	developing economies	2010-2022
Haiti	Caribbean	small island developing states,	2010-2022
Nicaragua	Central America	developing economies	2010-2022
Bolivia	South America	landlocked developing countries	2010-2022
Guatemala	Central America	developing economies	2010-2022
Jamaica	Caribbean	small island developing states	2010-2022
Paraguay	South America	landlocked developing countries	2010-2022
Ecuador	South America	developing economies	2010-2022
Belize	Central America	small island developing states	2010-2022
Colombia	South America	developing economies	2010-2022

Country	Location	Development stage	Time series
Peru	South America	developing economies	2010-2022
Brazil	South America	developing economies	2010-2022
Grenada	Caribbean	small island developing states	2010-2022
Cuba	Caribbean	small island developing states	2010-2022
Guyana	South America	small island developing states	2010-2022
Argentina	South America	developing economies	2010-2022
Panama	Central America	developing economies	2010-2022
Trinidad and Tobago	Caribbean	small island developing states	2010-2022
Chile	South America	developing economies	2010-2022
Uruguay	South America	developing economies	2010-2022
Barbados	Caribbean	small island developing states	2010-2022

Europe

Country	Location	Development stage	Time series
Moldova	Eastern Europe	Transition economies, landlocked developing countries	2010-2022
Russia	Eastern Europe	transition economies	2010-2022
Estonia	Channel islands	developed economies	2010-2022

Oceania

Country	Location	Development stage	Time series
Papua New Guinea	Melanesia	small island developing states	2010-2022
Micronesia	Micronesia	small island developing states	2010-2022

According to the United Nations World Economic Situation and Prospects report, the “development stages” of the 70 emerging economies covered by CEADs report include least developed countries, developing economies, transition economies and developed economies, corresponding to their level of socioeconomic development. Factoring geographical location and economic characteristics in, some are also categorized as small island developing states, landlocked developing countries or emerging market economies.

In this report, Chapters 2 to 6 cover relevant countries in the global regions of Asia, Latin America and the Caribbean, Africa, Europe and Oceania. Each chapter examines in turn these economies’ backgrounds, primary energy consumption, characteristics of fossil fuel emissions, sectoral emission contribution and comparison with international databases (Global Carbon Budget, the European Environment Agency's Global Atmospheric Emissions Database and the International Energy Agency) of CO_2 emissions from emerging economies.

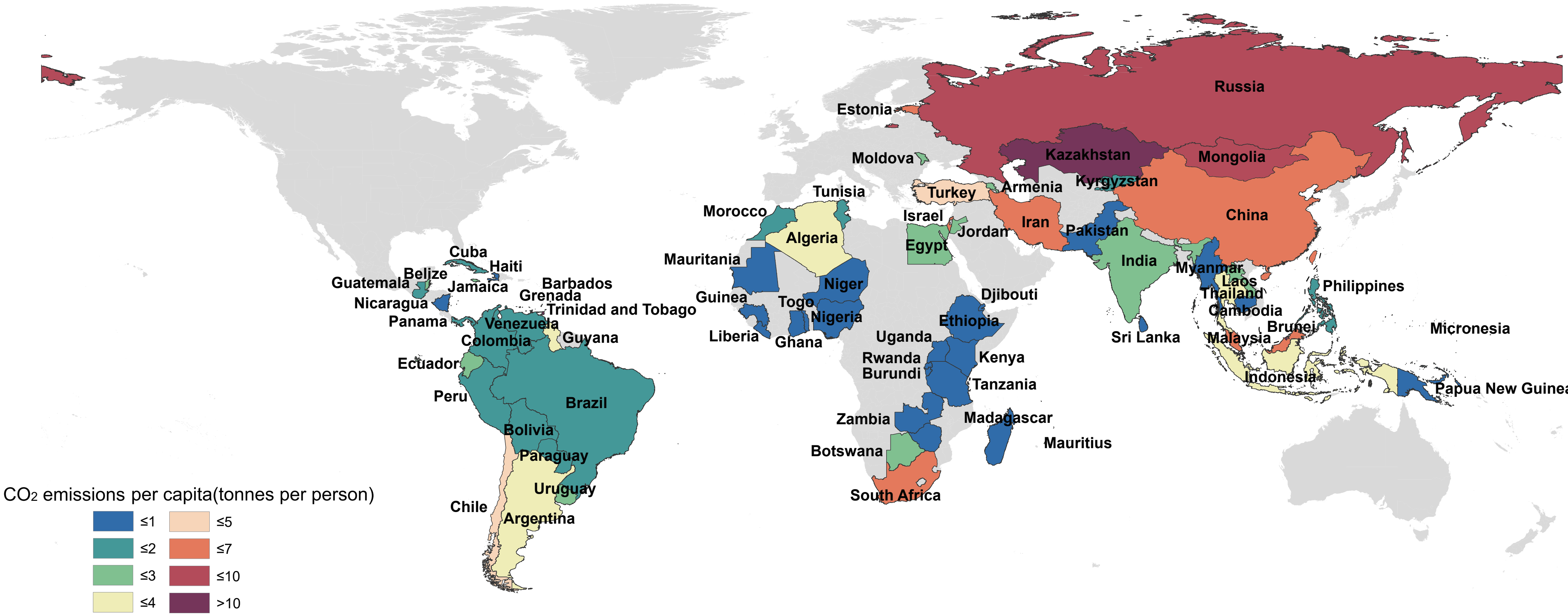


Figure 1.1 CO_2 emissions per capita from fossil fuels in emerging economies, 2022

* Country borders or names do not necessarily reflect the research team's official position. This map is for illustrative purposes and does not imply the expression of any opinion on the part of the research team concerning the legal status of any country or territory or concerning the delimitation of frontiers or boundaries

ASIA

Background

Myanmar, located on the Indochinese Peninsula in Southeast Asia, is bordered by Bangladesh and India in the northwest, China in the northeast, Laos in the east and the Andaman Sea to the south. From 2010 to 2022, its population grew steadily at an average annual growth rate of about 0.7%. According to the World Bank, Myanmar's total population exceeded 54,133,798 in 2022[10]. Its GDP grew at an average annual rate of 1.0% from 2010 to 2022. In 2022, Myanmar's GDP (at current prices) reached US$66.8 billion[11].

Myanmar's service sector is the largest contributor to the country's economy, accounting for 37.6% of the total GDP in 2022[12]. Its industrial sector is meanwhile the country's fastest-growing, accounting for 37.6% of total GDP that year[13]. Myanmar is rich in minerals, with oil and non-ferrous metal both key national economic resources. In terms of international trade, Myanmar's top three exports in recent years have been petroleum, non-knitted women's coats and refined copper, with Thailand, China and Japan being the top three importers. Refined petroleum, broadcasting equipment and synthetic cotton fabrics are Myanmar's main imports, usually brought in from China, Thailand and Singapore, among other countries[14].

In response to climate change, the Myanmar Ministry of Electricity and Energy has introduced renewable energy targets aiming to increase the proportion of renewable energy in electricity production to 8% by 2021 and 12% by 2025. But there are currently no specific incentives encouraging renewable energy projects[15]. The government of Myanmar aims to increase the country's forested area to 30% by 2030[16, 17]. In 2015, Myanmar submitted its Intended Nationally Determined Contributions (INDC) focusing on forestry and energy as major areas for mitigation [18].

Primary energy consumption

In 2022, Myanmar's fossil fuel consumption accounted for 63.0% of the primary energy consumption, with petroleum as the mainstay. Among them, coal, petroleum, and natural gas accounted for 2.0%, 48.4%, and 12.5%, respectively. In addition, biomass accounted for 33.0% of primary energy consumption, with other renewable energy sources such as hydropower and solar making up 4.1% of the primary energy supply.

Characteristics of fossil fuel emissions

Among all CO_2 emissions from fossil fuel consumption, those from petroleum products dominate: they accounted for 65.9% in 2022 and show a significant increase of 7.1 Mt in 2010 to 18.7 Mt in 2022, with an average annual growth rate of 13.7%. Natural gas is another prime source of CO_2 emissions. Between 2010 and 2022, CO_2 emissions linked to natural gas rose from 4.1 Mt in 2010 to 7.7 Mt in 2022.

Sectoral emission contribution

The transportation, storage and postal services sector is the largest fossil fuel carbon-emitting industries in Myanmar, followed by the production of electricity, heat, gas, and water, and other manufacturing sectors. In 2022, the CO_2 emissions from fossil fuel consumption in the transportation, storage and postal services sector reached 12.5 Mt, accounting for 43.8% of the total CO_2emissions from fossil fuel. Meanwhile, the share of CO_2 emissions from the utility sector grew rapidly, from 24.3% in 2010 to 27.0% in 2022.

Biomass emissions

In 2022, biomass accounted for about 33.0% of the primary energy consumption structure, mainly for household consumption. Biomass in Myanmar is mainly derived from the overharvesting of forest timber[19], leading inevitably to a reduction in forest cover and to forest degradation. This pattern of overuse is not renewable or sustainable over time, due to the long cycle needed for forest restoration. Therefore, biomass energy combustion in Myanmar is not carbon neutral, and should be counted in overall CO_2 emissions together with fossil fuel combustion in national and regional accounting. CO_2 emissions from biomass consumption in the country increased from 36.7 Mt in 2010 to 35.2 Mt in 2022.

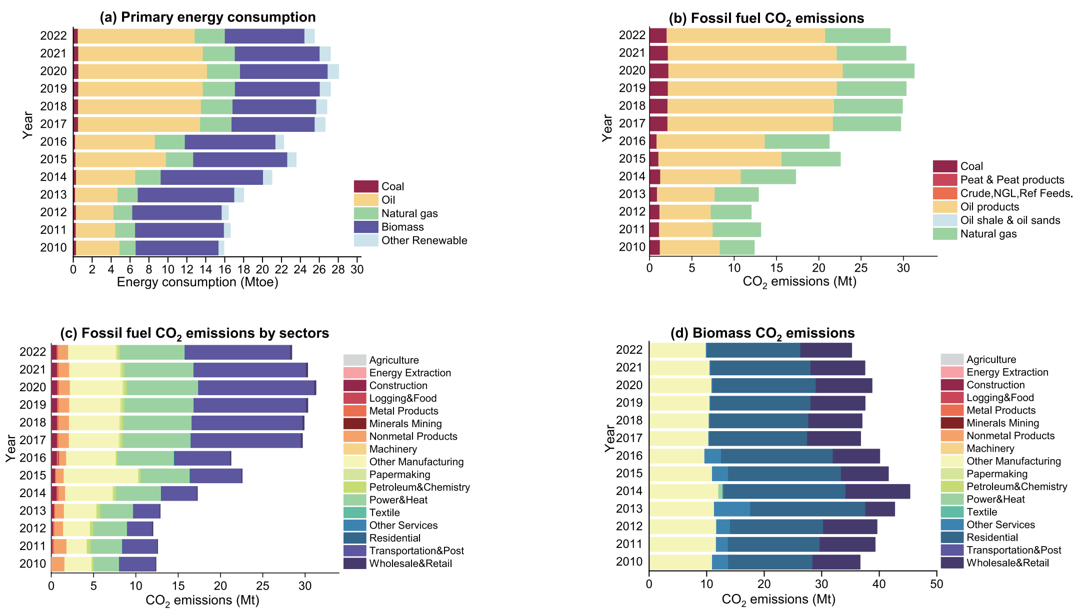
Emission trends

Myanmar's overall CO_2 emissions showed an upward trend. Between 2010 and 2022, emissions from fossil fuel combustion increased from 12.4 Mt to 28.4 Mt, with an average annual growth rate of 7.2%. During this period, CO_2 emissions from biomass combustion increased from 36.7 to 35.2 Mt, with an average annual growth rate of -0.3%.

Comparison with international databases

Under a unified accounting standard that excludes biomass CO_2 emissions, the fossil energy CO_2 emissions calculated by CEADs for Myanmar are almost identical in trend to those of other institutions, but there are annual discrepancies when compared to major international institutions. Specifically, compared to EDGAR's statistics, CEADs reported higher figures in 2010 and 2011. However, starting from 2012, EDGAR's figures began to exceed those of CEADs, and this trend has continued. Compared to GCB's data, CEADs showed a consistent trend and discrepancy until 2017; after which, CEADs demonstrated a higher growth rate, maintaining this trend until 2022. In contrast to IEA's data, CEADs' figures were lower from 2010 to 2012, but from 2013 onwards, the figures from both started to surpass each other. However, there are differences in sector-specific emissions. For instance, in 2017, CO_2 emissions from the transportation, warehousing, and postal sectors accounted for 12.8 Mt according to CEADs, while IEA reported only 5.94 Mt. For GCB's statistics, the values and trends highly coincide with those of CEADs; before 2017, GCB's figures were lower than those of CEADs, but then they exceeded them, with a gap ranging between 3.0% to 8.2%.

CEADs provides a more detailed energy classification. For instance, petroleum products are categorized into gasoline, diesel, fuel oil, etc., each with its own emission factor, whereas under IEA's methodology, energy types are only classified as one category of petroleum products. The emission factors used by IEA differ from those used by CEADs, leading to discrepancies in carbon emission data. Another reason for these differences is the divergence in the energy consumption data used by the two organizations. CEADs employs energy consumption data from the Economic Research Institute for ASEAN and East Asia (ERIA), while IEA sources its data from multiple providers such as Myanmar's Central Statistical Organization, the International Renewable Energy Agency (IRENA), and the Asia Pacific Energy Research Centre (APERC), among others. There is a noticeable gap between these institutions' statistics on energy consumption. For example, in 2017, the IEA reported that Myanmar's transportation, warehousing, and postal sectors consumed 1875 ktoe in petroleum products, whereas the ERIA data used by CEADs showed a consumption of 4196 ktoe. These factors contribute to the discrepancies in sector-specific CO_2 emissions between IEA and CEADs. Additionally, when including CO_2 emissions produced from biomass consumption, CEADs' accounting data for 2022 was 63.6 Mt.



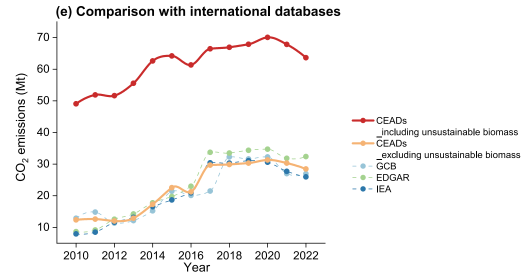


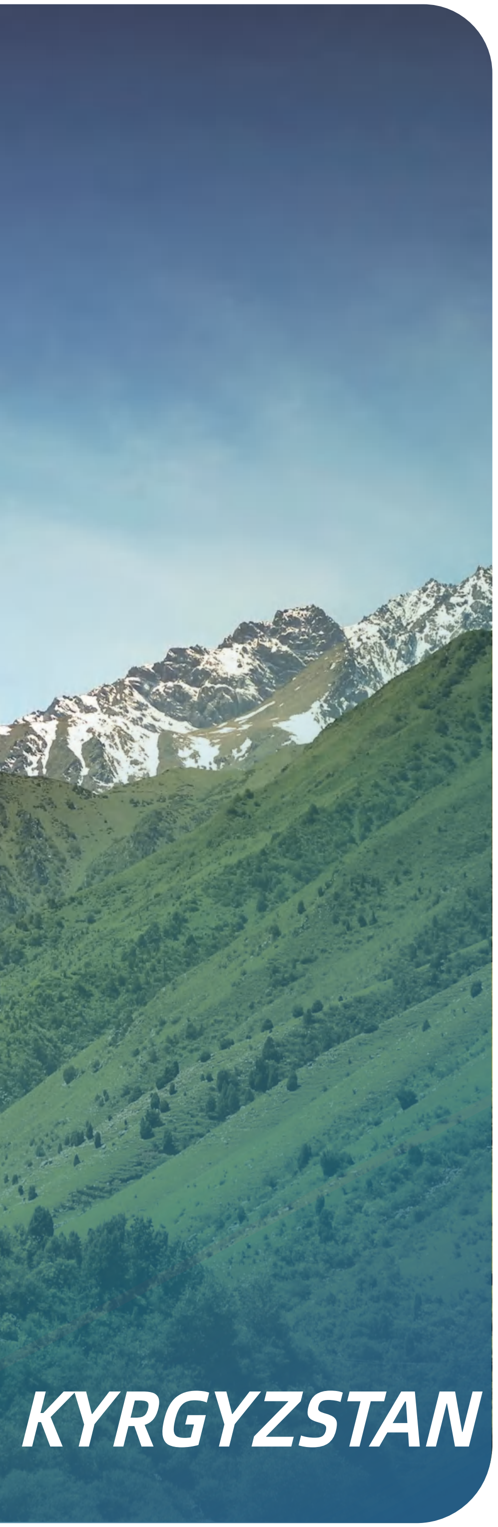
Figure 2.1: Myanmar's energy consumption and CO_2 emissions from 2010 to 2022 (a) Primary energy consumption; (b) Fossil fuel CO_2 emissions; (c) Fossil fuel CO_2 emissions by sectors; (d) Biomass CO_2 emissions; (e) Comparison with international databases.

Brief description of data sources:

The energy data featured in this report is from the energy balance sheet provided by ERIA for 2010-2017. Statistically, there are five main types of fossil fuel consumed in Myanmar: coal, crude oil and NGL, petroleum products, natural gas and "others" — that is, biomass. Although this is not specified in the ERIA report, it can be inferred from the explanation of the legend in the report. Three sectors (industry, transport and "others") are the main consumers of these fossil fuels. To further refine these three main sectors into 47, CEADs used GDP data provided by the Asian Development Bank (ADB).

Table 2.1: Data sources for Myanmar's emission accounting

Data type	Source	Website
Energy balance sheet	East Asia-ASEAN Economic Research Center (ERIA)	https://www.eria.org/publications/energy-demand-and-supply-of-the-republic-of-the-union-of-myanmar-2010-2017/
Emission factor	Intergovernmental Panel on Climate Change (IPCC)	https://www.ipcc-nggip.iges.or.jp/EFDB/
Sectoral mapping indicator	Asian Development Bank - Gross Domestic Product	https://data.adb.org/dataset/myanmar-key-indicators
	UN Comtrade	https://comtradeplus.un.org/



Background

Kyrgyzstan is a country located in Central Asia, bordered by Kazakhstan, Uzbekistan, Tajikistan and China. The capital of Kyrgyzstan is Bishkek. According to the Statistics Bureau of Kyrgyzstan[20], Kyrgyzstan has a land area of 199,951 square kilometers, a total population of 70 million in 2022, and a per capita GDP of 1,740.1 USD, ranking 134th in the world. Kyrgyzstan is a member of the Commonwealth of Independent States, the Eurasian Economic Union, the Collective Security Treaty Organization, the Shanghai Cooperation Organization, the Organization of Islamic Cooperation, the Organization for Security and Cooperation in Europe, the Organization of Turkic States, and the International Turkic Cultural Organization.

Kyrgyzstan's natural resources include gold, antimony, tungsten, and rare metals. The output of antimony ranks third in the world and first in the CIS, the output of tin and mercury ranks second in the CIS, and the hydropower resources rank third in the CIS countries.

Primary energy consumption

Fossil fuel consumption accounted for nearly 77.0% of the primary energy mix in Kyrgyzstan and is dominated by coal. In 2022, coal consumption accounted for 41.3%, petroleum products for 27.9%, and natural gas for 7.7%. In addition, hydropower, wind and other renewable energy sources accounted for 23.0% of primary energy consumption.

Characteristics of fossil fuel emissions

Coal and oil consumption were the main sources of fossil fuel CO_2 emissions in Kyrgyzstan. In 2022, coal consumption generated 6.2 Mt of CO_2 emissions, accounting for 57.7% of fossil fuel CO_2 emissions. Emissions from petroleum consumption increased from 2.7 Mt in 2010 to 3.8 Mt in 2022, accounting for 34.8% of fossil fuel CO_2 emissions. CO_2 emissions from diesel consumption reached 0.8 Mt, accounting for 7.5% of fossil fuel CO_2 emissions.

Sectoral emission contribution

Fossil fuel consumption in Kyrgyzstan is mainly from the production of electricity, heat, gas, and water sector, and the CO_2 emissions in this sector have increased from 2.0 Mt in 2010 to 3.6 Mt in 2022, accounting for 33.6% of total fossil fuel CO_2 emissions. The transportation, storage and postal services sector was Kyrgyzstan's second largest fossil fuel CO_2 emission industry, increasing from 1.9 Mt in 2010 to 3.2 Mt in 2022, accounting for 30.1% of total fossil fuel CO_2 emissions.

Emission trends

From 2010 to 2022, Kyrgyzstan's fossil fuel CO_2 emissions showed a steady growth trend, with an average annual growth rate of 4.9%, increasing from 6.7 Mt in 2010 to 10.8 Mt in 2022. During this period, CO_2 emissions from coal consumption increased from 3.5 Mt in 2010 to 6.2 Mt in 2022.

Comparison with international databases

Under the unified accounting scope, that is, when biomass CO_2 emissions are not included, the gap between emissions calculated by CEADs, IEA, EDGAR and GCB are relatively small. The main reasons for the differences are: firstly, CEADs and IEA, EDGAR and GCB differ in the selection of emission factors. Secondly, CEADs data has a more detailed energy classification, while other agencies have relatively vague statistical coverage of energy types.

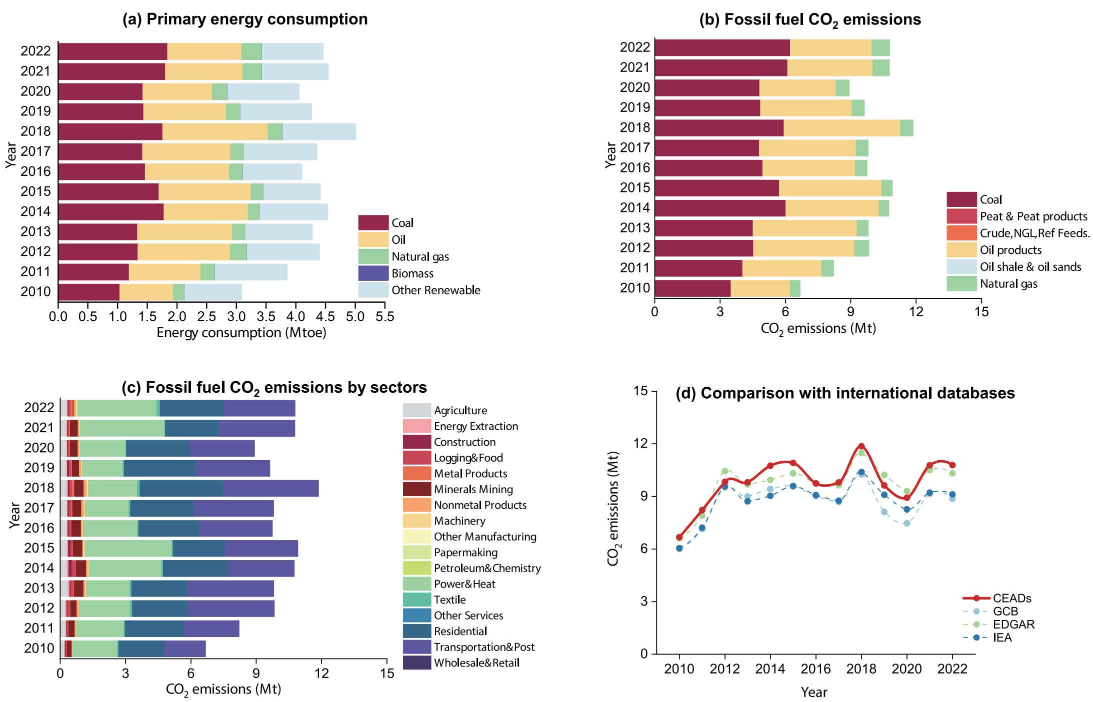


Figure 2.2: Kyrgyzstan's energy consumption and CO_2 emissions from 2010 to 2022 (a) Primary energy consumption; (b) Fossil fuel CO_2 emissions; (c) Fossil fuel CO_2 emissions by sectors; (d) Comparison with international databases.

Brief description of data sources:

Kyrgyzstan's energy balance sheet lists 8 energy types, among which the main energy type are coal, oil and natural gas and other. Kyrgyzstan's energy balance sheet divides industries into six sectors: industry, construction, transportation, agriculture, household, and others.

Table 2.2: Data sources for Kyrgyzstan's emission accounting

Data type	Source	Website
Energy balance sheet	National Statistical Committee of the Kyrgyz	https://www.eria.org/publications/energy-demand-and-supply-of-the-republic-of-the-union-of-myanmar-2010-2017/
Emission factor	Intergovernmental Panel on Climate Change (IPCC)	https://www.ipcc-nggip.iges.or.jp/EFDB/
Sectoral mapping indicator	National Statistical Committee of the Kyrgyz	http://www.stat.kg
	United Nations Comtrade database (UN Comtrade), export data	https://comtradeplus.un.org/

Background

Pakistan is situated in the northwest of the South Asian subcontinent and shares borders with the Republic of India to the east, Iran to the west, Afghanistan to the north-northwest, the Arabian Sea to the south, and the Persian Gulf's northern departure. It abuts the Kashgar region of China's Xinjiang. Pakistan is located between latitudes 23°30′ and 36°45′ north and longitudes 61° and 75°31′ east. With a total population of about 240 million in 2022, it will be the fifth most populous country in the world[21]. In 2022, Pakistan's GDP (current price) is $374.9 billion[22].

Data published by the Pakistan Bureau of Statistics indicate that the total value of agricultural output in Pakistan accounted for 22.7% of GDP in 2022. Major crops include wheat, rice, corn, cotton, and sugarcane, with the value of these major crops contributing 4.41% to GDP, while other crops contributed 3.14%. The livestock, forestry, and fisheries sectors contributed 14.04%, 0.49%, and 0.32% to GDP, respectively. The total value of industrial output contributed 19.1% to GDP, representing a year-on-year growth of 7.2%. In terms of industrial composition, manufacturing is a pillar of Pakistan's economic development, accounting for 12.4% of GDP, while mining and the power sector accounted for 1.71% and 2.41% of GDP, respectively, with the construction sector contributing 2.56%. In the manufacturing sector, the proportion of light textile industries is relatively large, while the development of machinery and electronics manufacturing industries is insufficient[23]. Pakistan's natural resources are relatively poor, and the exploration and development of mineral resources lag far behind the growth of population. There are 47 kinds of mineral resources discovered in Pakistan so far, and important minerals include antimony, barite, bauxite, and ferrochrome. Chromite reserves are quite rich. Petroleum and coal resources are scarce, but natural gas reserves are abundant, with 441.13 billion cubic meters. In recent years, the Pakistani government has exerted significant effort to accelerate industrialization, increase exports, and reduce foreign trade deficits. It maintains trade relations with over 90 countries and regions. It mainly imports petroleum products, machinery and transportation equipment, iron and steel products, chemical fertilizers and electrical products among others.

Pakistan's primary import partners are Saudi Arabia, China, the United Arab Emirates, Kuwait, the United States, Japan and India. It exports predominantly rice, cotton, textiles, leather products, and carpets. Pakistan's export destinations are United States, the United Arab Emirates, Afghanistan, the United Kingdom, Germany, Italy, and China[24].

Pakistan possesses a variety of renewable energy sources, including wind, solar, hydro and biomass. These resources have the potential to contribute to the advancement of renewable energy production, the mitigation of climate change mitigation, and the development of sustainable energy at a national level[25]. During COP27, Pakistan pledged financial, practical, or technical support for the Early Warning for All initiative. Pakistan has made a promise to achieve 60% clean energy, and 30% electric vehicles targets by 2030. This demonstrates Pakistan's efforts to surpass its obligations in addressing climate change. Furthermore, Pakistan is asking industrialized nations to fulfil their commitments regarding climate finance.

Primary energy consumption

In 2022, Pakistan's fossil energy consumption accounted for 59.6% of the primary energy structure, of which coal consumption accounted for 15.0%, oil consumption accounted for 20.2%, and natural gas consumption accounted for 24.5%. In addition, other renewable energy sources such as solar energy and hydropower accounted for 10.2% of primary energy consumption; biomass accounted for 30.2% of primary energy consumption.

Characteristics of fossil fuel emissions

Pakistan's CO_2 emissions from fossil energy consumption are about 181.1 $MtCO_2$. From the perspective of CO_2 emissions by type of fossil energy, CO_2 emissions generated by oil consumption are 62.4Mt CO_2, accounting for 34.5% of fossil energy CO_2 emissions; followed by CO_2 emissions generated by coal and natural gas consumption, accounting for 33.3% and 32.2% respectively.

Sectoral emission contribution

The production of electricity, heat, gas, and water sectors was the largest CO_2 emissions. In 2022, the fossil fuel CO_2 emission of this sector was 50.03 Mt, accounting for 27.6% of total fossil fuel CO_2 emissions. The transportation, storage and postal services sector is the second largest fossil fuel CO_2 emission sector with 45.8 Mt, accounting for 25.3% of total fossil fuel CO_2 emissions in 2022.

Biomass emissions

In 2022, Pakistan's biomass accounted for about 30.2% of the primary energy consumption, which was mainly used for household and service sector. Since Pakistan's biomass sources were mainly sustainable renewable resources, with life cycle "zero carbon" attribute. Therefore biomass should not be included in the overall CO_2 emission accounting.

Emission trends

Pakistan’s CO_2 emissions from fossil energy consumption fluctuated slightly between 2010 and 2013. From 2013 to 2018, CO_2 emissions increased by 35.5%, and Pakistan’s CO_2 emissions increased from 145.8 Mt to 197.6 Mt. Then there was a slow decline from 2018 to 2020. Affected by the epidemic, CO_2 emissions fell sharply to 185.2 Mt in 2020. In 2021, Pakistan's fossil energy CO_2 emissions rebounded to 196.5 Mt, an increase of 6.1% from 2020. In 2022, Pakistan’s CO2 emissions from fossil energy exhibited a declining trend, decreasing to 181.1 Mt, representing a 7.8% reduction compared to 2021.

Comparison with international databases

Under the same accounting caliber (excluding emissions from biomass), the CEADs accounting of Pakistan's fossil energy CO_2 emissions has a relatively small error in comparison with the results published by the IEA, and a slightly larger difference in comparison with the results of EDGAR and GCB, but the overall trend is generally in line with each other. Differences in accounting methods and basic data do lead to differences in results, and the main reasons for the differences are: firstly, the selection of emission factors between CEADs and IEA, EDGAR and GCB, and secondly, the CEADs data has a more detailed classification of energy sources, whereas the other organizations have a more ambiguous calibre of statistics on the types of energy sources.

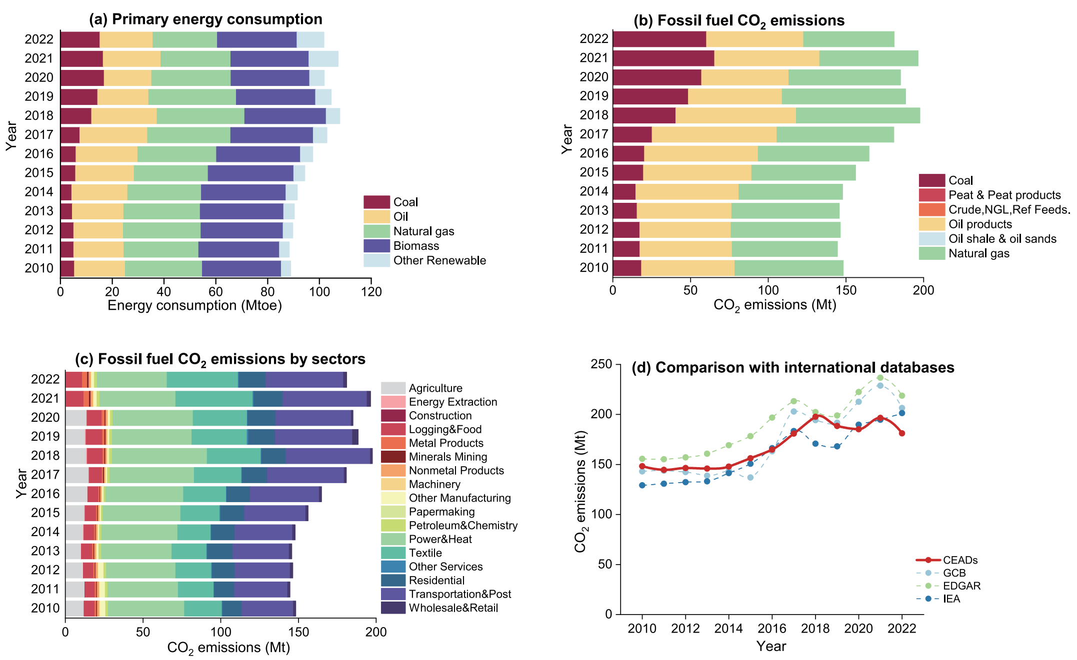


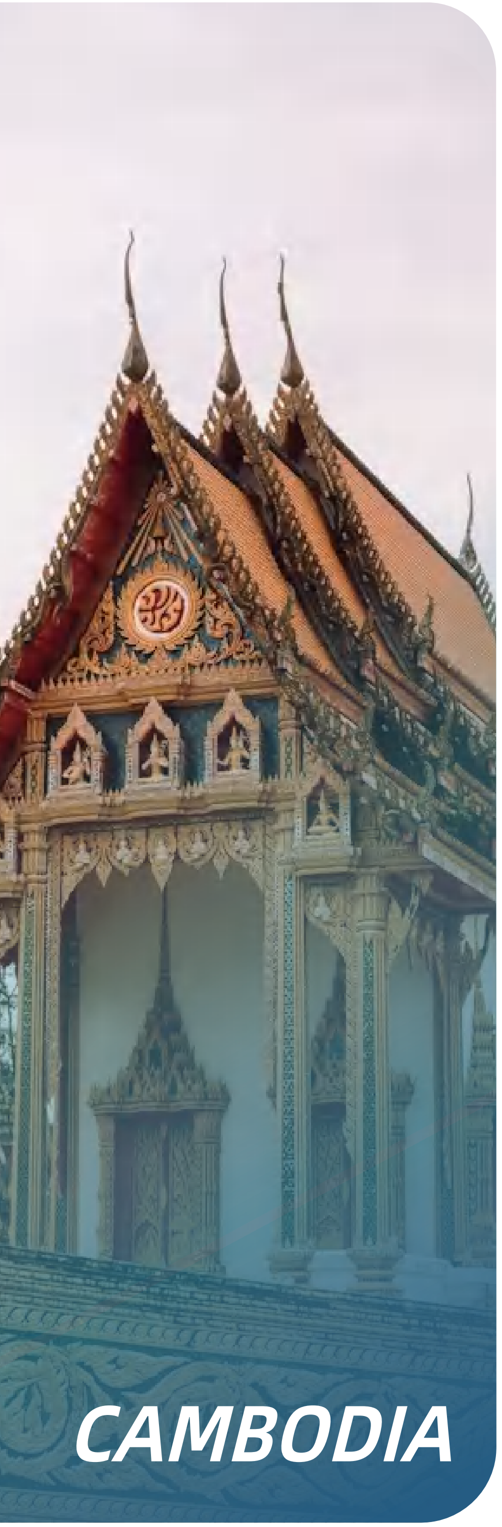
Figure 2.3: Pakistan’s energy consumption and CO_2 emissions from 2010 to 2022 (a) Primary energy consumption; (b) Fossil fuel CO2 emissions; (c) Fossil fuel CO_2 emissions by sectors; (d) Comparison with international databases.

Brief description of data sources:

Pakistan's energy balance sheet comes from the statistics of energy consumption by the Pakistan Statistics Bureau, and the time covers the data from 2010 to 2020. Energy balance sheets involve 4 energy varieties and 6 sectors. In 2021, Pakistan's energy balance sheet involves 9 energy types and 6 sectors. In 2022, Pakistan’s data is extrapolated from the annual rate of change in per capita energy use provided by Our World in Data, an international institution. The data comes from the energy consumption statistics of the Hydrocarbon Development Institute of the Ministry of Energy of Pakistan. The sub-sector data for matching is taken from Pakistan's official statistics website and UN Comtrade, and it is downscaled and divided into 47 sectors based on the output of the industrial sector, the gross product of agriculture, construction and transportation, and the proportion of urban residents.

Table 2.3: Data sources for Pakistan's emission accounting

Data type	Source	Website
Energy balance sheet	Pakistan Statistics Hydrocarbon Development Institute of Pakistan Our World in Data	https://www.sbp.org.pk/departments/stats/pakEconomy_HandBook/Chap-2.3.pdf https://www.scribd.com/document/623119848/EYB-2021 https://ourworldindata.org/energy
Emission factor	Intergovernmental Panel on Climate Change (IPCC)	https://www.ipcc-nggip.iges.or.jp/EFDB/
Sectoral mapping indicator	Pakistan Statistics	https://www.pbs.gov.pk/
	The United Nations Comtrade database	https://comtradeplus.un.org/



Background

Cambodia is the smallest country on the Indochina Peninsula, covering 181,035 square kilometers. Over the past decade, Cambodia's annual population growth rate has steadied at 1.6%, reaching 16.77 million by 2022[26]. Although Cambodia is still one of the least developed countries in the world, its economy grown significantly in the past few decades. In 2015, the country made the transition from a low-income country to a low- and middle-income country. Its GDP grew rapidly between 1998 and 2019, at an annual rate of 7.7%, and in 2022 reached US$39.99 billion at current prices[27].

In recent years, Cambodia's service industry has also grown rapidly, with value added in 2022 taking up as much as 34.2%. Garment exports and tourism are gradually becoming the two main engines of Cambodia's economic growth. In terms of international trade, Cambodia’s exports are primarily clothing, shipped to the United States, Germany, Japan and China; while its most important imports are gold, light rubberized knitted fabric and refined petroleum, usually sourced from Thailand, China and Singapore[28].

Cambodia has abundant renewable energy resources, including hydropower and solar power. However, due to monetary constraints and gaps in technology, the development of renewable energy has been relatively slow[29] . As a country highly dependent on climate-sensitive industries such as agriculture and fisheries, Cambodia is also highly vulnerable to climate change. Therefore, in response to climate issues, Cambodia, like many other countries, has authored climate policies: the government has decided to reduce emissions by 27% and increase national forest cover from 57% to 60% by 2030 under its baseline scenario [30, 31].

Primary energy consumption

Cambodia's primary energy consumption structure is dominated by petroleum. In 2022, coal consumption accounted for 19.1%; oil consumption accounted for 46.9%; and total fossil fuel consumption accounted for nearly 66%. Hydropower, solar and other renewable energy sources accounted for 5.3% of primary energy consumption, with biomass making up 28.7% of the primary energy supply.

Characteristics of fossil fuel emissions

Oil and coal account for all of Cambodia's fossil fuel emissions. In 2022, the consumption of petroleum products produced 10.4 Mt of CO_2 emissions, or 64.5% of all CO_2 emissions from fossil fuels. In comparison, the contribution of coal to such emissions has dramatically increased from 0.1 Mt in 2010 to 5.7 Mt in 2022.

Sectoral emission contribution

Cambodia's transportation, storage and postal services sector is the country's highest-emitting sector. Fossil fuel CO2 emissions in this sector was 7.1 Mt in 2022, accounting for 43.7% of Cambodia's total CO_2 emissions from fossil fuel consumption. With the increase of urbanization and motorization in Cambodia, the CO_2 emissions of the transportation industry, storage and postal services sector showed a rapid growth trend during 2010-2022, increasing by 1.5 times. The second-highest source of these emissions is primarily the production and supply sectors of electricity, heat, gas and water, which accounted for as much as 36.5% in 2022.

Biomass emissions

In 2022, biomass accounted for about 28.7% of the primary energy consumption. The main forms of biomass used in Cambodia are agricultural residues (such as rice husks and peanut shells, sugarcane processing residues, etc.) and wood. Some 80% of biomass is consumed by households, mainly for cooking and heating in rural areas. Timber is the most important source of biomass energy in Cambodia and is mainly derived from forests. The rapid population growth has led to a sharp increase in demand for wood, causing serious forest degradation: only a small proportion of Cambodian woodlands have been restored, putting significant pressure on the environment as a whole. Most biomass sourced from unrestored forests is thus seen as unsustainable. Biomass should be included in the country's overall CO_2 emissions accounting. (The data provided in this paragraph can be used for reference.) In terms of temporal trends, emissions generated by biomass showed a slight fluctuation, rising slowly from 7.5 Mt in 2010 to 8.8 Mt in 2015, followed by a slight increase between 2016 and 2022. CO_2 emissions reached 8.9 Mt in 2022.

Emission trends

Between 2010 and 2022, CO_2 emissions from fossil fuel consumption have maintained a relatively stable growth rate of 11.3% as a yearly average, rising from 4.5 Mt in 2010 to 16.2 Mt in 2022. CO_2 emissions from biomass consumption increased from 7.5 Mt to 8.9 Mt, increased by 19.1%.

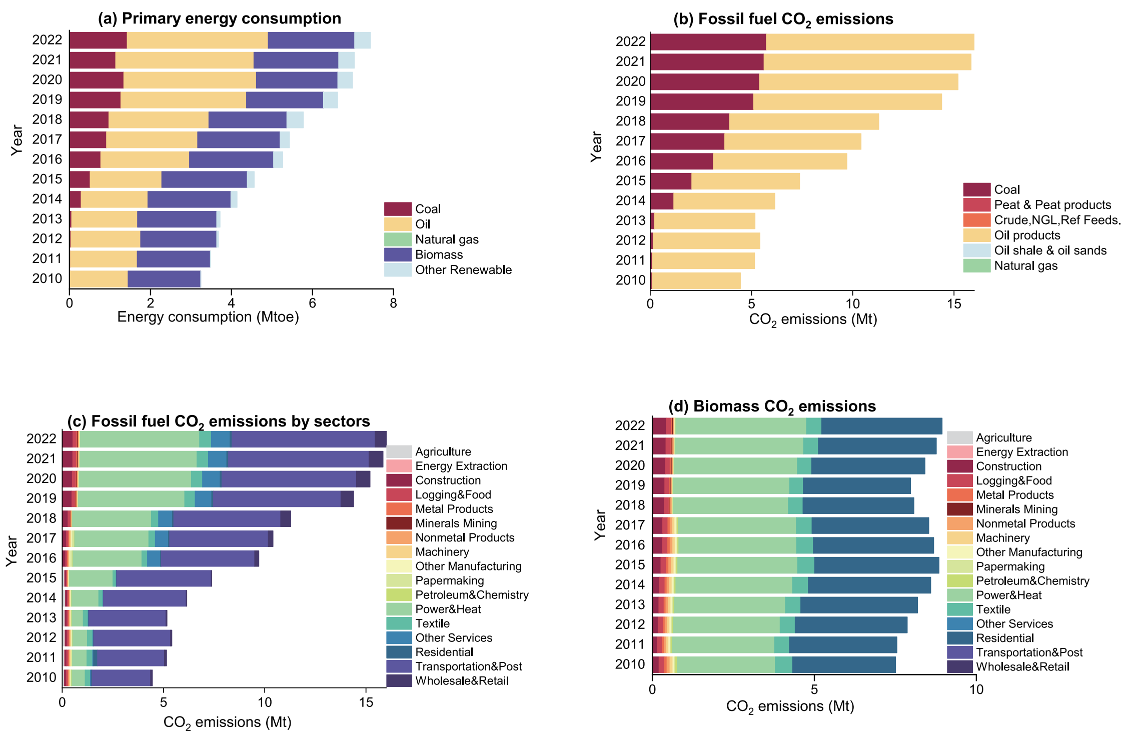
Comparison with international databases

Under the same accounting caliber (excluding emissions from biomass), the Cambodian data calculated by CEADs is basically consistent with the statistical results from other institutions, both in terms of volume or trend of fossil fuel CO_2 emissions. However, the slight differences are mainly caused by the differences of accounting methods and basis. Since 2014, the gap between EDGAR and CEADs data has widened, while IEA and CEADs data have maintained a broadly similar growth trend, but with differing outcomes: in 2017, CEADs' transportation sector emissions data was 4.9 Mt; the IEA's data was 5.3 Mt.

The difference can be explained in two ways. Firstly, from the perspective of statistical caliber, CEADs data have more detailed energy classifications. For example, petroleum products accounted for by CEADs are divided into categories such as gasoline, diesel and fuel oil; and each category has a corresponding emission factor. By contrast, the IEA's categorization stops at the level of petroleum products. Therefore, the emission factors adopted by the IEA are different from those adopted by CEADs, leading to discrepancies in emission data.

Secondly, the energy consumption data sources of the two institutions are different. CEADs uses data from the East Asia-ASEAN Economic Research Institute (ERIA). The IEA data has multiple sources, including ERIA, the Cambodian Electric Power Authority and the Cambodian Petroleum Administration. The diversity of sources leads to subtle differences in the two sets of energy consumption statistics. For example, for the year 2017, the figure used by the IEA for petroleum product consumption by the Cambodian transportation sector was 1,744 Ktoe; the equivalent, ERIA-derived figure used by CEADs was 1,612 Ktoe.

When the CO_2 produced by biomass consumption is included, CEADs' account for emissions for the year 2022 was 25.1 Mt.



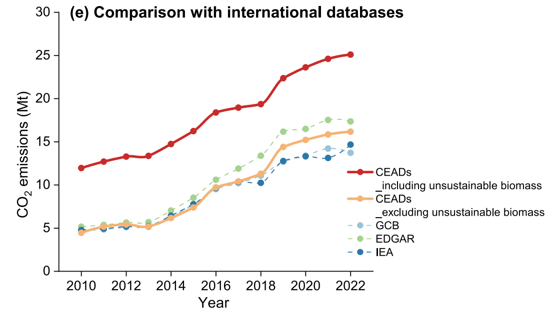


Figure 2.4: Cambodia's energy consumption and CO_2 emissions from 2010 to 2022 (a) Primary energy consumption; (b) Fossil fuel CO_2 emissions; (c) Fossil fuel CO_2 emissions by sectors; (d) Biomass CO_2 emissions; (e) Comparison with international databases.

Brief description of data sources:

The energy data used in this report comes from the 2010-2019 energy balance sheet provided by ERIA. The data in 2020-2022 were based on the energy data in the East Asia Energy Outlook report. Statistically, there are four main types of fossil fuel consumed in Cambodia: coal, crude oil and NGL, petroleum products and others. that is, and "others" — that is, biomass. Although this is not specified in the ERIA report, it can be inferred from the explanation of the legend in the report. Three sectors are involved: industry, transport, and "others". To break these sectors down into 47 sectors, CEADs used the Asian Development Bank (ADB) input-output table.

Table 2.4: Data sources for Cambodia's emission accounting

Data type	Source	Website
Energy balance sheet	East Asia-ASEAN Economic Research Center (ERIA)	https://www.eria.org/RPR_FY2015_No.8_Chapter_2.pdf
Emission factor	Intergovernmental Panel on Climate Change (IPCC)	https://www.ipcc-nggip.iges.or.jp/EFDB/
Sectoral mapping indicator	Asian Development Bank - Input -Output Table	https://data.adb.org/dataset/cambodia-input-output-economic-indicators

Background

India, which occupies most of the Indian subcontinent in South Asia, is bounded by the Indian Ocean in the south, the Arabian Sea in the southwest and the Bay of Bengal in the southeast. It shares land borders with seven countries — among them Pakistan, China, Nepal and Bhutan. India thus enjoys a strategic geographic location. According to the latest census by the Bureau of Statistics of India, the country has a population of 1.38 billion, making it the second most populous country in the world after China. India is the sixth largest economy in the world in terms of nominal GDP: US$3.35 billion dollars [32]. Due to its huge population size, the per capita GDP is only 2352.6 US dollars, which is among the world's low-income countries.

Services and agriculture are the largest economic sectors in India; industry accounts for less than a third of its economy. Despite its worldwide economic leadership, its industrial level is far behind other major economies, and it imports most industrial items. India imports mostly mineral, mechanical, electrical, and precious metal items from China, the US, and the Middle East. The majority of India's imports (14.1%) come from China[33]. In 2019, India exported to 238 countries and regions around the world its primary exports are petroleum products, diamonds, pharmaceuticals, precious metals and manned motor vehicles, collectively accounting for 30.4% of the total.

India is the world's third-largest energy consumer and national source of CO_2 emissions. Climate change has thus become a major threat to the country's economic and social development, and has attracted the attention of the Indian government. India has made some progress in green energy development, with a current renewable energy capacity exceeding 100GW. The country is also currently implementing the world's largest clean energy plan, aiming to reach 175 GW of renewable energy installed capacity in 2022, including a solar capacity of 100 GW. The government has also pledged to reduce its CO_2 emissions by 33% to 35% from 2005 levels by 2030, while meeting 40% of the country's electricity needs through non-fossil power generation in a major push to develop clean electricity, ethanol, "green transportation" and battery-saving technologies[34].

Primary energy consumption

Fossil fuel dominates India's energy sources, accounting for 76.6% of total primary energy consumption in 2022. Among them, coal and oil were the main types of fossil energy consumption, accounting for 51.48% and 22.5% of the total primary energy consumption respectively; natural gas consumption accounted for only 2.6%. In addition, biomass accounts for 20.3% of primary energy consumption, and renewable energy accounts for 3.1%.

Characteristics of fossil fuel emissions

Among all CO_2 emissions from fossil fuel combustion, those from coal are the largest with a share of 74.1%. As India's most important fossil fuel source, coal's CO_2 emissions increased from 1032.9 Mt in 2010 to 2162.8 Mt in 2022, with an average annual growth rate of 9.1%. Emissions from the consumption of petroleum products increased from 319.2Mt in 2010 to 691.6 Mt in 2022- a significant growth rate. Natural gas consumption is responsible for far lower CO_2 emissions in comparison to other fossil fuels: just 2.2% in 2022.

Sectoral emission contribution

Utility sector was responsible for the most fossil fuel CO_2 emissions in India. In 2022, this sector's use of fossil fuels generated CO_2 emissions of 1554.6 Mt, accounting for 53.3% of India's total of such emissions. It is followed by the non-metal product manufacturing industry, whose fossil fuel CO_2 emissions were405.0Mt in 2022, accounting for 13.9%. In addition, fossil fuel CO_2 emissions from other service sectors also generated a significant 306.1 Mt emission.

Biomass emissions

The main sources of biomass in India are crop residues (wheat straw, straw and bark), animal manure and wood. India contains large tracts of undeveloped land and mainly uses wasteland to grow trees for biofuel production. The main source of biomass in India is therefore sustainable, and carbon neutral over its life cycle; thus, the overall CO_2 emissions from biomass in India should not be included in the overall carbon accounting process. At present, the biomass data of the country has not been disclosed on the official website of the country and the IEA. India's biomass is also not disclosed by other international agencies.

Emission trends

Emissions from using fossil fuels grew by 109.4% between 2010 and 2022, from 1352.1 Mt to 2775.8 Mt. From 2018 to 2020, India's fossil energy CO_2 emissions fell from 2679.7 million tons to 2418.2 million tons in 2020, a decrease of 9.8%, growing to 2918.8 million tons in 2022.

Comparison with international databases

Under the same accounting caliber (excluding emissions from biomass), the fossil energy CO_2 emissions data of CEADs and the data of GCB, EDGAR and IEA differ to a degree. In 2022, CEADs' data was 2918.8 Mt, GCB's was 2663.9 Mt, EDGAR's was 2740.8 Mt, and IEA's was 2514.0 Mt. The main reason for any gaps is differences in the source and version of statistical data used. The CEADs energy data comes released by the Ministry of Statistics and Program Implementation and indicators used by CEADs updated across years. By contrast, the IEA's data source is its own national report data, which differ from those published in the Ministry of Statistics and Program Implementation of India.

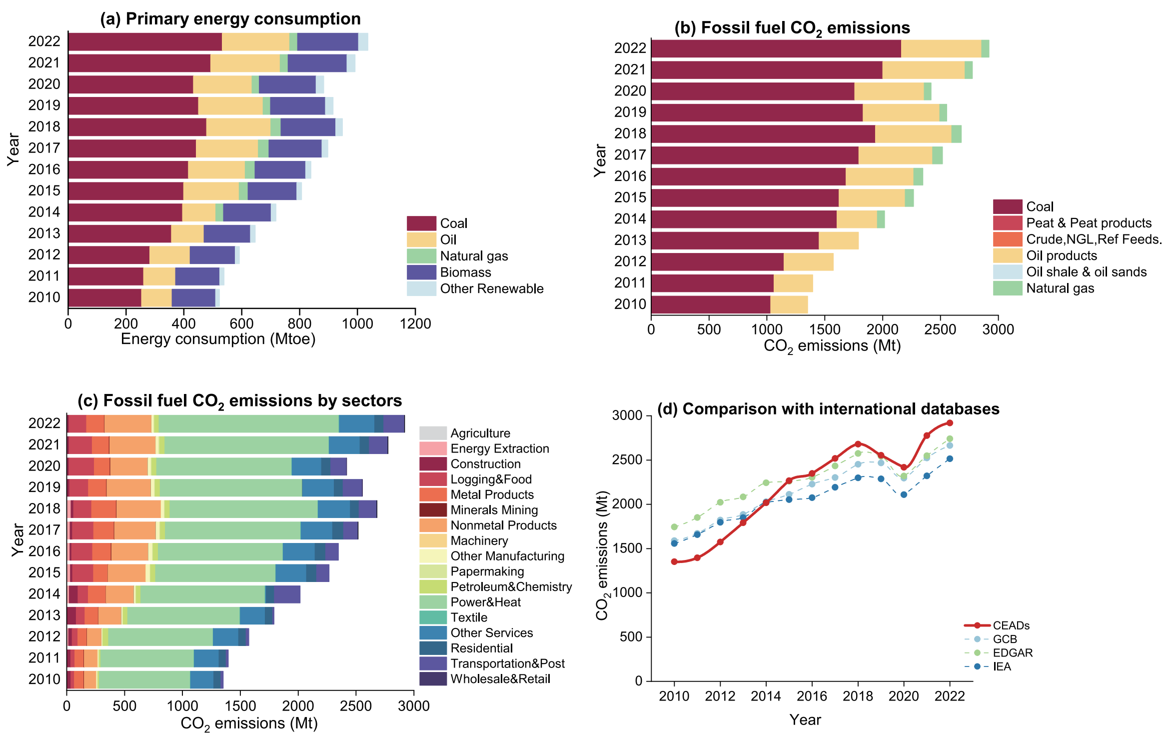


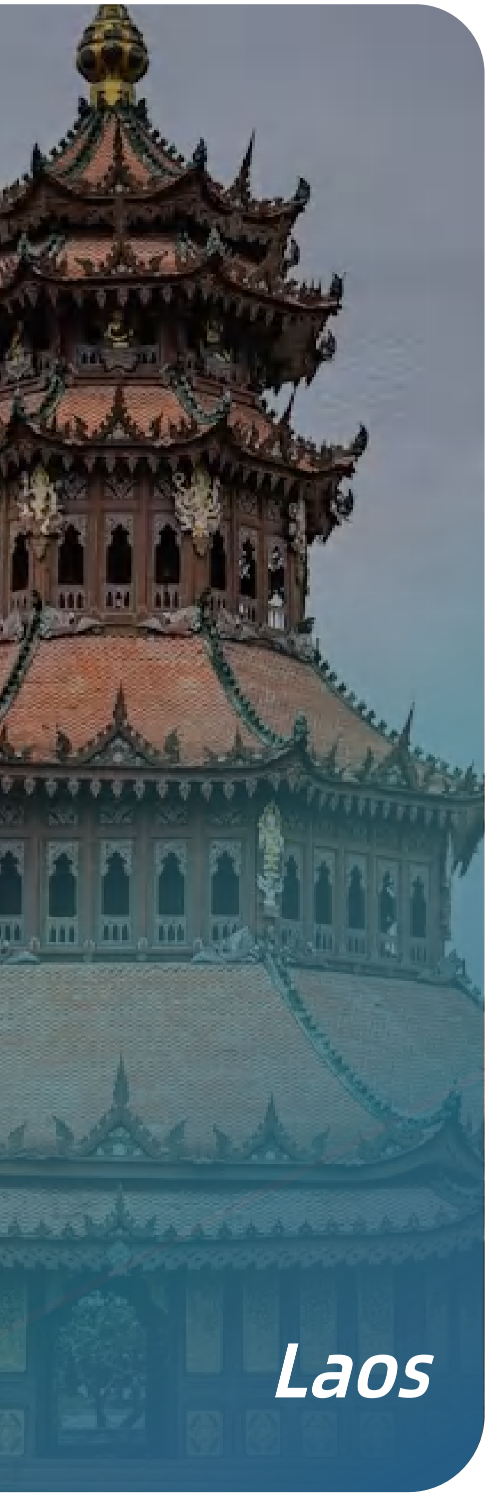
Figure 2.5: India's energy consumption and CO_2 emissions from 2010 to 2022 (a) Primary energy consumption; (b) Fossil fuel CO_2 emissions; (c) Fossil fuel CO_2 emissions by sectors; (d) Comparison with international databases.

Brief description of data sources:

India's energy balance sheet comes from its National Bureau of Statistics, covering the data from 2010 to 2022, involving 14 energy types and 19 industries. In terms of sub-industry matching, the export data from United Nations Comtrade database (UN Comtrade) is used to further downscaling.

Table 2.5: Data sources for India's emission accounting

Data type	Source	Website
Energy balance sheet	Office for National Statistics	http://mospi.gov.in/
Emission factor	Intergovernmental Panel on Climate Change (IPCC)	https://www.ipcc-nggip.iges.or.jp/EFDB/
Sectoral mapping indicator	United Nations Comtrade database (UN Comtrade), export data	https://comtradeplus.un.org/



Background

Laos is located on the Indochina Peninsula in Southeast Asia. It is the only landlocked country in Southeast Asia, with an area of 237,955 square kilometers. Over the past decade, Laos' population has grown steadily, with an average annual growth rate of 1.5%. According to the National Bureau of Statistics, the total population of Laos will reach 7.442 million in 2022[35]. The economy has been developing rapidly, with an annual GDP growth rate of 8.8% from 1993 to 2022 [36]. This shift has been due primarily to the government's innovative and open policy implemented in 1986 and its active foreign trade policy, which has seen Laos joining ASEAN and the World Trade Organization (WTO) in 1997 and 2015, respectively.

The agricultural sector of Laos' economy has steadily given way to the service sector in recent years. The service sector contributed to 40.3% of Laos' GDP in 2022[37]. The industry has also had remarkable growth over the last 10 years, Industry accounts for 30.5% of Laos' GDP in 2021[37]. Nevertheless, the Lao economy was sensitive and vulnerable to climate change because more than two thirds of the people still reside in rural regions and work in agriculture[38]. Laos is rich in hydrological and mineral resources; the latter include tin, lead, potassium salt, copper, iron, gold, gypsum, coal and rare earth, among other minerals. Most of the country's oil and natural gas are imported. In terms of international trade. Laos' main partners in import and export are Thailand, China and Japan. Its primary export products are electricity, copper and broadcasting equipment; its key imports are refined petroleum, automobiles and broadcasting equipment.

In response to climate change, Laos has formulated a series of ambitious plans to reduce greenhouse gas emissions while improving resilience to climate change. These include, for instance, increasing the use of renewable energy and accelerating the development of hydropower resources to a capacity of 13 GW[39]. The Lao Renewable Energy Development Strategy aims to encourage the development of renewable energy at the national level by setting a target of 30% renewably sourced energy consumption by 2025. Laos is the first country in Asia to announce an Intended Nationally Determined Contributions (INDC), in 2015, but its current progress towards low-carbon emission reduction is slow.

Primary energy consumption

Laos' consumption of fossil fuels accounted for 63.2% of its overall energy consumption in 2022. Coal dominated, accounting for 39.8%; petroleum made up 23.4%. Hydropower, solar and other renewable energy sources accounted for 21.3% of primary energy consumption, while biomass contributed 15.5%.

Characteristics of fossil fuel emissions

Laos is dominated by CO_2 emissions from coal consumption. Since 2015, the Hongsa power plant in Laos has been in operation, leading to a sharp increase in coal consumption, which generated 16.5 Mt of CO_2 emissions in 2021, accounting for 82% of fossil fuel CO_2 emissions. In addition, CO_2 emissions from the consumption of petroleum products increased from 1.9 Mt in 2010 to 3.6 Mt in 2022 accounting for 18% of fossil fuel CO_2 emissions in 2020.

Sectoral emission contribution

From 2010 to 2022, CO_2 emissions from fossil energy consumption in the production of electricity, heat, gas, and water sector in Laos increased significantly. In 2010, CO_2 emissions from fossil energy consumption in this industry were 0.5 thousand tons, accounting for only 0.03% of total CO_2 emissions from fossil energy. Since the inauguration of the Hongsa power plant in 2015, CO_2 emissions from the production and supply of electricity, heat, gas and water have dramatically grown, making this sector the main source of CO_2 emissions from fossil fuels. Fossil fuel CO_2 emissions from industry totaled 16.0 Mt in 2022, and it represented 79.5% of total emissions. Although the transportation, storage, and postal services industry ranks second in terms of fossil fuel CO_2 emissions, its emission contribution has decreased from 72.1% in 2010 to 16.8% in 2022.

Biomass emissions

In 2022, biomass accounted for about 15.5% of the primary energy consumption. Biomass remains an important energy source in rural areas, mainly used in the residential sector and mainly consisting of wood and charcoal. The country's rapid population growth has led to a sharp increase in demand for wood, causing serious forest degradation: only a small proportion of Lao woodlands have been restored, putting serious pressure on the environment as a whole. Most biomass sourced from unrestored forests is thus seen as unsustainable. Biomass should be included in the country's overall CO_2 emissions accounting. In 2010 and 2021, CO_2 emissions from biomass consumption in Laos were 6.3 Mt and 6.6 Mt, respectively.

Emission trends

The CO_2 emissions generated by fossil fuel consumption increased rapidly between 2010 and 2022, from 1.9 Mt to 20.2 Mt, an increase of 21.8%. During this period, emissions from biomass consumption increased from 6.3 to 6.6 Mt, with an average annual growth rate of 0.3%.

Comparison with international databases

Under the same accounting caliber (excluding emissions from biomass), in terms of trend, the fossil energy carbon emissions of Laos accounted for by CEADs are basically consistent with the statistics of GCB and IEA, and the difference between the statistics of EDGAR in 2022 and the others is relatively large; in terms of value, the fossil energy carbon emissions of Laos accounted for by CEADs in the period 2010-2022 are basically consistent with those of IEA, EDGAR, and GCB statistics, and in 2022, the IEA (18.8 Mt), GCB (17.9 Mt), and CEADs (20.2 Mt) of each database, all of which are partially deviated from EDGAR (24.5 Mt).

When CO_2 from biomass consumption is included, the CEADs figure for 2022 was 26.7 Mt.

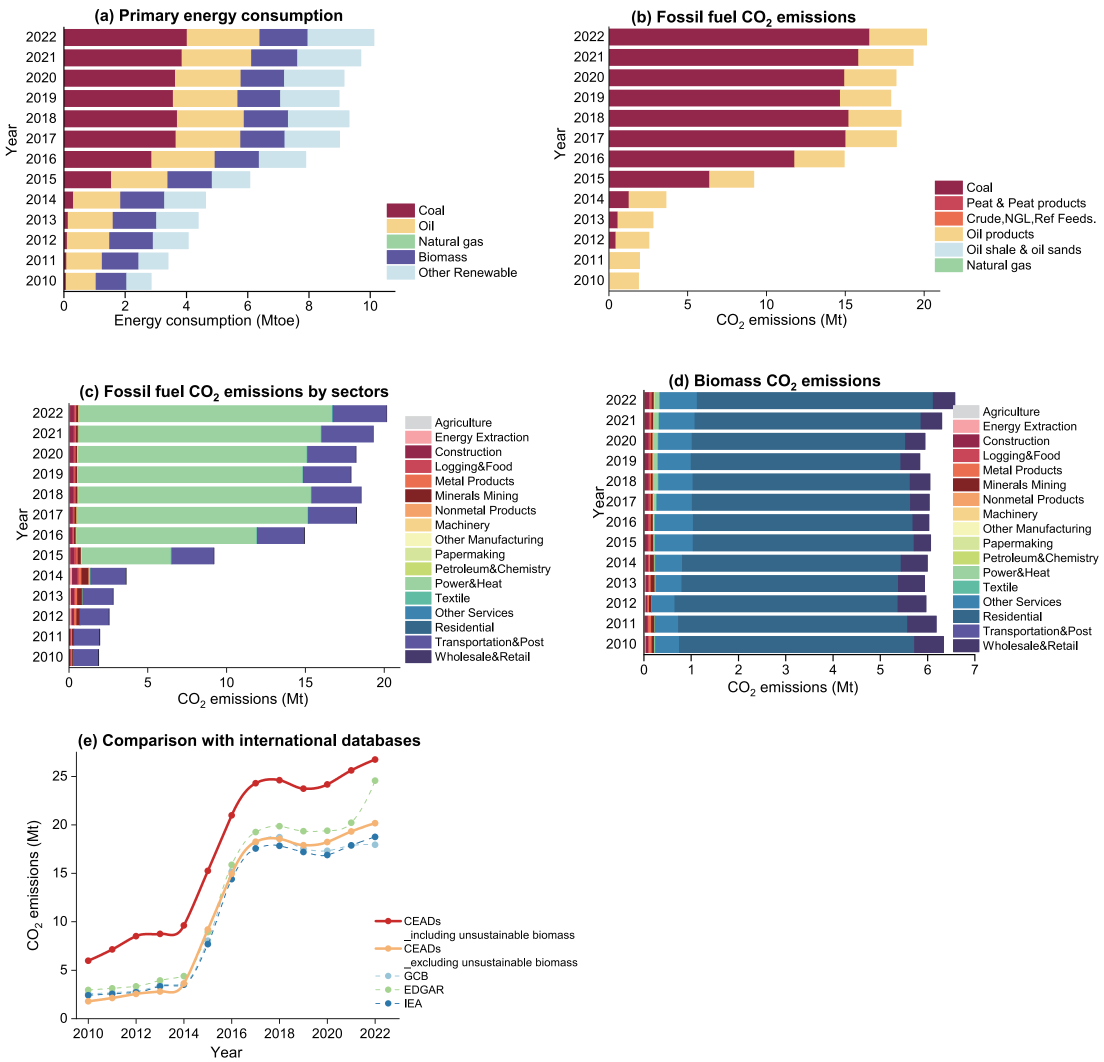


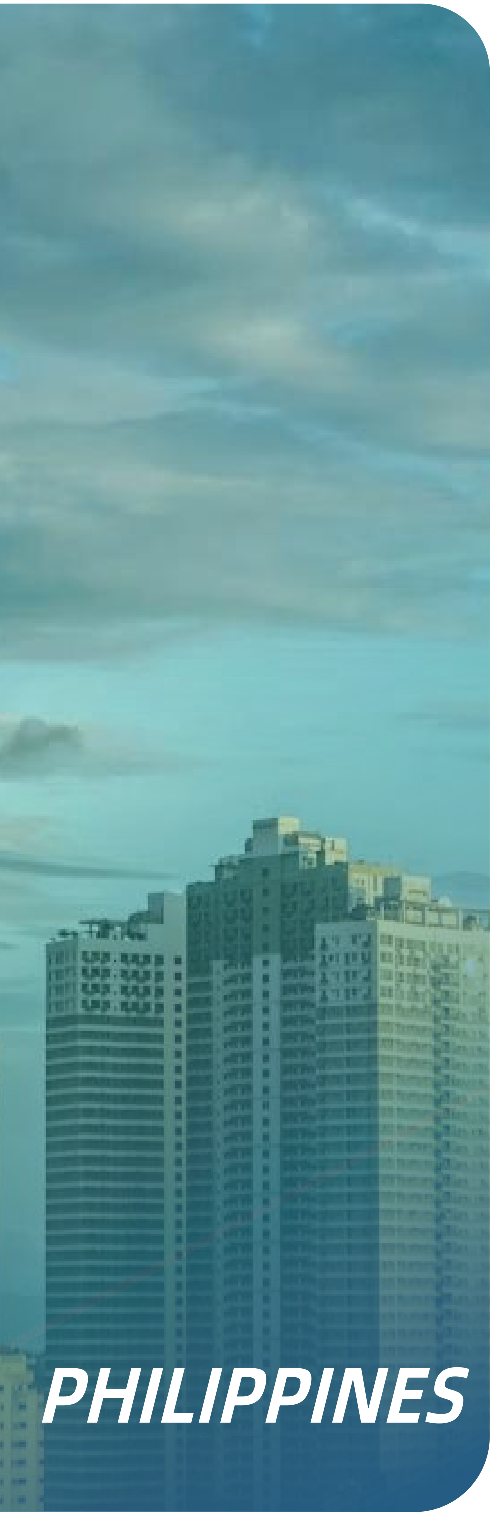
Figure 2.6: Laos' energy consumption and CO_2 emissions from 2010 to 2022 (a) Primary energy consumption; (b) Fossil fuel CO_2 emissions; (c) Fossil fuel CO_2 emissions by sectors; (d) Biomass CO_2 emissions; (e) Comparison with international databases.

Brief description of data sources:

The energy data used in this report are from ERIA. Statistically, there are three main types of fossil fuels consumed in Laos, namely coal, crude oil and "others", meaning biomass. Although this is not specified by ERIA, it can be inferred from the explanation of the legend in the report. Three sectors — industry, transport and "others" — are the main consumers of these fossil fuels. To further break down these three sectors into 47, CEADs used GDP data provided by the Lao Statistics Bureau and export data from UN Comtrade database.

Table 2.6: Data sources for Laos' emission accounting

Data type	Source	Website
Energy balance sheet	East Asia-ASEAN Economic Research Center (ERIA)	https://www.eria.org/publications/energy-demand-and-supply-of-the-lao-peoples-democratic-republic-2010-2018/
Emission factor	Intergovernmental Panel on Climate Change (IPCC)	https://www.ipcc-nggip.iges.or.jp/EFDB/
Sectoral mapping indicator	United Nations Comtrade database (UN Comtrade), export data	https://comtradeplus.un.org/
	Lao Statistics Office - Gross Domestic Product	https://laosis.lsb.gov.la/tblInfo/TblInfoList.do



Background

The Philippines, an archipelagic nation in Southeast Asia, spans 299,764 square kilometers and comprises over 7,000 islands, with Luzon and 10 other major islands accounting for 96% of its total land area and a coastline stretching approximately 18,533 kilometers[40]. According to the Philippine Statistics Authority, the country's population reached 110 million in 2022, making it the world's 12th and Southeast Asia's second nation to surpass 100 million inhabitants. The total fertility rate declined from 2.7 children per woman in 2017 to 1.9 in 2022[41]. In 2022, the nominal GDP stood at $404.35 billion, reflecting a 7.3% growth from pre-pandemic levels and a $195.98 billion expansion since 2010[42].

The Philippines maintains an export-driven economy heavily reliant on global markets, characterized by a service-dominated structure with industrial support and underdeveloped agriculture. In 2022, services contributed 61.2% to GDP, industry 29.2%, and agriculture, forestry, fishery, and livestock 9.5%. The nation boasts abundant natural resources, including 4.8 billion metric tons of copper reserves, 1.09 billion tons of nickel, 140 million tons of gold, and geothermal resources equivalent to 2.09 billion barrels of crude oil. With trade partnerships across 150 countries, its top trading partners include China, Japan, and the United States, exporting minerals, raw materials, garments, and electronic products.

To advance renewable energy development, the Department of Energy launched the Philippine Energy Plan 2020-2040 in 2021, outlining targets to increase renewable energy's share in the power generation mix to 35% by 2030 and 50% by 2040[43]. This strategy supports the country's commitment to reducing carbon emissions by 70% by 2030.

Primary energy consumption

In 2022, the consumption of fossil energy — mainly oil and coal — accounted for nearly 66.3% of primary energy consumption in the Philippines. coal and oil accounted for 31.9% and 30.1% respectively. In addition, hydropower, solar energy and other renewable energy accounted for 19.7% of primary energy consumption; biomass accounted for 14.0% of primary energy consumption.

Characteristics of fossil fuel emissions

In 2022, the Philippine's fossil fuel CO_2 emissions were 134.7 Mt, of which the consumption of petroleum and coal products is the main source of. In 2022, the consumption of petroleum products produced 52.7.Mt of CO_2 emissions, with a decrease in the proportion from 51.6% to 39.1% of fossil fuel CO_2 emissions compared with 2010. The consumption of coal products generated 75.2 Mt of CO_2 emissions, accounting for 55.8% of fossil fuel CO_2 emissions. The contribution of natural gas to fossil fuel CO_2 emissions is relatively small. The natural gas emission share has dropped from 10.9% in 2010 to 5.1% in 2022.

Sectoral emission contribution

The prime sources of CO_2 emissions from fossil energy consumption in the Philippines are production and supply of electric power, heat, gas and hot water and the transportation, storage and postal services. Since 2010, CO_2 emissions from the production and consumption of electricity, heat, gas and water have been on the rise, reaching 77.0 Mt in 2020, and accounting for 57.2% of the total CO_2 emissions from fossil energy. This sector represents the most significant growth in carbon emissions since 2010, rising by 138.5% in 2022 relative to 2010. The transportation industry, warehousing and postal services are the second largest industries in terms of fossil energy CO_2 emissions. In 2022, CO_2 emissions were 34.7 Mt, accounting for 25.8% of related emissions.

Biomass emissions

Biomass accounted for 14.0% of primary energy consumption. The Philippines lacks fossil fuel energy reserves, but it attaches great importance to the development of renewable energy. In rural areas, most households use plant residues as kitchen fuel, and other biomass types, such as animal manure, are also agriculture by-products. Since biomass sources in the Philippines are primarily renewable, they are classed as "zero carbon" resources and so should not be included in the overall carbon accounting process.

Emission trends

From 2010 to 2022, fossil fuel CO_2 emissions in the Philippines showed an increasing trend, from 73.2 Mt in 2010 to 134.7 Mt in 2022, with an average annual growth rate of 5.2%.

Comparison with international databases

Under the same accounting caliber (excluding emissions from biomass), the annual trend of CO_2 emissions from fossil energy in the Philippines, as calculated by CEADs, is almost the same as that reported by other institutions. CEADs' data aligns particularly closely with, though slightly lower than, figures from the IEA and GCB agencies, with marginal deviations of approximately 1.5% and 3.0% respectively, while showing a wider disparity of around 10% compared to EDGAR. Notably, these discrepancies have narrowed substantially since 2019. From the perspective of the reasons for the gap, CEADs' data has a more detailed energy classification, with each type of oil product having a corresponding emission factor. In contrast, according to the statistical scope of other institutions like the IEA, energy varieties are only divided into one category of petroleum products. Therefore, the emission factors used by CEADs differ from those used by the IEA, resulting in differences in carbon emission data. Another reason for the disparity is that CEADs and the IEA use different sources for energy consumption data. CEADs utilizes data from the Philippine Statistics Authority, while other institutions such as the IEA have multiple data sources, including the International Renewable Energy Agency (IRENA). This leads to significant discrepancies in energy consumption statistics between these institutions, further contributing to differences in CO_2 emissions data between CEADs and other entities like the IEA.

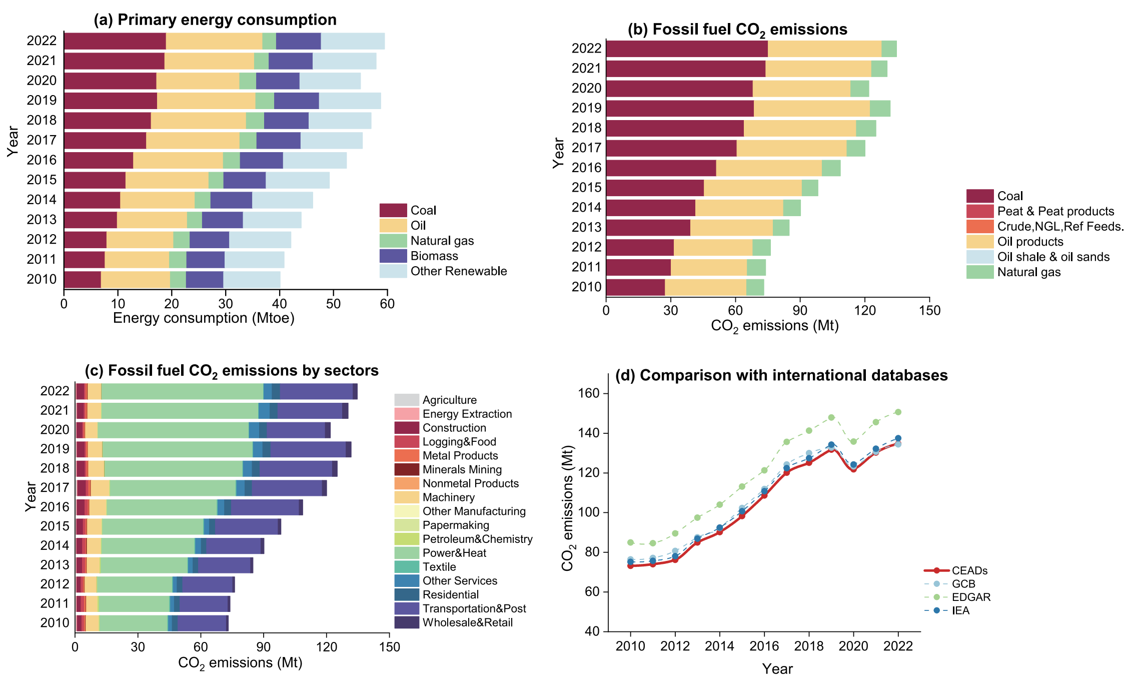


Figure 2.7: Philippines' energy consumption and CO_2 emissions from 2010 to 2022 (a) Primary energy consumption; (b) Fossil fuel CO_2 emissions; (c) Fossil fuel CO_2 emissions by sectors; (d) Comparison with international databases.

Brief description of data sources:

The energy balance sheet of the Philippines comes from the National Bureau of Statistics, covering the data from 2010 to 2022, involving 13 energy types and 5 departments. In terms of sectoral match index, CEADs used its industrial characteristics as the basis for down-scale matching to 47 sectors refined by export data published by UN Comtrade.

Table 2.7: Data sources for Philippines' emission accounting

Data type	Source	Website
Energy balance sheet	Philippine Statistics Authority	https://www.google.com/url?client=internal-element-cse&cx=002003278549005806711:omtq4bysgs4&q=https://psa.gov.ph/system/files/enrad/Table%25202.7%2520Energy%2520Balance%2520Table%252C%25202012%2520to%25202022.xlsx&sa=U&ved=2ahUKEwiLnpLp0tyFAxWhywIHHZZiC2AQFnoECAMQAQ&usg=AOvVaw2zFZ7cvzDtaATPVC_JFn9T
Emission factor	Intergovernmental Panel on Climate Change (IPCC)	https://www.ipcc-nggip.iges.or.jp/efdb/
Sectoral mapping indicator	Philippine Statistics Authority, GDP data	https://psa.gov.ph/philippine-statistical-yearbook
	United Nations Comtrade database (UN Comtrade), export data	https://comtradeplus.un.org/
	World Bank, World Urbanization Prospects	https://data.worldbank.org.cn/indicator/SP.URB.TOTL.IN.ZS

Background

Sri Lanka, known as Ceylon before 1972, is an island nation in South Asia, lying in the Indian Ocean off the southern reaches of the Indian subcontinent. Its political capital is Sri Jayawardenepura Kotte, generally called Kotte; its economic capital is Colombo. According to the World Factbook[44], the land area of Sri Lanka is 65,610 square kilometres. Sri Lanka's population in 2023 was approximately 22.04 million, with a per capita GDP of around $3828, placing it 132nd in the world in terms of economic output per person[45]. The western part of Sri Lanka, particularly the capital and its surrounding areas, exhibits the highest population density. The Sinhalese represent the largest ethnic group in the country, comprising 74.9% of the total population.

Sri Lanka's economy is dominated by gemstone exports and agriculture. Tissa Jayatilaka, executive director of the United States-Sri Lanka Fulbright Commission, has pointed out that the main agricultural products in tropical regions are representative cash crops such as rice, rubber, coconut and coffee. The country's most important export is Ceylon black tea: Sri Lanka is one of the three largest tea-producing countries in the world. Sri Lanka's annual report also shows that its tourism resources are abundant, but since the 2004 Indian Ocean earthquake and tsunami, the country's coastline has been severely damaged, and tourism has also been affected to some extent.

In Sri Lanka, residents commonly use firewood as a primary energy source during weekdays. Despite the government's efforts to promote alternatives such as natural gas to replace firewood, significant progress has yet to be achieved. In September 2021, Sri Lanka announced a pivotal shift in its energy policy, declaring that it would halt the construction of new coal-fired power plants and focus on renewable energy sources instead. The country has set ambitious goals for its energy sector: to meet 70% of its electricity demand through renewable energy by 2030 and to achieve carbon neutrality by 2050. To reach the 70% renewable energy target by 2030, Sri Lanka has attracted substantial investment in solar and wind power projects exceeding 50 megawatts. The plan includes adding 4,800 megawatts to the current solar power generation capacity of 458 megawatts, and increasing wind power capacity by 3,500 megawatts from the existing 248 megawatts.

Primary energy consumption

Primary energy consumption in Sri Lanka is dominated by petroleum products. In 2022, oil consumption accounted for 38.4% of the total, and coal consumption for 11.9%. In addition, biomass such as firewood accounts for 32.3% of primary energy consumption. Other renewable energy sources, primarily hydropower, account for 17.3% of such consumption.

Characteristics of fossil fuel emissions

Fossil energy CO_2 emissions in Sri Lanka are mainly derived from oil and coal consumption. Petroleum products generated a total of 12.9 Mt of CO_2 emissions in 2022, accounting for 70.6% of the CO_2 emissions from fossil energy. CO_2 emissions from coal consumption have grown significantly, from 0.2 Mt in 2010 to 5.3 Mt in 2022.

Sectoral emission contribution

The key fossil energy CO_2 emissions in Sri Lanka originate from the transportation, storage and postal services and the utility sectors. In 2017, the emissions generated by the transportation, storage and postal services reached their peak in recent years, with CO_2 emissions of 11.0 Mt, and have gradually decreased thereafter. In 2022, this sector generated 8.9 Mt, accounting for 48.9% of the total. Diesel and gasoline were the primary sources. In addition, electricity, heat, gas and water production generated close to 6.7 Mt of CO_2 emissions in 2022, or around 37.1% of the total.

Biomass emissions

In 2022, biomass energy in Sri Lanka accounted for 32.3% of primary energy consumption, both domestic and industrial. The two main types of biomass in Sri Lanka are bagasse or plant fibre, and firewood. The latter is derived primarily from deforestation and is thus an unsustainable resource. In the overall carbon accounting process, it should be included in overall CO_2 emissions. Biowastes such as bagasse, by contrast, mainly come from local plantations and can be derived from repeated plantings. They are thus sustainable renewable resources, viewed as “zero-carbon” throughout their life cycle, and should not be included in the overall carbon accounting process. Biomass CO_2 emissions have decreased from 21.5 Mt in 2010 to 16.7 Mt in 2022.

Emission trends

CO_2 emissions in Sri Lanka are growing rapidly. Between 2010 and 2022, CO_2 emissions from fossil energy consumption increased from 12.1 Mt to 18.2 Mt, with an average annual growth rate of 3.5%. During this period, CO_2 emissions from biomass consumption decreased slightly, from 21.5 Mt to 16.7 Mt.

Comparison with international databases

Under the same accounting caliber (excluding emissions from biomass), the fossil energy CO_2 emissions of Sri Lanka accounted for by CEADs, and other institutions show similar trends, but values differ. Compared with the results of EDGAR and GCB, CEADs accounting results show a higher starting point in 2010; but since 2012, CEADs' results have been lower than those in other databases. Emission factors are a key reason for the differences. CEADs has more detailed energy classifications and used the emission factors released by Sri Lanka in its calculation, while IEA's statistical caliber of energy varieties is relatively rough.

In addition, when CO_2 generated by biomass consumption is included, in 2022, the CEADs accounting data is 34.8 Mt.

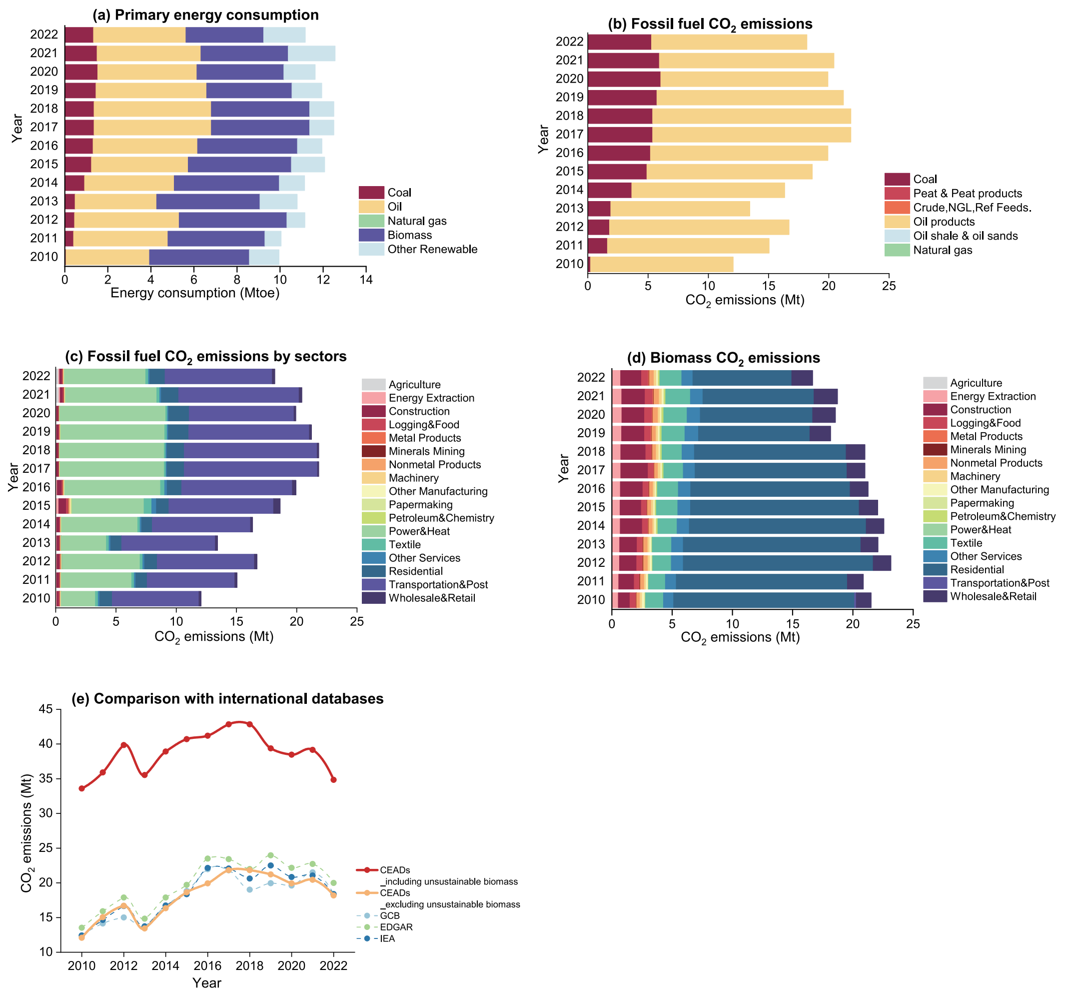


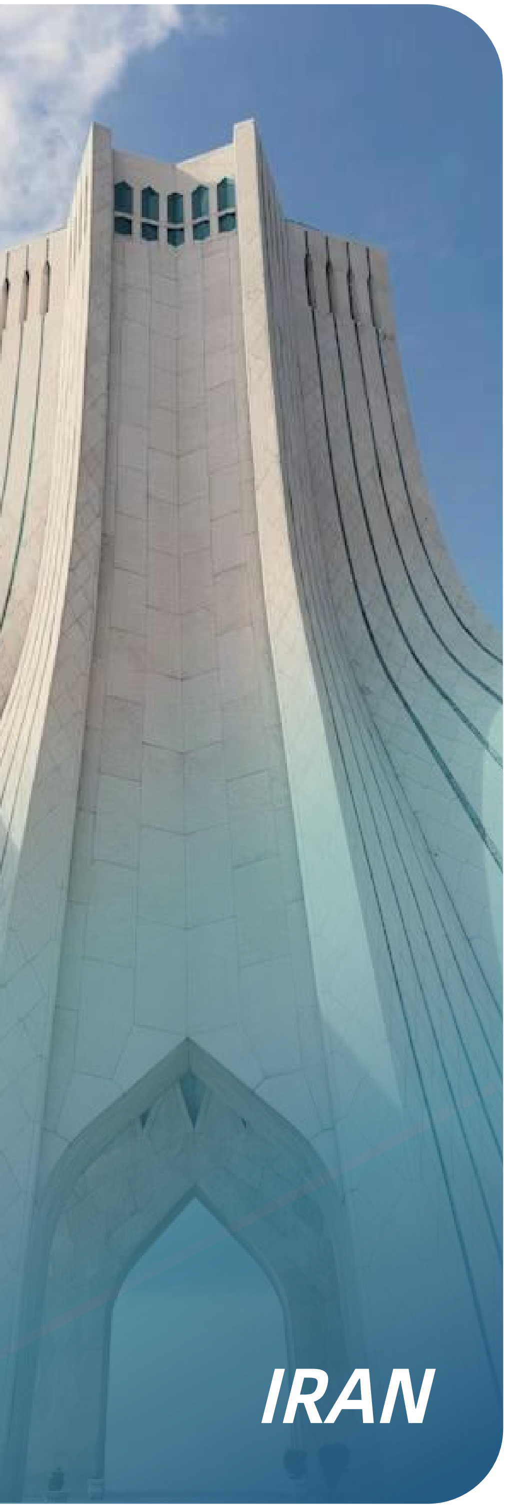
Figure 2.8: Sri Lanka's energy consumption and CO_2 emissions from 2010 to 2022 (a) Primary energy consumption; (b) Fossil fuel CO_2 emissions; (c) Fossil fuel CO_2 emissions by sectors; (d) Biomass CO_2 emissions; (e) Comparison with international databases.

Brief description of data sources:

Sri Lanka's energy balance sheets are all from the Sri Lanka Sustainable Energy Authority, covering data from 2012 to 2022 and 2010, involving 9 energy varieties and 7 sectors. For subsector matching, we use value added by industries from UNdata and export data from the United Nations Commodity Trade Statistics Database (UN Comtrade) to downscale the sectoral matching and assign to 47 sectors.

Table 2.8: Data sources for Sri Lanka's emission accounting

Data type	Source	Website
Energy balance sheet	Sustainable Energy Authority	http://www.energy.gov.lk/index.php/en/
Emission factor	IPCC	https://www.ipcc-nggip.iges.or.jp/EFDB/
Sectoral mapping indicator	UN Comtrade	https://comtrada.un.org
	UNdata - Value added by industries	http://data.un.org/Explorer.aspx#marts



Background

Iran is strategically situated in southwest Asia, in the Middle East region, which is a part of West Asia. It has borders with several nations, including Pakistan, Afghanistan, and Turkey, and is bordered to the south by the Persian Gulf and the Arabian Sea. According to information provided by Iran's National Statistical Office, the country's GDP in 2022 was around $404.6 billion[46], and GDP per capita was $4465.6[47]. Iran still falls under the category of emerging nations as a result of the extensive economic and energy restrictions.

Agriculture, industry, and services, Iran's three largest economic sectors, contributed 12.8%, 36.2%, and 48.3% of GDP[48-50], respectively, in 2022. Iranian reserves of proven natural gas and oil rank second and fourth in the world, respectively, and the country has abundant oil and gas resources. Iran's petrochemical industry has thrived thanks to its superior natural resource endowment, and the government now depends heavily on the oil sector for its foreign exchange profits, with oil income making up more than half of all foreign exchange earnings[51]. The General Administration of Customs in Iran estimates that the country's overall imports and exports will amount to $73.88 billion in 2022, of which $34.99 billion will come from exports and $38.89 billion from imports. China, the United Arab Emirates, Turkey, and Iraq are Iran's top five export destinations, with petrochemicals and petroleum products accounting for about 50% of its exports and minerals for 20%. China, the United Arab Emirates, and Turkey are its top three import sources[52].

Iran also has a wealth of solar and wind energy, which can help the nation lessen its reliance on imported energy and lessen the socioeconomic effects of climate change. Government organizations have promoted an increase in the proportion of renewable energy sources, such as nuclear and geothermal energy, although they have only suggested a 4% decrease in greenhouse gas emissions by 2030 and have not included any explicit clean energy targets in their nationally owned contributions[53]. Iran lacks the advanced technology and adequate financial resources to support the development of a strong environmental policy and is still dependent on highly carbon-intensive industries and oil exports to sustain its economy. This is due to a number of factors, including the political climate and high rates of poverty.

Primary energy consumption

Iran's primary energy consumption structure is dominated by natural gas and petroleum products. In 2022, the proportion of natural gas consumption was 70.9%, while petroleum product consumption accounted for 26.9%. Coal consumption represented a mere 0.2% share, resulting in a combined fossil fuel consumption of nearly 98.1%. Additionally, biomass contributed 0.5% to the primary energy consumption, while other renewable sources like wind and solar energy comprised 1.4% of the total.

Characteristics of fossil fuel emissions

Fossil energy CO_2 emissions in Iran are mainly derived from and natural gas and oil consumption. Natural gas, as Iran's primary fossil fuel, emitted a total of 378.6 Mt of carbon in 2022, accounting for 66.4% of the CO_2 emissions from fossil fuel consumption. CO_2 emissions from petroleum product consumption decreased from 229.4 Mt in 2010 to 189.5 Mt in 2022 marking a reduction of 17.4%. Iran's petroleum production has continuously declined since 2016, primarily due to the impact of international energy sanctions resulting from the JCPOA (Joint Comprehensive Plan of Action) and the global economic downturn.

Sectoral emission contribution

The largest fossil energy carbon-emitting sectors in Iran are the production of electricity, heat, gas, and water. In 2022, this sector generated 175.6 Mt of CO_2 emissions from fossil fuel consumption, accounting for 30.8% of the total fossil fuel CO_2 emissions. This proportion remained relatively stable during this period. Iran's second-largest contributor to fossil fuel CO_2 emissions was transportation, storage, and postal services, accounting for 25.2% of the total in 2022. The third-largest sector in terms of fossil fuel CO_2 emissions was residential sector, with its CO_2 emissions from fossil fuel consumption making up 20.3% of the total fossil fuel CO_2 emissions.

Biomass emissions

In 2022, biomass accounted for 0.5% of Iran's primary energy consumption structure, mainly utilized in the residential sector. Iran's biomass energy primarily consists of solid biomass derived from agricultural waste and animal dung, as well as biogas[54]. Since Iran's biomass sources mainly originate from sustainable renewable resources, with a complete life cycle exhibiting a "zero-carbon" attribute, they should not be included in the overall CO_2 emissions during the comprehensive carbon accounting process.

Emission trends

CO_2 emissions in Iran are growing rapidly. Between 2010 and 2019, CO_2 emissions from fossil fuel consumption increased by 15.7%, rising from 471.7 Mt to 545.7 Mt. In 2020, influenced by the global economic situation, CO_2 emissions from fossil fuel consumption decreased to 534.7 Mt, marking a reduction of 2.0 %, compared to 2019. In 2022, total CO_2 emissions from fossil energy rebounded to 570.3 Mt.

Comparison with international databases

Under the same accounting caliber (excluding biomass CO_2 emissions), the overall trend shows that the accounting results of various institutions are generally similar. Differences in accounting methods and fundamentals lead to variations in results. Among these, EGDAR exhibits the highest CO_2 emissions, and the gap between CEADs and both EDGAR and GCB widen year by year. CEADs and IEA data share a similar starting point, with a difference in total emissions of approximately 6%. When comparing CEADs and IEA sector emissions, differences are observed. One factor contributing to the disparity is emission factors—CEADs has a more detailed energy classification, while IEA's statistical framework for energy types is relatively coarse. Additionally, variations arise from energy consumption data in different sectors. For instance, IEA's statistics for energy usage in certain industries differ from officially published energy balance sheets, thereby leading to divergent accounting outcomes.

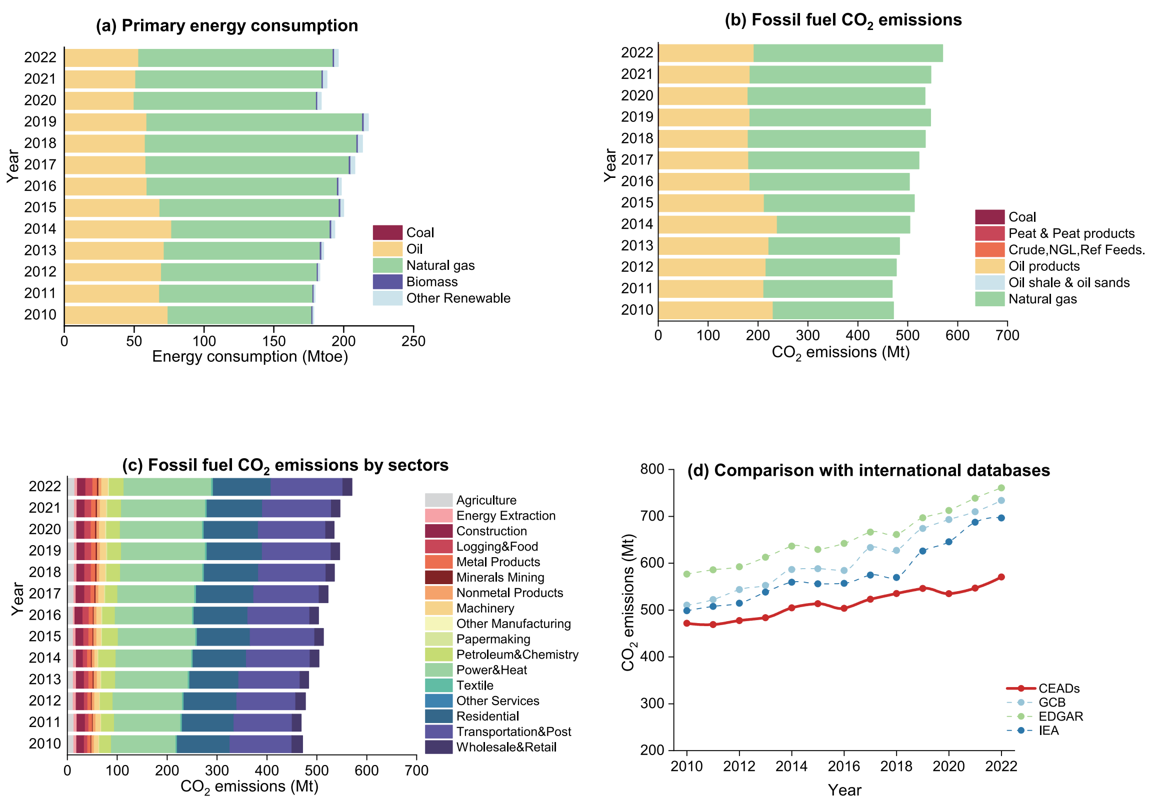


Figure 2.9: Iran’s energy consumption and CO_2 emissions from 2010 to 2022 (a) Primary energy consumption; (b) Fossil fuel CO_2 emissions; (c) Fossil fuel CO_2 emissions by sectors; (d) Comparison with international databases.

Brief description of data sources:

Iran's energy balance data from 2010 to 2018 is sourced from its national statistical bureau, providing reliable and authentic information. Energy data for 2019 is supplemented based on historical trends, while energy data for 2020-2022 is extrapolated using Ener data energy indicators. The official energy balance has been published, encompassing five energy types and five sectors. Further disaggregation to 47 sectors is done based on industrial output data and urban-rural population data and export data from the UN Comtrade.

Table 2.9: Data sources for Iran’s emission accounting

Data type	Source	Website
Energy balance sheet	Iranian Electricity and Energy Programme	https://pep.moe.gov.ir/
Emission factor	IPCC	https://www.ipcc-nggip.iges.or.jp/EFDB/
Sectoral mapping indicator	Statistics Iran	https://www.amar.org.ir/english/Iran-Statistical-Yearbook
	UN Comtrade	https://comtradeplus.un.org/

JORDAN

Background

Jordan, located in western Asia in the northwest of the Arabian Peninsula, is bordered by Israel, Palestine and Syria, among other countries, and sits at the intersection of Asia, Europe and Africa. In ancient times, Jordan stood on the Middle East's main trade route. It now enjoys a reputation for political stability in the region. Jordan has one of the smallest economies in the Middle East, with a combined GDP of US$50.97 billion at current prices in 2023[55] and a population of 11.44 million[56], 11.6% of whom live below the poverty line.

Jordan's manufacturing sector is relatively developed, accounting for about 17.0% of GDP in 2023[57]; agriculture accounts for just 4.8%[58]. Unlike neighboring Arab states, Jordan's natural resources are limited, with only small oil and gas reserves. In terms of international trade, its top export products have been non-metals, refined oil, cement and fertilizers, shipped mainly to the United States, Saudi Arabia and Iraq. Its main imports included mechanical equipment and components, rail vehicles and accessories, electrical equipment and components, petroleum products, and liquefied natural gas. Its main trading partners are Saudi Arabia, the United States, China and India. China is Jordan's second-largest source of imports; in 2021, these were worth US$3.14 billion[59].

Jordan is rich in solar and wind energy. In order to reduce the dependence on external energy and mitigate the impact of climate change on the country's socio-economic, the government agency proposed to reach 50% of the power structure by 2030. In addition, the government plans to invest in the construction of solar power generation and wind power generation equipment with a total capacity of 1.0GW[60]. Jordan's Nationally Determined Contribution (INDC) is to reduce its greenhouse gas emissions by 14% by 2030[61].

Primary energy consumption

Jordan's primary energy consumption is dominated by natural gas and petroleum products. In 2022, oil, natural gas, coal accounted for 48.8%, 40.6%, and 2.6% of primary energy consumption. Total fossil fuel consumption accounted for nearly 92%. Biomass accounted for 0.4% of primary energy consumption. Other renewable energies accounted for 7.6%.

Characteristics of fossil fuel emissions

Among the fossil fuel CO_2 emissions, oil and natural gas predominated. As the most important fossil fuel in Jordan, petroleum products produced 12.7 Mt of fossil fuel CO_2 emissions in 2022, accounting for 55.6% of the total fossil fuel CO_2 emissions. The fossil fuel CO_2 emissions from natural gas significantly increased from 6.2 Mt in 2010 to 9.4 Mt in 2022.

Sectoral emission contribution

The production of electricity, heat, gas, and water sector accounted for 40.2% of Jordan's total fossil fuel CO_2 emissions with 9.0 Mt of CO_2 emissions in 2022. Since 2015, however, this proportion has been decreasing primarily due to the ratification of a purchase agreement between the Hashemite government of Jordan, the national power company NEPCO, and the Leviathan gas field. It began supplying Jordan with 15 billion cubic meters of natural gas annually to supplant oil-based electricity production. It is the second largest fossil fuel CO_2 emission sector in Jordan, after the transportation, storage, and postal services sector, accounting for 38.4% of the total fossil fuel CO_2 emissions in 2022, primarily through the use of diesel, petrol, and fuel.

Biomass emissions

In 2022, Jordan's biomass accounted for 0.4% of the primary energy consumption, mainly used in the household. Biomass types mainly included agricultural residues (grain, fruit, and vegetable residues), animal manure, and municipal solid waste[62, 63]. Since Jordan's biomass sources are mainly sustainable renewable resources, with "zero carbon" attribute, it should not be included in the overall CO_2 emissions.

Emission trends

Between 2010 and 2017, CO_2 emissions from fossil fuel consumption increased by 32.0%, from 20.4 Mt to 26.9 Mt. Then, CO_2 emissions from fossil energy consumption have maintained a continuous downward trend, and the total CO_2 emissions from fossil energy have decreased to 19.9 Mt in 2020. Between 2010 and 2017, CO_2 emissions from fossil fuel consumption increased slightly, and reached 22.8 Mt in 2022.

Comparison with international databases

Under the same accounting caliber (excluding emissions from biomass), CEADs calculations of CO_2 emissions in Jordan show almost the same annual emission trends as those of other agencies, but its accounting methods and results differ somewhat. The statistics from EDGAR and CEADs have similar starting points, but the gap between them is widening annually. The disparity between calculations from CEADs and IEA on total emissions from fossil fuels is, at around 5%, not significant. When comparing the CO_2 emissions of the CEADs and the IEA sector, the results are different. In 2018, for example, CEADs' calculation for emissions of Jordan's manufacturing and construction industries was 2.4 Mt. The IEA's data was 1.6 Mt — a gap of 33.9%. The main reason for this disparity lies with emission factors: CEADs uses more detailed energy classifications, while IEA's statistical caliber of energy types is relatively rough. The second reason involves the energy consumption data of various sectors. For example, IEA statistics on the agricultural sector's energy use are missing, and its data for other unclassified industries do not tally with the official energy balance sheet.

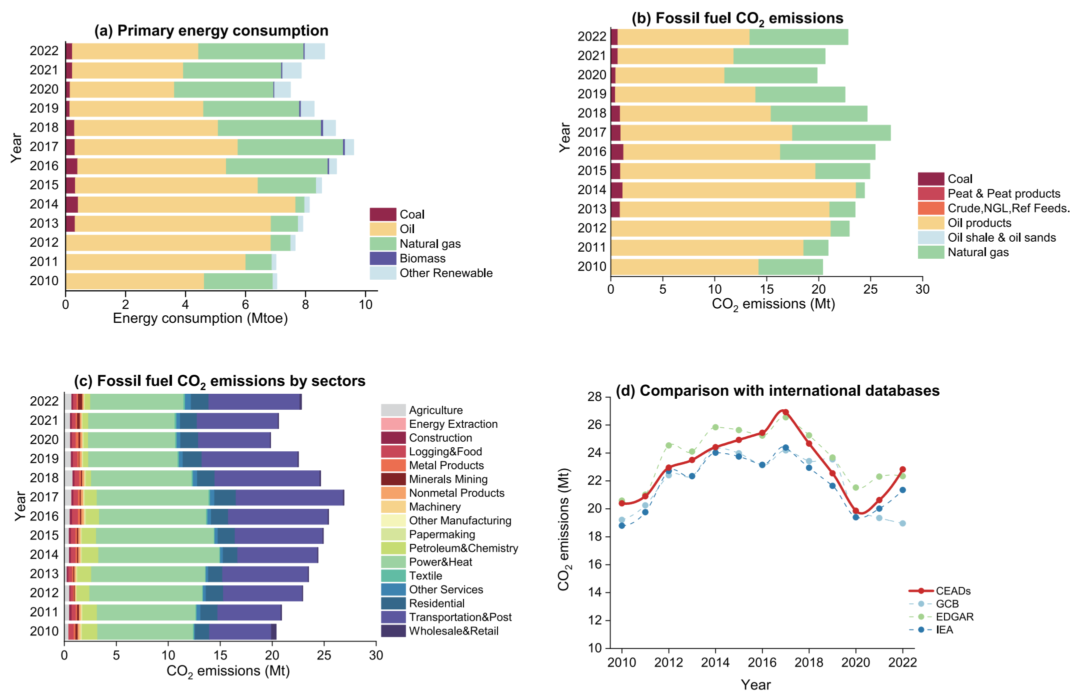


Figure 2.10: Jordan's energy consumption and CO_2 emissions from 2010 to 2022 (a) Primary energy consumption; (b) Fossil fuel CO_2 emissions; (c) Fossil fuel CO_2 emissions by sectors; (d) Comparison with international databases.

Brief description of data sources:

Jordan's energy balance sheets are all from the Ministry of Energy and Mineral Resources, covering the data from 2010 to 2022. The energy balance table involves 13 energy varieties and 6 sectors. Among them, in terms of sectoral match index, CEADs used the industrial output data released by the National Bureau of Statistics and the gross production value of agriculture, service industries, and construction industries and export data from the UN Comtrade as the basis to downscale to 47 industries.

Table 2.10: Data sources for Jordan's emission accounting

Data type	Source	Website
Energy balance sheet	Ministry of Energy and Mineral Resources	https://www.memr.gov.jo/Default/Ar
Emission factor	Intergovernmental Panel on Climate Change (IPCC)	https://www.ipcc-nggip.iges.or.jp/EFDB/
Sectoral mapping indicator	Jordan Statistical Authority (Industry)	http://jorinfo.dos.gov.jo/Databank/pxweb/ar/DOS_Database/START__10__1001__1101/FIN_T1/
	Jordan Statistics Authority (Agriculture, Services and Construction)	http://jorinfo.dos.gov.jo/Databank/pxweb/ar/NationalAccount/
	UN Comtrade	https://comtradeplus.un.org/

Background

Indonesia is a transcontinental country in Oceania and Southeast Asia, straddling the Equator and bordering Papua New Guinea, East Timor and Malaysia. It is the world's largest archipelagic nation, consisting of approximately 17,508 islands between the Pacific and Indian Oceans and covering a land area of approximately 190.4 square kilometers. As of February 2023, Indonesia's population stood at 280 million — the world's fourth largest. Indonesia has enjoyed relatively steady economic growth since the 1960s; significant progress in agriculture, energy extraction and textiles has made it the largest economy in the Association of Southeast Asian Nations (ASEAN). In 2023, the country's GDP was US$1.37 trillion, the 16th largest globally. The per capita GDP is about 4876.3 US dollars, returning to the ranks of upper-middle-income countries as determined by the World Bank[64].

International trade plays an important role in Indonesia's national economy. The Indonesian government has taken a series of measures to encourage and promote the export of manufacturing products. At present, in addition to oil and gas, Indonesia's export products are mainly textiles, clothing, wood, rubber, etc., while imports mainly include machinery and transportation equipment, chemical products, automobiles and spare parts. The main trading partners are China, Japan, Singapore, and the United States. In 2021, Indonesia's total import and export trade of goods was US$427.713 billion, a year-on-year increase of 40.3%. Among them, the import value was US$196.19 billion, a year-on-year increase of 38.58%; the export value was US$231.523 billion, a year-on-year increase of 41.87%. The trade surplus was US$35.333 billion, the highest since 2011[64].

Indonesia is one of the world's largest carbon emitters, and the government has pledged to reduce CO_2 emissions by 29% by 2030. If the country receives US$6 billion in international assistance, it will raise its target to 41%[65]. Indonesia is also one of the five biggest national users of renewable energy in the Asia-Pacific region, with hydropower and geothermal contributing about 8% and 5%, respectively, to its power sector. In addition, the government plans to adopt a national policy to increase the share of renewable energy in primary energy to 23% by 2025, and 31% by 2050[66].

Primary energy consumption

Indonesia's primary energy sources are dominated by coal and oil. In 2022, the use of fossil fuels - mainly coal, oil and natural gas - accounted for more than 96.2% of primary energy consumption. Coal accounted for 56.2%, oil for 28.0%, and natural gas for 12.0%. Meanwhile, biomass accounted for 2.4%, and other renewables for 1.4%.

Characteristics of fossil fuel emissions

Among the CO_2 emissions generated by Indonesia's fossil energy consumption, coal has always been the largest source of fossil energy CO_2 emissions in Indonesia, except for 2010 and 2014, and has grown rapidly, from 180.8 Mt in 2010 to 606.5 Mt in 2022. In 2022, CO_2 emissions generated by coal consumption accounted for 68.9% of total fossil energy CO_2 emissions. Oil is the second largest fossil energy carbon emission source in Indonesia, ranking first in fossil energy CO_2 emissions in 2010 and 2014, but in 2015-2019, due to a significant reduction in oil consumption, its fossil energy CO_2 emissions also decreased. In 2022, CO_2 emissions generated by oil consumption accounted for 23.4% of total fossil energy CO_2 emissions. In addition, natural gas consumption also generates certain CO_2 emissions, accounting for about 7.8% of total fossil energy CO_2 emissions.

Sectoral emission contribution

Between 2010 and 2022, the utility sector was the largest in terms of CO_2 emissions in Indonesia. In 2022, it accounted for more than 43.9% of the total from fossil sources, followed by household consumption sector, and the transportation, storage and postal services sector, which accounted for 10.6% and 8.6% of the country's total such emissions in 2022, respectively.

Biomass emissions

In 2022, Indonesian biomass accounted for 2.4% of the primary energy consumption, and was mainly used for household and construction. The main types of biomasses used are rubber wood waste and palm oil residue. Since Indonesia's biomass sources are relatively sustainable renewable resources with "zero carbon" attribute, it should not be included in the accounting process.

Emission trends

Indonesia's overall CO_2 emissions show an upward trend. Between 2010 and 2012, emissions from fossil fuel combustion increased by 34.5%, from 426.5 Mt to 537.5 Mt. This rise is mainly due to the fact since the financial crisis of 2008, Indonesia has striven to rebuild or industrialize its economy, and CO_2 emissions have kept pace. As the economy continues to grow rapidly, CO_2 emissions have also increased. Since 2012, CO_2 from fossil fuel consumption has fluctuated slightly and showed a downward trend from 2012 to 2015, when it fell by 11.4%. Subsequently, CO_2 emissions from fossil energy showed a slight decline, falling to 626.0 Mt in 2020. However, in 2022, CO_2 emissions from fossil energy increased to 880.5 Mt.

Comparison with international databases

Under the same accounting caliber (excluding emissions from biomass), CO_2 emissions in Indonesia calculated by CEADs show almost the same annual emission trends as equivalent statistics from other institutes. The trends in CO_2 emission data from CEADs and EDGAR are almost completely consistent, with the values being the closest and showing a difference of about 10%. The trends from CEADs and GCB's CO_2 emission data are also roughly similar. Although there is a notable discrepancy between the results from 2012 to 2013, the data align closely after 2014. However, when comparing CEADs with IEA's statistical data, the numerical gap is the largest, at approximately 20%. The primary reason for this discrepancy is the difference in data sources, which consequently leads to divergent accounting results. The main reason for these disparities is that a variety of data sources are used. CEADs' energy data come from Statistics Indonesia (BPS), while IEA's main data sources are Indonesia's Ministry of Energy and Mineral Resources (ESDM), BPS, the Indonesian Ministry of Agriculture and the country's State Electricity Company (PTPLN).

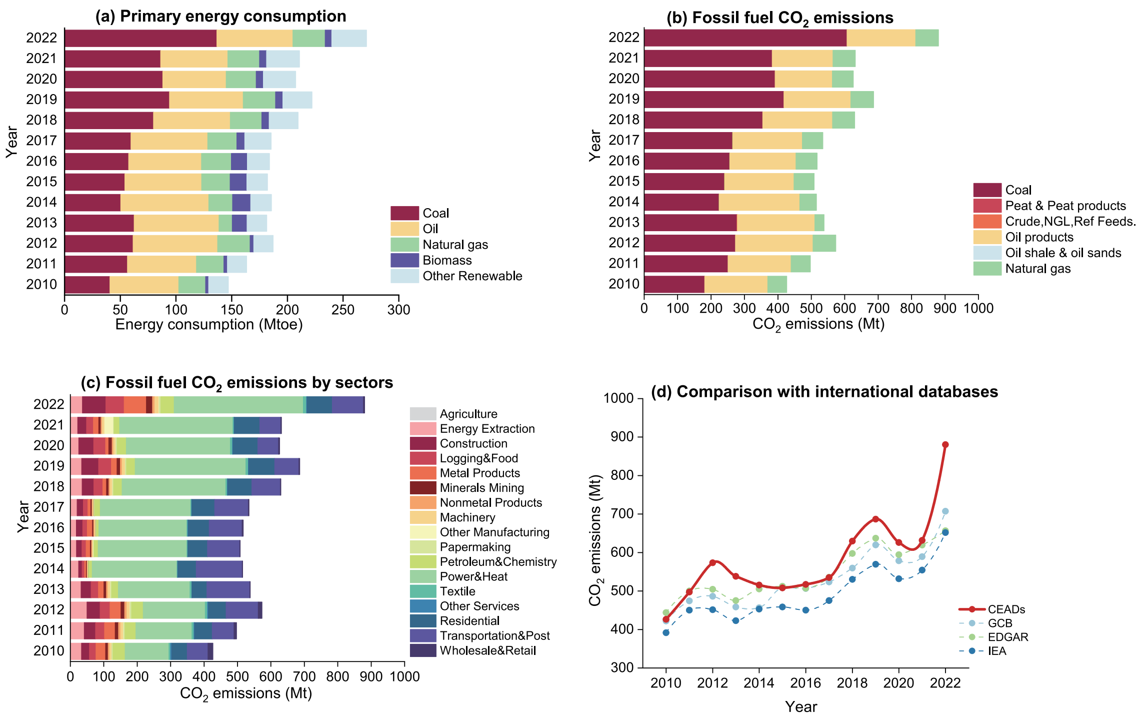


Figure 2.11: Indonesia's energy consumption and CO_2 emissions from 2010 to 2022 (a) Primary energy consumption; (b) Fossil fuel CO_2 emissions; (c) Fossil fuel CO_2 emissions by sectors; (d) Comparison with international databases.

Brief description of data sources:

Indonesia's energy balance tables come from the Indonesian National Bureau of Statistics, including energy consumption of 12 types of energy and 17 industries, and the time series is from 2010 to 2022. The industry matching indicators used in this study are the added value from the CEIC database and export data from the UN Comtrade.

Table 2.11: Data sources for Indonesia's emission accounting

Data type	Source	Website
Energy balance sheet	Statistics Indonesia	https://pep.moe.gov.ir/
Emission factor	Intergovernmental Panel on Climate Change (IPCC)	https://www.ipcc-nggip.iges.or.jp/EFDB/
Sectoral mapping indicator	Statistics Indonesia	https://www.bps.go.id/
	UN Comtrade: export data	https://comtradeplus.un.org/

Background

Mongolia is a landlocked country in East Asia, located between China and Russia. Given its special geographical location, Mongolia plays an important role as a bridge in international cooperation. Covering an area of 1.57 million square kilometers, the country is the second largest landlocked country after Kazakhstan. Mongolia is one of the fastest-growing economies in Asia, and globally. In 2021, according to the current price, its GDP reached US$17.2 billion[67]. Its population is 3.4 million[68] and its per capita GDP is slightly more than US$4993.5[69], making it a middle- and low-income country.

The agriculture and mining sectors are the main contributors to the national economy. Animal husbandry is Mongolia's most important contributing activity. In 2021, the output value of animal husbandry accounted for 13.1 % of the GDP, and the industrial output value accounted for 37.1%, of which the mining industry accounted for 22%. In recent years, Mongolia's stable economic growth has been driven primarily by the export of minerals other than oil and gas. The country is rich in natural resources, including coal, crude oil and metals. In terms of international trade, its main imports are mechanical and electrical goods and spare parts, road, aviation, and waterway transportation equipment and steel, among other products. China is Mongolia's closest trading partner[70].

In response to climate change, Mongolia has formulated policies on renewable energy, proposing that wind power account for 20% of total energy by 2023, and 30% by 2030[71]. It also plants to increase the installed capacity of renewable energy, especially hydropower, with the share of renewable energy in the energy mix reaching 20 % in 2023, increasing to 30 % in 2030, and power production reaching 1,260GW[72, 73].

Primary energy consumption

In 2022, fossil fuels overwhelmingly dominated Mongolia's primary energy consumption, accounting for 99.2% of the total and including coal and petroleum products, and to a much lesser extent natural gas. Coal accounted for 76.4% of consumption, and oil for 22.9%. In addition, hydropower, solar energy and other renewable energy sources made up 0.2% of the country's primary energy consumption. Biomass accounted for 0.6% of primary energy consumption.

Characteristics of fossil fuel emissions

Among the CO_2 emissions from fossil fuel consumption, coal consumption is the most important source of fossil fuel CO_2 emissions in Mongolia. In 2022, coal consumption generated 22.1 Mt of CO_2 emissions, accounting for 80.9% of the total CO_2 emissions from fossil fuel. In addition, petroleum products are also an important fossil fuel source in Mongolia. CO_2 emissions from the consumption of petroleum products have increased from 2.3 Mt in 2010 to 5.2 Mt in 2022.

Sectoral emission contribution

The production of electricity, heat, gas, and water sector was the industry, with the largest CO_2 emissions from fossil fuel in Mongolia, with 19.3 Mt, accounting for 70.4% of Mongolia's total fossil fuel CO_2 emissions in 2022. The second largest emitter is the transportation, storage and postal services sector, which relies primarily on gasoline for road transport, accounting for 10.9% of the total from fossil fuels. The service and consumer sectors followed with 6.4% and 4.1%, respectively. From 2010 to 2022, that contribution remained basically unchanged.

Biomass emissions

In 2022, biomass accounted for about 0.6% of the primary energy consumption structure in Mongolia. The country's biomass is primarily derived from animal manure, such as cow dung, horse dung, and sheep dung. Given that Mongolia's biomass sources are mainly sustainable and renewable, they possess a "zero carbon" attribute throughout their life cycle. Consequently, they should not be included in the overall CO_2 emissions in the carbon accounting process.

Emission trends

Mongolia's fossil fuel CO_2 emissions are on the rise. During 2010 and 2022, Fossil fuel CO_2 emissions increased by 60.8%, from 17 Mt to 27.4 Mt in 2022.

Comparison with international databases

Under the same accounting caliber (excluding emissions from biomass), CEADs' calculations for CO_2 emissions in Mongolia show almost the same annual emission trends as those from other agencies, but there are differences in values. Among them, GCB has the highest CO_2 emissions, and CEADs has significantly lower values than GCB. The difference between the total amount of CEADs and EDGAR and IEA results is about 10%. From the results, the main reason for the difference is that the statistical caliber of energy consumption data for the production of electricity, heat, gas, and water by various institutions is different, which has caused the gap between the CO_2 emissions of fossil energy in this industry.

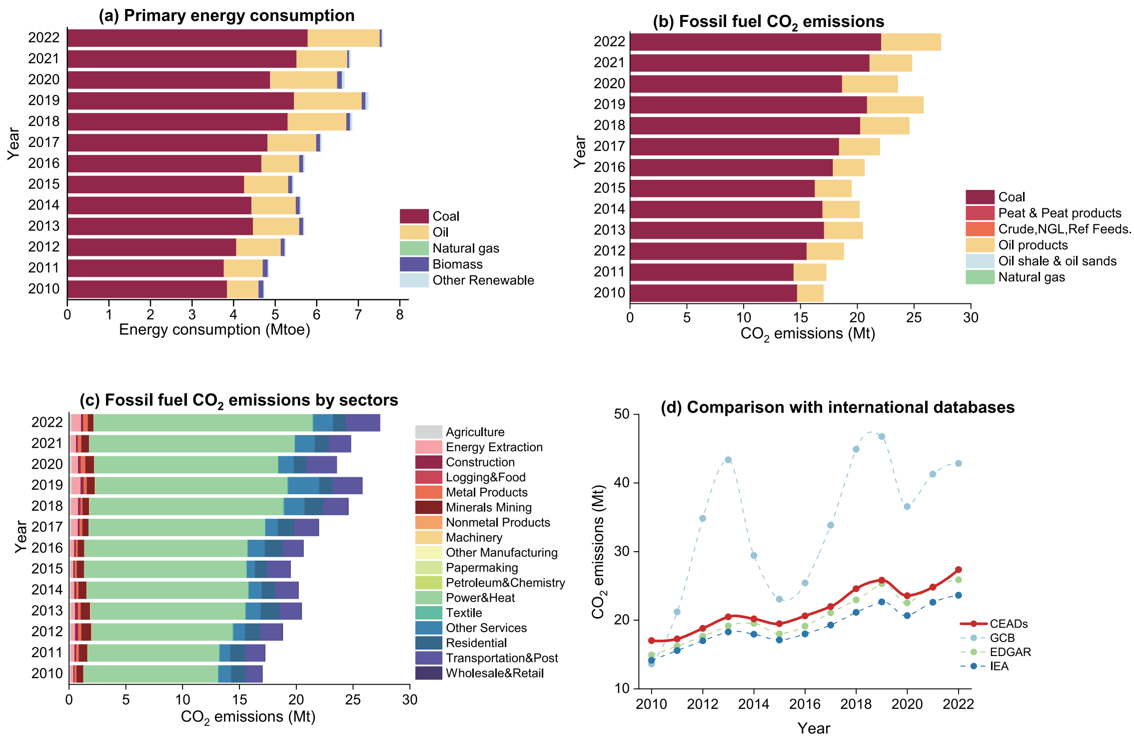


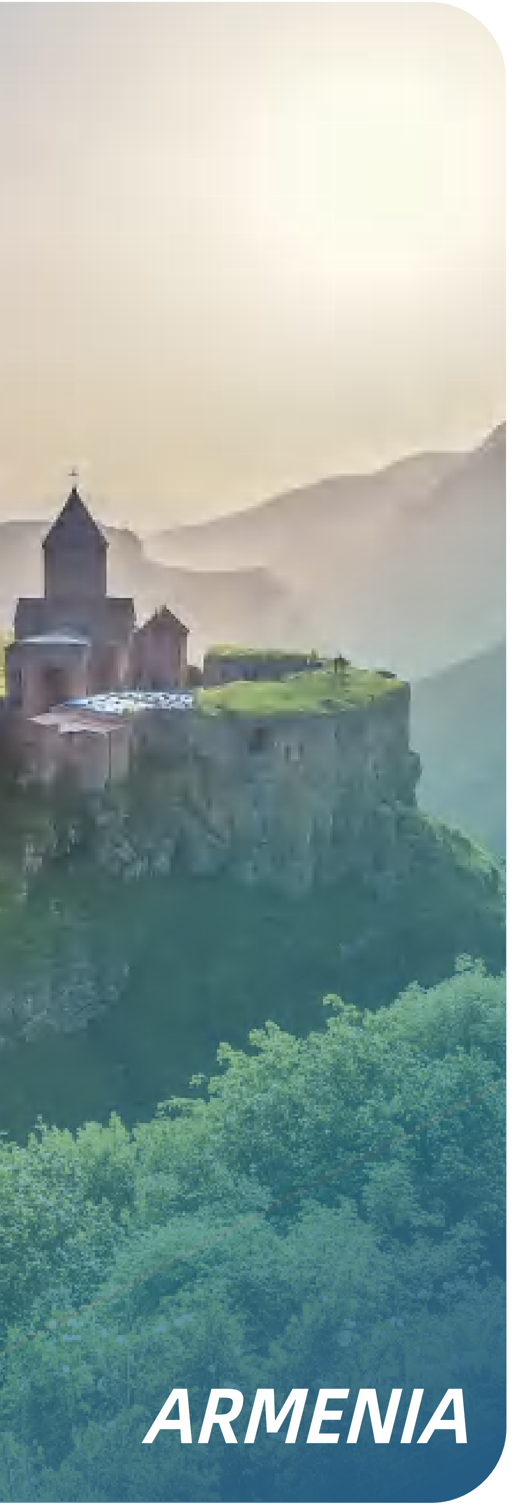
Figure 2.12: Mongolia's energy consumption and CO_2 emissions from 2010 to 2022 (a) Primary energy consumption; (b) Fossil fuel CO_2 emissions; (c) Fossil fuel CO_2 emissions by sectors; (d) Comparison with international databases.

Brief description of data sources:

The energy data for Mongolia used by CEADs is from the energy balance sheet provided by the National Statistical Office of Mongolia for 2010-2022. The energy balance sheet is divided into 7 industries, which CEADs further downscaled and allocated to 47 sectors based on industrial output data, urban and rural population data and export data from the UN Comtrade. Mongolia has 1 city and 21 provinces, and each of provinces publishes detailed annual industrial output data.

Table 2.12: Data sources for Mongolia's emission accountin

Data type	Source	Website
Energy balance sheet	Statistics Bureau of Mongolia	https://www.1212.mn/Stat.aspx?LIST_ID=976_L11&type=tables
Emission factor	Intergovernmental Panel on Climate Change (IPCC)	https://www.ipcc-nggip.iges.or.jp/EFDB/
Sectoral mapping indicator	Industry and construction - sales and production of industry	https://www.1212.mn/Stat.aspx?LIST_ID=976_L11&t
	Residential sector	https://www.1212.mn/Stat.aspx?LIST_ID=976_L03&type=tables
	UN Comtrade	https://comtradeplus.un.org/



Background

Landlocked Armenia is located in southern Transcaucasia, on the dividing line between Asia and Europe. Turkey to the west, Iran to the south, Georgia to the north, and Azerbaijan to the east form its external borders[74] Armenia's population increased substantially between 2010 and 2020, and the World Bank projects that more than 2,961,000 people would call Armenia home overall in 2022[75]. Armenia's economy has been growing quickly in recent years. Since 2009, the Armenian government has taken steps to mitigate the effects of the financial crisis, and it has seen some success. These steps include changing the industrial structure, increasing domestic demand, accelerating infrastructure development, and vigorously promoting agriculture. Armenia's GDP will reach $13.9 billion in 2021, up 5.7% from the previous year, and its foreign trade will reach $8.4 billion, up 17.7% from the previous year. Asia's GDP will be at $19.5 billion in 2022, up 12.6% annually, and its foreign trade will be around $14.1 billion, up 70% annually[76].

Primary energy consumption

In 2022, fossil energy consumption in Armenia accounted for 72.5% of the primary energy consumption mix, dominated by natural gas. Of this, 57.5% was natural gas consumption and 14.7% was oil consumption. In addition, hydro-solar and other renewable energy sources accounted for 24.4% of primary energy consumption; biomass accounted for 3.1% of primary energy consumption.

Characteristics of fossil fuel emissions

Natural gas consumption dominates Armenia's CO_2 emissions, accounting for 77.5% of fossil energy carbon emissions in 2022 and shows a significant increase from 3.9 Mt in 2010 to 6.2 Mt in 2022, with an average annual growth rate of 4.1%. Petroleum products were also a major source of CO_2 emissions in the country, with CO_2 emissions from petroleum and products showing an increase from 0.6 Mt in 2010 to 1.8 Mt in 2022.

Sectoral emission contribution

The transport sector, storage, and postal services are the largest sectoral CO_2 emitter in Armenia. In 2022, its CO_2 emissions from fossil fuel consumption were 2.5Mt, accounting for 30.7% of total fossil fuel carbon emissions. This is followed by production of electricity, heat, gas, and water, which accounted for 1.9 Mt or 23.7% of total fossil energy carbon emissions in 2022. Meanwhile, fossil energy carbon emissions from the residential sector are more stable, accounting for about 22.9% of total fossil energy carbon emissions in 2022.

Biomass emissions

In 2022, biomass accounted for only about 3.1% of the primary energy consumption mix, mainly for domestic consumption. Biomass feedstock in Armenia is mainly derived from forest wood. The latter is derived primarily from deforestation and is thus an unsustainable resource. In the overall carbon accounting process, it should be included in overall carbon emissions. Carbon emissions from biomass consumption in the country increased from 0.3 Mt in 2010 to 0.5 Mt in 2022.

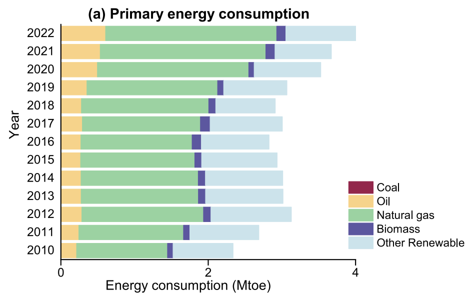
Emission trends

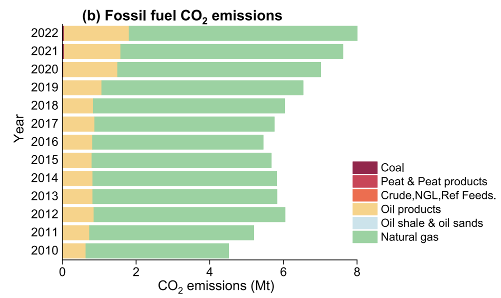
Between 2010 and 2022, carbon emissions from fossil energy consumption increased from 3.9 Mt in 2010 to 8.1 Mt in 2022, with an average annual growth rate of 4.7%. Carbon emissions from biomass consumption increased from 0.3 Mt to 0.5 Mt.

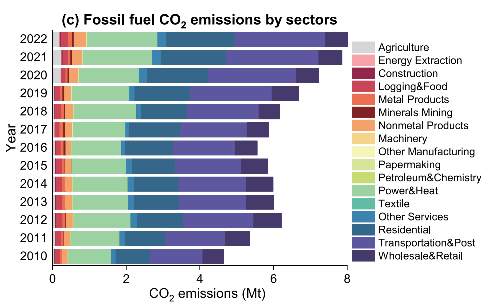
Comparison with international databases

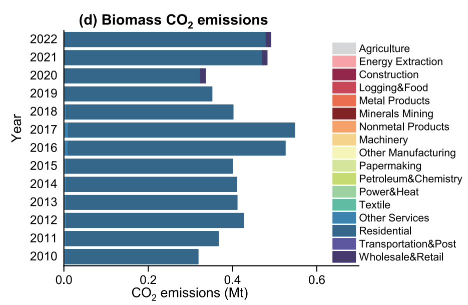
Under the same accounting caliber (excluding biomass carbon emissions), Armenia's fossil energy carbon emissions from CEADs are almost identical to those of other agencies in terms of emission trends and dendrites, with only minor differences from the 2021 and 2022 values of the major international agencies. Specifically, the CEADs statistics are largely in line with those of the IEA and EDGAR, with alternating increases in different years, but with almost negligible variations, with the CEADs accounting for 8.1 Mt in 2022, compared to 7 Mt for the IEA and 7.3 Mt for the EDGAR. Compared to the GCB statistics, the CEADs accounting data and the GCB statistics remain consistent in terms of trend and value from 2010-2019, and the CEADs statistics in 2020, 2021 and 2022 are slightly higher than the GCB statistics. GCB statistics were 6.7 Mt in 2022. Overall, the CEADs accounting data are consistent with the statistics of international agencies.

In addition, when CO_2 generated by biomass consumption is included, in 2022, the CEADs accounting data is 8.5 Mt.









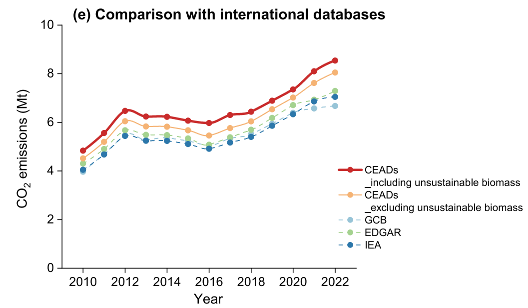


Figure 2.13: Armenia's energy consumption and CO_2 emissions from 2010 to 2022 (a) Primary energy consumption; (b) Fossil fuel CO_2 emissions; (c) Fossil fuel CO_2 emissions by sectors; (d) Biomass CO_2 emissions; (e) Comparison with international databases.

Brief description of data sources:

The energy data used in this report comes from the Energy Balance Sheet 2015-2022 provided by the Armenian Agricultural Statistics Committee. Statistically, Armenia consumes fossil energy involving 19 types of energy, mainly lignite, bituminous coal, liquefied petroleum gas, kerosene, diesel, gasoline and natural gas. These energy sources are consumed in 23 industries, such as Chemical and petrochemical, Iron and steel, Mining and quarrying, Construction, Textiles and leather and Transportation. In order to further refine its industries to 47 industries, export data from the United Nations Commodity Trade Statistics Database (UN Comtrade) were used.

Table 2.13: Data sources for Armenia's emission accounting

Data type	Source	Website
Energy balance sheet	Armenian Committee on Agricultural Statistics	https://armstatbank.am
Emission factor	IPCC	https://www.ipcc-nggip.iges.or.jp/EFDB/
Sectoral mapping indicator	UN Comtrade	https://comtradeplus.un.org/

Background

Thailand, located on the Indochina Peninsula in Southeast Asia, lies at the center of Southeast Asia, and serves as a natural gateway to India, Myanmar, and southern China. The country's total population is close to 70 million, ranking fourth among Southeast Asian countries[77]. In the past few decades, Thailand's economy has leapt ahead, and in 2022 its GDP reached $515 billion (in current prices)[78].

Thailand is a mixed economy: its primary economic sectors are industry and tourism[79]. In terms of international trade, the country's top three exports in 2018 were mechanical parts, automobiles and integrated circuits, with China, the United States and Japan the prime destinations. Crude oil, integrated circuits and gold are Thailand's most important imports and China, Japan and Malaysia are three of its key sources for these[80]. Thailand's final energy consumption has grown steadily in recent years.

The country has long been committed to promoting and supporting energy development, especially in terms of renewables and energy efficiency. The Thai government has thus encouraged the growth of solar, wind and geothermal energy and hydropower to reduce the use of fossil fuels (mainly natural gas) and thus mitigate the impact on the environment. In response to climate change and energy security, the government plans to reduce greenhouse gas emissions by 20% of 2005 levels by 2030 and by 25% with international support[81]. In terms of renewable energy, the Thai government aims for 30% of the country's total energy consumption to be sourced from renewables by 2037. Regarding power supply, the government will increase investment in smart grid energy management, investing $6.4 billion up to 2036 to strengthen the resilience of the country's power grid and thus reduce total carbon emissions[82].

Primary energy consumption

Fossil fuels are the dominant sources of primary energy consumption in Thailand in 2022, accounting for 79.3% of the total, with oil making up 37.4%, natural gas 27.3% and coal 14.6%. In addition, hydropower, solar and other renewable energy sources accounted for 1.2% of primary energy consumption, while biomass makes up 19.5%.

Characteristics of fossil fuel emissions

Among the carbon emissions generated by fossil fuel consumption, petroleum products contributed the most, generating 122.3 Mt of CO_2 in 2022 — that is, 47.4% of fossil fuel carbon emissions. Carbon emissions generated by natural gas consumption are also relatively stable, accounting for 29.1% of carbon emissions from fossil energy in 2010 to 27.7% in 2022, showing a slight decrease trend. In contrast, the proportion of carbon emissions from coal consumption are relatively stable, from 24.4% in 2010 to 25% in 2022.

Sectoral emission contribution

The sector responsible for the highest emissions from fossil energy consumption in Thailand is Transportation, storage and postal services, reaching 97.3Mt in 2022 and accounting for 37.7% of total carbon emissions from fossil energy. Electricity, heat, gas, and water production sector followed closely: carbon emissions from this sector reached 82.3 Mt in 2022, accounting for 31.9% of the total in 2021.

Biomass emissions

In 2022, biomass accounted for about 19.5% of the primary energy consumption, and was used mainly in the production of electricity, heat, combustion, water, domestic consumption, and manufacturing industries. There are many kinds of biomass in Thailand, including rice husks, bagasse or plant fibers, agricultural waste, firewood and black liquor and residual gases from wood processing. Of these, rice husks, sugarcane bagasse, agricultural waste and secondary energy derived from its processing, including biogas, bioethanol, and biodiesel, are sustainable renewable resources with "zero carbon" attributes throughout their life cycle, and should not be included in the overall carbon accounting process. Non-sustainable resources, such as black liquor and residual gases from firewood and wood processing, must be included in that process. Carbon emissions from firewood consumption dropped from 31.7 Mt in 2010 to 12.8Mt in 2022.

Emission trends

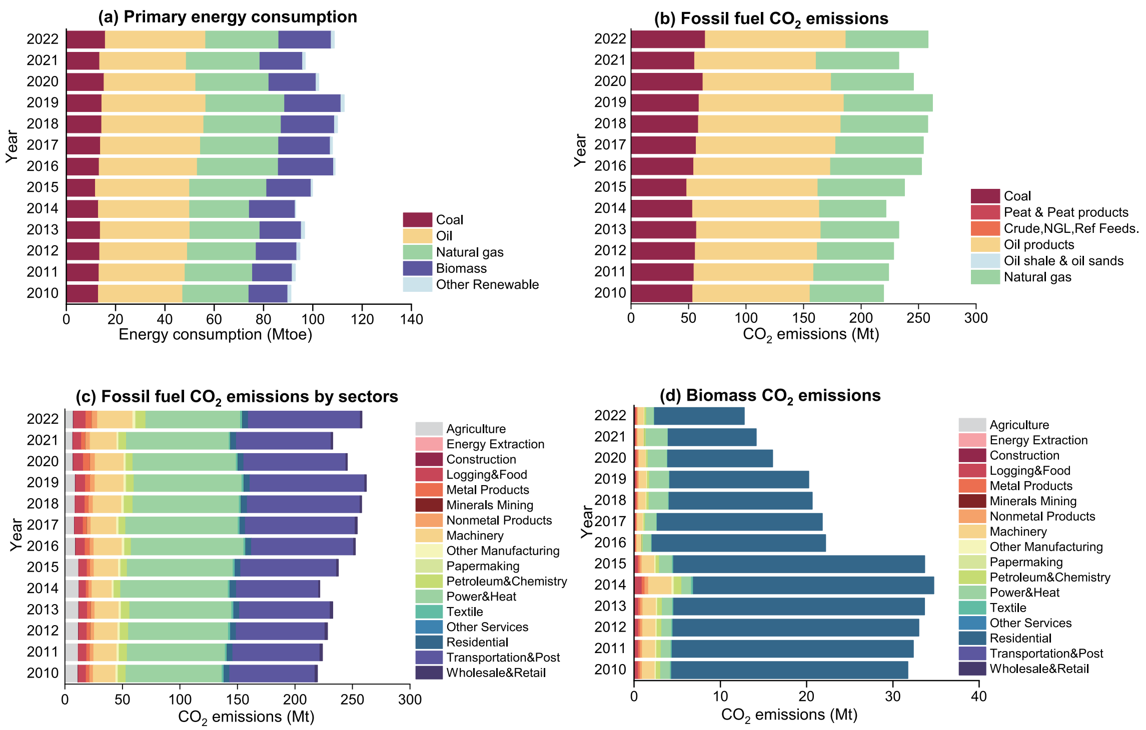
Between 2010 and 2022, CO_2 emissions from fossil energy consumption increased by 17.6%, from 219.6 Mt to 258.3 Mt in 2021, with an average annual growth rate of 1.36%. During this period, CO_2 emissions from biomass consumption fell from 31.7 Mt to 12.8 Mt.

Comparison with international databases

Under the same accounting caliber (excluding emissions from biomass), CEADs' calculation of carbon emissions from fossil fuels in Thailand differs from statistics provided by other institutions, despite having similar trends. In 2022, international databases reported carbon emissions as follows: GCB 251.2 Mt, EDGAR 275.9 Mt, IEA 250 Mt, and CEADs 258.3 Mt. Overall, the differences in data are not substantial. When comparing carbon emissions from different sectors' consumption of fossil fuels between CEADs and IEA, variations exist. For instance, in 2019, CEADs reported carbon emissions from the transportation sector as 99.9 Mt, while IEA's data was only 73.6 Mt, indicating a 26% difference.

CEADs data also feature a more detailed energy breakdown in terms of emission factors. Each petroleum product, for example, has its own emissions factor, while IEA's metric does not break petroleum products into subcategories. Thus, IEA and CEADs emission factors differ, leading to discrepancies in the data. There is also a gap between the energy consumption data used by CEADs and IEA. In the transportation sector, CEADs uses energy data that includes all domestic and international aviation fuels. The IEA, however, calculates fuel consumption separately for domestic and international flights, leading to differences in fuel statistics and, in turn, sectoral emissions differences between IEA and CEADs findings. In addition, the EDGAR data are significantly higher than those of CEADs.

When including CO_2 emissions from sources like firewood consumption, CEADs' calculated CO_2 emissions for 2022 amounted to 271 Mt.



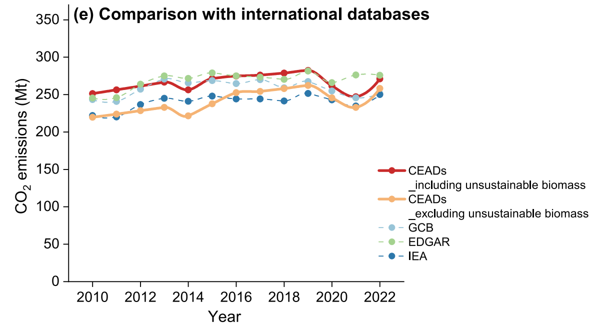


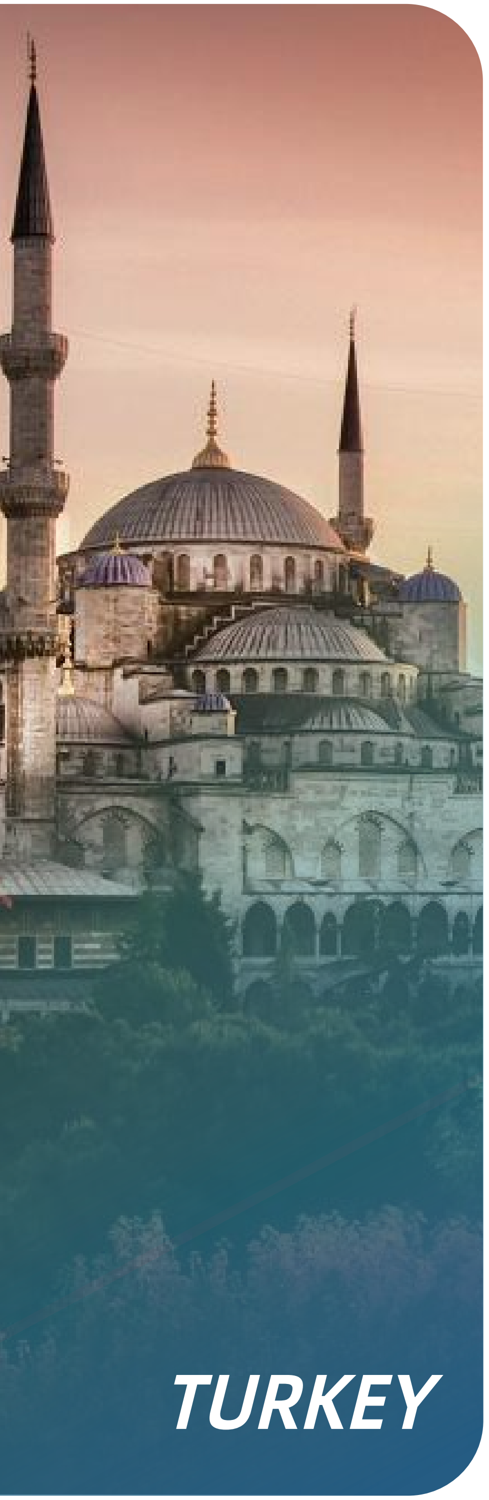
Figure 2.14: Thailand's energy consumption and CO_2 emissions from 2010 to 2022 (a) Primary energy consumption; (b) Fossil fuel CO_2 emissions; (c) Fossil fuel CO_2 emissions by sectors; (d) Biomass CO_2 emissions; (e) Comparison with international databases.

Brief description of data sources:

The energy data used in this report is from the energy balance sheets provided by the Thai Ministry of Energy for 2013-2022. According to statistics, there are a total of 47 types of energy consumed, of which 40 are fossil fuels. The main types of fossil fuels include coal, crude oil and natural gas, petroleum products and biomass. The energy is consumed in 7 main sectors: agriculture, mining, manufacturing, construction, housing, commerce, and transportation. In order to further subdivide the main sectors into 47 sectors, the GDP data from the ADB and export data from the UN Comtrade database are used.

Table 2.14: Data sources for Thailand's emission accounting

Data type	Source	Website
Energy balance sheet	Ministry of Energy	https://www.dede.go.th/ewt_news.php?nid=47340
Emission factor	IPCC	https://www.ipcc-nggip.iges.or.jp/EFDB/
Sectoral mapping indicator	ADB: GDP	https://data.adb.org/dataset/thailand-key-indicators
	UN Comtrade	https://comtradeplus.un.org/



Background

Turkey straddles Europe and Asia, facing the Black Sea in the north, the Mediterranean Sea in the south and the Aegean Sea in the west. The country shares land borders with a number of nations, including Syria, Greece, and Georgia, which makes it of great significance in terms of geographical location and geopolitical strategy. As a newly industrialized country, its GDP in 2022 (at current rates) was US$907.1 billion, ranking 19th in the global economy. According to the latest population data from the Turkish Statistical Institute, the country's population in 2022 was 85.0 million, and the per capita GDP was $10,674.5.

Turkey is highly vulnerable to natural disasters, and climate change has become a major threat to national economic and social development. The country's Eleventh Development Plan (2019-2023) emphasizes the importance of environmental issues, including climate change, cleaner production, waste management and the use and development of renewable energy [83]. Turkey is rich in renewables including hydropower, which has been fully developed and accounts for about one-fifth of the country's electricity supply. Turkey aims towards the goal of renewables providing two thirds of its electricity by 2023 [84]. In addition, the government has pledged to improve energy efficiency and reduce greenhouse gas emissions by 21% by 2030, while increasing solar capacity to 10 GW and wind capacity to 16 GW [85].

Primary energy consumption

Fossil fuels accounted for 81.8% of primary energy consumption, with coal, oil, and natural gas the most important sources in 2022. Among them, oil consumption accounted for 26.4% of primary energy consumption, natural gas for 28.3%, and coal for 27.1%. In addition, solar, geothermal, and other renewable energy sources accounted for 15.2% of primary energy consumption, while biomass made up only 3.0%.

Characteristics of fossil fuel emissions

Among all CO_2 emissions from fossil fuel consumption, those from coal dominate. As the country's most important fossil fuel, coal generated 174.7 Mt of these emissions in 2022, accounting for 44.1%, an increase compared with 124.0 Mt in 2010. The consumption of petroleum products produced 124.0 Mt of CO_2, accounting for 31.3%. Natural gas consumption meanwhile is responsible for 24.7% of CO_2 emissions.

Sectoral emission contribution

Among sectors, electricity, heat, gas, and water production contributes the highest fossil fuel carbon emissions in Turkey, in 2022 amounting to 152.5 Mt — 38.5% of the total. The transportation, storage and postal services sector meanwhile accounted for 24.1% of the total. The third highest emitter is the consumer sector, which contributed 47.8 Mt of carbon emissions, accounting for 12.1% of the total from fossil fuels.

Biomass emissions

In 2022, biomass accounted for about 3.0% of primary energy consumption and was mainly consumed domestically. The types of biomass used in Turkey are mainly waste wood (wood, bark, dead trees), agricultural residues, animal manure and municipal solid waste [86]. Since Turkey's biomass sources are mainly sustainable, renewable resources and carbon neutral throughout their life cycle, biomass should not be included in overall carbon emissions during the accounting process.

Emission trends

Overall, Turkey's overall CO_2 emissions show an upward trend between 2010 and 2022: emissions from fossil fuel consumption increased from 289.6 Mt to 396.5 Mt, accounted for 36.9%.

Comparison with international databases

Under the same accounting caliber (excluding emissions from biomass), CEADs' calculation of carbon emissions from fossil fuels in Turkey shows a general alignment with the results from various institutions, with minor variations. In 2022, CEADs reported 396.5 Mt, IEA reported 383.2 Mt, EDGAR reported 433.7 Mt, and GCB reported 392.5 Mt. The differences between CEADs and IEA data results amount to 3.48%, which is significantly smaller than the disparities observed with EDGAR and GCB calculations. The variations in results might stem from specific emission factors and energy classifications. CEADs employs a more detailed energy classification, whereas IEA's statistical scope regarding energy types is less precise. Moreover, CEADs utilizes emission factors specifically published by the Turkish Statistical Institute, while IEA employs IPCC emission factors.

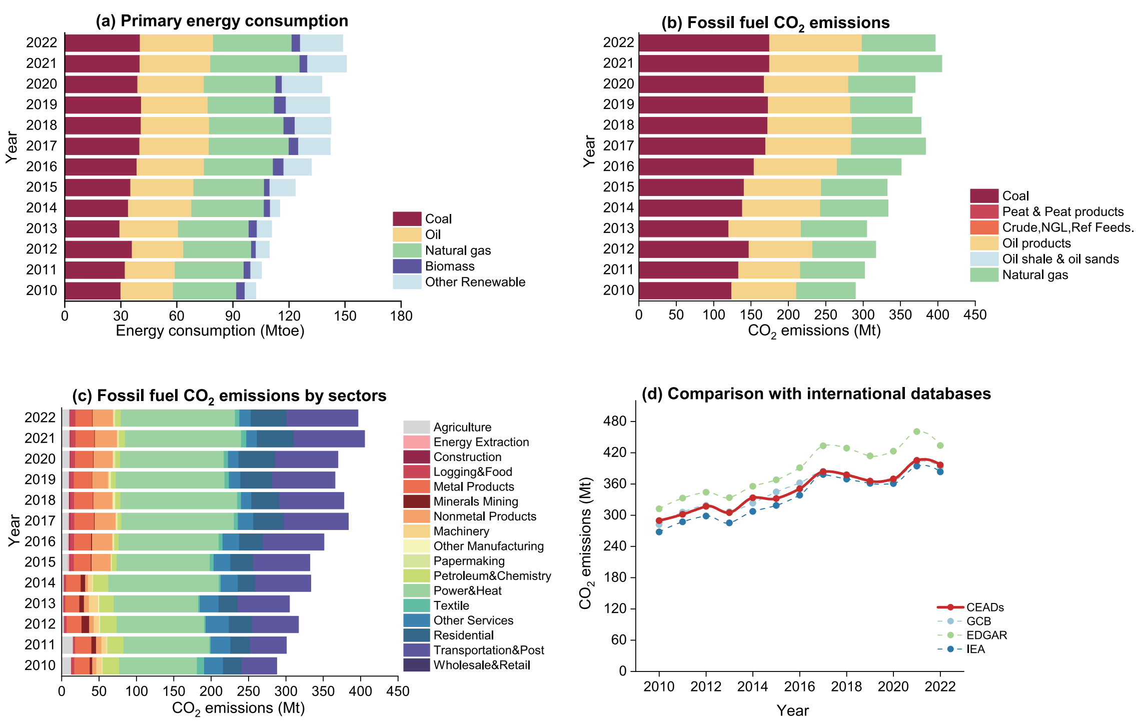


Figure 2.15: Turkey's energy consumption and CO_2 emissions from 2010 to 2022 (a) Primary energy consumption; (b) Fossil fuel CO_2 emissions; (c) Fossil fuel CO_2 emissions by sectors; (d) Comparison with international databases.

Brief description of data sources:

The energy data used in this report is from the energy balance sheet provided by the Turkish National Committee of the World Energy Council for 2010-2022, including a total of 29 energy varieties and 36 sectors. Among them, in terms of sub-sector matching, we use the economic data of industrial exports to allocate 36 sectors to 47 sectors.

Table 2.15: Data sources for Turkey's emission accounting

Data type	Source	Website
Energy balance sheet	Turkish National Committee of the World Energy Council	https://www.dunyaenerji.org.tr/turkiye-enerji-denge-tablolari/
Emission factor	United Nations Framework Convention on Climate Change (UNFCCC):Country List	https://unfccc.int/process-and-meetings/transparency-and-reporting/reporting-and-review-under-the-convention/greenhouse-gas-inventories-annex-i-parties/national-inventory-submissions-2020
Sectoral mapping indicator	Turkish Statistical Institute	https://www.tuik.gov.tr/Home/Index

Background

Kazakhstan is located in central Asia, bordering Russia to the north, Uzbekistan, Turkmenistan, and Kyrgyzstan to the south, the Caspian Sea to the west, and China to the east, with an area of 2.72 million square kilometers. Kazakhstan's territory spans Asia and Europe, with the Ural River as the continental boundary. It is a landlocked country in Central Asia and also the largest landlocked country in the world. Kazakhstan has a complex terrain, with mostly plains and lowlands. It is characterized by high southeast and low northwest, and most of the territory is plains and lowlands. Most residents believe in Islam (Sunni). In addition, there are Orthodox, Catholic and Buddhist. In 2022, Kazakhstan's GDP (current price) was US$225.5billion and its population was 20 million[87].

The mining industry is a pillar industry of Kazakhstan's national economy. In 2022, the output value of Kazakhstan's mining industry was approximately US$54.2 billion, a year-on-year decrease of 0.9%, accounting for 51.1% of the total industrial output value. In 2022, the output value of Kazakhstan's manufacturing industry was approximately US$46.0 billion, a year-on-year increase of 3.6%, accounting for 43.4% of the total industrial output value, mainly including petroleum processing and petrochemical industries, light textile industries, building materials, household appliances and automobile manufacturing. In 2022, Kazakhstan's total foreign trade in goods was US$135.5 billion, an increase of 33.5% over the previous year. In 2022, Kazakhstan's top five trading partners were Russia, China, Italy, Turkey and South Korea. The main export commodities were energy and mineral products (accounting for 66%), metal products (17.5%), and agricultural products and food (6.2%). Kazakhstan is rich in oil and mineral resources, with proven oil reserves of 14 billion tons (on land and in the Caspian Sea) and more than 90 kinds of mineral deposits. Many mineral reserves account for a high proportion of global reserves, such as more than 50% of tungsten, 25% of uranium, 23% of chromium, 19% of lead, 13% of zinc, and 10% of copper and iron[88].

According to the Strategy Kazakhstan 2050: A New Political Course of the Established State, it is planned to increase the proportion of renewable energy electricity to 30% by 2030 and 50% by 2050. In addition, Kazakhstan is a signatory to the Paris Agreement. According to the agreement, Kazakhstan should reduce greenhouse gas emissions by 15% from 1990 to 328.4 million tons by 2030. At the same time, the Kazakhstan government has formulated the Policy Statement on Achieving Carbon Neutrality by 2060, which states that by 2060, Kazakhstan's overall economy will reach a zero-emission balance, most emissions will be avoided, and the remaining emissions will be collected using carbon capture and storage technology (CCS) and absorbed by vegetation and soil.

Primary energy consumption

Kazakhstan's primary energy structure is dominated by coal products. In 2022, coal consumption accounted for 48.8%, natural gas consumption accounted for 26.1%, petroleum product consumption accounted for 23.4%, and total fossil energy consumption accounted for 98.3%. In addition, biomass accounted for 0.02% of primary energy consumption, and other renewable energy sources such as wind and solar energy accounted for 1.7% of primary energy consumption.

Characteristics of fossil fuel emissions

In 2022, Kazakhstan's carbon emissions from fossil energy consumption were about 230.8 Mt. From the perspective of carbon emissions by type of fossil energy, carbon emissions from coal consumption were about 154.6 million tons, accounting for about 67.0% of total fossil energy carbon emissions; followed by carbon emissions caused by petroleum products and natural gas consumption, which accounted for approximately 18.9% and 14.1% respectively. Among them, carbon emissions caused by coal consumption showed an overall trend of first rising and then fluctuating downward from 2010 to 2022, increasing from 175.3 Mt in 2010 to 197.5 Mt in 2013, and then falling from 197.5 Mt to 154.6 Mt from 2013 to 2021.

Sectoral emission contribution

Kazakhstan's largest fossil energy carbon emissions come from the production of electricity, heat, gas and water industries. In 2022, the total emissions in this industry were close to 124.7 Mt, an decrease of about 1.0 Mt compared with 2010, accounting for 54.0% in 2021 and 52.4% in 2010 of Kazakhstan's total fossil energy emissions. Secondly, Kazakhstan's fossil energy carbon emissions come from consumption, and its fossil energy carbon emissions are much smaller than the production of electricity, heat, gas and water industries. In 2022, the carbon emissions from this industry were close to 27.1 Mt, an increase of about 20.8 Mt compared with 2010, accounting for 11.7% of Kazakhstan's total fossil energy carbon emissions. Following closely is the transportation industry. In 2022, the carbon emissions from fossil energy in the transportation industry were about 23.5 Mt, an increase of about 8.9 Mt compared with 2010, accounting for 10.2% of the total fossil energy carbon emissions.

Biomass emissions

In 2022, Kazakhstan's biomass accounted for 0.02% of the primary energy consumption structure, mainly used in the consumer industry. The types of biomass mainly include agricultural residues and animal manure. Since Kazakhstan's biomass sources are mainly sustainable renewable resources, it has a zero-carbon attribute throughout its life cycle and should not be included in the overall carbon emissions in the overall carbon accounting process.

Emission trends

Kazakhstan's CO_2 emissions showed an upward trend from239.8 Mt to 270.2 Mt in 2010-2013, a downward trend from 270.2 Mt to 205.9 Mt in 2013-2016, and an upward trend again from 205.9 Mt to 230.8 Mt in 2016-2022.

Comparison with international databases

Under the unified accounting caliber, when biomass carbon emissions are not included, the accounting results of Kazakhstan's total carbon emissions in 2022 were 230.8 Mt for CEADs, 225.9Mt for IEA, 240.2Mt for EDGAR, and 234.3 Mt for GCB; the fossil energy carbon emission data of CEADs has the same overall trend as IEA, EDGAR, and GCB, and is similar to the values of IEA and EDGAR, while the values of GCB are generally higher than those calculated by the EDGAR, IEA, and CEADs teams. In addition, starting in 2020, the gap between CEADs and IEA has narrowed, and the gap in the total results is not very obvious, about 2%. Judging from the results, the main reason for the difference is the difference in statistical caliber. CEADs uses the energy balance sheet results of the Kazakhstan Statistics Bureau, while IEA uses the annual energy questionnaire survey data.

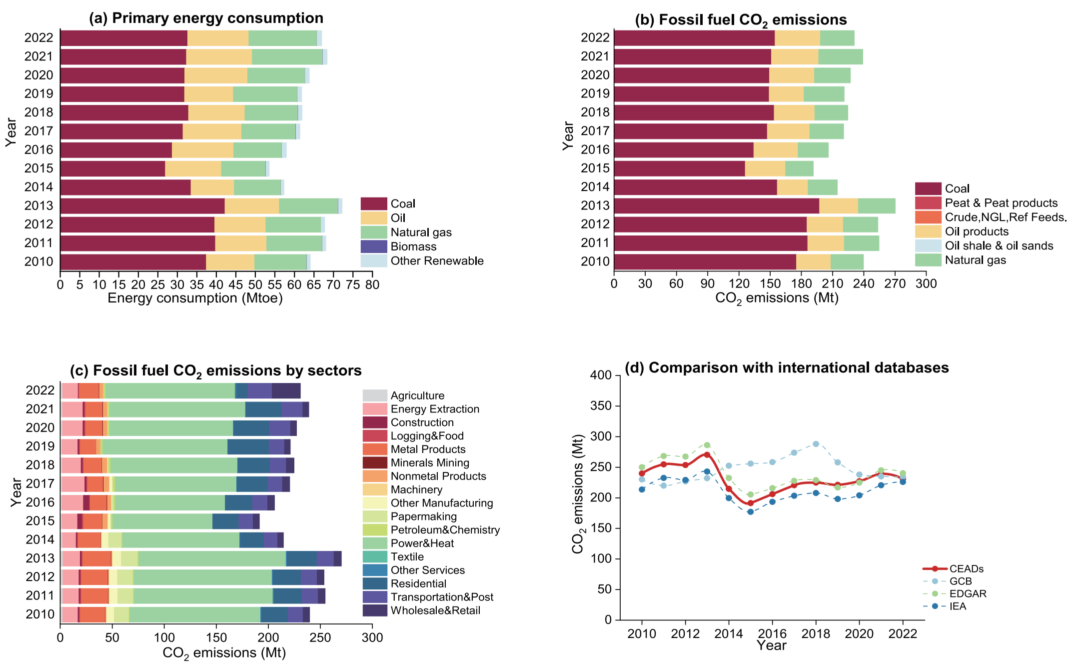


Figure 2.16: Kazakhstan's energy consumption and CO_2 emissions from 2010 to 2022 (a) Primary energy consumption; (b) Fossil fuel CO_2 emissions; (c) Fossil fuel CO_2 emissions by sectors; (d) Comparison with international databases.

Brief description of data sources:

Kazakhstan's energy balance sheets are all from the Kazakhstan Statistics Bureau, covering data from 2010 to 2022, involving 40 energy types and 24 sectors in 2022. In terms of matching by sector, we use export data from the UN Comtrade and Kazakhstan's own sub-sectoral data as the basis for allocation, downscale the sectors and allocate them to 47 sectors.

Table 2.16: Data sources for Kazakhstan's emission accounting

Data type	Source	Website
Energy balance sheet	Kazakhstan Bureau of Statistics	https://stat.gov.kz/en/industries/business-statistics/stat-energy/dynamic-tables/
Emission factor	IPCC	https://www.ipcc-nggip.iges.or.jp/EFDB
Sectoral mapping indicator	Kazakhstan Bureau of Statistics	https://stat.gov.kz/
	UN Comtrade，export data	https://comtradeplus.un.org/

Background

Malaysia is a Southeast Asian country that shares borders with Singapore, Brunei, and Indonesia. Malaysia's capital, Kuala Lumpur, symbolizes the country's most populous and wealthiest region. According to Malaysia's statistical bureau[89], the nation spans an area of 330,345 square kilometers, with a population of 35.13 million in 2023. Its GDP per capita is $11,379, ranking 110th globally.

One of the Asian nations with a sophisticated infrastructure is Malaysia. Seven international ports are present in the country. The industrial industry and foreign trade that the country receives from its closeness to the Malacca Strait route are essential to its economy. Oil is Malaysia's most valuable export, although it also exports natural resources and agricultural products. In the past, it was the biggest producer of palm oil, tin, and rubber in the world. Malaysia has been actively pushing its tourist industry, which has grown to be the nation's third-largest source of foreign money, in an effort to diversify its economy. As indicated by Global Economy[90], agriculture accounted for 8.17% of Malaysia's GDP in 2020. Due to the impacts of the COVID-19 pandemic, tourism represented just 1% of the GDP in 2020, down from 6.08% in 2019. MATRADE [91]indicates that in international trade, Malaysia's main exports include palm oil, rubber, petroleum, and steel. Major export destinations include Singapore (14.5%), China (13.5%), the USA (9.5%), and Japan (8%). Its imports mainly consist of electronic and chemical products, with primary sources being China (19.6%) and Singapore (11.1%).

KPMG[92]noted that to address the threat of global warming, Malaysia ratified the Paris Agreement and has committed to reduce its emission intensity of GDP by 45% by 2030 from 2005 levels. By 2019, the country had already reduced its carbon emission intensity by 33%. In 2021, after the unveiling of Malaysia's 12th Plan, the Prime Minister announced a carbon neutrality target for 2050. The Malaysian government will cease construction of new coal-fired power plants and will soon introduce a comprehensive national energy policy. After reviewing a low-carbon development strategy by the end of 2022, carbon pricing and carbon taxes will be rolled out alongside other carbon reduction measures.

Primary energy consumption

In 2022, Malaysia's fossil fuel consumption accounted for approximately 94.3% of its primary energy structure. Natural gas consumption represented 30.1% of the total, petroleum product consumption was at 31.0%, and coal consumption accounted for 33.2%. The proportion of other renewable energy sources primarily based on hydropower was 4.1%. Additionally, biomass constituted 1.6% of the primary energy consumption.

Characteristics of fossil fuel emissions

Coal and coke consumption are the primary sources of fossil fuel CO2 in Malaysia. As the major fossil fuels in Malaysia, coal and coke consumption contributed to CO_2 emissions of 94.2 Mt in 2022, accounting for 44.5% of the total fossil fuel CO_2. Coal and coke consumption contributed to CO_2 emissions of 58.5 Mt in 2010, accounting for 32.4% of the total fossil fuel CO_2. From 2010 to 2022, coal and coke consumption contributed to CO_2 emissions increased significantly. CO_2 emissions from petroleum product consumption increased from 61.7 Mt in 2010 to 66.2 Mt in 2022. Natural gas is also a significant fossil fuel source in Malaysia, with CO_2 emissions from natural gas consumption reaching 51.3 Mt in 2022, constituting 24.3% of the total fossil fuel CO_2 emissions.

Sectoral emission contribution

The largest fossil energy carbon-emitting industries in Malaysia are electricity, heat, gas, and water production sector. The CO_2 from fossil energy consumption in electricity, heat, gas, and water production sector increased from 95.8 Mt in 2010 to 116.5 Mt in 2022, accounting for 55.0% of the total fossil fuel CO_2. The transportation, storage, and postal services sector is the second-largest contributor to fossil fuel CO_2 in Malaysia. Emissions from this sector grew from 49.6 Mt in 2010 to 53.1 Mt in 2022, constituting 25.1% of the total fossil fuel CO_2.

Biomass emissions

In 2022, emissions generated from biomass consumption in Malaysia amounted for 1.6% of the primary energy consumption structure. Biomass was primarily utilized in the electricity sector as well as in transportation, storage, and postal services. Malaysia's biomass mainly comprises biodiesel and biogas, deriving from sustainable renewable resources. With a complete life cycle characterized by a "zero-carbon" attribute, these emissions should not be included in the overall carbon accounting process.

Emission trends

From 2010 to 2022, CO_2 emissions from fossil fuel consumption in Malaysia exhibited a steady growth trend with an average annual growth rate of 1.4%. These emissions increased from 180.2 Mt in 2010 to 211.7 Mt in 2022.

Comparison with international databases

Under the same accounting caliber (excluding emissions from biomass), CEADs' calculation of CO_2 emissions from fossil fuel consumption in Malaysia shows relatively small discrepancies compared to data results published by IEA, EDGAR, and GCB. The primary reasons for these differences are firstly, variations in emission factors chosen by CEADs, IEA and EDGAR, secondly, CEADs provides a more detailed energy classification, whereas other institutions have a less distinct statistical scope regarding energy types.

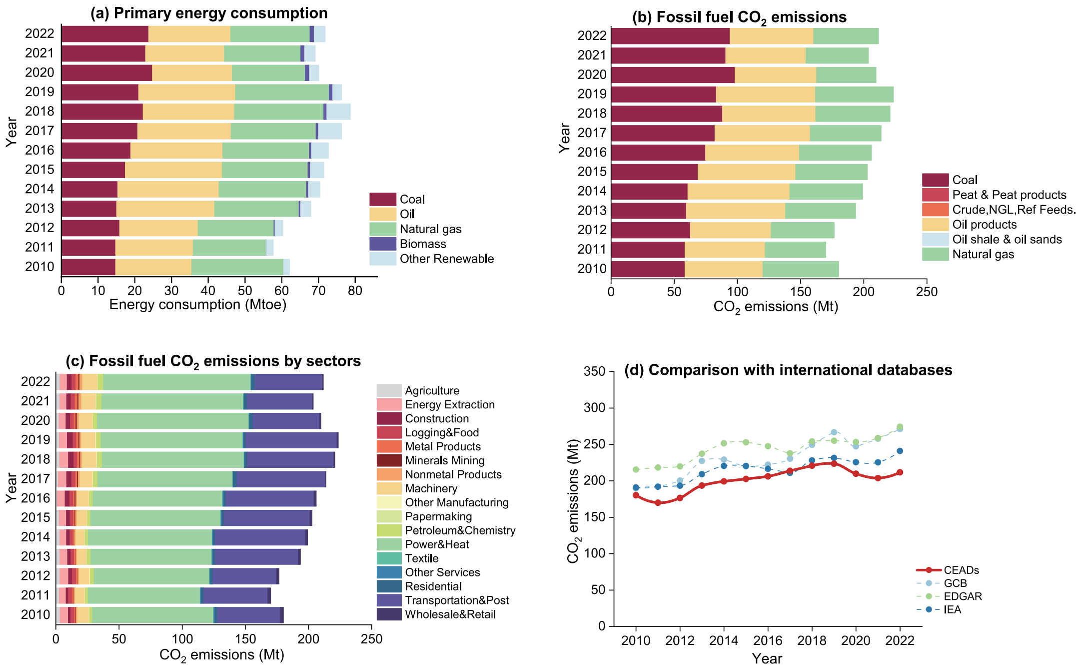


Figure 2.17: Malaysia's energy consumption and CO_2 emissions from 2010 to 2022 (a) Primary energy consumption; (b) Fossil fuel CO_2 emissions; (c) Fossil fuel CO_2 emissions by sectors; (d) Comparison with international databases.

Brief description of data sources:

Malaysia's energy balance sheet lists 14 energy commodities, with prominent ones including natural gas, gasoline, and diesel. The energy balance sheet categorizes sectors into six divisions: residential consumption, commercial sector, transportation sector, industrial sector, agriculture, and fisheries. For subsector matching, we use export data from the United Nations Commodity Trade Statistics Database (UN Comtrade) and GDP data from the Department of Statistics Malaysia to downscale the sectoral matching and assign to 47 sectors.

Table 2.17: Data sources for Malaysia's emission accounting

Data type	Source	Website
Energy balance sheet	Malaysia Energy Centre	https://meih.st.gov.my/
Emission factor	IPCC	https://www.ipcc-nggip.iges.or.jp/EFDB/
Sectoral mapping indicator	Department of Statistics Malaysia (GDP)	https://www.dosm.gov.my/v1/index.php
	UN Comtrade	https://comtradeplus.un.org/

Background

China is located in the eastern part of Asia, on the western coast of the Pacific Ocean, China borders the South China Sea, Vietnam, Myanmar, India and Nepal to the south, Afghanistan, Tajikistan and Kazakhstan to the northwest, Pakistan to the west, and Mongolia, Russia and North Korea to the north, with a land area of approximately 9.6 million square kilometers[93]. As of 2022, China's population stands at 1.4118 billion, with a birth rate of 6.77 per thousand and a natural growth rate of -0.60 per thousand[94]. In terms of the economy, China has emerged as the world's second-largest economic powerhouse, with its Gross Domestic Product (GDP) surging from 40 trillion yuan in 2010[95] to over 120 trillion yuan in 2022[94]. China's remarkable economic growth rate has attracted widespread global attention.

Over the past few decades, manufacturing has remained a key driver of China's economic growth, encompassing energy-intensive sectors such as steel, cement, and chemicals. However, alongside economic expansion, the manufacturing sector has faced growing challenges, including rising labor costs, worsening environmental pollution, and escalating international trade frictions[96]. In recent years, the Chinese government has been actively promoting the intelligent, high-end, and environmentally sustainable transformation of the manufacturing industry, fostering its integration with the service sector while maintaining a stable share of manufacturing in the national economy. The service sector has become a cornerstone of the national economy, with its share of Gross Domestic Product steadily increasing[97], especially in fields such as finance, insurance, real estate, information technology, and technology services. At the same time, China's high-tech sectors have made significant progress in fields such as electronic information, biopharmaceuticals, new energy, and high-end equipment manufacturing. Since 2013, China has led the world in photovoltaic installations for ten consecutive years, while the new energy vehicle market has experienced rapid expansion, maintaining its global leadership for eight consecutive years. China has become a crucial industrial hub for renewable energy manufacturing on a global scale.

China has experienced a remarkable expansion in renewable energy. The installed capacity has surpassed 1.2 billion kilowatts, accounting for over 45% of the country's total power generation capacity[98]. Specifically, the installed capacity of hydroelectric, wind, solar photovoltaic power, and biomass power has ranked first in the world for consecutive years, respectively, emphasizing their growing international competitive edge. In 2022, China's renewable power generation amounted to 2.7 trillion kilowatt-hours, making up 30.8% of the total electricity generation. The utilization rates for major hydroelectric, wind, and solar photovoltaic sources were 98.7%, 96.8%, and 98.3%, respectively[99]. To achieve high-quality advancement in renewable energy, China has set a target for 2025: to consume approximately one billion tons of standard coal from renewable sources and to ensure that the increase in renewable energy consumption accounts for over 50% of the growth in primary energy consumption[100].

Primary energy consumption

Fossil fuels accounted for 92.4% of primary energy consumption, with coal, oil, and natural gas the most important sources in 2022. Among them, oil consumption accounted for 19.1% of primary energy consumption, natural gas for 8.3%, and coal for 65%. In addition, solar, geothermal, and other renewable energy sources accounted for7.6% of primary energy consumption.

Characteristics of fossil fuel emissions

Over the past decade, energy types have exhibited varying emission trends. Among them, emissions from raw coal consumption peaked at 5,271.8 Mt in 2013; since then, there has been a decline, but the overall trend has remained relatively stable. It is worth mentioning that its share in fossil fuel emissions has continued to decline. Emissions from oil products consumption increased from 936.9 Mt in 2010 to 1,266.2 Mt in 2022, while its share of total fossil fuel emissions grew from 12.7% in 2010 to 12.9% in 2022. Emissions from natural gas consumption rose from 182.6 Mt in 2010 to 524.5 Mt in 2022, with its share in total fossil fuel emissions increasing from 2.5% in 2010 to 5.3% in 2023[101-105].

Sectoral emission contribution

Among all sectors, the Production and Supply of Electric Power, Steam and Hot Water sector accounted for the highest fossil fuel emissions in China, generating 5,442.3 Mt in 2022, which represented 55.3% of country's total fossil fuel emissions. Following was the Smelting and Pressing of Ferrous Metals sector, which emitted 1,891.5 Mt in 2022, contributing 19.2% to the total. Additionally, the service sector was a major contributor, with fossil fuel emissions reaching 870.8 Mt in 2022[101-105].

Biomass emissions

Between 2010 and 2022, China's energy-related emissions increased from 7,357.7 Mt to 9,845.4 Mt, representing a 33.8% rise. The overall trend shows that emissions are continuing to increase, primarily due to the surge in energy consumption driven by industrialization and urbanization. This indicates that China's emissions have yet to reach their peak. In the "The People's Republic of China First Biennial Transparency Report on Climate Change" [106] (hereinafter referred to as the "Transparency Report"), the Chinese government published CO_2 emissions data at the national level. This report presents the most recent emissions data disclosed by the Chinese government. We compared CEADs' estimated data with the figures provided in the "Transparency Report," and the results indicate that in 2021, CEADs estimated China's energy-related emissions at 9,665.4 Mt, while the "Update Report" disclosed a value of 10,095.0 Mt, reflecting a difference of 4.3%.

Comparison with international databases

Under the same accounting caliber (excluding emissions from biomass), while CEADs energy-related emissions data may show numerical differences when compared to data from GCB, EDGAR, and IEA, the overall trends remain highly consistent. It is noteworthy that CEADs data consistently appears lower than that of GCB and IEA. This discrepancy primarily arises from the higher IPCC default emission factors adopted by GCB and IEA compared to those used in CEADs. CEADs relies on empirical research on coal quality in China, indicating that the average emission factor for Chinese coal is 40% lower than the default values recommended by the Intergovernmental Panel on Climate Change (IPCC) [107]. Therefore, we believe that accurate emissions accounting for China requires the use of these field-measured adjusted emission factors. EDGAR's data considers only emissions from fossil fuels, and although its estimates are relatively higher, this suggests that there is some level of uncertainty in the estimates from each database. It is worth noting that the difference between CEADs accounting data and emissions officially released by the Chinese government is less than 5.0%, and the uncertainty of the data is within a range of -3.42% to 3.51% in the 97.5% confidence interval. Hence, we consider CEADs accounting data to be highly reliable.

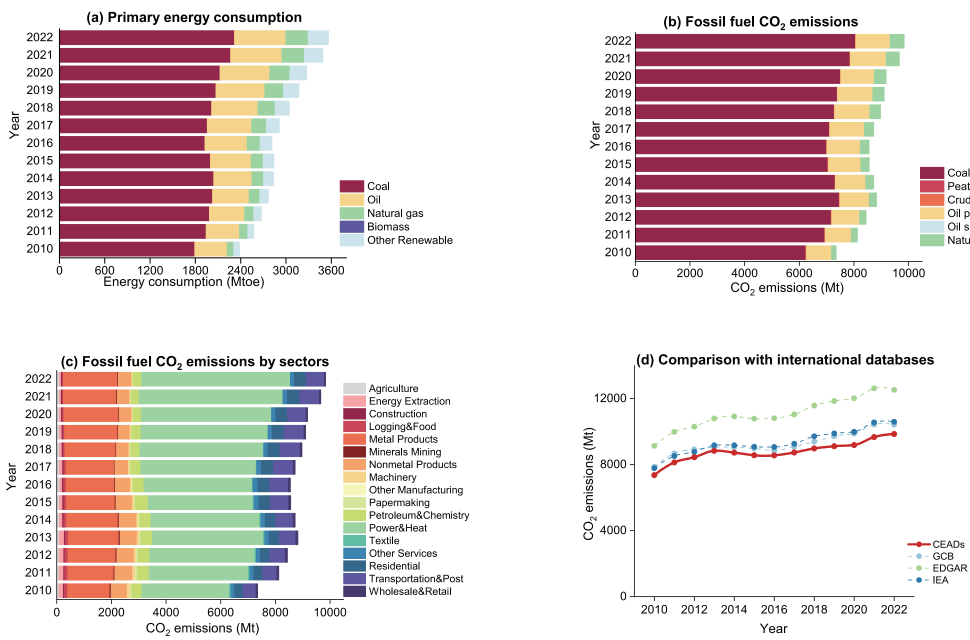


Figure 2.18: China's energy consumption and CO_2 emissions from 2010 to 2022(a) Primary energy consumption; (b) Fossil fuel CO_2 emissions; (c) Fossil fuel CO_2 emissions by sectors; (d) Comparison with international databases.

Brief description of data sources:

The energy data in this report is sourced from the National Energy Balance Sheets and sectoral energy consumption data for 2010-2022, provided by the Energy Department of China's National Bureau of Statistics. The main types of fossil fuels include coal, oil, and natural gas. These energy sources are consumed across 47 industries, primarily in agriculture, industry, and the service sector.

Table 2.18: Data sources for China's emission accounting

Data type	Source	Website
Energy balance sheet at country-level	China Energy Statistical Yearbook	http://60.16.24.131/CSYDMirror/area/Yearbook/Single/N2019080025?z=D07
Emission factor	Zhu Liu et al. published a study titled "Reduced carbon emission estimates from fossil fuel combustion and cement production in China" in Nature	https://doi.org/10.1038/nature14677

Background

The Nation of Brunei, the Abode of Peace (commonly known as Brunei), is a monarchy located on the northern coast of Borneo in Southeast Asia. It is bordered by the South China Sea to the north and is surrounded by Malaysia's Sarawak state on the east, south, and west. The largest city is its capital, Bandar Seri Begawan. Brunei covers a total land area of 5,765 square kilometers and is divided into four districts. In 2022, the total population of Brunei was approximately 0.455 million. Thanks to its abundant oil and gas resources, Brunei enjoys a strong economic standing. In 2022, Brunei's GDP (at current prices) reached $16.68 billion, a 1.6% decrease compared to the previous year. Despite this, it's per capita GDP (at current prices) remained high at $37,000 [108], placing it among the leading nations in Asia.

Brunei's economy is characterized by its heavy reliance on the oil and gas industry, with a relatively weak agricultural and industrial base. In 2021, oil and gas extraction accounted for approximately 52.7% of the country's GDP, while downstream oil and gas industries contributed about 21.1% to GDP[109]. To diversify its economy and reduce dependence on a single sector, Brunei has been actively developing its downstream oil and gas industries, as well as tourism. The country is also increasing investments in agriculture, forestry, fisheries, and infrastructure development. In terms of natural resources, Brunei is rich in oil and gas but has limited other mineral resources. As a result, Brunei is both exploring new oil and gas fields and adhering to a policy of controlled extraction. Regarding international trade, Brunei's main imports include machinery and transport equipment, industrial goods, food, and pharmaceuticals. Its primary export markets are Malaysia, Russia, and Saudi Arabia. The main export products are crude oil, petroleum products, and liquefied natural gas (LNG). Brunei primarily exports crude oil to countries like Australia, India, and Thailand, while LNG is mainly exported to Japan, China, and Malaysia.

Brunei places a strong emphasis on green development and was one of the first ASEAN member states to submit its ratification of the Paris Agreement. In July 2020, the Brunei government announced ten strategies aimed at fostering a low-carbon lifestyle and combating climate change. These strategies include plans to increase the share of electric vehicles to 60% of total car sales by 2035 and to raise the proportion of renewable energy, primarily solar power, to 30% of the total energy generation by 2035. Additionally, at the 26th UN Climate Change Conference (COP26) in November 2021, Brunei signed a declaration supporting the global transition from coal to clean energy, committing to expand the deployment of clean power generation technologies, halt the issuance of new coal-fired power plant licenses, and prohibit the construction of new coal-fired power projects[110].

Primary energy consumption

Brunei's primary energy consumption structure is predominantly based on fossil fuels. In 2022, natural gas accounted for 64.5% of the total primary energy consumption, while oil made up 15.4%. In recent years, coal has also become increasingly significant in Brunei's energy consumption mix, with coal consumption reaching 19.8% of the total primary energy consumption in 2022. In addition, other renewable energy consumption accounted for 0.3% of primary energy consumption.

Characteristics of fossil fuel emissions

Petroleum products, coal, and natural gas consumption are the primary sources of fossil fuel CO_2 in Brunei. As the major fossil fuels, natural gas and coal consumption contributed to CO_2 emissions of 5.1 Mt and 2.7 Mt in 2022, accounting for 54.9% and 28.5% of the total fossil fuel CO_2, respectively. CO_2 from petroleum products consumption is also a significant fossil fuel source in Brunei, with CO_2 from petroleum products consumption reaching 1.6 Mt in 2022.

Sectoral emission contribution

The largest fossil energy carbon-emitting industries in Brunei are electricity, heat, gas, and water production sector. The CO_2 from fossil energy consumption in electricity, heat, gas, and water production sector remain stable from 2010 to 2019, increasing rapidly from 2020, the emissions from this sector reach to 7.8 Mt in 2022, accounting for 83.2% of the total fossil fuel CO_2. The transportation, storage, and postal services sector is the second-largest contributor to fossil fuel CO_2 in Brunei. Emissions from this sector reached to 1.1 Mt, constituting 11.7% of the total fossil fuel CO_2, the share of emissions from this sector reduced by 12.2 % than that of 2019. This reduction may be due to the economic lockdown measures implemented in response to the COVID-19 pandemic.

Emission trends

Brunei's CO_2 emissions have shown a fluctuating upward trend. From 2010 to 2014, CO_2 emissions from fossil fuel consumption in Brunei increased from 6.2 Mt to 8.3 Mt, increased by around 33.4%. Subsequently, CO_2 decreased year by year, reaching an all-time low in 2019. However, in recent years, Brunei's CO_2 have started to rise annually, with a significant increase in 2020 and reaching 9.4 Mt in 2022.

Comparison with international databases

Under the same accounting caliber (excluding emissions from biomass), CEADs' calculation of CO_2 emissions from fossil fuel consumption in Brunei are generally lower than the data results published by EDGAR, and GCB. From a trend perspective, the CEADs calculations are relatively close to the EDGAR data, with an average difference of about 6.3%. However, this gap has been narrowing in recent years. Additionally, except for the period 2011, the CEADs results generally maintain a consistent trend with those of the IEA and EDGAR. The main reason for the discrepancy is the different sources of energy consumption data for each agency. Due to data constraints, CEADs uses energy balance sheet data published centrally by APEC, while other agencies do not specify the exact source.

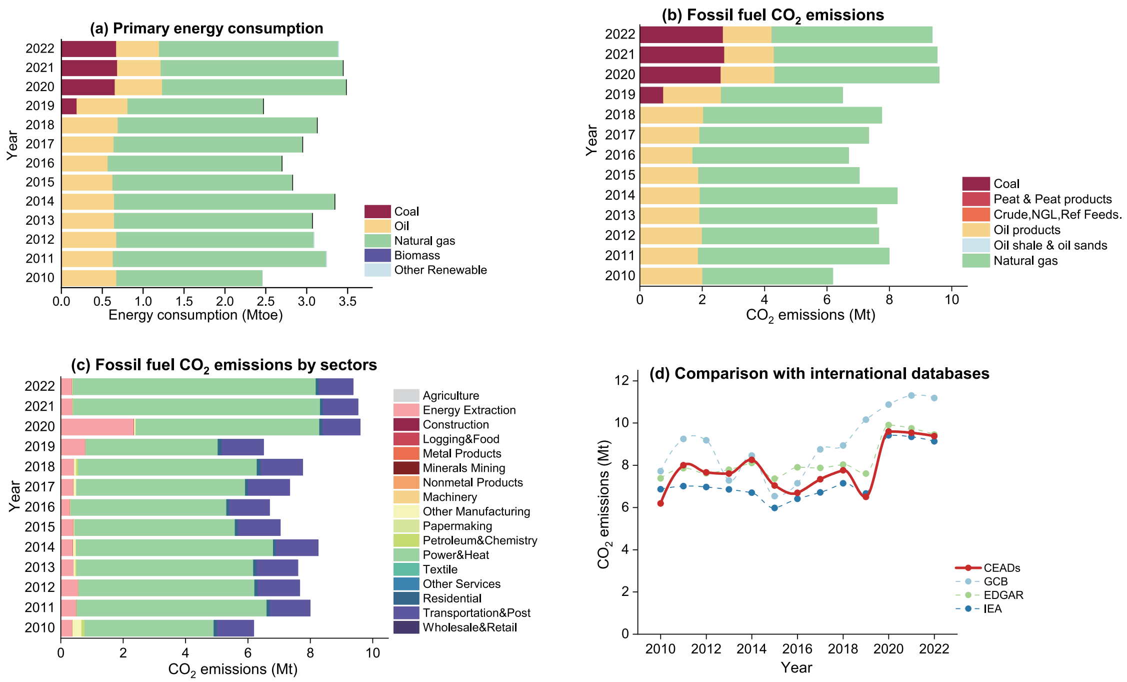


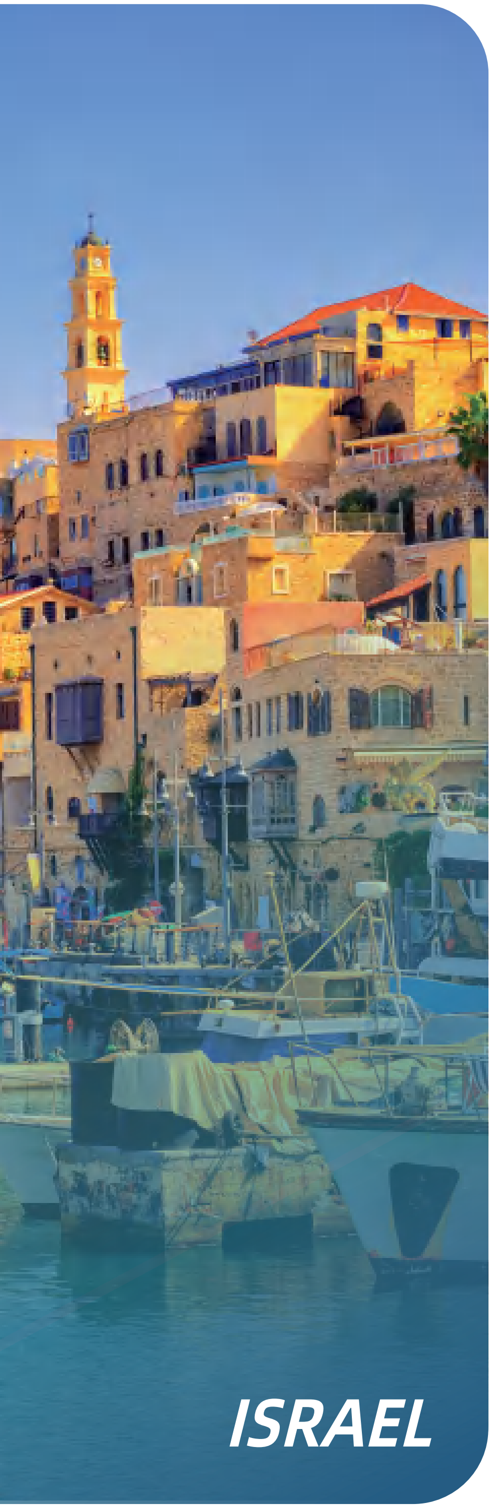
Figure 2.19: Brunei's energy consumption and CO_2 emissions from 2010 to 2022 (a) Primary energy consumption; (b) Fossil fuel CO_2 emissions; (c) Fossil fuel CO_2 emissions by sectors; (d) Comparison with international databases.

Brief description of data sources:

The compilation of CO_2 inventory in Brunei is based on the compilation method of Intergovernmental Panel on Climate Change (IPCC), and the CO_2 inventory of CEADs with unified format and unified statistical caliber is taken as the template. the APEC Energy Sector Energy balance sheet and the Intergovernmental Panel on Climate Change (IPCC) emission factors to calculate the CO_2 emissions sourced from fossil fuel consumption in Brunei. In terms of sub-sector matching, we used the UN Comtrade database to conduct downscaling matching of sectors and allocate them to 47 sectors. For subsector matching, we use export data from the United Nations Commodity Trade Statistics Database (UN Comtrade) and population data from the World Bank to downscale the sectoral matching and assign to 47 sectors.

Table 2.19: Data sources for Brunei's emission accounting

Data type	Source	Website
Energy balance sheet	APEC Energy Working Group	https://www.egeda.ewg.apec.org/egeda/database/newbalance_select_cond2.php
Emission factor	IPCC	https://www.ipcc-nggip.iges.or.jp/EFDB/main.php
Sectoral mapping indicator	The Brunei Darussalam GDP Report	https://deps.mofe.gov.bn/SitePages/eData%20library.aspx
	UN Comtrade	https://comtradeplus.un.org/
	Word Bank	https://data.worldbank.org.cn/indicator/SP.POP.TOTL?view=chart



Background

Israel, a country in West Asia, lies in the Levant region of the Fertile Crescent at the eastern end of the Mediterranean Sea. The country is bordered by Lebanon to the north, Syria to the northeast, Jordan to the east, and Egypt to the southwest. In addition, Israel borders the Palestinian territories in the West Bank and the Gaza Strip to the east and west. The country features diverse geographical features and temperature variations, with coastal areas such as Tel Aviv and Haifa having a typical Mediterranean climate with cool, rainy winters and long, hot summers. In 2022, Israel had a population of over 9.5 million, of whom 27.8% are under 15 years of age, 59.9% between 15 and 64 years of age, and 12.3% over 65 years of age. Israel's nominal GDP ranks 28st in the world and is expected to reach US$525.0 billion by the end of 2022[111].

Israel has scarce natural resources; 60% of the land is desert and the rest is also arid, with serious shortages of water resources. Israel has developed various water-saving technologies, including drip irrigation, and they have also explored solar energy: the country is a leader in per capita solar energy use. Israel's economy is mainly driven by exports in high-tech equipment and diamonds; it imports crude oil, grain, raw materials, and machinery. The service sector is key to total foreign trade[112].

Israel's energy is mainly derived from fossil fuels, and since energy demand is much higher than production, it is heavily dependent on energy imports. In 2018, it was reported that 70% of Israel's electricity came from natural gas and 4% from renewable energy, of which 95% was solar photovoltaics. In addition, Israel has a capacity of 1,500 megawatts of renewable energy production, 1,438 megawatts of which comes from solar power. Other energy sources include wind power (27 MW), biogas (25 MW), hydropower (7 MW) and other bioenergy sources (3 MW). As of 2019, solar photovoltaics dominate solar energy[113].

In 2018, Israel set a goal of phasing out vehicles running on fossil fuels by 2030. In addition, the Israeli cabinet approved its energy ministry's goal for 30% of the country's energy to come from renewable sources by 2030. In 2021 at COP26 of the UN Framework Convention on Climate Change (UNFCCC), Israel pledged that it would phase out coal power by 2025, and further proposed an interim goal. That is, by the middle of the 21st century, Israel will reduce greenhouse gas emissions by 27% (including 85% of CO2 emissions mainly related to transportation, the power sector and municipal waste) and strive to achieve net zero greenhouse gas emissions as soon as possible[114].

Primary energy consumption

Fossil fuels and renewable energy are the dominant sources of primary energy consumption in Israel. Regarding primary energy consumption in 2022, coal accounted for 17.5%, petroleum products for 33.3%, natural gas for 43.4%, renewable energy for 5.2%, biomass for 0.6%.

Characteristics of fossil fuel emissions

In the CO_2 generated from fossil fuel consumption, coal, oil, and natural gas emissions take the lead. Coal and oil, being the primary fossil fuels in Israel, contributed to CO_2 emissions of 34.6 Mt and 28.0 Mt in 2010, declining to 15.1 Mt and 21.3 Mt in 2022, accounting for 24.6% and 34.7% of the total fossil fuel CO_2, respectively. Meanwhile, CO_2 from natural gas consumption in 2022 reached 24.9 Mt, accounting for 40.6% of the total fossil fuel CO_2, a significant increase compared to the 11.6 Mt emitted in 2010 (representing 15.3% of emissions).

Sectoral emission contribution

CO_2 emissions from fossil fuel consumption in Israel primarily stem from the production of electricity, heat, gas, and water, as well as the transportation, storage, and postal industries. Emissions resulting from the consumption of fossil fuels in the production of electricity, heat, gas, and water have shown a decreasing trend, dropping from 48.3 Mt in 2010 to 40.2 Mt in 2022. These emissions accounted for approximately 65.5% of the total fossil fuel CO_2 in 2022. The transportation, storage, and postal industries comprise the second-largest source of fossil fuel CO_2 in Israel. Their emissions in 2022 amounted to around 18.5 Mt, constituting 30.1% of the total fossil fuel CO_2.

Emission trends

From 2010 to 2022, CO_2 from fossil fuel consumption in Israel showed a declining trend, decreasing from 75.3 Mt to 61.4 Mt, representing a reduction of approximately 18.5%.

Comparison with international databases

Under the same accounting caliber (excluding emissions from biomass), CO_2 emissions in Israel calculated by CEADs show minor discrepancies with the data published by IEA. From 2010 to 2016, whether in terms of fossil fuel CO2 or their trends, the data calculated by CEADs for Israel closely aligns with IEA's statistical data. In 2017, there is a slight difference between the two sources, but from 2018 to 2022, their statistics are again in close agreement. Overall, the differences between CEADs' calculations and IEA's statistics for Israel's fossil fuel CO_2 are minimal. When compared to the statistics provided by GCB and EDGAR, CEADs' calculated data aligns closely with both sources from 2010 to 2013, in terms of both quantity and trend. However, starting from 2014, discrepancies appear among the three sources. Specifically, EDGAR's statistics consistently exceed CEADs' calculations by around 4%-9%, while GCB's data consistently falls below CEADs' calculations by approximately 6%-9%. These differences can be explained in two ways:

1. Classification of Energy Sources: CEADs employs a more detailed energy source classification. For instance, petroleum products are broken down into gasoline, diesel, fuel oil, and others, each with its corresponding emission factor. In contrast, IEA's classification groups all petroleum products under a single category. This discrepancy in emission factors contributes to the differences in emission data.

2. Data Sources for Energy Consumption: CEADs relies on data from the Israeli Ministry of Energy and the Fuel and Gas Administration. In contrast, IEA's data sources are more varied. The differences in data sources can contribute to variations in energy consumption data between the two organizations.

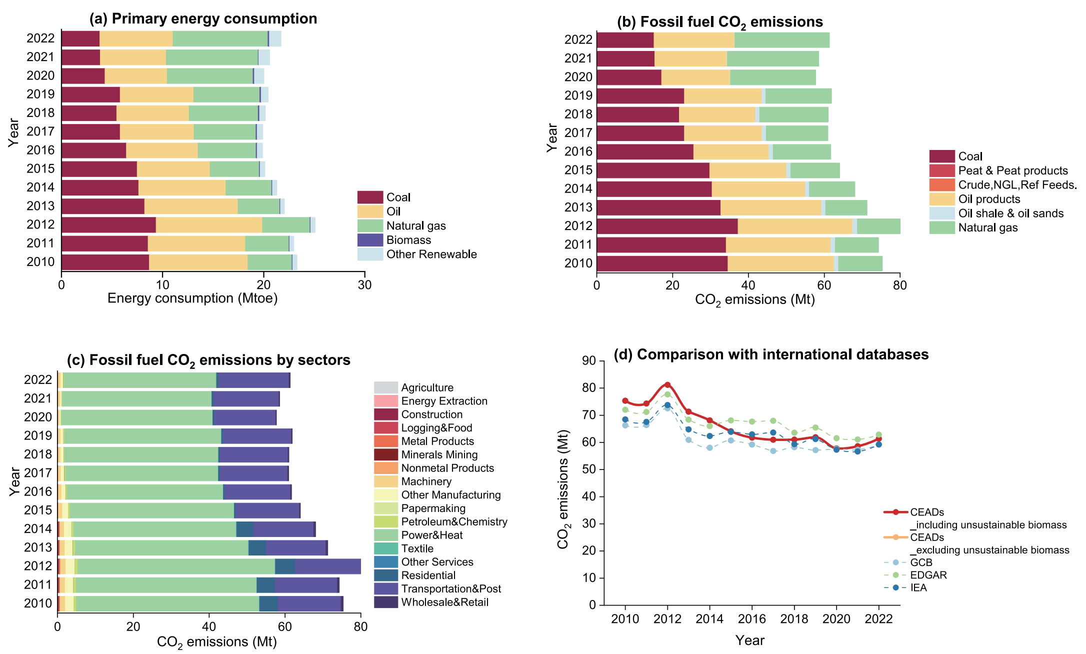


Figure 2.20: Israel's energy consumption and CO_2 emissions from 2010 to 2022 (a) Primary energy consumption; (b) Fossil fuel CO_2 emissions; (c) Fossil fuel CO_2 emissions by sectors; (d) Comparison with international databases.

Brief description of data sources:

The energy data used in this report is from the energy balance sheet provided by the Ministry of Energy of Israel and the Fuel and Liquefied Petroleum Gas Authority, Ministry of Energy of Israel. These data are collected by the Israel Central Bureau of Statistics (CBS) and contain information on the supply, conversion and availability of energy and the final use of petroleum, petroleum products and renewable energy by major economic sectors (3 sectors in 2013-2014; 5 sectors in 2015- 2022). We use the data from Israel Central Bureau of Statistics and United Nations classification of Commodity Trade export industries to allocate those sectors into 47 sectors.

Table 2.20: Data sources for Israel's emission accounting

Data type	Source	Website
Energy balance sheet	Israel's Ministry of Energy and the Fuel and Liquefied Petroleum Gas Authority	https://www.cbs.gov.il/en/subjects/Pages/Energy.aspx
Emission factor	IPCC	https://www.ipcc-nggip.iges.or.jp/efdb/
Sectoral mapping indicator	United Nations Commodity Trade Statistics Database: export data	https://comtrada.un.org
	Israel Central Bureau of Statistics	https://www.cbs.gov.il/he/cbsNewBrand/Pages/default.aspx

AFRICA

Background

Burundi is a small landlocked country in East Africa, surrounded by Rwanda, Tanzania, and the Democratic Republic of Congo to the north, east and west, respectively. One of the poorest countries in the world, Burundi’s GDP, GDP per capita and Human Development Index all sit in the lower part of international rankings. Burundi is also designated by the United Nations as one of the least developed countries, with a total GDP of US$3.3 billion and a 2022 population of 13.32 million, the per capita GDP (current price) is only US$250.6 [115].

Agriculture dominates Burundi’s industrial structure, but there is a lack of good arable land and farming methods are inadequate in terms of food production. In 2019 agriculture accounted for about 27.6% of the total GDP. Industry is still in its infancy, comprising coffee and cotton processing and beer and cement manufacturing, collectively accounting for about 10.6% of GDP[116]. Burundi’s mineral resources are scant, although small volumes of tin, tungsten and gold were mined in the past; no effective geological investigation of mineral resources in the country has taken place until now. In terms of international trade, Burundi’s export products are mainly coffee, tea, sugar, and cotton, among other products. Its main exporting countries are Switzerland, Britain, Pakistan, Belgium, and Rwanda, among others. Burundi imports primarily machinery and petroleum products, mainly from Saudi Arabia, Belgium, Uganda, Kenya, China and other countries.

Burundi has relatively abundant solar and hydro energy resources. The annual average potential of solar energy generation is about 2000 kWh/m2[117]. In order to reduce external energy dependence and mitigate the impact of climate change on the country's socioeconomy, government agencies have set a target of installing 204 MW of solar photovoltaic power by 2040, which is expected to reach 27% of the country's total installed capacity. According to the United Nations Framework Convention on Climate Change, Burundi's Intended Nationally Determined Contributions (INDC) is to reduce its greenhouse gas emissions by 3% (unconditional reduction) to 13% (depending on international support) by 2030[118].

Primary energy consumption

The primary energy structure of Burundi is dominated by biomass. In 2022, a 5.1% share of total fossil energy consumption and no coal or natural gas consumption. In addition, biomass accounted for 94.1% of primary energy consumption, while other renewable energy sources such as wind and solar energy account for 0.8%.

Characteristics of fossil fuel emissions

Petroleum products, the only fossil energy source in Burundi, generated a total of 0.36 Mt of CO_2 in 2022, an increase of 59.9% compared to 2010.

Sectoral emission contribution

Burundi's highest sectoral CO_2 emissions come from the transportation, storage, and postal services sector, which accounted for 0.21 Mt in 2022, or 57.3% of the total. This share has been increasing since 2010 with the ongoing construction of roads and rail lines and increase in transport volumes. Second is the Metal Products industry, with its share rising from 7.9% in 2010 to 11% in 2022. Third is the production and supply of electric power, heat, gas and hot water, whose share showed a small decline , from 19.2% in 2010 to 10.7% in 2022.

Biomass emissions

In 2022, biomass consumption in Burundi accounted for about 94.1% of the primary energy consumption mix; most was used domestically and wholesale and retail sector. The primary sources are firewood and charcoal. Burundians obtain firewood mainly through deforestation and use it for household cooking and heating. This has a large impact on the environment and is an unsustainable use of resources, so should be counted in the overall carbon accounting process. CO_2 emissions from wood consumption increased from 7.7 Mt in 2010 to 10.3 Mt in 2022.

Emission trends

Burundi's CO_2 emissions have increased at a flat rate. Between 2010 and 2016, emissions from fossil energy consumption increased by 4%, from 0.226 MT in 2010 to 0.235 MT in 2016. However, Burundi's CO_2 have rapidly increased since then, with emissions from fossil energy consumption increasing by 65.1% between 2017 and 2022.. From 2010 to 2022, CO_2 from biomass consumption increased from 7.7 Mt to 10.3 Mt.

Comparison with international databases

Under the same accounting caliber (excluding emissions from biomass), CEADs' accounting for Burundi is generally smaller than the statistics of the IEA, GCB and EDGAR. Especially after 2016, CEADS' accounting for fossil carbon emissions is almost half of the corresponding value of the GCB.. In 2017 CEADS accounted for fossil energy carbon emissions of 0.22 Mt, while the IEA value reached 0.54. This difference is mainly down to the different sources of energy consumption data used by each institution, with CEADs deploying energy consumption data from the African Energy Commission (AFREC), while IEA data does not indicate the specific source. The facts that Burundi experienced serious political unrest from 2015 to 2018[119]and that domestic socioeconomic development was badly hit points to AFREC more clearly revealing the realities of African countries than do international agencies; so the slightly declining emission trend calculated by CEADs is more in line with that reality.

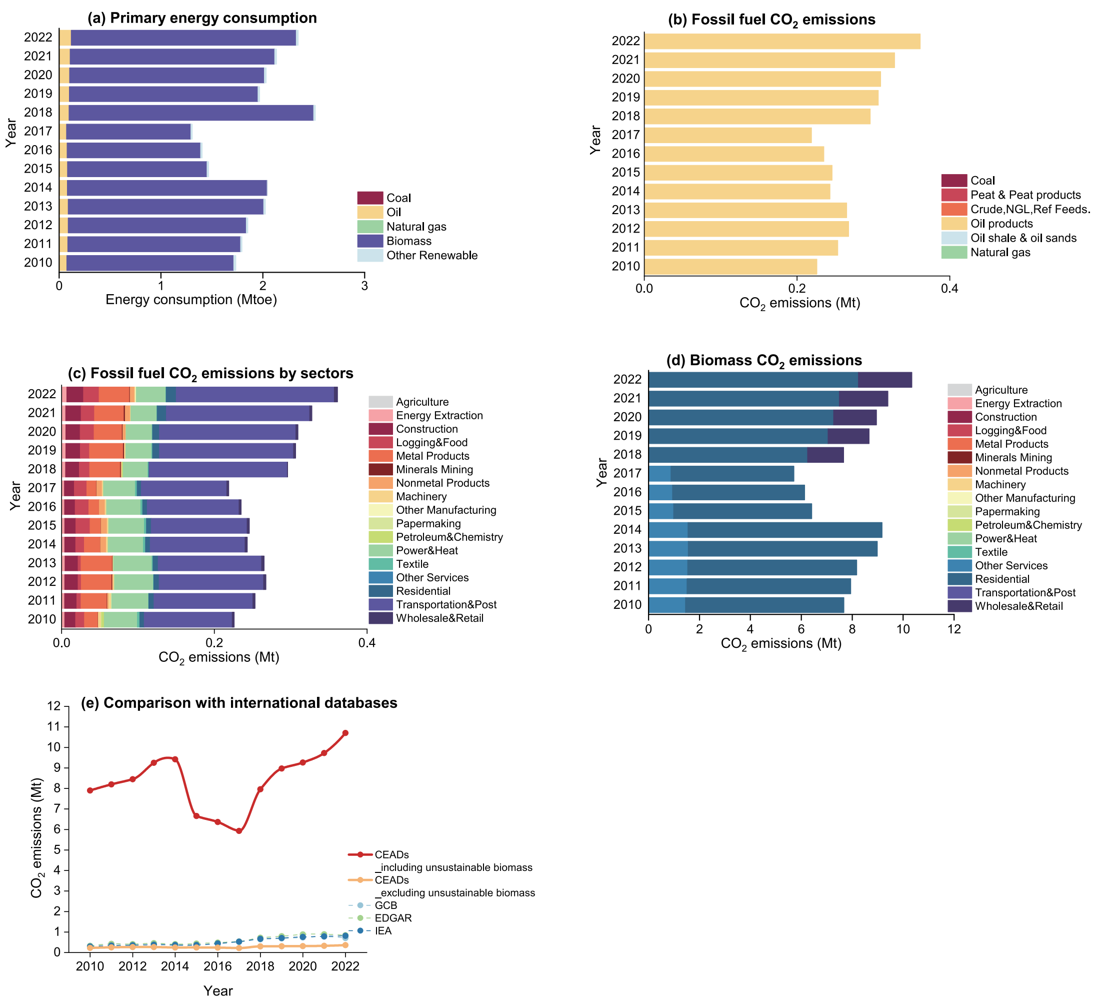


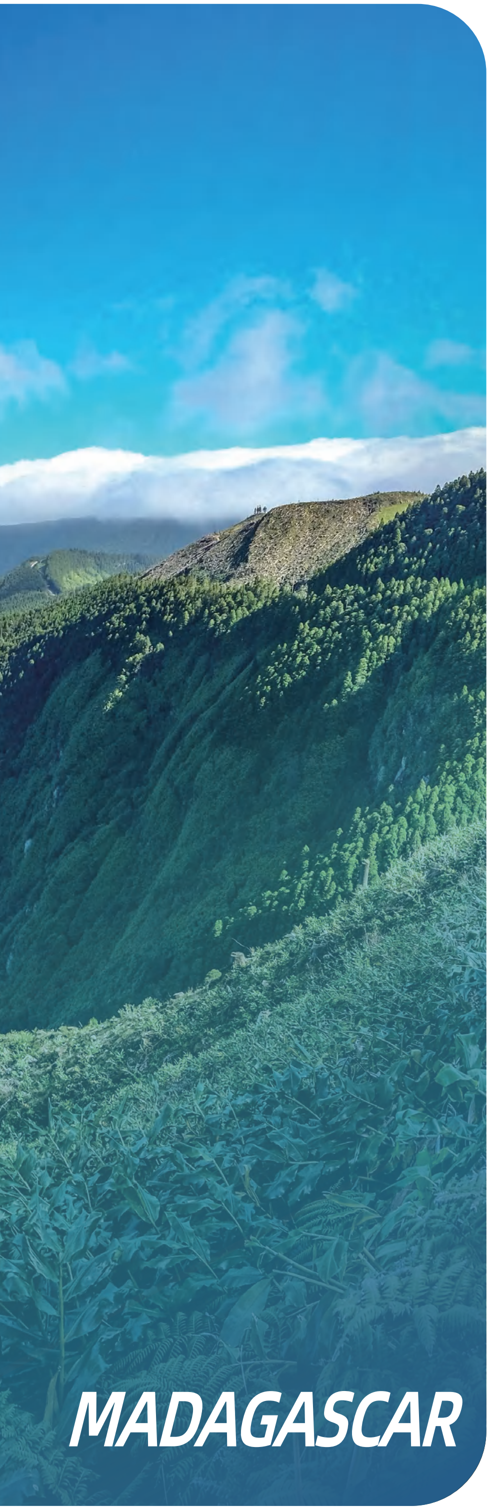
Figure 3.1: Burundi's energy consumption and CO_2 emissions from 2010 to 2022 (a) Primary energy consumption; (b) Fossil fuel CO_2 emissions; (c) Fossil fuel CO_2 emissions by sectors; (d) Biomass CO_2 emissions; (e) Comparison with international databases.

Brief description of data sources:

Burundi's energy balance sheets are all from the Ministry of Energy and Minerals and cover the period 2010-2022, with a total of 11 energy varieties and 6 sectors. In this case, for sector matching, we use data from Burundi Statistics Office, AFDB and export data published by UN Comtrade, as the basis for allocation, and downscaled sectoral matching to 47 sectors.

Table 3.1: Data sources for Burundi's emission accounting

Data type	Source	Website
Energy balance sheet	African Energy Commission	https://au-afrec.org/en/energy-balances
Emission factor	IPCC	https://www.ipcc-nggip.iges.or.jp/EFDB/
Sectoral mapping indicator	UN Comtrade, Export data	https://comtradeplus.un.org/
	Burundi Statistics Office	http://www.isteebu.bi/nada/index.php/catalog
	AFDB	https://dataportal.opendataforafrica.org/nbyenxf/afdb-socio-economic-database-1960-2023



Background

Madagascar is an island nation located off the eastern shore of Africa bordering the Indian Ocean. It is the largest island in Africa and the fourth largest in the world. The entire island is composed of volcanic rock, with a coastline of about 5,000 kilometers. Since 2009, the political situation in Madagascar has been highly volatile. Its economic base is weak, and it is heavily dependent on foreign aid. It is one of the least developed countries as designated by the United Nations, with a GDP of US$13.4 billion in current prices in 2022 and a population of 29.6 million [120], 80% of whom live below the poverty line[121].

Agriculture is Madagascar's dominant economic sector, accounting for approximately 21.9% of the total GDP in 2022[122] . Over 80% of the population work in agriculture, and 70% of export earnings are agriculture related. Madagascar's industrial base is weak, with its output accounting for approximately 21.7% of GDP in 2022[123]. Tourism is an important industry, and the country is rich in resources for it; but services are inadequate, and total numbers of foreign tourists in 2019 were 378,000. Madagascar is rich in deposits of minerals such as graphite, ferrochrome, and bauxite; its graphite reserves are the largest in Africa. There are also reserves of precious and semi-precious stones, as well as marble, granite, and fossils. In terms of international trade, its main exports are coffee, shrimp, chrome ore, vanilla, cloves, and cotton textiles, among other products. Its main imports include oil, vehicles, machinery and equipment, pharmaceuticals, consumer goods and foodstuffs. Madagascar's primary trading partners are France, the United States, China, the European Union, South Africa, the Southern African Development Community (SADC), some Southeast Asian countries and the Indian Ocean islands[120].

In addition, Madagascar is rich in renewable energy, including hydro, geothermal, wind and solar[124-127]. As such it has great potential for clean electricity production, which could help reduce external energy dependence and mitigate the socioeconomic impact of climate change on the country. Renewables are, however, under-exploited. Government agencies have actively adopted renewable energy policies and increased support for projects such as hydroelectric and wind power generation to promote electrification in rural and urban areas[126, 127]. Under the United Nations Framework Convention on Climate Change, Madagascar's Intended Nationally Determined Contributions (INDC) commit to reducing its greenhouse gas emissions by 14% by 2030[128].

Primary energy consumption

Madagascar's primary energy mix is dominated by diesel and coal. In 2022, Madagascar consumed 4.3% of coal and 17.5% of oil, amounting to a total fossil energy consumption share of almost 21%. In addition, biomass accounts for 76.8% of primary energy consumption. Renewable energy sources such as hydro account for a very small share, less than 1.3%.

Characteristics of fossil fuel emissions

The sources of CO_2 from fossil energy consumption are dominated by petroleum products such as diesel and coal. Petroleum products, as the primary fossil energy source in Madagascar, accounted for 75.5% of fossil energy-related CO_2 in 2022. Emissions from petroleum consumption have gradually increased from 1.9 Mt in 2010 to 3.0 Mt in 2022, consistently dominating the CO_2 from fossil energy consumption. The second-largest contributor to CO_2 was coal consumption, which accounted for 1.0 Mt of CO_2 emissions in 2022, representing approximately 24.5% of the fossil energy-related emissions for that year.

Sectoral emission contribution

The highest fossil energy CO_2 in Madagascar originate from the Electricity, heat, gas, and water production, emissions of this sector increased from 0.8 Mt in 2010 to 1.8 Mt in 2022, accounting for 45.9% of the total. Transportation, storage, and postal services sector was the second largest fossil energy carbon emitting sector in Madagascar in recent years. Since 2010, its annual CO_2 have shown a fluctuating upward trend, peaking at 2.3 Mt in 2018 before rapidly declining. In 2022, CO_2 amounted to over 1.4 Mt, accounting for approximately 36.0% of total fossil energy-related CO_2 emissions, primarily from the use of diesel and gasoline.

Biomass emissions

Biomass accounted for around 76.8% of the primary energy consumption mix in Madagascar in 2022. Most was used in the household and service sectors, and by industry. Fuelwood, charcoal, and plant and agricultural residues are the primary types used. The fuelwood and charcoal are mainly derived from the over-harvesting of forests by local people, which has led to a reduction in forest cover and forest degradation. Due to the long cycle of forest restoration, this type of biomass is not renewable or sustainable over time and should be included in national and regional carbon accounting along with fossil energy combustion for overall CO_2. By contrast, plant and agricultural residues are mainly sustainable renewable energy sources with a 'zero carbon' life-cycle attribute, and should not be included in the overall carbon accounting process[128]. CO_2 from biomass consumption decreased annually from 2010 to 2012, from 14.1 Mt to 13.9 Mt; then increased annually from 13.9 Mt in 2012 to 16.2 Mt in 2015, an average annual rise of 5.2%. In 2016, CO_2 from biomass briefly decreased to 16.0 Mt and, since then, CO_2 from biomass rapidly increased, reaching 20.4 Mt in 2018. From 2019 to 2021, emissions stabilized, fluctuating between 16 and 17 Mt. In 2022, CO_2 from biomass reached 18.7 Mt.

Emission trends

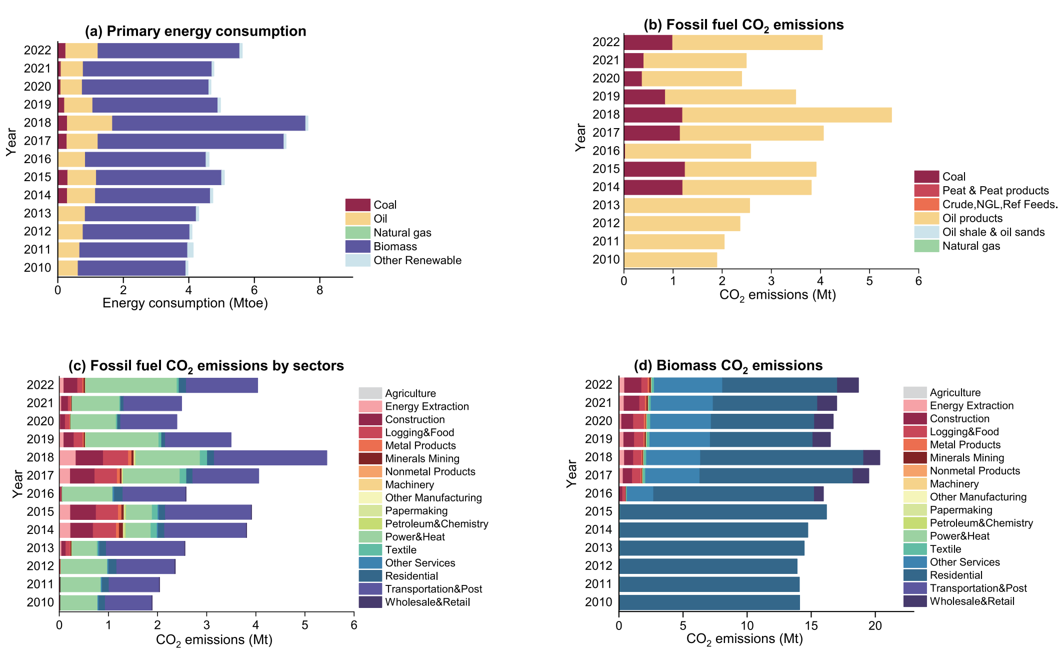
CO_2 emissions in Madagascar have shown a rapid overall growth trend. Between 2010 and 2022, CO_2 from fossil fuel consumption increased by more than 1.6 times, rising from 1.9 Mt to 4.0 Mt in 2022, demonstrating a swift increase. Within this period, CO_2 from fossil fuel consumption, apart from minor declines between 2015-2016 and 2018-2020, generally exhibited an upward trajectory. During the same period, CO_2 from biomass consumption grew from 14.1 Mt to 18.7 Mt, with an average annual growth rate exceeding 2.4%.

Comparison with international databases

Under the same accounting caliber (excluding emissions from biomass), the results from various institutions are generally quite similar, with differences arising from variations in calculation methods and underlying data. Among these institutions, CEADs' calculations of CO_2 from fossil fuel consumption are closest to IEA data. From 2010 to 2017, the discrepancy between CEADs and IEA is around 13%. However, a notable divergence emerges from 2014 onwards, with the largest deviation occurring in 2020, reaching nearly 50%. Looking at the time series, CEADs' results exhibit almost identical trends to IEA and GCB data, with similar starting points. Yet, the differences gradually widen due to substantial changes after 2014.

The primary source of these variations stems from the disparities in underlying data. This study employs the energy balance sheet released by the African Energy Commission (AFREC) as its data source. This energy balance sheet did not cover coal consumption in its energy categories from 2010 to 2013; coal consumption statistics were only included from 2014 onwards. Furthermore, there are substantial fluctuations in statistics across different years in this data source. As a result, the significant changes in this study's results from 2014 onwards are attributed to these data fluctuations.

Additionally, when including CO_2 from biomass consumption, the calculated data for 2022 by CEADs amounts to 22.7 Mt.



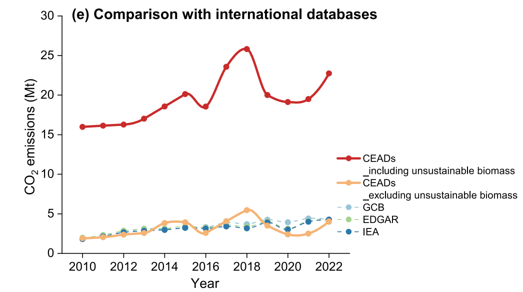


Figure 3.2: Madagascar's energy consumption and CO_2 emissions from 2010 to 2022 (a) Primary energy consumption; (b) Fossil fuel CO_2 emissions; (c) Fossil fuel CO_2 emissions by sectors; (d) Biomass CO_2 emissions; (e) Comparison with international databases.

Brief description of data sources:

The energy balance sheets for Madagascar are sourced exclusively from the African Energy Commission (AFREC). These sheets vary in terms of the included energy categories and sectors across different years. Taking the example of 2022, there were a total of 16 energy categories and 5 sectors included. In terms of sector disaggregation, we utilized the sector-specific GDP data provided by Madagascar's National Statistical Office and export data published by UN Comtrade as the basis for allocation. This allowed us to downscale and allocate to 47 sectors.

Table 3.2: Data sources for Madagascar's emission accounting

Data type	Source	Website
Energy balance sheet	AFREC	https://au-afrec.org/en/energy-balances
Emission factor	IPCC	https://www.ipcc-nggip.iges.or.jp/EFDB/
Sectoral mapping indicator	Madagascar Statistical Office	https://www.instat.mg/statistiques/bases-de-donnees/comptes-nationaux https://www.instat.mg/thematique/population
	UN Comtrade	https://comtrada.un.org

Background

Niger is a landlocked country on the southern edge of the Sahara Desert in western Africa, bordered by Algeria and Libya to the north, Nigeria and Benin to the south, Mali and Burkina Faso to the west and Chad to the east. Niger has a tropical desert climate in the north and a savannah climate in the south, making it one of the hottest countries in the world. Niger has been infiltrated by terrorist forces for years; its political situation is unstable and its economic base is weak. It is one of the least developed countries as designated by the United Nations, with a GDP of US$14.3 billion in current prices in 2022 and a population of 26.1 million[129], of whom 50.6% live below the poverty line[130].

Agriculture, livestock and forestry dominate Niger’s economy, accounting for approximately 42% of total GDP in 2022[131] . More than 80% of the population are engaged in agriculture, although food production is variable. Niger's industrial base is weak, accounting for approximately 17.5% of total GDP in 2022[132]. The country’s main natural resources are uranium, phosphate (as yet unexploited), coal and oil. In terms of international trade, its exports are mainly uranium, gold and oil; the main exporting countries are Nigeria, Burkina Faso, China and Mali[129].

In addition, Niger is rich in solar energy resources and has huge potential for clean electricity production[133,134]. In 2012, the member countries of the Economic Community of West African States (ECOWAS), including Niger, jointly adopted the ECOWAS Renewable Energy Policy, setting a target of 10% of renewable energy in the region by 2020, and 19% by 2030[135]. Niger has taken active policy action by establishing an energy market regulator and abolishing taxes on production of solar and wind power equipment in order to increase the use of renewable energy, increase the country's electrification rate and achieve the national target of universal access to electricity by 2035[136] Under the United Nations Framework Convention on Climate Change, Niger's Intended Nationally Determined Contributions (INDC) aim to reduce its greenhouse gas emissions by 10.6% by 2030[137].

Primary energy consumption

The primary energy mix in Niger is dominated by petroleum products such as diesel and gasoline. In 2022, coal consumption accounted for 3.5% of the mix, and oil consumption, 22.9%; the share of total fossil energy consumption in the total mix was 26.9%. In addition, biomass accounted for 73.0% of primary energy consumption, while other renewable energy sources such as solar accounted for less than 0.1%.

Characteristics of fossil fuel emissions

Petroleum products such as diesel and gasoline are the main source of CO_2 emissions from fossil energy consumption in Niger. Petroleum products, the dominant fossil energy source in Niger, generated 2.4 Mt of CO_2 in 2022, accounting for 81.4% of the total from fossil energy sources; these emissions rose from 1.1 Mt in 2010 to 2.4 Mt in 2022. Coal and natural gas meanwhile accounted for roughly 16.9% and 1.7% of emissions, respectively.

Sectoral emission contribution

The transportation, storage and postal services sector accounts for the highest emissions, which are mainly from consumption of fossil energy such as diesel and gasoline. The sector generated 1.5 Mt of CO_2 in 2022, accounting for 52.6% of the total. The electricity, heat, gas and water production sector meanwhile accounted for over 0.8 Mt of CO_2, or 28.1% of the total; the main source consumed was lignite.

Biomass emissions

Biomass accounted for about 73.0% of the primary energy consumption mix in Niger in 2022. Most was consumed in the household and service sectors. The most heavily used types, fuelwood and biosolid fuels, are over-harvested from forests, which has led to a reduction in forest cover and forest degradation[137]. This type of biomass use is not renewable or sustainable over time due to the long cycle of forest restoration. Therefore, biomass combustion in the country is not 'zero carbon' and should be included in the overall CO_2 in national and regional accounting, along with fossil energy consumption. CO_2 from biomass increased annually from 2010 to 2017, rising from 3.4 Mt to 7.4 Mt — an average annual increase of 11.6%, including a 53.7% increase from 2016 to 2017. Since then, CO_2 emissions from biomass have shown a downward trend followed by a sharp rise, from 7.4 Mt in 2017 to 5.6 Mt in 2018, and then another annual increase to 11.8 Mt in 2022.

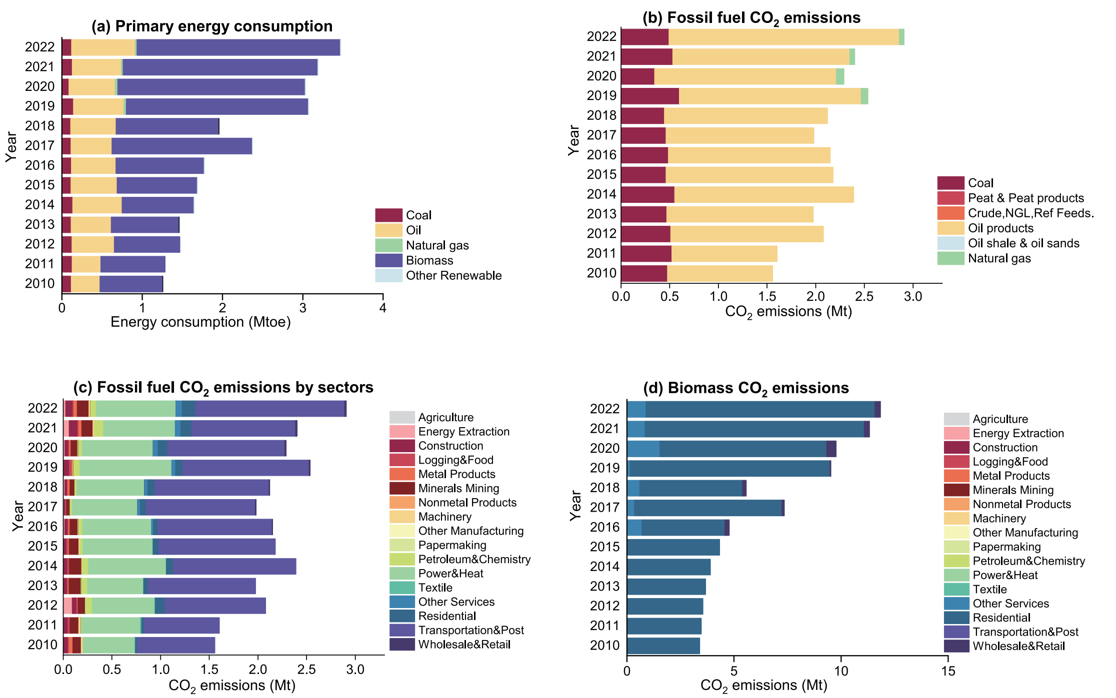
Emission trends

CO_2 emissions in Niger follow a fluctuating growth trend. CO_2 from fossil energy consumption increased by 86.6% between 2010 and 2022, from 1.6 Mt to 2.9 Mt. Emissions rose during 2010 to 2012, 2013 to 2014 and 2017 to 2019, 2020 to 2022, and decreased over the remaining years. During this period, CO_2 from biomass consumption increased from 3.4 Mt to 11.8Mt, with an average annual growth rate of 11.0%.

Comparison with international databases

Under the same accounting caliber (excluding emissions from biomass), the fossil energy CO_2 calculated in this study are closest to the EDGAR data, with an error of about 6%. The gap with the IEA data is around 10%. From the perspective of time series, CEADs' results of fossil energy CO_2 are almost identical to the data from IEA and EDGAR in terms of trend and magnitude of change from 2010 to 2014, while the data from 2014 to 2016 and 2017 to 2019 are similar regarding trends, but show a slightly larger magnitude of change; only in 2016 to 2017 do the trends differ. This is due to the differences in figures showing the consumption of petroleum products in the energy balance sheets of the African Energy Commission (AFREC) and IEA. The former showed a slight downward trend from 2016 to 2017, while the latter showed a slow increase from 2016 to 2017. CEADs relied on the AFREC data; IEA, on data sourced from the United Nations Statistics Division, the International Renewable Energy Agency (IRENA) and direct contact with the Ministry of Petroleum, Energy and Sustainable Energy in Niger.

In addition, when including CO_2 from biomass consumption, the CEADs accounting data is 14.7 Mt in 2022.



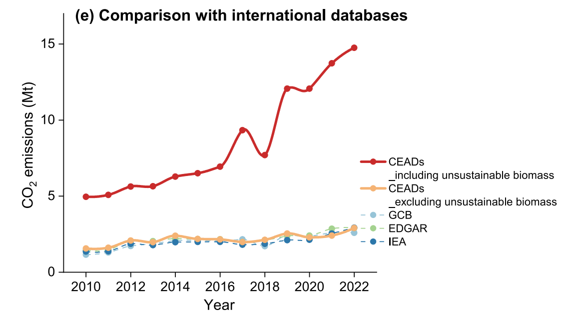


Figure 3.3: Niger's energy consumption and CO_2 emissions from 2010 to 2022 (a) Primary energy consumption; (b) Fossil fuel CO_2 emissions; (c) Fossil fuel CO_2 emissions by sectors; (d) Biomass CO_2 emissions; (e) Comparison with international databases.

Brief description of data sources:

The energy balance sheets for Niger are all from the African Energy Commission (AFREC) and cover the period 2010-2022, with the number of energy varieties and sectors involved differing slightly in different years. In 2022, for example, a total of 19 energy varieties and 5 sectors are covered. In particular, for sub-sector matching, we used the export data from UN Comtrade, and service output data from the Niger multi-regional input-output table in the input-output model for the global emerging economies (EMERGING) as the basis for allocation, and downscaled the sectors to 47 sectors.

Table 3.3: Data sources for Niger's emission accounting

Data type	Source	Website
Energy balance sheet	AFREC	https://au-afrec.org/en/energy-balances
Emission factor	IPCC	https://www.ipcc-nggip.iges.or.jp/EFDB/
Sectoral mapping indicator	UN Comtrade	http://data.un.org/Explorer.aspx#marts https://comtradeplus.un.org/
	CEADs	https://www.ceads.net/

LIBERIA

Background

Liberia, on the Atlantic coast of western Africa, is bordered by Guinea to the north, Sierra Leone to the northwest and Côte d'Ivoire to the east. Liberia is the oldest republic in Africa and has never been colonized[138]. Liberia is one of the least developed countries, with a total agricultural value-added GDP of US$4.0 billion (at current prices) in 2022 and a population of 5.37 million[139]. More than half of the population live below the poverty line.

Agriculture is Liberia's dominant industry, accounting for approximately 57% of total GDP in 2022. Industry is underdeveloped, its output accounting for just 6% of GDP[140]. Liberia is rich in natural resources and, prior to the civil war, it was one of the leading producers of iron ore in Africa, with proven reserves of over 10 billion tonnes. The production and export of natural rubber and timber form the main pillars of its national economy. In terms of international trade, its exports are mainly iron ore, natural rubber, gold and timber, and it exports primarily to Switzerland, Belgium, the United States and the UEA. Its imports are mainly mechanical transport equipment, petroleum products, foodstuffs and manufactured goods, from China, India, the United States and Côte d'Ivoire, among other nations[140,141].

Liberia has huge potential for renewable energy, but is largely dependent on fossil fuels for its electricity and bears some of the world's highest electricity generation costs. To increase the use of renewable energy and ensure a secure, reliable and sustainable electricity supply, Liberia has set a target of generating more than 75% of its electricity from renewable sources by 2030. Its master plan identifies 92 projects and investments that are expected to electrify 265,000 households and 1.34 million people outside of its capital city, Monrovia, by 2030 [142]. Under the United Nations Framework Convention on Climate Change, Liberia's Intended Nationally Determined Contributions (INDC) aim to reduce greenhouse gas emissions by at least 10% by 2030[143].

Primary energy consumption

Liberia's primary energy mix is dominated by biomass. Petroleum-based products, the only form of fossil energy consumed in the country, and in 2022 accounted for 20.2% of total primary energy consumption. Biomass accounts for 78.6% of such consumption, while renewable energy such as solar makes up a smaller proportion, which accounted for 1.2%.

Characteristics of fossil fuel emissions

Diesel is the primary source of CO_2 generated from fossil energy consumption. As the dominant fossil energy source in Liberia, diesel accounted for 0.8 Mt of fossil energy CO_2 in 2022, or 100% of the total from fossil sources. These emissions also grew significantly from 2010 to 2022, rising from 0.6 Mt to 0.8 Mt.

Sectoral emission contribution

The primary sectoral source of Liberia's fossil energy CO_2 is the transportation, storage and postal services sector. In 2022, its consumption of fossil energy generated 0.4 Mt of CO_2 from fossil energy, accounting for 46.3% of the total. Following is electricity, heat, gas and water production sector. This is Liberia's second-largest fossil fuel CO_2 sector in recent years, with CO_2 reaching 0.2 Mt in 2022, accounting for 28.1% of the total fossil fuel CO_2 for that year.

Biomass emissions

In 2022, biomass accounted for some 78.6% of the primary energy consumption mix in Liberia. Primarily firewood and charcoal, it is consumed mainly in the home. It is derived from overharvesting of forests, which has led to a reduction in forest cover and to forest degradation. Biomass in Liberia is thus not renewable or sustainable over time due to the long cycle of forest restoration, so its combustion is not 'zero carbon' and should be included in national and regional carbon accounting. In terms of temporal trends, the contribution of CO_2 emissions from biomass consumption increased annually from 2010 to 2015, from 4.9 Mt to 5.7 Mt; after a decline in 2016, it increased annually again from 2016 to 2018, and it declined again in 2019, further increased to 4.6 Mt in 2022.

Emission trends

Liberia's CO_2 are growing, but slowly. Between 2010 and 2022, CO_2 from fossil energy consumption increased by an average of 2.4% per year, while it fell slightly in 2019. During this period, CO_2 from biomass consumption also increased, from 4.9 Mt in 2010 to 5.7 Mt in 2015; after a decline in 2016, it increased again from 4.7 Mt in 2016 to 5 Mt in 2018, and fell to 3.4 Mt in 2019, and further increased to 4,6 Mt in 2022.

Comparison with international databases

In terms of trends, the accounting results are broadly the same across agencies, although differences in accounting methods and bases lead to differences in results. The IEA figures show Liberia's CO_2 as growing at a high rate, while CEADs' show that the country's fossil energy emissions are growing slowly. The reason for this is that the IEA uses energy consumption and supply data from United Nations statistics, while CEADs uses more refined data from the African Energy Commission (AFREC), and calculates carbon emission trends that are consistent with Liberia's economic trends.

When CO_2 from biomass consumption is included, the calculation from CEADs is 5.4 Mt in 2022.

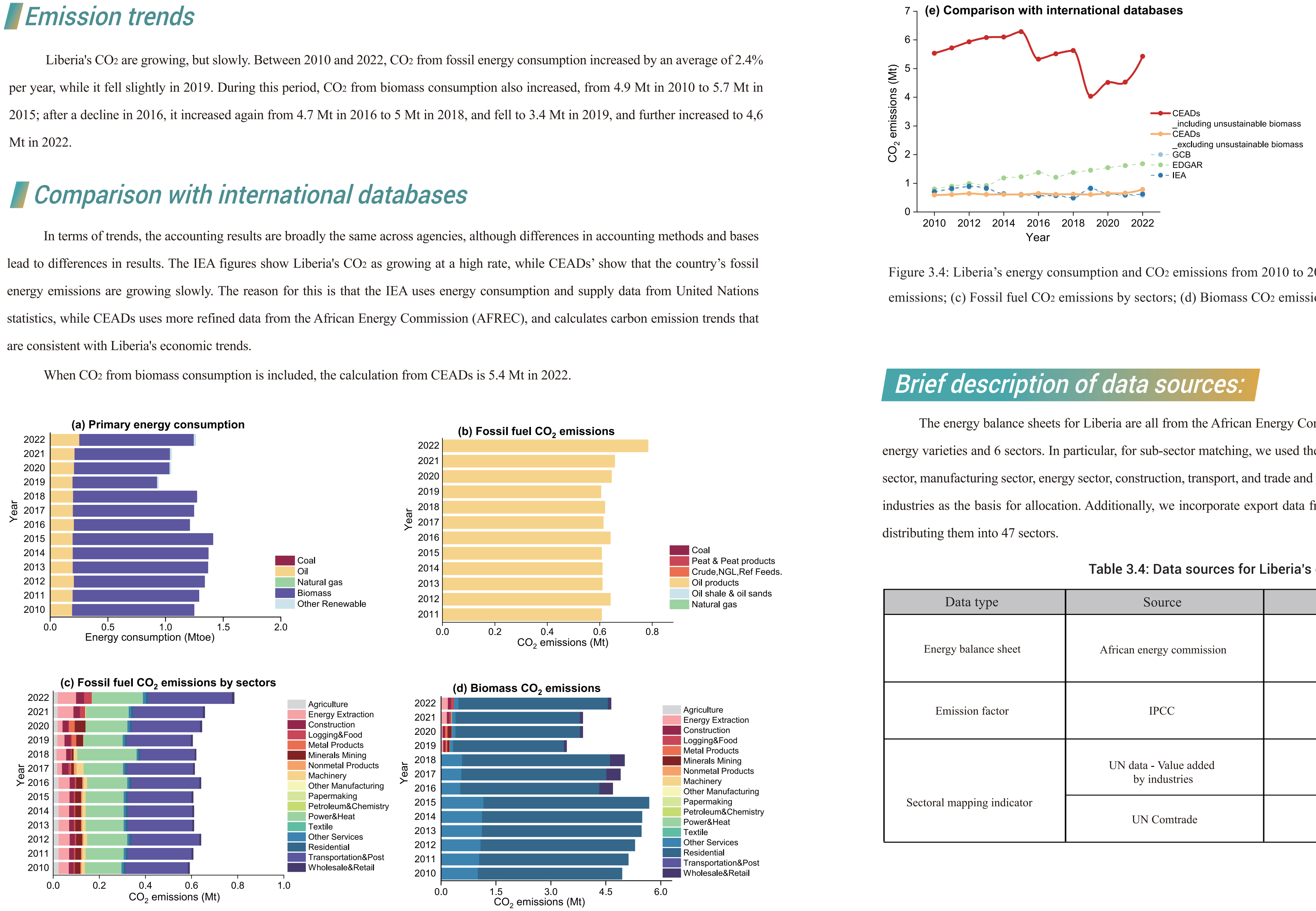


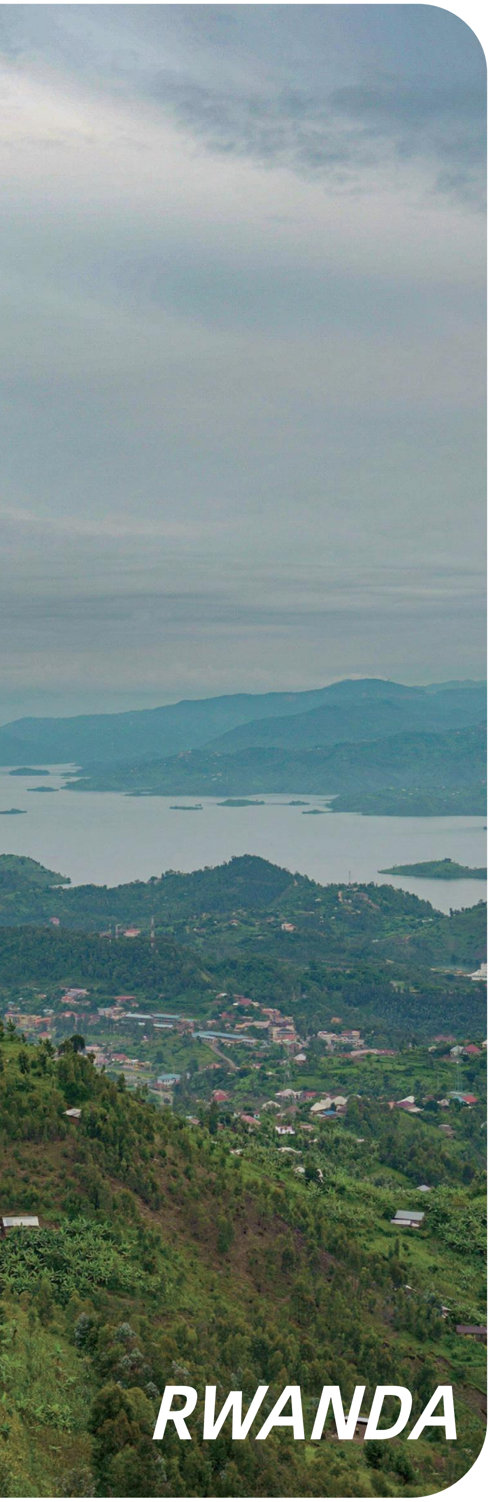
Figure 3.4: Liberia's energy consumption and CO_2 emissions from 2010 to 2022 (a) Primary energy consumption; (b) Fossil fuel CO_2 emissions; (c) Fossil fuel CO_2 emissions by sectors; (d) Biomass CO_2 emissions; (e) Comparison with international databases.

Brief description of data sources:

The energy balance sheets for Liberia are all from the African Energy Commission (AFREC) and cover 2010-2022, with a total of 11 energy varieties and 6 sectors. In particular, for sub-sector matching, we used the GDP of the agriculture, forestry and fishing sector, mining sector, manufacturing sector, energy sector, construction, transport, and trade and public services sectors available in UN data - value added by industries as the basis for allocation. Additionally, we incorporate export data from the UN Comtrade to downscale and match the sectors, distributing them into 47 sectors.

Table 3.4: Data sources for Liberia's emission accounting

Data type	Source	Website
Energy balance sheet	African energy commission	https://au-afrec.org/en/energy-balances
Emission factor	IPCC	https://www.ipcc-nggip.iges.or.jp/EFDB/
Sectoral mapping indicator	UN data - Value added by industries	http://data.un.org/Explorer.aspx#marts
	UN Comtrade	https://comtradeplus.un.org/



Background

Rwanda is located in the east of Central Africa, south of the Equator, and bordering Uganda, Tanzania, Burundi and the Democratic Republic of Congo. Rwanda is located in the Great Lakes region, at high altitude, and is geographically dominated by the mountains in the west and the savannah in the east, with several lakes scattered throughout the country. Rwanda is one of the smallest economies in East Africa. But since 2000, thanks to effective government economic policies, the country is experiencing high economic growth, attracting significant foreign investment to become the "Singapore of the African continent" and significantly improve the living standards of its people[144]. The country's GDP (at current prices) was US$13.3 billion in 2022, with a population of 14.0 million[145].

Rwanda's service sector is relatively well developed, accounting for about 46.5% of total GDP in 2022. Agriculture accounted for about 32.2% of total GDP, while the industrial base was relatively weak, accounting for about 21.3%, an increase of 5.0%. The country’s primary natural resources include tin ore, gold, methane and tungsten, but overall reserves are relatively small. In terms of international trade, its exports are mainly coffee, tea, hides and skins, and tin ore; the main exporting countries are the UAE, Kenya and Switzerland, among others. Its imports are mainly foodstuffs, machinery and equipment, iron and steel, petrochemicals, cement and building materials, mainly from China, Uganda and India[146].

Rwanda is rich in hydropower resources. To reduce external energy dependency and mitigate the socioeconomic impact of climate change on the country, the government has set a target in its Energy Sector Strategic Plan 2018-2024 to increase the share of renewable energy generation to 60% by 2030, mainly using hydro and solar sources, and to increase the total installed electricity capacity to 512 MW[147]. Under the United Nations Framework Convention on Climate Change, Rwanda’s Intended Nationally Determined Contributions (INDC) aim to reduce its greenhouse gas emissions by 16% (unconditional reductions) to 22% (depending on international support) by 2030.

Primary energy consumption

Rwanda's primary energy mix is dominated by biomass. In 2022, the share of total fossil energy consumption, from oil alone (15.8%), was close to19.2%. In addition, biomass accounted for 78.8% of primary energy consumption, and other renewable energy sources such as hydropower accounted for 2.1%.

Characteristics of fossil fuel emissions

In the CO_2 resulting from fossil fuel consumption, emissions from oil consumption dominate. As Rwanda's primary fossil fuel, petroleum products generated 1.2 Mt of CO_2 in 2022, accounting for 81.7% of the total fossil fuel emissions. This marks an increase from 0.8 Mt in 2010. Additionally, natural gas, a fossil fuel that Rwanda has only recently begun consuming, contributed 0.1 Mt of CO_2 in 2022, representing 7.8% of fossil fuel emissions. This figure has remained stable compared to the emissions in 2019.

Sectoral emission contribution

The sectors with the highest CO_2 emissions from fossil energy consumption in Rwanda are transportation, storage and postal services, followed by electricity, heat, gas and water production and domestic consumption. In 2022, the emissions from fossil energy consumption in the transportation, storage and postal services sector were 0.7 Mt, accounting for 47.2% of the total; this share has been increasing since 2010. The production of electricity, heat, gas and water production sector accounted for 16.2% (0.2 Mt) of total fossil energy CO_2 in 2022, and its share, mainly from the use of diesel and fuel oil, has remained stable.

Biomass emissions

Biomass in Rwanda accounted for around 78.8% of the primary energy consumption mix in 2022, and was used mainly in the domestic sector and, to a lesser degree, in the service sector. Local people gather firewood mainly through deforestation, and uses it for household cooking and heating; both customs have a significant impact on the environment, and constitute an unsustainable use of resources that should feature in the overall carbon accounting process. Waste biomass products such as crop residues, however, are sourced from family farms or plantations, and are considered to be a sustainable renewable resource with a 'zero carbon' life-cycle attribute; these should not figure in the overall carbon accounting process. Emissions from biomass consumption increased from 6.6 Mt in 2010 to 9.4Mt in 2022 but declined slightly to 6.0 Mt in 2015.

Emission trends

Emissions from fossil energy consumption decreased by 79.9% between 2010 and 2022, from 0.8 Mt to 1.5 Mt. During this period, CO_2 from biomass consumption increased from 6.6 Mt in 2010 to 9.4 Mt in 2022.

Comparison with international databases

CEADs' results for the period 2010 to 2014 were very close to the data from IEA and GCB, with a difference of less than 5%. From 2014 onwards, the gap between the IEA and CEADs data grows. Specifically, after 2015, IEA and GCB data show that Rwanda's CO_2 continue to grow at a high rate, while the CEADs calculations show a slow and steady growth trend. This discrepancy is mainly down to the different sources of energy consumption data used by the institutions. CEADs relies on those from the African Energy Commission (AFREC), while IEA data do not indicate a specific source. Secondly, CEADs data show a more detailed breakdown of energy sources in terms of statistical caliber. For example, CEADs divides petroleum products into subcategories such as gasoline, diesel, fuel oil, paraffin and aviation paraffin, each with a corresponding emission factor. The IEA's statistical caliber meanwhile only classifies this source of energy as petroleum products. Thus, differences arise in sectoral emissions calculated by the IEA and CEADs.

In addition, when including CO_2 from unsustainable biomass consumption, CEADs' figure for 2022 is 10.9 Mt.In addition, when including CO_2 from unsustainable biomass consumption, CEADs' figure for 2022 is 10.9 Mt.

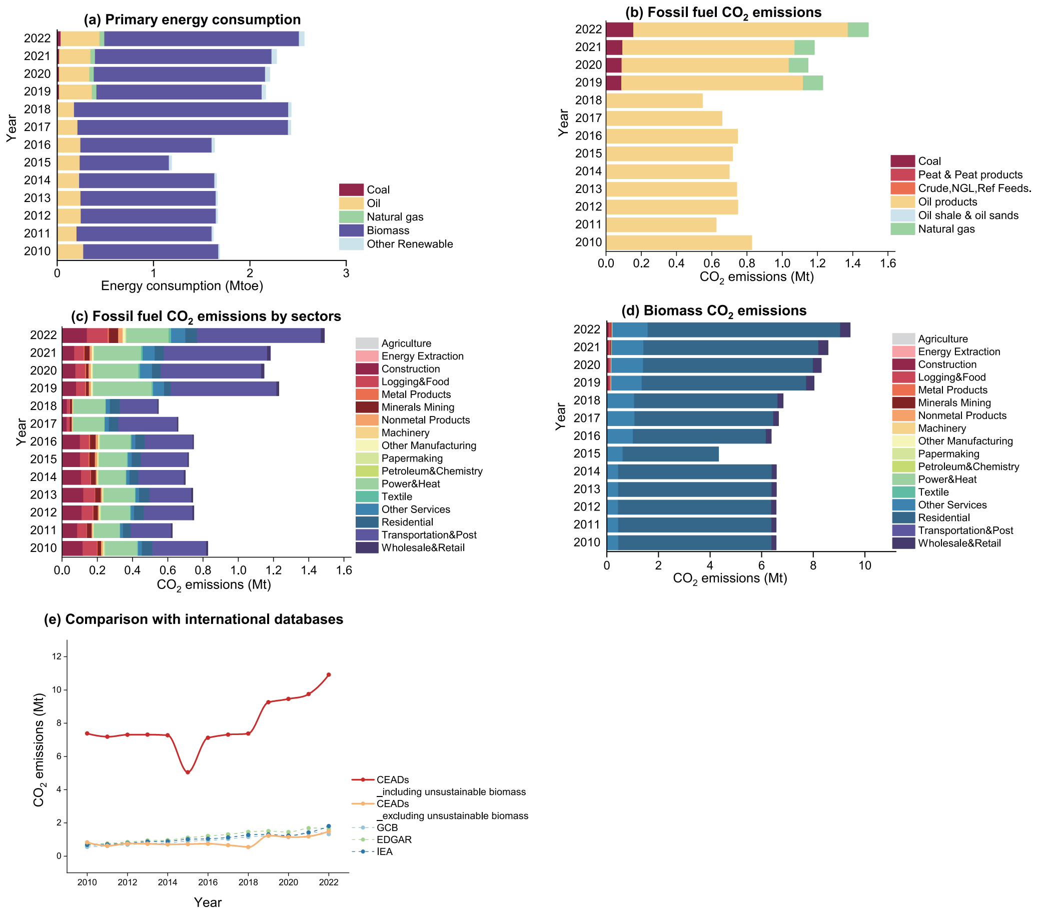


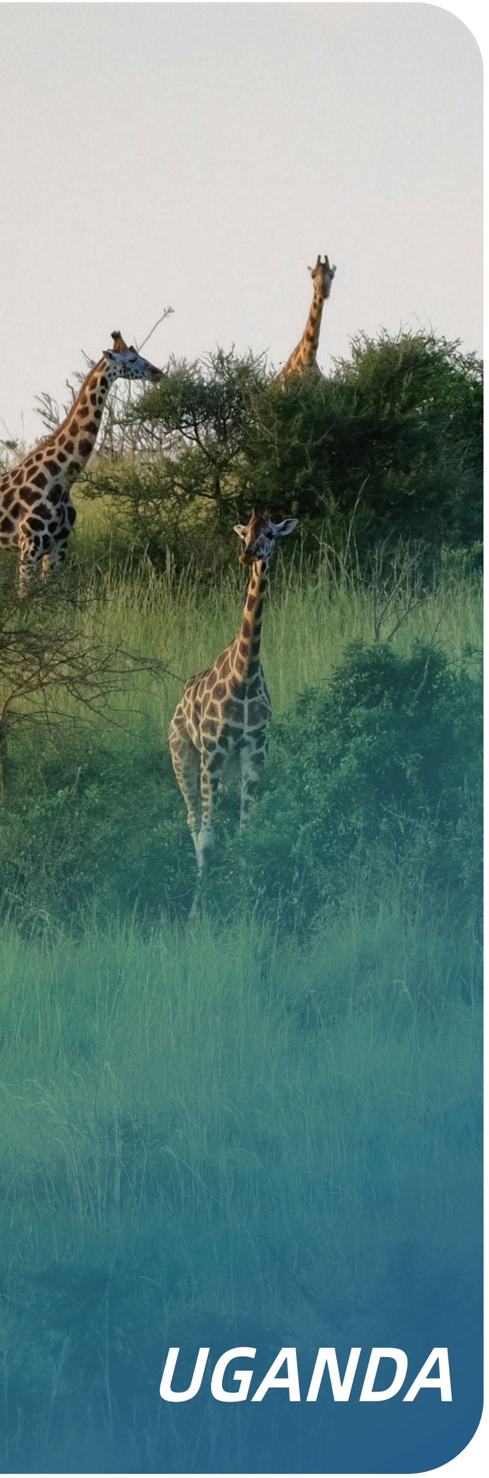
Figure 3.5: Rwanda's energy consumption and CO_2 emissions from 2010 to 2022 (a) Primary energy consumption; (b) Fossil fuel CO_2 emissions; (c) Fossil fuel CO_2 emissions by sectors; (d) Biomass CO_2 emissions; (e) Comparison with international databases.

Brief description of data sources:

The energy balance sheets for Rwanda are all from the African Energy Commission (AFREC) and cover the period 2010-2022, with a total of 13 energy varieties and 6 sectors. In particular, for sub-sector matching, CEADs used output data for the industrial sector published by their Bureau of Statistics and the GDP for agriculture, services and construction as the basis for allocation, and downscaled the sector matching to 47 sectors.

Table 3.5: Data sources for Rwanda's emission accounting

Data type	Source	Website
Energy balance sheet	African Energy Council (AFREC)	https://au-afrec.org/en/energy-balances
Emission factor	IPCC	https://www.ipcc-nggip.iges.or.jp/EFDB/
Sectoral mapping indicator	National Institute of Statistics of Rwanda	https://www.statistics.gov.rw/statistical-publications/subject/statistical-yearbook



Background

Uganda is a landlocked country located in east-central Africa, bordered by Kenya to the east, Tanzania and Rwanda to the south, the Democratic Republic of Congo to the west and South Sudan to the north[148]. The southern territory of the country contains part of the watershed area of Lake Victoria, which is shared by Uganda, Kenya and Tanzania. In 2022, Uganda's GDP was 44.15 billion USD (at constant 2015 prices), with a population of 47.25 million people, 63% of whom live below the poverty line[149].

Uganda's industrial structure remains relatively homogeneous, with agriculture, construction and wholesale and retail trade as the country's mainstays. Agriculture employs the most people in Uganda, but productivity is low, which in 2022 led to the country’s agricultural GDP being even lower than that of the services sector, Agricultural value added accounted for only 24% of the GDP [150] . Meanwhile, industrial value added constituted 26.8% of the GDP [151] . Foreign trade is an important part of Uganda's economy. Primary exports are agricultural products, including coffee and cotton, while the country imports mainly machinery and equipment, electronics and energy from countries such as China.

In Uganda, climate change is widely perceived to be a major threat to the country's economic and social development, and this view is reflected in major national policies and strategic plans such as the National Development Plan 2016-2021, and Uganda Vision 2040[152]. In 2015 Uganda adopted the Smart Agriculture Plan on Climate Change to actively reorient agricultural development patterns and thereby promote energy efficiency and reduce emissions. In addition, many of Uganda's key policies also propose strategic measures to increase the use of renewable energy. For example, Uganda Vision 2040 envisages increasing the country's total installed capacity for electricity production to 2,500 MW by 2040, with 2,000 MW of this capacity contributed by renewable energy sources, and the large-scale development of hydropower[153]. Uganda's Nationally Determined Contribution (NDC) aims to reduce its greenhouse gas emissions by 24.7% by 2030 [154] .

Primary energy consumption

In 2022, Uganda's fossil energy consumption accounted for 11.9% of the primary energy consumption mix. Of this, oil consumption is dominant, with no coal or natural gas consumption. In addition, biomass accounts for 85.4% of primary energy consumption; hydro, solar and other renewable energy sources account for a very small share of 2.8% of primary energy consumption.

Characteristics of fossil fuel emissions

The consumption of petroleum products is the major source of CO_2 emissions from fossil energy consumption in Uganda; these emissions rose from 1.6 Mt in 2010 to 5.6 Mt in 2022. These products are imported mainly from the port of Mombasa in Kenya. The fossil energy sources that generate the most CO_2 emissions are petrol and diesel: their consumption already accounted for more than 97% of such emissions.

Sectoral emission contribution

The largest fossil energy carbon emitting sector in Uganda is the transportation, storage and postal services sector, which was responsible for a rapid increase in CO_2 emissions between 2010 and 2022, from 1.0 Mt to 3.8 Mt in 2022, with an average annual growth rate of about 11.3%. In 2022 the sector's consumption of fossil energy accounted for 67.0% of total fossil energy CO_2. The agriculture sector is the second-highest such emitter in Uganda; in 2022, this sector generated over 0.5 Mt of CO_2 emissions from the consumption of fossil energy, accounting for 9.5% of the total.

Biomass emissions

In 2022, Uganda's biomass consumption accounted for 85.4% of the primary energy consumption mix, and was concentrated in the domestic sector. Most biomass used in the country is fuelwood, biosolid fuels and other products derived from the overharvesting of forests, which has led to a reduction in forest cover and forest degradation. This type of biomass use is not renewable or sustainable over time due to the long cycle of forest restoration. Therefore, biomass combustion in the country is not 'zero carbon' and should be included in national and regional carbon accounting, along with fossil energy combustion, as part of overall CO_2. In terms of temporal trends, the overall CO_2 emissions from biomass consumption have shown a rapid and substantial rise from 25.5 Mt to 54.1 Mt in 2022. Of these, CO_2 from biomass consumption declined slightly between 2010 and 2011, from 25.5 Mt to 22.8 Mt. CO_2 from biomass consumption showed a steady increase between 2011 and 2019, with average annual growth rates of 15.7% over the periods. CO_2 from biomass consumption fell between 2019 and 2022, from 73.2 Mt to 54.1 Mt.

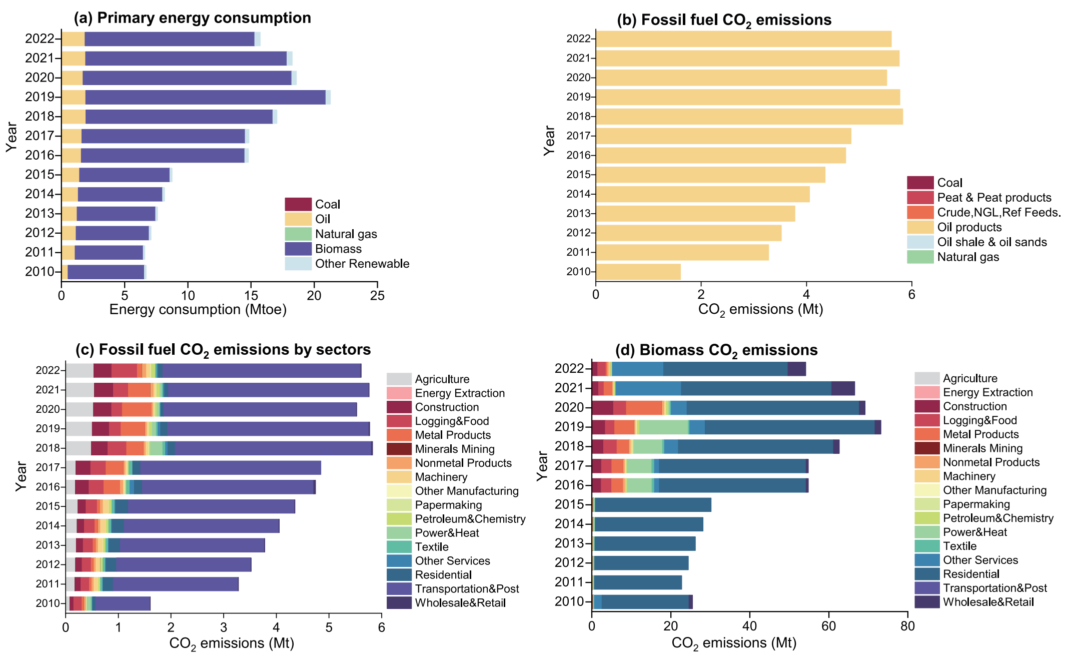
Emission trends

Between 2010 and 2022, Uganda's CO_2 from fossil energy consumption showed a trend of volatile change in phases. From 2010 to 2022, CO_2 from fossil fuel consumption increased 2.5 times, from 1.6 Mt to 5.6 Mt, with average annual growth rates of 11.0%. Among them, CO_2 showed a downward trend from 2019 to 2021, and from 2021 to 2022, while the remaining years showed an increasing trend. Emissions from biomass consumption increased from 25.5 Mt to 54.1 Mt over 2010-2022, with an average annual growth rate of nearly 6.5%.

Comparison with international databases

Under the same accounting caliber (excluding emissions from biomass), CEADs' calculations of Uganda's fossil energy emissions are relatively consistent in results and trends with those of the IEA, GCB and EDGAR. The CEADs data is particularly close to that of IEA and GCB, with a margin of error of 10-15%. The primary cause of the discrepancies in the results appears to stem from differences in data sources. CEADs uses the energy balance sheets published by the African Energy Commission (AFREC) as its data foundation, which differs from the sources used by other institutions.

Furthermore, when including CO_2 from biomass consumption, the CEADs figure for 2022 is 59.8 Mt.



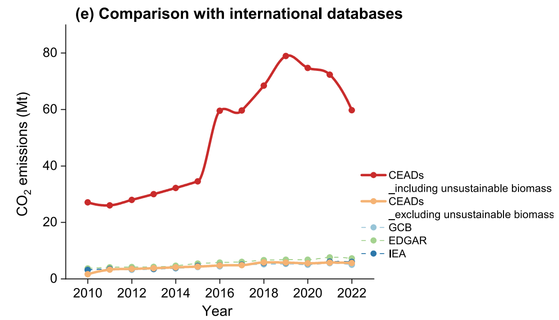


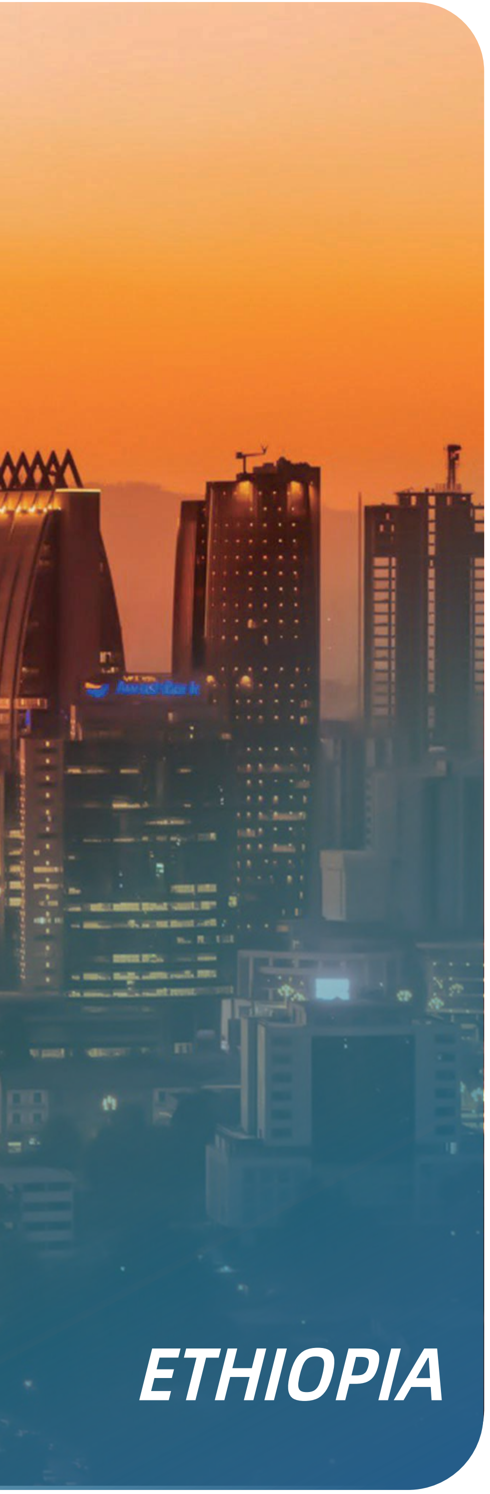
Figure 3.6: Uganda's energy consumption and CO_2 emissions from 2010 to 2022 (a) Primary energy consumption; (b) Fossil fuel CO_2 emissions; (c) Fossil fuel CO_2 emissions by sectors; (d) Biomass CO_2 emissions; (e) Comparison with international databases.

Brief description of data sources:

The energy balance sheets for Uganda are all from the African Energy Commission (AFREC) and cover the period 2010-2022. The number of energy varieties and sectors involved are not exactly the same in different years; for example, in 2022, 17 energy varieties and 5 sectors are covered. The sector-matched indicators in this study are GDP data, urban and rural population data published by the Uganda Bureau of Statistics (UBOS), and export data published by UN Comtrade.

Table 3.6: Data sources for Uganda's emission accounting

Data type	Source	Website
Energy balance sheet	African Energy Commission	https://au-afrec.org
Emission factor	IPCC	https://www.ipcc-nggip.iges.or.jp/EFDB/
Sectoral mapping indicator	Uganda Bureau of Statistics (UBOS)	https://www.ubos.org/explore-s
	UN Comtrade	https://comtrada.un.org



ETHIOPIA

Background

Ethiopia is located in northeast Africa, bordering Djibouti and Somalia to the east, Sudan and the Republic of South Sudan to the west, Kenya to the south, and Eritrea to the north. Ethiopia is one of the fastest-growing economies in the world: from 2010-2022, its average annual GDP growth rate was 8.1%. The current GDP in 2021 is US$126.8, with a population of about 125 million[155,156] . High economic growth, accompanied by a huge energy demand, indicates significant potential for high emissions. Over the past 20 years, Ethiopia has experienced dramatic structural changes in its economy. The share of industry in its GDP has increased significantly from 9.4% in 2010 to 19.5% in 2022. In 2021, Ethiopia's exports were mainly coffee (US$1.2 billion), petroleum products (US$630 million) and oil seeds ($360 million). Ethiopia's imports are dominated by machinery and equipment (US$1.6 billion), petroleum products (US$1.4 billion), and metal products ($870 million). Exports of transport services have grown steadily since 2010[157] .

Ethiopia was the first country in East Africa to issue Intended National Determined Contributions (INDC). The government stopped subsidizing fossil fuels in 2008, showing their commitment to promoting renewable energy. The country's potential in that arena centres on hydro and wind. Since 2007, Ethiopia has been promoting the widespread use of small-scale solar, wind and hydro energy to meet the decentralized electricity demand in rural areas[158, 159]. The goal is to boost power generation by 25,000 MW by 2030, including 22,000 MW of hydropower, 1,000 MW of geothermal power, and 2,000 MW of wind power[160]. The Grand Ethiopian Renaissance Dam, with an installed capacity of 6,000 MW, will be the largest hydroelectric facility in Africa when completed.

Primary energy consumption

In 2022, Ethiopia's fossil energy consumption accounted for 14.5% of the primary energy consumption mix, dominated by oil. Of this, coal consumption accounted for 1.8%, and oil consumption for 12.7%; there was no use of natural gas. In addition, hydro, solar, wind and other renewable energy sources accounted for 4.4% of primary energy consumption; among them, hydro was the most important. Biomass meanwhile accounted for 81.1% of primary energy consumption.

Characteristics of fossil fuel emissions

Of the CO_2 emissions from fossil energy consumption, those from petroleum products and coal consumption dominated. Petroleum products, Ethiopia's dominant fossil fuel, generated a total of 12.6 Mt of CO_2 emissions in 2022, accounting for 84.8% of CO_2 from fossil energy sources. CO_2 emissions from coal consumption increased from 0.1 Mt in 2010 to 2.3 Mt in 2022.

Sectoral emission contribution

The exponential growth in CO_2 emissions from fossil energy consumption in Ethiopia is mainly driven by two sectors: the transportation, storage and postal services sector, and construction. The former sector — the country's fastest-growing in terms of emissions — produced 11.1 Mt of CO_2 emissions from fossil energy consumption in 2022, with a 8.2 Mt increase than that of 2010, accounting for approximately 74.2% of the total. According to World Trade Organization (WTO) and UN Comtrade trade data, the country has seen a sharp increase in imports of transport equipment, including aircraft from Germany and the United States, and rail and tram locomotives from Belgium. The construction sector, the second largest fossil energy carbon emitter in Ethiopia in recent years, accounted for 16.8% of total fossil energy CO_2 in 2022, with oil and coal dominating. The construction sector's energy demand has surged since 2010 because the government has been building a range of infrastructure, including the Grand Ethiopian Renaissance Dam, resulting in a rapid increase in CO_2 from fossil energy consumption.

Biomass emissions

In 2022, biomass consumption in Ethiopia accounted for 81.1% of the primary energy consumption mix, and was mainly confined to the domestic sector. The biomass type predominating in Ethiopia is wood, and is used in volumes that are environmentally unsustainable. That excess demand has exacerbated deforestation and led to serious environmental impacts such as the ecological degradation of grasslands[161, 162]. This use of biomass is not renewable or sustainable over time due to the long cycle of forest restoration. Therefore, biomass in the country is not 'zero carbon' and should be included in national and regional carbon accounting, along with fossil energy combustion, as part of overall CO_2. CO_2 emissions from biomass consumption increased from 116.7 Mt in 2010 to 154.2 Mt in 2021 and declined to 107.9 Mt in 2022.

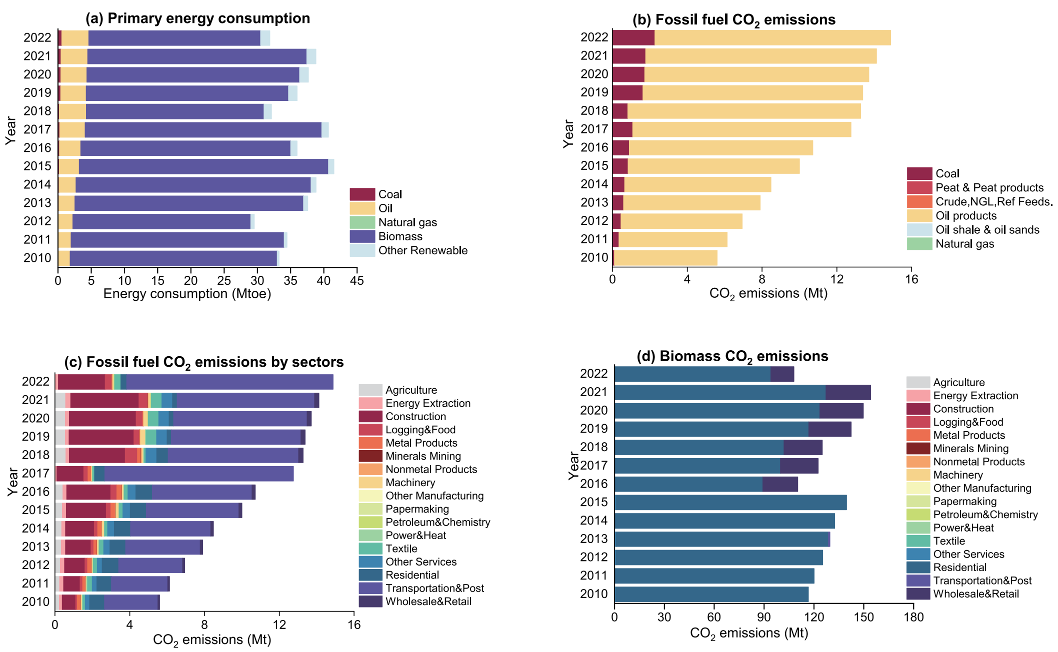
Emission trends

Between 2010 and 2022, CO_2 emissions from fossil energy consumption in Ethiopia rose from 5.6 Mt to 14.9 Mt, an average annual growth rate of 8.5%. During 2010 to 2021, CO_2 emissions from biomass consumption increased from 116.7 Mt to 154.2 Mt and decreased to 107.9 Mt in 2022.

Comparison with international databases

In terms of trends, the results are broadly similar across agencies, with differences in accounting methods and underlying data responsible for differences in results. Under the same accounting caliber (excluding emissions from biomass), the fossil energy CO_2 accounted for by CEADs are very close to the IEA data. This is because the main source for IEA's data is direct communication with ministries such as the Ministry of Water, Irrigation and Energy, whereas the dataset used by CEADs is from their official website. Most of the discrepancy with the IEA's data is with 2014 figures, and is mainly due to a statistical bias in the figures of petroleum products. The IEA data shows a slight spike in consumption of petroleum products in 2014, while data from the Ethiopian Ministry of Water, Irrigation and Energy show an even increase in petroleum consumption from 2011-2015, without a trend of increase followed by decrease. Furthermore, the emissions reported in this study are lower than those of EDGAR and GCB, with a difference of about 7.2% and 31.2%, respectively.

Furthermore, when including CO_2 emissions from unsustainable biomass consumption, the CEADs calculation for 2022 was 122.8 Mt.



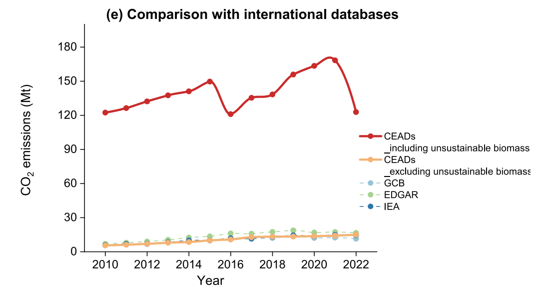


Figure 3.7: Ethiopia's energy consumption and CO_2 emissions from 2010 to 2022 (a) Primary energy consumption; (b) Fossil fuel CO_2 emissions; (c) Fossil fuel CO_2 emissions by sectors; (d) Biomass CO_2 emissions; (e) Comparison with international databases.

Brief description of data sources:

Ethiopia's energy balance sheet for 2010-2022 was obtained from African Energy Commission (AFREC), which contains data on energy processing conversions for 17 primary and secondary energy species, and energy consumption data for 6 broad economic sectors in Ethiopia. In this case, for sector matching, we use sectoral value-added data and export data published by UN and UN Comtrade as the basis for allocation, and downscaled sectoral matching to 47 sectors.

Table 3.7: Data sources for Ethiopia's emission accounting

Data type	Source	Website
Energy balance sheet	AFREC	https://au-afrec.org/en/energy-balances
Emission factor	IPCC	https://www.ipcc-nggip.iges.or.jp/EFDB/
Sectoral mapping indicator	UN data - Value added by industries	http://data.un.org/Explorer.aspx#marts
	UN Comtrade，Export data	https://comtradeplus.un.org/

Background

Togo, a West African nation, is bordered by Benin to the east, Ghana to the west, Burkina Faso to the north and the Gulf of Guinea to the south. It covers an area of 56,785 square kilometers and has a coastline just 53 kilometers long. The capital and largest city is Lomé[163]. Togo is one of the world's least developed countries, with a total GDP of US$8.2 billion in 2022 and a total population of 9.1 million[164].

Togo's industrial base is weak, with industrial output accounting for 20% of GDP in 2022[165]. Its primary industrial sectors are mining, agricultural processing, textiles, leather, chemicals and building materials; its three most economically important industries are agriculture, phosphates and re-export trade. In 2022, agriculture accounted for around 18.3%[166] of GDP, with food crops - mainly maize, sorghum, cassava and rice - accounting for 67% of agricultural output. Cash crops, which account for about 20% of GDP, include groundnuts, cotton, oil palm, coffee and cocoa. Togo's phosphate production is the highest in sub-Saharan Africa, with proven reserves of 260 Mt of high-quality ore and about 1 billion tons of carbonate[163]. Togo's free trade policy encourages import and export trade, which accounts for around 43% of GDP. The main export commodities are chemical products, petroleum products, cotton and phosphates; the main imports are consumer goods and semi-finished products.

More than half of Togo's population still has no access to electricity and there are no other existing renewable energy projects other than hydropower, which accounts for 96% of the total, and photovoltaics, which accounts for just 4%. The Togolese government plans to prioritize the development of photovoltaics and to achieve 100% access to electricity by 2030. With the entry into force of the 2015 Paris Agreement, Togo has unconditionally pledged to reduce its greenhouse gas (GHG) emissions by 20.5% by 2030[166].

Primary energy consumption

Togo's primary energy mix is dominated by biomass, which in 2022 accounted for 71.1% of primary energy consumption. Its share of total fossil energy consumption is nearly 28.3%. Among these, oil consumption accounts for 21.3%, natural gas consumption accounts for 7%, and there is no coal consumption. Hydropower and other renewable energy sources accounted for 0.6% of primary energy consumption.

Characteristics of fossil fuel emissions

Petroleum products account for most of Togo's fossil energy CO2. Consumption of petroleum products generated 1.5 Mt of CO_2 in 2022, accounting for 79.2% of total CO_2 from fossil energy sources. There was a fluctuating downward trend in petroleum-based emissions from 2010 to 2020, with the highest volume, at 2.1 Mt, emitted in 2010 and the next highest, 2.0 Mt, emitted in 2016. After the end of the COVID-19 pandemic, CO_2 from oil products rapidly increased, reaching 1.8 Mt in 2021, with an annual growth rate exceeding 24.5%, and declining to 1.47 megatonnes in 2022. In recent years, natural gas has also become an important fossil fuel for Togo. CO_2 from its consumption grew from less than 0.1 Mt in 2018 to over 0.39 Mt in 2022, accounting for 20.8% of the total fossil fuel CO_2 in 2022.

Sectoral emission contribution

The transport, storage and postal sector is the biggest fossil energy carbon emitting sector. In 2022, CO_2 from fossil fuel consumption in the sector accounted for 65.8% of the total fossil fuel carbon dioxide emissions. Since 2010, the sector's CO_2 have shown a trend of initially decreasing, followed by fluctuating increases. Emissions decreased from 1.6 Mt in 2010 to less than 0.2 Mt in 2019, and then increased again to 1.2 Mt by 2022. The production of electricity, heat, gas, and water is the second largest fossil energy carbon emitting sector in Togo in recent years. In 2022, it generated 0.4 Mt of CO_2, accounting for 21.2% of the total.

Biomass emissions

Biomass accounted for around 71.1% of the primary energy consumption mix in Togo in 2022, and was used mainly in the domestic and service sectors. The prime biomass types include firewood, charcoal and plant waste products. The Togolese obtain firewood mainly through deforestation and make some of it into charcoal, the use of which has a significant environmental impact; both represent an unsustainable use of resources that should be included in the overall carbon accounting process. Togo also uses biomass waste such as bagasse, which is sourced from local plantations and can be grown repeatedly, and thus is considered a sustainable renewable resource with a 'zero carbon' life cycle. In terms of temporal trends, CO_2 from wood and charcoal consumption fluctuated from 7.0 Mt to 7.6 Mt between 2010 and 2022 — an average annual growth rate of 0.69%.

Emission trends

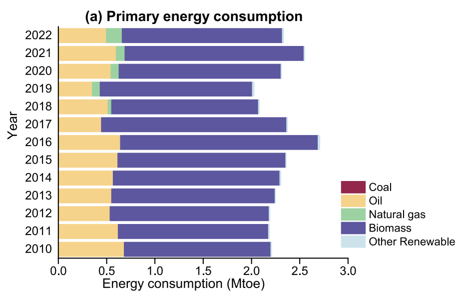
Togo's overall total CO_2 emissions are on a slow downward trend. Emissions from fossil energy consumption decreased by 10.1% between 2010 and 2022, from 2.1 Mt to 1.9 Mt, with an average growth rate -0.76%. During this period, emissions from biomass consumption increased from 7.0 Mt to 7.6 Mt, with an average annual growth rate of 0.69%.

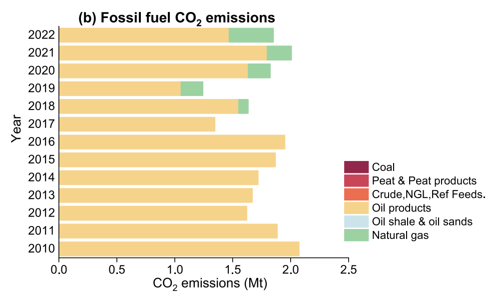
Comparison with international databases

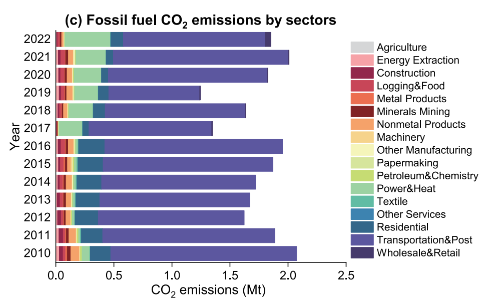
Under the same accounting caliber (excluding emissions from biomass), the results are generally consistent across agencies, with differences in accounting methods and databases emerging in different results. The results of CEADs and IEA are generally consistent in terms of trends, especially in 2017-2022 when the calculation of CEADs are highly similar to the result of IEA, but there is a large difference in the 2013-2016 values.

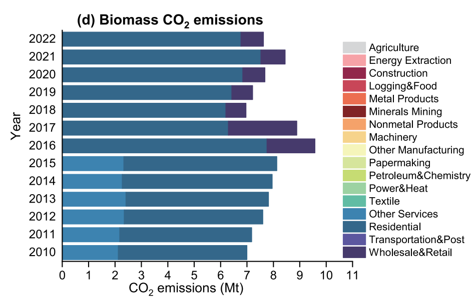
In addition to differences in the raw data, there are several other possible reasons for differences in results. One is emission factors. CEADs used the recommended IPCC values for fossil energy sources in Togo, while IEA used a rougher caliber of statistics for energy types. For example, in 2011 CEADs calculated 477.1 kilotons of oil equivalent as Togo's total fossil energy consumption, while the IEA's figure was 620 kilotons of oil equivalent. This resulted in CEADs showing a lower total fossil energy carbon emission of 1.5 kilotons in 2011, compared to the IEA's 1.9 kilotons.

In addition, when including CO_2 from biomass consumption, CEADs accounted for 9.5 Mt in 2022.









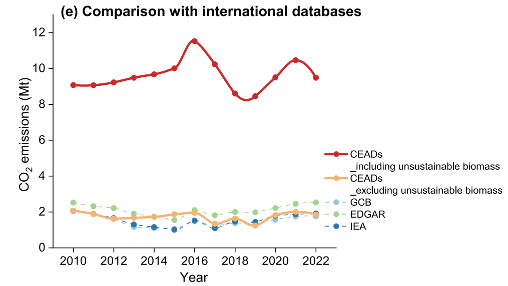


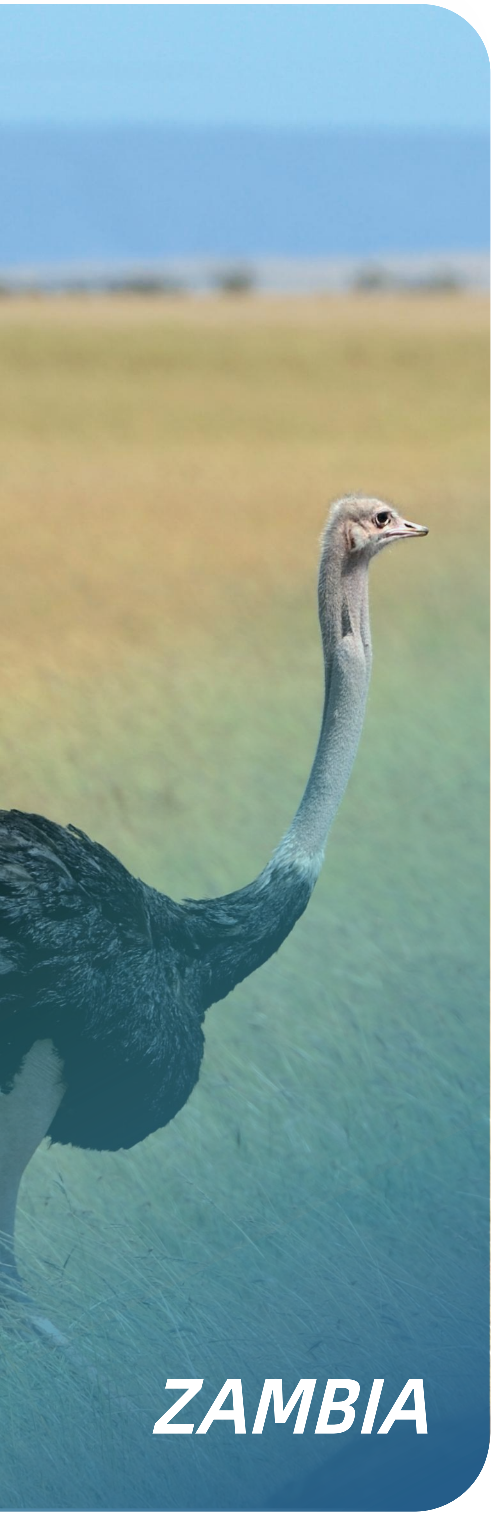
Figure 3.8: Togo's energy consumption and CO_2 emissions from 2010 to 2022 (a) Primary energy consumption; (b) Fossil fuel CO_2 emissions; (c) Fossil fuel CO_2 emissions by sectors; (d) Biomass CO_2 emissions; (e) Comparison with international databases.

Brief description of data sources:

Togo's energy balance sheet for 2010-2022 was obtained from the African Energy Commission (AFREC) website, which contains energy processing conversion data for 11 primary and secondary energy species in Togo. In terms of sub-sector matching, we used the UN data - value added by industries, export data in the UN Comtrade database and population data from INSEED to conduct downscaling matching of sectors and allocate them to 47 sectors.

Figure 3.8: Togo's energy consumption and CO2 emissions from 2010 to 2022

Data type	Source	Website
Energy balance sheet	African Energy Council(AFREC)	https://au-afrec.org/en/energy-balances
Emission factor	IPCC	https://www.ipcc-nggip.iges.or.jp/EFDB/
Sectoral mapping indicator	UN Comtrade	https://comtrada.un.org
	UN data - Value added by industries	http://data.un.org/Explorer.aspx#marts
	INSEED	https://inseed.tg/comptes-nationaux/



Background

Zambia is a landlocked country in Southern Africa, predominantly consisting of highland areas. It is bordered to the north by the Democratic Republic of the Congo, to the northeast by Tanzania, to the east and southeast by Malawi and Mozambique, respectively, and to the south by Zimbabwe, Botswana, and Namibia. To the west, it shares a border with Angola. With a land area of 750,000 square kilometers, Zambia's terrain generally slopes from the northeast to the southwest and features a tropical savanna climate, divided into three seasons: cool and dry, hot and dry, and warm and wet. In 2022, Zambia's GDP (current prices) was $29.2 billion, with a population of 20.2million. In 2022, approximately 64.3% of population lived below the poverty line [167].

Zambia's major economic sectors include wholesale and retail trade, mining and quarrying, and construction. In 2022, the nominal value added by the mining and quarrying sector was 68,289.6million Zambian Kwacha. Zambia is notably rich in forest resources, with forested areas accounting for 59.8% of its land area in 2022. It is also the second largest copper and cobalt resource country in Africa, with significant deposits of copper, cobalt, zinc, lead, nickel, platinum, manganese, tin, iron, and gold. Zambia's proven copper reserves total 19 million tons, representing approximately 6% of the world's total copper reserves, and its per capita copper reserves are the highest in the world.

In international trade, Zambia's primary export product is copper, with other exports including sugar, tobacco, gemstones, cotton, and electricity. Its main export partner is Switzerland, with other key partners including China, South Africa, the United Kingdom, Zimbabwe, and the Democratic Republic of the Congo.

Additionally, Zambia boasts significant potential for renewable energy sources such as wind, solar, and small-scale hydropower technologies. The country's electricity is predominantly generated from hydropower, while solar energy is still in the early stages of development. The Zambian government has introduced a series of renewable energy policies to enhance the development and utilization of these resources. Zambia has submitted its Nationally Determined Contributions (NDCs) under the United Nations Framework Convention on Climate Change (UNFCCC), committing to reduce greenhouse gas emissions by 25% to 47% by 2030.

Primary energy consumption

Zambia's primary energy mix is dominated by biomass, which in 2022 accounted for 51.0% of primary energy consumption. The share of oil consumption is nearly 19.6%, coal accounted for 11.3% for fossil fuel consumption. Hydropower and other renewable energy sources accounted for 18.1% of primary energy consumption.

Characteristics of fossil fuel emissions

In 2022, Zambia's CO_2 from fossil fuel consumption were approximately 8.6 Mt. Among these, CO_2 from oil products amounted to about 4.9 Mt, accounting for around 57.3% of the total fossil fuel emissions. The second largest contributor was coal consumption, which represented approximately 42.7% of the total emissions. Notably, emissions from coal consumption have shown an overall increasing trend from 2010 to 2022, rising from 0.002 Mt in 2010 to 3.7 Mt in 2022.

Sectoral emission contribution

The transportation, warehousing, and postal sector is the biggest fossil energy carbon emitting sector. In 2022, CO_2 from fossil fuel consumption in the sector is 2.7 Mt, accounted for 31.5% of the total fossil fuel CO_2. The production of electricity, heat, gas, and water is the second largest fossil energy carbon emitting sector in Zambia in recent years. In 2022, it generated 2.2 Mt of CO_2, accounting for 25.5% of the total.

Biomass emissions

Biomass accounted for around 51.0% of the primary energy consumption mix in Zambia in 2022, and was used mainly in the domestic and service sectors. The prime biomass types include firewood, charcoal and plant waste products. In Zambia, biomass mainly consists of wood and charcoal, which predominantly come from forests. Excessive logging has led to a reduction in forest cover and forest degradation. Due to the long recovery period of forests, this form of biomass utilization lacks renewability and sustainability over time. Therefore, during the accounting period, biomass does not possess "zero-carbon" properties. In national and regional CO_2 accounting, biomass should be included together with fossil fuel consumption in the overall CO_2. CO_2 from biomass consumption generally show an increasing and then decreasing trend, with emissions from biomass rising from 24.6 Mt in 2010 to 34.8 Mt in 2021, and falling from 34.8 Mt in 2021 to 19.6 Mt in 2022.

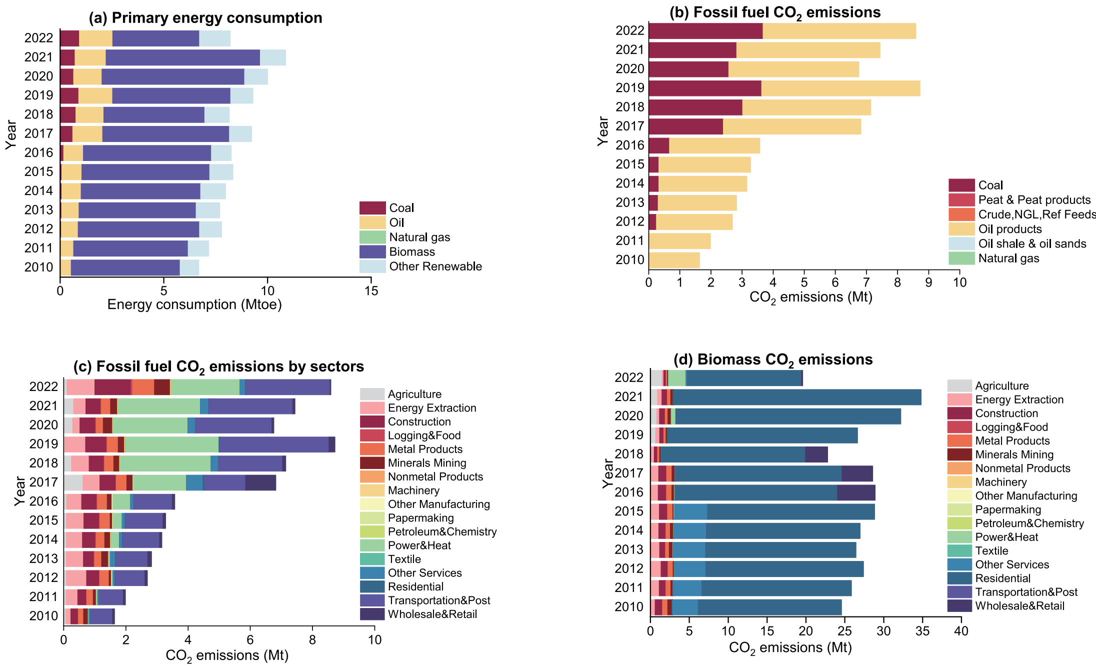
Emission trends

Zambia's overall total CO_2 emissions are on a slow increase trend. Emissions from fossil energy consumption increased from 1.6 Mt in 2010 to 8.6 Mt in 2022. During this period, emissions from biomass consumption decreased from 24.6 Mt to 19.6 Mt.

Comparison with international databases

Under the same accounting caliber (excluding emissions from biomass), In 2022, the CO_2 estimate for Zambia are as follows: CEADs reports 8.6 Mt, IEA reports 9.0 Mt, EDGAR reports 7.8 Mt, and GCB reports 6.5 Mt. The fossil fuel CO_2 data from CEADs align with the overall trends of IEA, EDGAR, and GCB, with figures closely matching those of IEA and GCB. However, the EDGAR numbers are generally higher compared to GCB, IEA, and CEADs calculations. Additionally, since 2021, the gap between CEADs and IEA has narrowed, with the difference in total estimates being relatively minor, around 7% or less. The primary cause of these differences appears to be the variation in statistical methodologies: CEADs uses data from the African Energy Commission (AFREC) energy balance tables, while IEA relies on annual energy questionnaire data.

In addition, when including CO_2 from biomass consumption, CEADs accounted for 28.2 Mt in 2022.



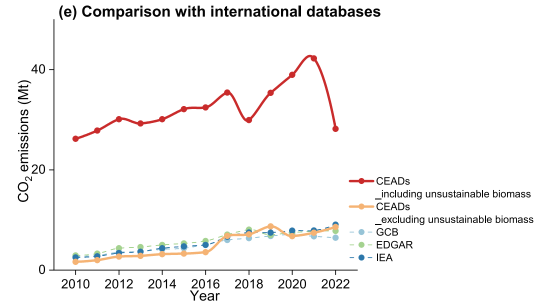


Figure 3.9: Zambia's energy consumption and CO_2 emissions from 2010 to 202 (a) Primary energy consumption; (b) Fossil fuel CO_2 emissions; (c) Fossil fuel CO_2 emissions by sectors; (d) Biomass CO_2 emissions; (e) Comparison with international databases.

Brief description of data sources:

The energy balance sheets for Zambia are all from the African Energy Commission (AFREC) and cover 2010-2022, with a total of 15 energy varieties. For the sectoral allocation, we use export data from the UN Comtrade and Zambia's own sub-sectoral data as the basis for distribution, allocating it to 47 sectors through downscaling.

Table 3.9: Data sources for Zambia's emission accounting

Data type	Source	Website
Energy balance sheet	African energy commission	https://au-afrec.org/en/energy-balances
Emission factor	IPCC	https://www.ipcc-nggip.iges.or.jp/EFDB/
Sectoral mapping indicator	Zambia Bureau of Statistics (ZBS)	https://www.zamstats.gov.zm/
	UN Comtrade，export data	https://comtradeplus.un.org/

TANZANIA

Background

Tanzania is a country in East Africa, located within the continent's Great Lakes region. It is bordered by Kenya and Uganda to the north; Zambia, Malawi and Mozambique to the south; Rwanda, Burundi and the Democratic Republic of Congo to the west; and the Indian Ocean to the east. The country has experienced steady economic growth in recent years, with an average annual GDP growth rate of 6.43% from 2010-2023. In 2022, Tanzania's GDP was US$75.8 billion and its population was 64.7 million[168, 169] .

The country's main exports are minerals and primary agricultural products. In 2020, Tanzania's main exports were gold (US$1.8 billion), coffee ($150 million) and tin ($130 million), mostly to Rwanda ($710 million), while the country's most important imports were refined petroleum products ($1.69 billion) and refined copper ($1.42 billion).

Tanzania's Intended National Determined Contributions (INDC) involves the promotion of renewable energy sources such as geothermal, wind and solar power as a means of achieving the 2030 target of a 10 to 20% reduction in greenhouse gas emissions [170]. Since 2008, the Tanzanian government has been promoting solar energy by investing in and subsidizing the country's Energy Development Access Programme (TEDAP)[171], which provides subsidies averaging $1/watt-hour to power producers and solar photovoltaic projects using renewable energy sources.

Primary energy consumption

Tanzania's primary energy mix is dominated by biomass and oil. In 2022, coal consumption accounted for 7.9%, oil consumption for 27.0% and natural gas consumption for 7.5%, adding up to a total of 42.4% for fossil energy consumption. In addition, solar, wind and other renewable energy sources accounted for 2.8% of primary energy consumption, and biomass for 54.9%.

Characteristics of fossil fuel emissions

CO_2 emissions from fossil energy consumption in Tanzania are dominated by petroleum products and coal. Consumption of petroleum products, the top fossil fuel used in Tanzania, generated a total of 8.3 Mt of CO_2 emissions in 2022, accounting for 63% of carbon emissions from fossil energy sources. CO_2 emissions from the consumption of petroleum products increased by 80.9% from 2010 to 2022. During this period, the contribution from coal consumption increased, reaching 3.1 Mt in 2022.

Sectoral emission contribution

The sector in Tanzania responsible for most CO_2 emissions from fossil energy consumption in Tanzania is transportation, storage and postal services. In 2022, its emissions reached 6.5 Mt, accounting for 49.2% of the country's total fossil energy carbon emissions. The second is the construction industry. In 2022, the construction industry's consumption of fossil energy produced 1.81 Mt of carbon emissions, accounting for 13.7% of the total carbon emissions from fossil energy.

Biomass emissions

In 2022, biomass consumption in Tanzania accounted for 54.9% of its primary energy consumption mix, mainly for domestic consumption. The main types of biomass in Tanzania are firewood and charcoal, and their use is growing rapidly as the population increases. As a result, forests are becoming overharvested, resulting in reduced forest cover and forest degradation. Forest recovery cycles are long and this type of biomass use is not renewable or sustainable over time; it is therefore not 'zero carbon' and should be included in national and regional carbon accounting along with fossil energy combustion for overall carbon emissions. From 2010 to 2022, carbon emissions from biomass consumption increased from 7.1 Mt to 25.9 Mt. Carbon emissions from biomass consumption increased slowly after rising sharply in 2017. This was due to a significant increase in biomass consumption. Compared with 2016, biomass consumption increased by 221.2% in 2017.

Emission trends

Tanzania's fossil energy emissions are growing relatively fast. Emissions from fossil energy consumption increased by 116.6% between 2010 and 2022, from 6.1 Mt to 13.2 Mt. During this period, carbon emissions from biomass consumption increased from 7.1 Mt to 25.9 Mt.

Comparison with international databases

In terms of trends, the results are broadly similar across agencies, with differences in accounting methods and underlying data leading to differences in the results. From 2010 to 2020, the fossil energy carbon emissions calculated by CEADs were very close to the IEA data, with an error of 1% to 5%, but slightly lower than the results of EDGAR. In 2022, the fossil energy carbon emissions calculated by CEADs were closer to GCB, with an error of about 2%. From a time series perspective, the results calculated by CEADs are relatively consistent with the IEA, but there was a difference in 2017. The oil consumption in the energy balance table released by AFREC showed a slight downward trend from 2016 to 2017, while the oil consumption in the IEA data showed a slow upward trend from 2016 to 2017. The data of the IEA comes from the annual reports of the Bank of Tanzania and the Tanzania Energy and Water Utilities Authority, and the data of this report comes from the African Energy Commission.

In addition, when the carbon emissions generated by biomass consumption is included, the data calculated by CEADs in 2022 is 39.1 Mt.

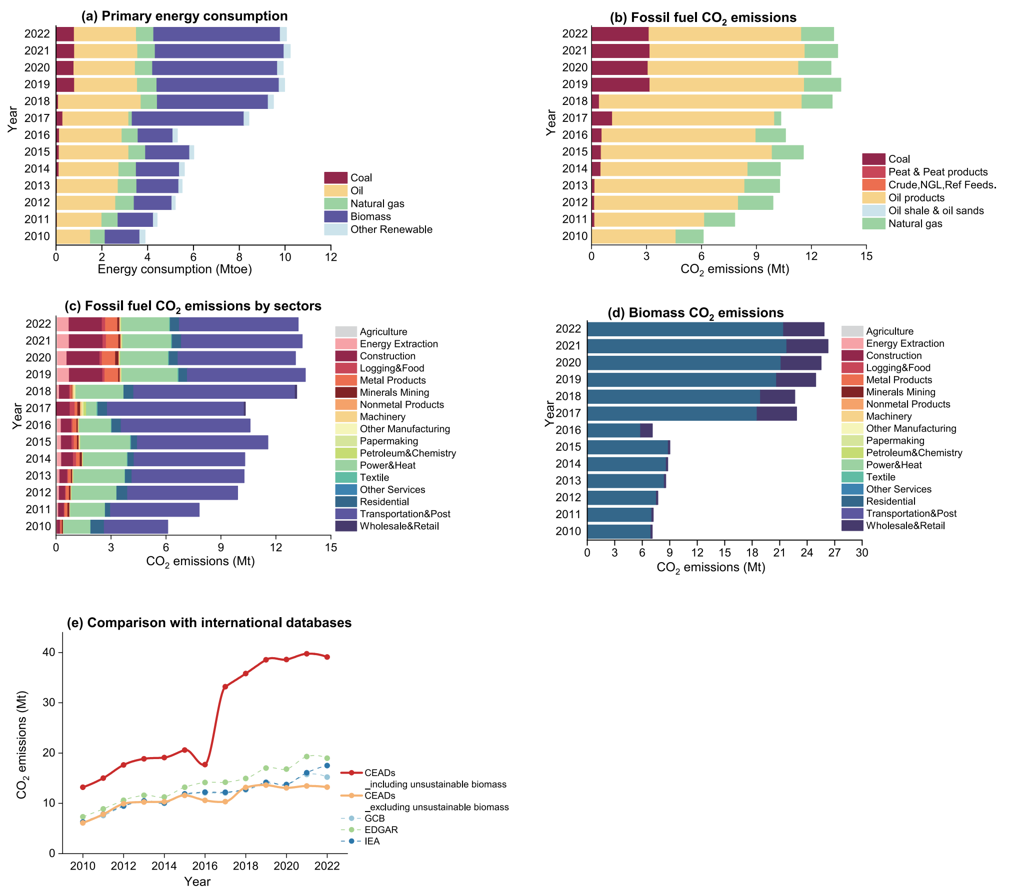


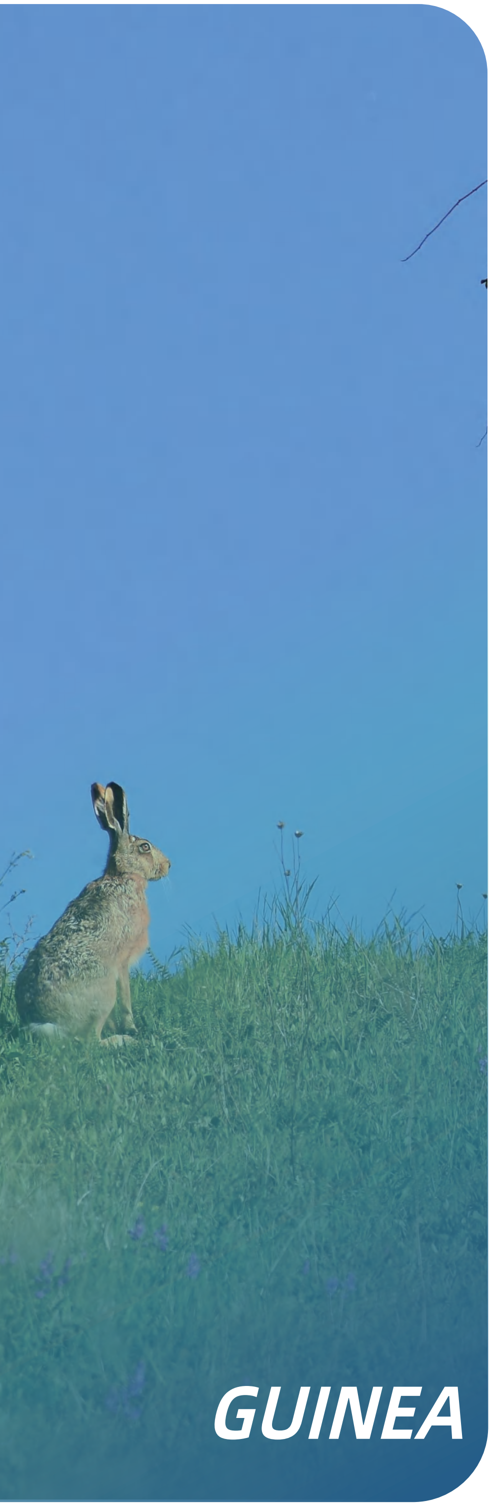
Figure 3.10: Tanzania's energy consumption and CO_2 emissions from 2010 to 2022 (a) Primary energy consumption; (b) Fossil fuel CO_2 emissions; (c) Fossil fuel CO_2 emissions by sectors; (d) Biomass CO_2 emissions; (e) Comparison with international databases.

Brief description of data sources:

Tanzania's energy balance sheet for 2010-2022 was obtained from the African Energy Commission (AFREC) website, which contains energy processing conversion data for 9 primary and secondary energy species in Tanzania. In this case, for sector matching, we use data published by National Bureau of Statistics and export data published by UN Comtrade as the basis for allocation, and downscaled sectoral matching to 47 sectors.

Table 3.10: Data sources for Tanzania's emission accounting

Data type	Source	Website
Energy balance sheet	AFREC	https://au-afrec.org/en/energy-balances
Emission factor	IPCC	https://www.ipcc-nggip.iges.or.jp/EFDB/
Sectoral mapping indicator	UN Comtrade，Export data	https://comtradeplus.un.org/
	National Bureau of Statistics	National Bureau of Statistics - NA Publications (nbs.go.tz)



GUINEA

Background

Guinea (full name: Republic of Guinea) is located on the west coast of West Africa, bordering Guinea-Bissau, Senegal and Mali to the north, Côte d'Ivoire to the east, Sierra Leone and Liberia to the south, and the Atlantic Ocean to the west. It has a land area of 245,857 square kilometers. There are 7 regions and 1 capital city, Conakry (at the same level as the region), 33 provinces, and 304 districts in the country. There are more than 20 ethnic groups in the country, of which the Fula (also known as the Poul) accounts for more than 40% of the national population, the Malinke accounts for more than 30%, and the Susu accounts for about 20%[172]. In 2022, the total population of Guinea was about 14.06 million [173].

Guinea is an underdeveloped country. Its economy is mainly based on agriculture and mining. Its industrial foundation is weak and it cannot be self-sufficient in food. It is rich in natural resources and is known as the "miracle of the land". It has large reserves of bauxite and iron ore with high quality. Among them, the proven reserves of bauxite are about 40 billion tons, ranking first in the world. In addition, there are diamonds, gold, copper, uranium, cobalt, lead, zinc, etc. Oil and natural gas have also been preliminarily discovered on the coastal continental shelf. It has a 350-kilometer-long coastline and rich coastal fishery resources. At the same time, Guinea has many rivers and rich freshwater resources. It is the source of the three major rivers in West Africa and is known as the "Water Tower of West Africa". The hydropower reserves reach 6 million kilowatts, but only about 15% has been developed so far. The forest coverage rate ranks first in West Africa, with 6 million hectares of arable land, 80% of which is uncultivated, and the conditions for agricultural development are unique. At the same time, Guinea is also a member of the World Trade Organization, a member of the Mano River Union, and a signatory to the West African Second Monetary Area Agreement.

In 2022, Guinea's GDP was approximately US$19.9 billion (current value), and its per capita GDP was approximately US$1416.6 (current value). The GDP grew by 16.6% year-on-year, an increase of approximately US$2.8billion (current value) over the previous year[174]. In 2022, the contributions of agriculture, industry, and services to the GDP of Guinea were 27.3%, 28.8%, and 35.3%, respectively[175].

Primary energy consumption

In 2022, Guinea's oil consumption accounted for 33.2%; In addition, biomass accounted for 62.9% of primary energy consumption, and other renewable energy sources such as solar energy and hydropower accounted for 4% of primary energy consumption.

Characteristics of fossil fuel emissions

Since Guinea has no carbon emission data for coal and natural gas in 2022, the carbon emissions generated by its fossil energy consumption are the carbon emissions of oil. As Guinea's main fossil energy, the carbon emissions generated by its consumption of oil increased from 1.5 Mt in 2010 to 6.5 Mt in 2022, an increase of 333.3%.

Sectoral emission contribution

Guinea's largest source of carbon emissions comes from the transportation, warehousing and postal sectors. In 2022, the sector's fossil energy carbon emissions were 4.3 Mt, accounting for 66.3% of Guinea's total fossil energy carbon emissions. Closely following is the Minerals Mining sector, which is Guinea's second largest fossil energy carbon emission sector in recent years. In 2022, the sector's fossil energy carbon emissions were 1.1 Mt, accounting for 17.4% of Guinea's total fossil energy carbon emissions.

Biomass emissions

In 2022, biomass energy accounted for 62.9% of the primary energy consumption in Guinea, mainly used in the living consumption sector. Its biomass types mainly include wood, charcoal and other common fuels in the daily life of the household sector. Carbon emissions generated by traditional biomass consumption accounted for an important proportion in Guinea. Local residents mainly obtain firewood by cutting down forests and use it for household cooking and heating, which has a great impact on the environment. It is an unsustainable use of resources and should be included in the overall carbon emissions in the overall carbon accounting process. From the perspective of time trend, biomass carbon emissions have generally shown an upward trend, from 11.3 Mt in 2010 to 18.8 Mt in 2022, of which biomass emissions decreased slightly in 2017. In addition, although the proportion of carbon emissions from the wholesale and retail sectors in Guinea's total biomass carbon emissions is small, it has also increased year by year from 2017 to 2022, which may be related to its national development process. Between 2017 and 2022, Guinea's total biomass carbon emissions showed a steady upward trend year by year.

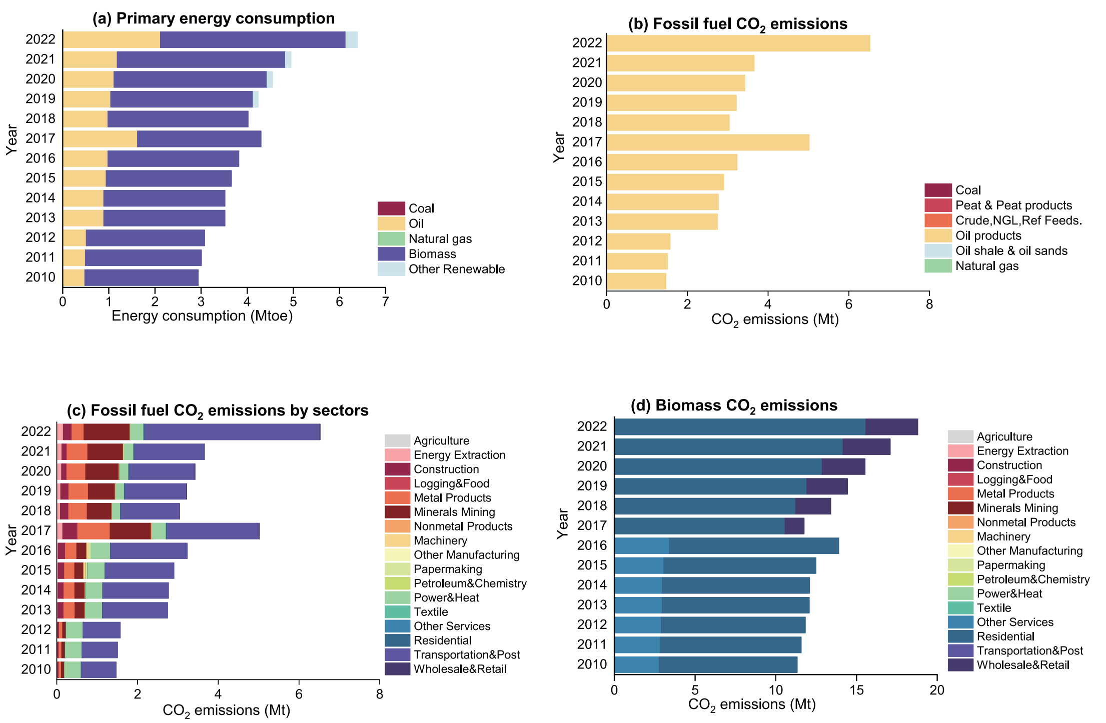
Emission trends

Guinea's total carbon emissions showed a slight fluctuation and an overall upward trend from 2010 to 2022, increasing by 97.7% from 12.8 Mt in 2010 to 25.3 Mt in 2022. Among them, carbon emissions from fossil energy consumption increased from 1.5 Mt in 2010 to 6.5 Mt in 2022, an increase of 333.3%. CO_2 emissions from biomass increase from 11.3 Mt in 2010 to 18.8 Mt in 2022.

Comparison with international databases

Under the unified accounting caliber, when biomass carbon emissions are not included, the accounting results of various institutions are roughly the same. The differences in accounting methods and basic data make the results slightly different. Comparing the carbon emissions of fossil energy, the total carbon emissions of fossil energy of IEA in 2022 were 4.5 Mt, the total carbon emissions of fossil energy of CEADs were 6.5 Mt, while the data of EDGAR was 3.8 Mt and the data of GCB was 4.2 Mt. There is a gap of 30.8% and 35.4% between the total carbon emissions of fossil energy of CEADs and IEA and GCB respectively. Among them, the carbon emission data of IEA is estimated based on second-hand data of multiple existing institutions, and its statistical process is relatively rough; while CEADs' result is directly calculated based on the energy balance sheet officially released by Guinea in the African Energy Commission, and the data statistics are more accurate, which leads to different accounting results.

In addition, when emissions produced by biomass consumption is included, the CEADs accounting data is 25.3 Mt in 2022.



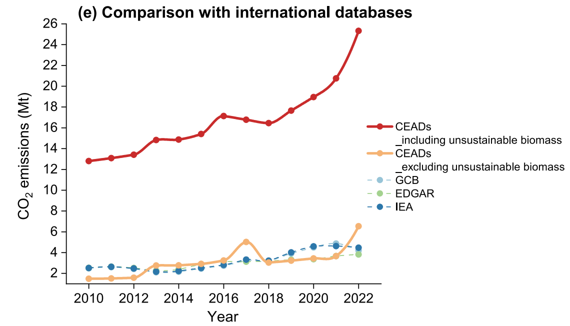


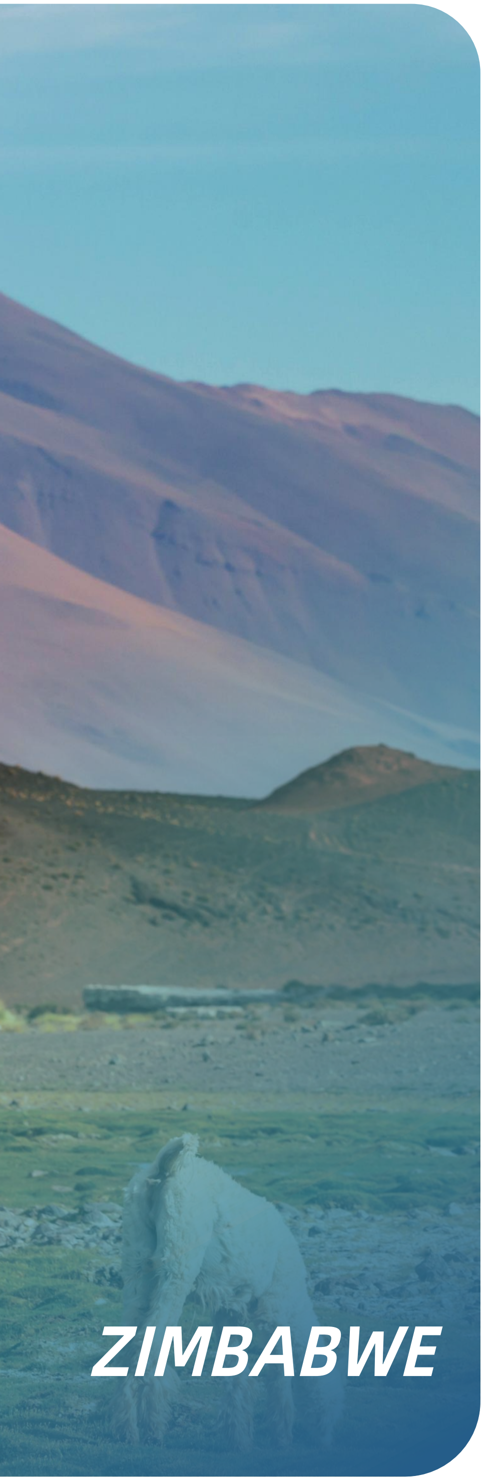
Figure 3.11: Guinea's energy consumption and CO_2 emissions from 2010 to 2022 (a) Primary energy consumption; (b) Fossil fuel CO_2 emissions; (c) Fossil fuel CO_2 emissions by sectors; (d) Biomass CO_2 emissions; (e) Comparison with international databases.

Brief description of data sources:

Guinea's energy balance sheet involves 13 energy types and 6 sectors. The data for each year comes from the statistics on energy consumption of the African Energy Commission, covering the period from 2010 to 2022. The sector matching uses data from the World Bank, export data from UN Comtrade and globalEDGE, and the sectors are downscaled and allocated to 47 sectors based on the gross domestic product of the industrial sector, agriculture, commerce and public services, and the proportion of urban residents.

Table 3.11: Data sources for Guinea's emission accounting

Data type	Source	Website
Energy balance sheet	African Energy Commission	https://au-afrec.org/data-statistics-energy-balances
Emission factor	IPCC	https://www.ipcc-nggip.iges.or.jp/EFDB/
Sectoral mapping indicator	World Bank (Population Data)	https://data.worldbank.org/country/guinea
	UN Comtrade (Industrial Sector)	https://comtrada.un.org
	globalEDGE (Agricuturial and Public Service Sector)	https://globaledge.msu.edu/countries/guinea/economy



Background

Zimbabwe, often known as the Republic of Zimbabwe, is an inland plateau nation in southeast Africa. With a land area of roughly 391,000 square kilometers, it is bordered by the Limpopo River and South Africa on the south, and the Zambezi River on the north and northwest. It has borders with Zambia on the east, northeast, and Mozambique on the east, as well as Botswana on the west. There were 16.07 million people living in Zimbabwe in 2022, mostly from the Shona and Ndebele ethnic groupings[176]. Due to recent illnesses and natural calamities, Zimbabwe's economic problems have gotten worse. In 2022, Zimbabwe's GDP reached US$32.79 billion at current prices, with GDP per capita of US$2040.6. The country's GDP growth rate was 6.1%, while inflation rate was 104.7%[176].

Zimbabwe is a relatively industrially developed country in Africa, with manufacturing, agriculture, and mining being the three main economic sectors. The value of Zimbabwe's three main industries—the agricultural, industrial, and service sectors—accounted for 18.8%, 39.7%, and 41.5% of the country's GDP in 2022[176]. Coal, chromium, iron, platinum, gold, and diamonds are among the abundant natural resources found in Zimbabwe. There are over 250 Mt of iron reserves and approximately 27 billion tons of coal reserves. Zimbabwe's total commerce volume in 2022 was $15.3 billion, consisting of $8.7 billion in imports and $6.6 billion in exports[177]. Trade links exist between Zimbabwe and 196 nations and areas. In contrast to its major imports of machinery, industrial goods, and chemicals, it exports gold, tobacco, and ferroalloys.

Zimbabwe has a lot of potential for producing electricity via biomass, hydropower, and solar energy. The National Renewable Energy Policy (NREP), which the Zimbabwean government introduced in 2019, is expected to stimulate the country's renewable energy market over the course of the forecast period. The policy aims to reduce greenhouse carbon emissions by 33% by 2030 and has as its target the percentage of electricity generated from renewable sources to be between 16.5% and 26.5% (excluding large hydro) [178].

Primary energy consumption

The largest percentage of biomass is found in Zimbabwe's energy mix. In 2022, Zimbabwe's coal consumption accounted for 16.9%, oil consumption accounted for 14.7%, and total fossil fuel consumption accounted for nearly 31.6%. In addition, biomass consumption accounted for 63.7% of primary energy consumption in 2022. Other renewable energy sources such as solar energy accounted for 4.7% of the primary energy consumption.

Characteristics of fossil fuel emissions

Coal and petroleum products are responsible for the great bulk of carbon emissions from the burning of fossil fuels. 60.1% of carbon emissions from fossil fuels in 2022 came from coal, with 7.3 Mt of emissions. 39.9% of carbon emissions were produced by petroleum products, which accounted for 4.8 Mt. Coal burning produced emissions that rose from 5.6 Mt in 2010 to 7.3 Mt in 2022, a 29.3% rise.

Sectoral emission contribution

The production of electricity, heat, gas, and water accounts for the majority of Zimbabwe's emissions. From 2010 to 2022, carbon emissions from fossil energy generated by the electricity, heat, gas and water production sectors showed a fluctuating upward trend. In 2022, carbon emissions from the electricity, heat, gas and water production sectors were 4.0 Mt, accounting for 32.8% of total fossil energy carbon emissions. In addition, the transportation, warehousing, and postal sector is the second largest emitting sector in Zimbabwe, with a total carbon emission of about 2.3 Mt, accounting for 19.0% of total fossil energy emissions.

Biomass emissions

In 2022, Zimbabwe's biomass consumption accounted for 63.7% of the primary energy consumption structure, mainly used for living consumption. Zimbabwe's biomass is mainly firewood, which comes from excessive deforestation, resulting in reduced forest cover and forest degradation. Due to the long cycle of forest recovery, this way of biomass utilization is not renewable and sustainable within a certain period of time. Therefore, the country's biomass consumption does not have a "zero carbon" attribute, and biomass and fossil energy consumption should be included in the overall carbon emissions in national and regional carbon emission accounting. Carbon emissions from biomass consumption experienced a slight fluctuation between 2010 and 2022, with emissions fluctuating from 24.0 Mt to 32.3 Mt.

Emission trends

Zimbabwe's carbon emissions showed a fluctuating growth trend. Between 2010 and 2022, carbon emissions from fossil energy consumption increased by 62.7%, fluctuating from 7.5 Mt to 12.1 Mt. In addition, carbon emissions from biomass consumption slowly fluctuated from 24.0 Mt to 32.3 Mt from 2010 to 2022.

Comparison with international databases

Under the unified accounting caliber, when biomass emissions are not included, the carbon emissions generated by fossil energy consumption calculated by CEADs show similar trend characteristics to the statistical data of other institutions except for some years. From 2010 to 2018 and in 2021, CEADs data was most similar to GCB data, with a difference of approximately 10%. In 2019, CEADs data was closest to IEA data, with a difference of around 4%. In 2020 and 2022, CEADs data was most comparable to EDGAR data, with a difference of approximately 20%.

In addition, when the carbon emissions generated by biomass consumption is included, in 2022, the CEADs data is 44.5 Mt.

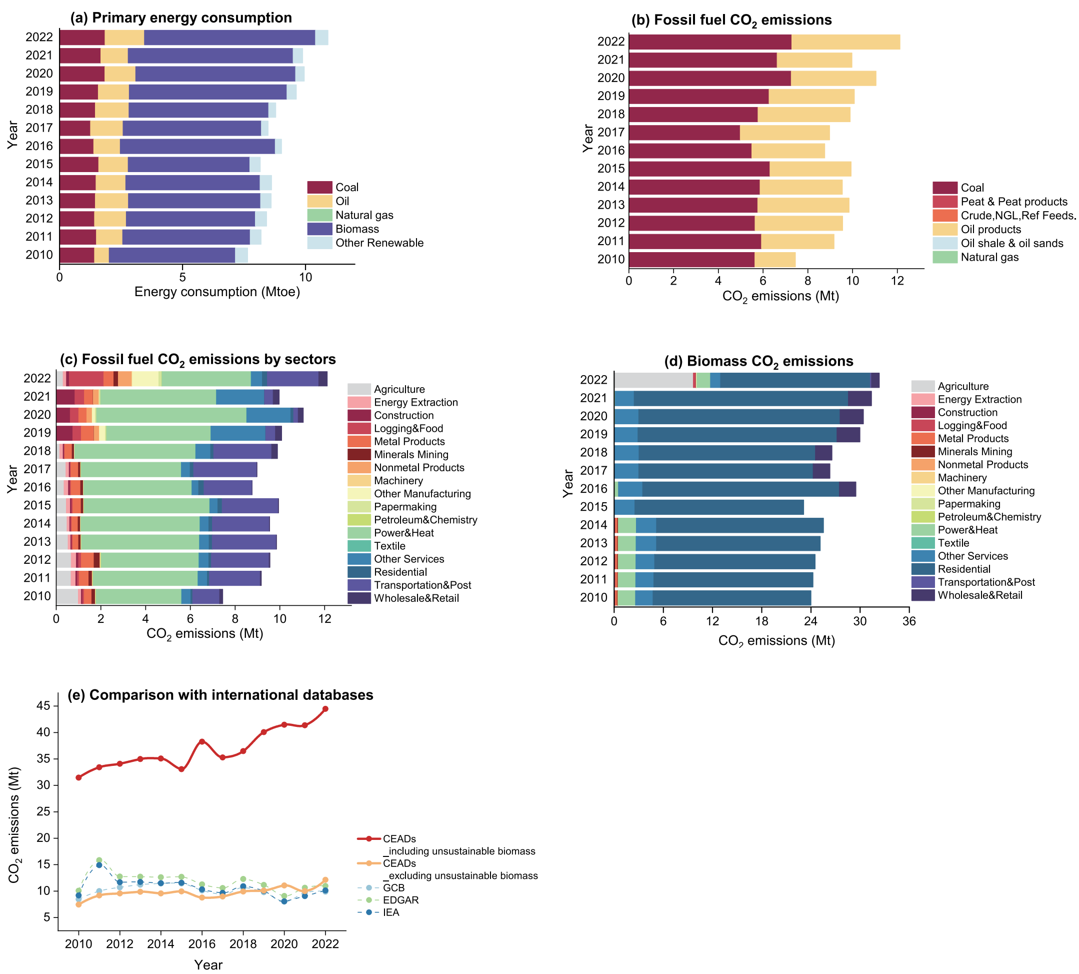


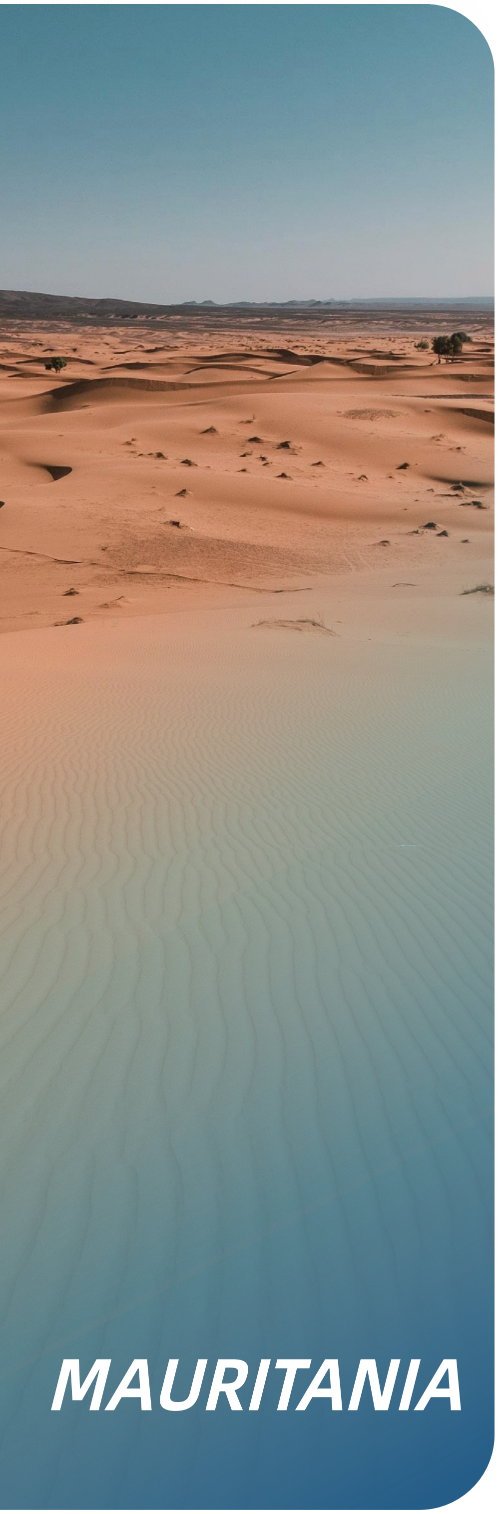
Figure 3.12: Zimbabwe's energy consumption and CO_2 emissions from 2010 to 2022 (a) Primary energy consumption; (b) Fossil fuel CO_2 emissions; (c) Fossil fuel CO_2 emissions by sectors; (d) Biomass CO_2 emissions; (e) Comparison with international databases.

Brief description of data sources:

The energy data used in this report comes from Zimbabwe's 2010-2022 energy balance sheet provided by the African Energy Commission. For sectoral matching, we use Zimbabwe's official economic data and export data from the UN Comtrade as the allocation basis. The sectors are then downscaled and allocated into 47 sectors.

Table 3.12: Data sources for Zimbabwe's emission accounting

Data type	Source	Website
Energy balance sheet	African Energy Commission	https://au-afrec.org/
Emission factor	IPCC	https://www.ipcc-nggip.iges.or.jp/efdb/
Sectoral mapping indicator	Zimbabwe Data Portal	https://zimbabwe.opendataforafrica.org/
Sectoral mapping indicator	United Nations Commodity Trade Statistics (UN Comtrade) - Exports	https://comtradeplus.un.org/



Background

Mauritania is located in the northwest of Africa, between 15- and 27-degrees north latitude, with an area of 1.03 million square kilometers. Mauritania borders the Atlantic Ocean to the west, Western Sahara and Algeria to the north, Mali to the southeast, and Senegal to the south. The region has a tropical desert climate. The vast northern and central regions are located in the southwest of the Sahara Desert. Three-quarters of the country's area is desert, and it is known as the "Desert Republic". Mauritania is located between the Maghreb and West Africa. Its special geographical location gives it the dual attributes of an Arab and sub-Saharan African country. In 2022, Mauritania's GDP (current price) was US$9.56billion and its population was 4.9million[179].

Mining and fisheries are the pillar industries of Mauritania. It is rich in mineral resources, with evidence of the existence of 400 minerals such as uranium, cobalt, manganese, coal, and diamonds. The reserves of iron ore are about 10.7 billion tons, and iron ore exports account for 70% of Mauritania's foreign exports and 30% of the country's fiscal revenue. In addition, Mauritania's coastline on the Atlantic Ocean is 754 kilometers long, with a sea area of 163,500 square kilometers. It is one of the regions with the richest fishery resources in the world, with an estimated reserve of 4 Mt of fishery resources, and about 1.6 Mt can be caught annually. The oil and gas industry is an emerging industry in Mauritania, and agricultural and forestry resources are relatively scarce. There are 535,000 hectares of arable land, of which 135,000 hectares are irrigated fields, 350,000 hectares are rainwater fields, and 50,000 hectares are oases. However, due to the scarcity of water resources and weak water conservancy facilities, the actual planting area is very small[180]. Mauritania mainly exports iron ore and fishery products. Iron ore is mainly exported to China, and fishery products are exported to Spain, Japan, Nigeria and other countries.

Mauritania has an advantage in geographical location. Although the electrification rate in 2022 is 49.0%, it is suitable for the development of solar and wind power generation. According to the International Renewable Energy Agency, Mauritania's national renewable energy power generation potential is as high as 4 gigawatt-hours. Mauritania's original goal was to have renewable energy account for 20% of its energy structure by 2020 (achieved in 2018), and the new goal is to increase the share of renewable energy to 50% by 2030.

Primary energy consumption

Mauritania's primary energy structure is dominated by petroleum products. In 2022, fossil energy consumption only consisted of petroleum products, and total fossil energy consumption accounted for 61.7% of primary energy consumption. In addition, biomass accounted for 37.0% of primary energy consumption, and other renewable energy sources such as wind and solar energy accounted for 1.3% of the primary energy consumption structure.

Characteristics of fossil fuel emissions

In 2022, Mauritania's carbon emissions from fossil energy consumption were about 3.9 Mt, of which the only fossil energy was petroleum products. Carbon emissions from petroleum product consumption showed an overall upward trend from 2010 to 2022, increasing from 2.1 Mt in 2010 to 3.9 Mt in 2022.

Sectoral emission contribution

Mauritania's largest fossil energy carbon emissions come from the transportation, warehousing and postal sectors. In 2022, the carbon emissions generated by the consumption of fossil energy in this industry were close to 1.4 Mt, accounting for 36.9% of Mauritania's total fossil energy carbon emissions. Following closely is the production of electricity, heat, gas, and water; its emissions in 2022 were close to 1.3 Mt, accounting for 33.4% of Mauritania's total fossil energy carbon emissions in 2022 from 14.8% in 2010. Next is minerals mining, whose fossil energy carbon emissions are much smaller than those of the production of electricity, heat, gas, and water; its emissions were about 0.3Mt, accounting for 7.8% of the total fossil energy carbon emissions.

Biomass emissions

In 2022, biomass accounted for 37.0% of the primary energy consumption in Mauritania, which was mainly used for living consumption. The main types of biomass in Mauritania are wood and charcoal, which mainly come from forests. Excessive logging has led to reduced forest cover and forest degradation. Due to the long cycle of forest recovery, this way of biomass utilization is not renewable and sustainable within a certain period of time. Therefore, the country's biomass does not have a "zero carbon" attribute during the accounting period, and biomass and fossil energy consumption should be included in the overall carbon emissions in the national and regional carbon emission accounting. Carbon emissions generated by biomass consumption showed an upward trend from 2016 to 2022, increasing from 2.5 Mt in 2016 to 3.6 Mt in 2022.

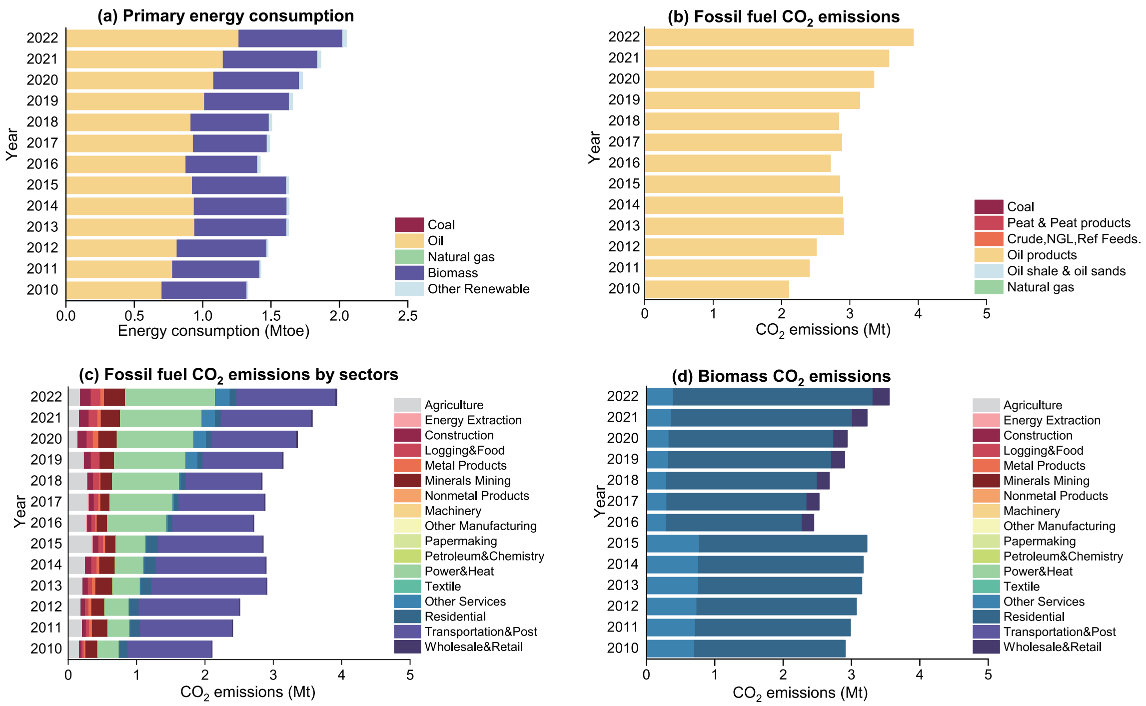
Emission trends

Mauritania's CO_2 emissions are on the rise. Between 2010 and 2022, carbon emissions from fossil energy consumption increased from 2.1 Mt to 3.9 Mt in 2022. During this period, carbon emissions from biomass consumption increased from 2.9 Mt to 3.6 Mt.

Comparison with international databases

Under the unified accounting caliber (excluding biomass carbon emissions) the total carbon emissions of Mauritania in 2022 were 3.9 Mt for CEADs, 4.4 Mt for IEA, 4.8 Mt for EDGAR, and 4.6 Mt for GCB; the fossil energy carbon emissions data of CEADs were lower than the values calculated by the IEA and GCB teams, and were similar to the values of EDGAR in 2010-2016, and lower than the EDGAR values in 2016-2022. In addition, the gap between CEADs and IEA in 2022 has narrowed, and the difference in the total amount is not very obvious, about 13%. The main reason for the difference is the difference in statistical caliber. CEADs uses the energy balance sheet results in the African Energy Commission (AFREC), while the IEA uses the annual energy questionnaire survey data.

In addition, when the carbon emissions generated by biomass consumption is included, the data calculated by CEADs in 2022 is 7.5 Mt.



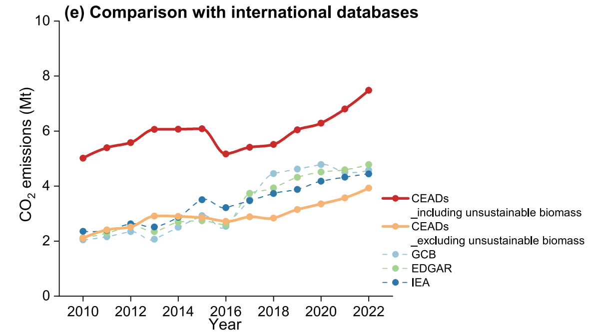


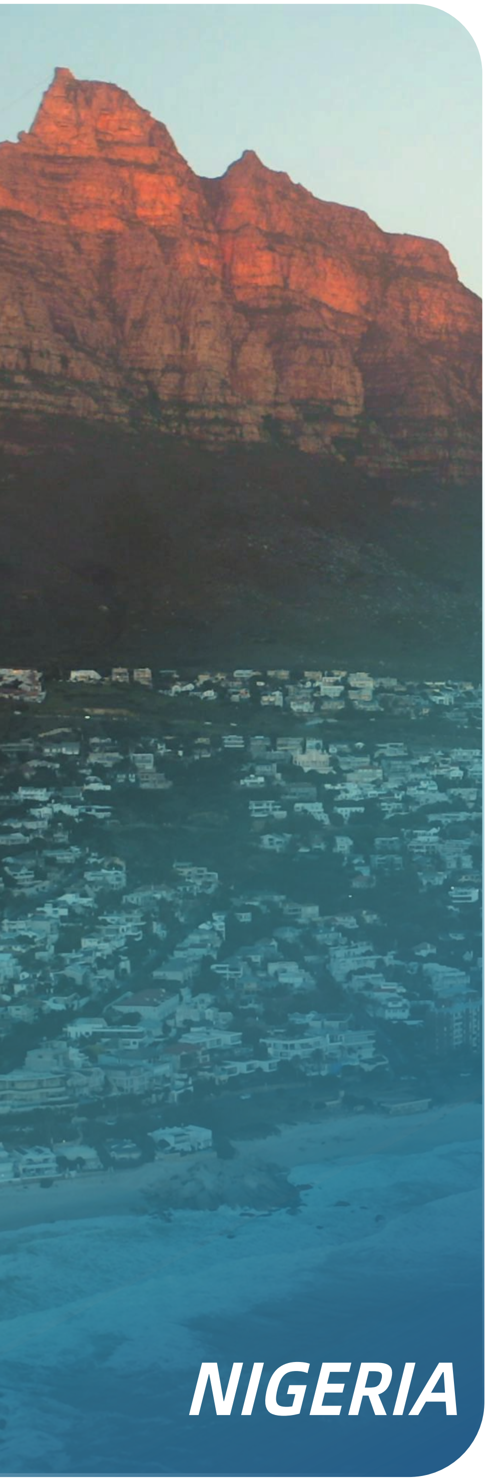
Figure 3.13: Mauritania's energy consumption and CO_2 emissions from 2010 to 2022 (a) Primary energy consumption; (b) Fossil fuel CO_2 emissions; (c) Fossil fuel CO_2 emissions by sectors; (d) Biomass CO_2 emissions; (e) Comparison with international databases.

Brief description of data sources:

Mauritania's energy balance sheets are all from the African Energy Commission (AFREC), covering data from 2010 to 2022, involving 12 energy types and 6 sectors. In terms of sub-sector matching, we use export data from the UN Comtrade and Mauritania's own subsectoral data as the basis for allocation, downscaling the sectors and allocating them to 47 sectors.

Table 3.13: Data sources for Mauritania's emission accounting

Data type	Source	Website
Energy balance sheet	AFREC	https://au-afrec.org/en/energy-balances
Emission factor	IPCC	https://www.ipcc-nggip.iges.or.jp/EFDB/
Sectoral mapping indicator	Mauritania Bureau of Statistics	https://ons.mr/
	UN Comtrade，export data	https://comtradeplus.un.org/



Background

Nigeria (full name: Federal Republic of Nigeria), located in the southeast of West Africa, is the apex of the west coast of the Gulf of Guinea in Africa. It borders Benin to the west, Niger to the north, and Chad across Lake Chad in the northeast. It borders Cameroon to the east and southeast, and the Gulf of Guinea in the Atlantic Ocean to the south. As an important country in West Africa, Nigeria is the most populous country in Africa, with a total population of 223 million in 2022; it is also the largest economy in Africa. Nigeria's GDP in 2022 was US$477.4 billion at current prices[181].

Nigeria's pillar industry is the oil industry, which accounts for 83% of the country's total revenue. Nigeria's oil reserves rank second in Africa and tenth in the world, making it the largest oil producer and exporter in Africa. Nigeria also has abundant natural gas reserves, with proven natural gas reserves ranking first in Africa and eighth in the world. In order to change its economy's excessive dependence on the oil industry, Nigeria has vigorously developed natural gas resources. With coal reserves of about 2.75 billion tons, Nigeria is the only coal-producing country in West Africa. In addition to energy mining, Nigeria's other industries are relatively backward, with the main manufacturing industries being textiles, vehicle assembly, wood processing, cement, and food processing. Agriculture accounts for 40% of the country's GDP, but it cannot achieve self-sufficiency in food. Nigeria has abundant energy resources. As of 2014, more than 30 mineral resources with commercial mining value have been discovered, but Nigeria's mining industry is still in its infancy. In terms of international trade, a large number of industrial products and food rely on imports, and a large amount of energy resources are exported to all parts of the world. Oil exports account for 98% of total export revenue[182].

Nigeria is rich in renewable energy resources, with solar, wind, biomass and other previously under-appreciated sources of renewable energy serving as the driving force of its economy[183]. The Nigerian government has launched a Renewable Energy Development Plan (REMP), which aims to achieve 10% renewable energy consumption by 2025. To this end, the government is vigorously promoting the development of renewable energy industries, particularly solar energy, to contribute to the security of the country’s electricity supply[184]. Speaking at COP26 of the United Nations Framework Convention on Climate Change (UNFCCC), President Muhammadu Buhari said that Nigeria will reach net zero emissions by 2060. Meanwhile, President Muhammadu Buhari also said that the greater investment is being made to restore biodiversity, develop hydropower and solar projects to find partners, technology and funding, and use solar solutions to power 5 million households and enable 25 million people.

Primary energy consumption

Nigeria's primary energy structure is dominated by biomass. In 2022, Nigeria's oil consumption accounted for 30.6%, natural gas consumption accounted for 18.2%, and total fossil energy consumption accounted for nearly 48.8%. In addition, biomass accounted for 50.3% of primary energy consumption, and other renewable energy sources such as solar energy accounted for 1.0% of primary energy consumption.

Characteristics of fossil fuel emissions

Among the carbon emissions generated by fossil energy consumption, emissions generated by oil and natural gas consumption dominate. As the main fossil energy in Nigeria, petroleum products generated a total of 75.0 Mt of carbon emissions in 2022, accounting for 67.7% of fossil energy carbon emissions. Carbon emissions generated by natural gas consumption increased from 19.3 Mt in 2010 to 35.8 Mt in 2022, and its share gradually increased.

Sectoral emission contribution

Nigeria's largest carbon emissions come from the transportation, warehousing and postal sectors. In 2022, the sector's fossil energy carbon emissions were 66.1 Mt, accounting for 59.7% of Nigeria's total fossil energy carbon emissions. At the same time, this sector was also the sector with the fastest growth in fossil energy carbon emissions in recent years. It was followed by the production of electricity, heat, gas and water, which was the second largest fossil energy carbon emission sector in Nigeria in recent years, accounting for 16.7% of the total fossil energy carbon emissions in 2022, mainly using diesel, gasoline and fuel oil. The third was energy extraction, with emissions from oil and natural gas extraction accounting for 9.4% of the total fossil fuel carbon emissions.

Biomass emissions

In 2022, biomass energy accounted for about 50.3% of Nigeria's primary energy consumption, mainly used for consumption in the residential sector and the production of electricity, heat, gas, and water, and occupied an important position in Nigeria's energy structure. The main types of biomass are wood, charcoal, manure, crop residues, etc., and carbon emissions from traditional biomass energy account for an important proportion in Nigeria[185]. From a temporal perspective, biomass carbon emissions exhibited an overall increasing trend, rising from 650.8 Mt in 2010 to 747.4 Mt in 2021, before sharply declining to 190.5 Mt in 2022. Among them, biomass carbon emissions showed a significant decline from 2015 to 2016, which may be related to the background of the oil price crash and economic recession at the time. In addition, the Nigerian government is also vigorously promoting the use and popularization of renewable energy. Although carbon emissions from biomass energy have continued to grow in recent years, the growth rate has slowed down. Since traditional biomass is not fully traded in the economic market, statistical data may be uncertain [186].

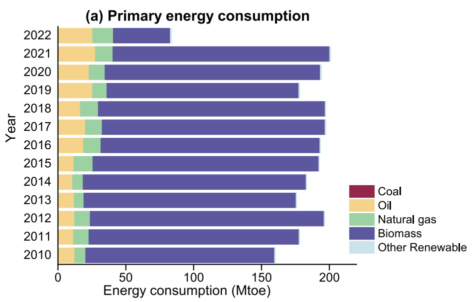
Emission trends

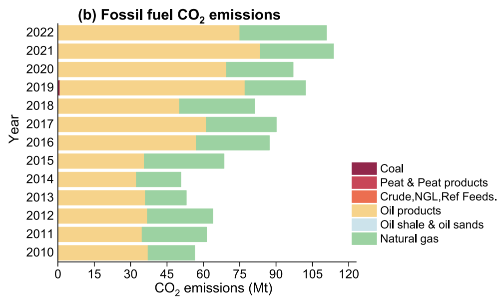
Nigeria's fossil fuel carbon emissions showed a fluctuating upward trend. Between 2010 and 2022, carbon emissions from fossil fuel consumption increased by 96.2%, rising from 56.4 Mt to 110.7 Mt. Additionally, from 2010 to 2021, carbon emissions from biomass consumption fluctuated upward from 650.8 Mt to 747.4 Mt, before sharply declining to 190.5 Mt in 2022.

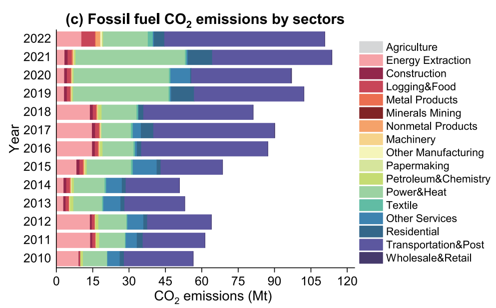
Comparison with international databases

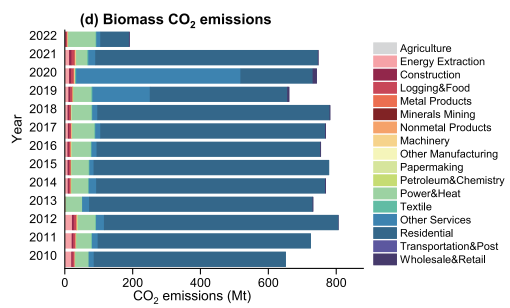
Under the same accounting caliber (excluding emissions from biomass), Nigeria's CO_2 emissions as calculated by various agencies show almost the same annual emissions trends. In 2022, the GCB data was 110.3 Mt, the CEADs data was 110.7 Mt, the EDGAR was 130.1 Mt, and the IEA's was 100.4 Mt. From 2013 to 2014, CEADs data showed significant discrepancies compared to data from various institutions, with a margin of error of approximately 50%. This discrepancy may be attributed to the sharp decline in Nigeria's natural gas energy transformation and self-consumption sectors during this period.

In addition, when including CO_2 produced by biomass consumption, in 2022, CEADs accounting data is 301.2 Mt.









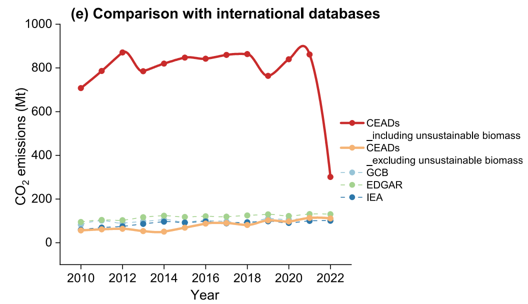


Figure 3.14: Nigeria's energy consumption and CO_2 emissions from 2010 to 2022 (a) Primary energy consumption; (b) Fossil fuel CO_2 emissions; (c) Fossil fuel CO_2 emissions by sectors; (d) Biomass CO_2 emissions; (e) Comparison with international databases.

Brief description of data sources:

Nigeria's energy balance sheet covers a total of 7 energy varieties and 6 sectors. The data for 2015 are from the Nigeria Energy Support Programme Statistical Report; the data for the rest of the years are from the African Energy Commission (AFREC) statistics on energy consumption. The sub-sector matching uses data from Nigeria's official statistics website, and down-scales the sectors to 47 based on the output of the industrial sector, agriculture, construction, transportation and other sectors, and the urban and rural populations.

Table 3.14: Data sources for Nigeria's emission accounting

Data type	Source	Website
Energy balance sheet	AFREC	https://au-afrec.org/en/western-africa/nigeria
Emission factor	IPCC	https://www.ipcc-nggip.iges.or.jp/EFDB/
Sectoral mapping indicator	Nigeria Official Statistics Website	https://nigeria.opendataforafrica.org/NGNBSNGDPPTO2016/ nigerian-gross-domestic-product-report#

Background

Kenya is a country located in eastern Africa, with the equator running through the middle and the East African Rift Valley running from north to south. It borders Somalia to the east, Tanzania to the south, Uganda to the west, Ethiopia and South Sudan to the north, and the Indian Ocean to the southeast. The coastline is 536 kilometers long. 18% of the country's land area is arable land, and the rest is mainly suitable for animal husbandry. The land area is 583,000 square kilometers. In 2022, Kenya's GDP is US$114.45 billion in current prices. In terms of population, Kenya has a population of 54 million.

Kenya is the fourth largest economy in sub-Saharan Africa. Agriculture, forestry and animal husbandry remain the dominant industries in Kenya, but due to unfavorable weather conditions and increasingly stringent logging bans, its share in GDP was 22.3% in 2022, down 0.1% year-on-year. Tea and coffee remain Kenya's traditional cash crops and an important part of its export trade. Kenya's manufacturing industry accounts for only 8.3% of GDP and is on a downward trend. In terms of the service industry, tourism remains one of Kenya's main economic drivers.

According to its National Development Plan, Kenya plans to reduce its greenhouse gas emissions by 43 Mt (30%) before 2030, compared to 143 Mt of CO2 emissions in the baseline scenario. According to its 2015-2035 Power Generation and Transmission Master Plan, geothermal will account for a third of installed power generation capacity and provide more than half the annual power generation by 2035, making Kenya a leader in geothermal power generation in Africa[187].

Primary energy consumption

Kenya's primary energy is dominated by biomass. In 2022, fossil energy consumption accounted for about 19.5% of the total, specifically, coal consumption accounted for 2.6%, oil consumption accounted for 16.9%, and no natural gas was used. In addition, geothermal energy, hydropower, wind power and other renewable energy accounted for 34.1% of the primary energy, most of which was geothermal energy; biomass accounted for 46.4% of primary energy consumption.

Characteristics of fossil fuel emissions

Among the carbon emissions generated by fossil energy, petroleum products and coal consumption are the main sources of fossil energy carbon emissions in Kenya. As the most important fossil energy in Kenya, petroleum products (mainly diesel and gasoline) generated 14.2 Mt of CO2 emissions in 2022, accounting for 83.3% of fossil energy carbon emissions. CO2 emissions generated by coal consumption increased from 1.1 Mt in 2010 to 2.9 Mt in 2022, with a significant growth rate.

Sectoral emission contribution

The industries with the largest emissions from fossil energy consumption in Kenya are transportation, warehousing and postal services, which are also the industries with the fastest growth rate of fossil energy carbon emissions, increasing from 4.7 Mt in 2010 to 9.1 Mt in 2022, accounting for about 53.4% of fossil energy carbon emissions in 2022. Fossil energy carbon emissions from other service industries have grown rapidly, reaching 1.1 Mt in 2022, accounting for 6.2% of fossil energy carbon emissions. The production of electricity, heat, gas and water is also an important source of fossil energy carbon emissions in Kenya. The carbon emissions generated by the consumption of fossil energy in this industry show a trend of increasing first and then decreasing. Due to the rapid development of geothermal energy and hydropower, the growth trend of fossil energy carbon emissions in this industry has slowed down since 2013.

Biomass emissions

In 2022, Kenya's biomass consumption accounted for 46.4% of the primary energy consumption, mainly for residential sector. Kenya's biomass types are mainly firewood and charcoal, which mainly come from forests. Excessive logging has led to reduced forest cover and forest degradation. Due to the long cycle of forest recovery, this way of biomass utilization is not renewable and sustainable within a certain period of time. Therefore, the country's biomass does not have a "zero carbon" attribute, and biomass and fossil energy consumption should be included in the overall carbon emissions in the national and regional carbon emission accounting. From 2010 to 2014, biomass consumption gradually increased, and in 2014 it produced 71.4 Mt of carbon emissions. However, considering the harm of wood burning to the environment and human health, since 2015, the government has adopted a policy of banning logging and restricting charcoal trade, and biomass consumption has declined to a certain extent. In 2022, emissions generated by biomass consumption were 60.7 Mt. Due to differences in statistical caliber, biomass emissions vary in industry distribution. In the energy balance sheets released in 2015 and later, the biomass energy consumption that was originally classified as "residential consumption" in 2014 and before was classified into the two industries of "residential consumption" and "other consumption". The change in statistical caliber resulted in an increase in the calculated results of biomass carbon emissions from other consumption after 2016, and a decrease in the calculated results of biomass carbon emissions from residential consumption.

Emission trends

Kenya's CO_2 emissions from fossil fuel consumption increased from 10.3 Mt to 17.0 Mt between 2010 and 2022, an average annual growth rate of 4.3%. During this period, CO_2 emissions from biomass consumption increased by about 38.0%, from a peak of 44.0 Mt to 71.4 Mt in 2014, before falling to 60.7Mt in 2022.

Comparison with international databases

Under the same accounting caliber (excluding biomass carbon emissions), the fossil energy carbon emissions calculated by CEADs are basically consistent with the IEA and GCB data, slightly higher than the IEA results, and slightly lower than the GCB results. From 2010 to 2022, CEADs data were slightly lower than EDGAR data, and from 2016 to 2020, CEADs data were slightly higher than IEA data. The gap between CEADs results and IEA data is between 3% and 13%. The IEA data comes from the Economic Survey of the Kenya Central Bureau of Statistics and the Renewable Energy Statistics 2020 of the International Renewable Energy Agency, while the CEADs data comes from the Economic Survey of the Kenya Central Bureau of Statistics, so the data consistency is high.

When including CO_2 linked to biomass consumption for 2022, data calculated by CEADs is 77.8 Mt.

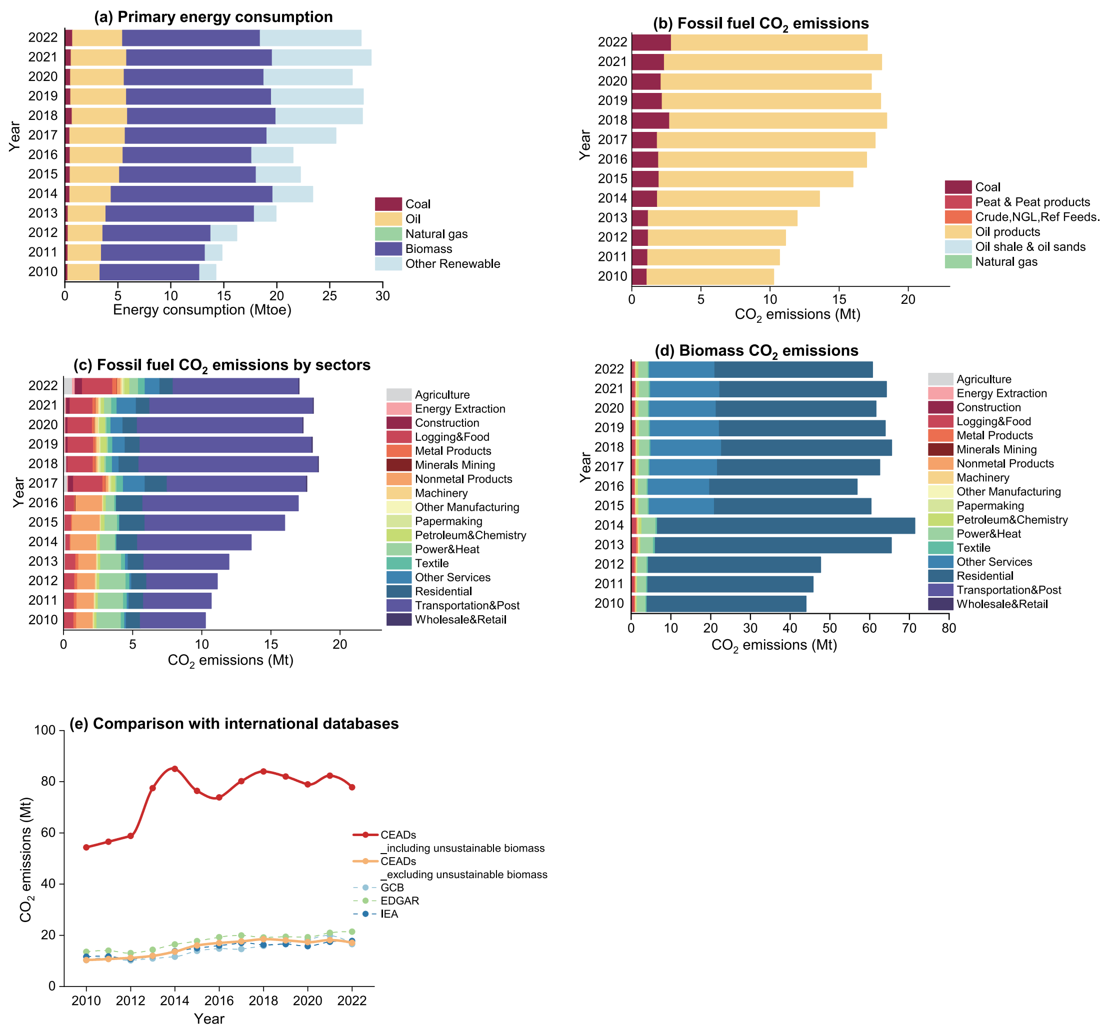


Figure 3.15: Kenya's energy consumption and CO_2 emissions from 2010 to 2022 (a) Primary energy consumption; (b) Fossil fuel CO_2 emissions; (c) Fossil fuel CO_2 emissions by sectors; (d) Biomass CO_2 emissions; (e) Comparison with international databases.

Brief description of data sources:

The energy data used in this report is from the energy balance sheets provided by the Kenya National Bureau of Statistics for 2012-2022. The balance sheets contain primary and secondary energy processing and conversion data from 9 main types of fossil fuels consumed in Kenya, and energy consumption data from 7 major economic sectors. In terms of sub-sector matching, we used the data from Kenya National Bureau of Statistics and export data in the UN Comtrade database to conduct downscaling matching of sectors and allocate them to 47 sectors.

Table 3.15: Data sources for Kenya's emission accounting

Data type	Source	Website
Energy balance sheet	Kenya National Bureau of Statistics	https://www.knbs.or.ke/
Emission factor	IPCC	https://www.ipcc-nggip.iges.or.jp/EFDB/
Sectoral mapping indicator	Kenya National Bureau of Statistics	https://www.knbs.or.ke/
	UN Comtrade	https://comtrada.un.org

Background

Ghana, in West Africa, is sited on the north shore of the Gulf of Guinea and borders Côte d'Ivoire to the west, Burkina Faso to the north, Togo to the east and the Atlantic Ocean to the south, with a coastline of about 562 kilometers. The country's area is 238,535 square kilometers. In 2022, Ghana's GDP was US$74.26 billion in current prices and its population was 33.2 million, making it the sixth largest economy in Sub-Saharan Africa.

Ghana has a rich natural resource base, and its main export industries include the manufacture of digital technology products, the construction and export of automobiles and ships, and diversified resource exports such as oil, gas and industrial minerals. The service industry dominates the national economy (about 50%), the GDP share of industry has increased from 18.5% in 2009 to 32.0% in 2019, and agriculture has decreased from 31.0% in 2009 to 17.3% in 2019. Ghana is the second largest gold producer in Africa (after South Africa) and the second largest cocoa producer (after Côte d'Ivoire) [188]. In 2020, Ghana's top exports were gold (about US$11.4 billion), crude oil (about US$2.9 billion), cocoa beans (about US$2.4 billion) and cocoa paste, mainly exported to Switzerland, India and China. Ghana has also participated in the Belt and Road Initiative and has strengthened economic and trade cooperation with China.

According to Ghana's Strategic National Energy Plan (2006-2020), the government set a goal to increase the proportion of renewable energy to 10% by 2030. With the signing of its Intended National Determined Contributions (INDC), Ghana's emission reduction goal is to unconditionally reduce its greenhouse gas emissions by 15% from the 73.95 Mt of CO_2 emissions under its pre-2030 baseline scenario.

Primary energy consumption

In 2022, fossil fuel accounted for 65.2% of primary energy consumption in Ghana and was dominated by oil and natural gas, with no coal consumption. Oil consumption accounted for 37.8% of fossil fuel-based primary energy consumption, and natural gas for 27.4%, slightly down from 2021. In addition, solar, wind and other renewable energy sources accounted for 6.4% of primary energy consumption, and biomass for 28.5%.

Characteristics of fossil fuel emissions

Among the carbon emissions from fossil energy consumption, petroleum products and natural gas consumption are the main sources of fossil energy carbon emissions in Ghana, accounting for 63.3% and 36.3% of fossil energy carbon emissions respectively in 2022. CO_2 emissions from petroleum products consumption have been on a rising trend from 2010 to 2022. It decreased slightly in 2019 and reached 12.7 Mt in 2022. Ghana has been actively promoting the use of natural gas; its CO_2 emissions from consumption are small in volume but growing fast, reaching 7.3 Mt in 2022.

Sectoral emission contribution

CO_2 emissions from fossil fuel consumption in Ghana mainly come from the transportation, storage and postal services sector. In 2022, the carbon emissions from fossil energy consumption in this sector were 10.0 Mt, accounting for 50.0% of the total fossil energy carbon emissions. The utility sector, the second largest CO_2 emitter, produced 7.0 Mt in 2022, an increase of 13.5% compared to 2021, reflecting rising demand in Ghana's power sector.

Biomass emissions

In 2022, Ghana's biomass consumption accounted for 28.5% of the primary energy consumption in Ghana, a slight increase in proportion, and was mainly used for residential sector. The main types of biomass in Ghana are wood and charcoal, which mainly come from forests. Excessive logging has led to reduced forest cover and forest degradation. The proportion of forest area has dropped from 44% in 1990 to 35% in 2020. Due to the long cycle of forest recovery, this way of biomass utilization is not renewable and sustainable within a certain period of time. Therefore, the country's biomass does not have a "zero carbon" attribute during the accounting period, and biomass and fossil energy consumption should be included in the overall carbon emissions in the national and regional carbon emission accounting. The carbon emissions generated by biomass consumption have generally shown an upward trend, from 13.8 Mt in 2010 to 15.1 Mt in 2022.

Emission trends

From 2010 to 2022, emissions from fossil energy consumption in Ghana increased rapidly from 10.2 Mt to 20.0 Mt. During this period, emissions from biomass consumption increased from 13.8 Mt to 15.1 Mt.

Comparison with international databases

Ghana's CO_2 emissions as calculated by various agencies show almost the same annual emission trends; differences in results are mainly caused by differences in accounting methods and basic data. Under the same accounting caliber (excluding emissions from biomass), emissions calculated by CEADs are close to the GCB data, with an error of about 0.3%. From 2018 to 2022, CEADs' emissions were slightly higher than the GCB results, with a gap of less than 10% (mainly due to data differences in petroleum products). The IEA's data source is the energy statistics of the Ghana Energy Commission, which is consistent with the data source of CEADs, with an error of about 7%. However, CEADs data was lower than EDGAR data between 2010 and 2022, with an error of between 10% and 17%.

When including the CO_2 emissions due to biomass consumption for 2022, data calculated by CEADs is 35.1 Mt.

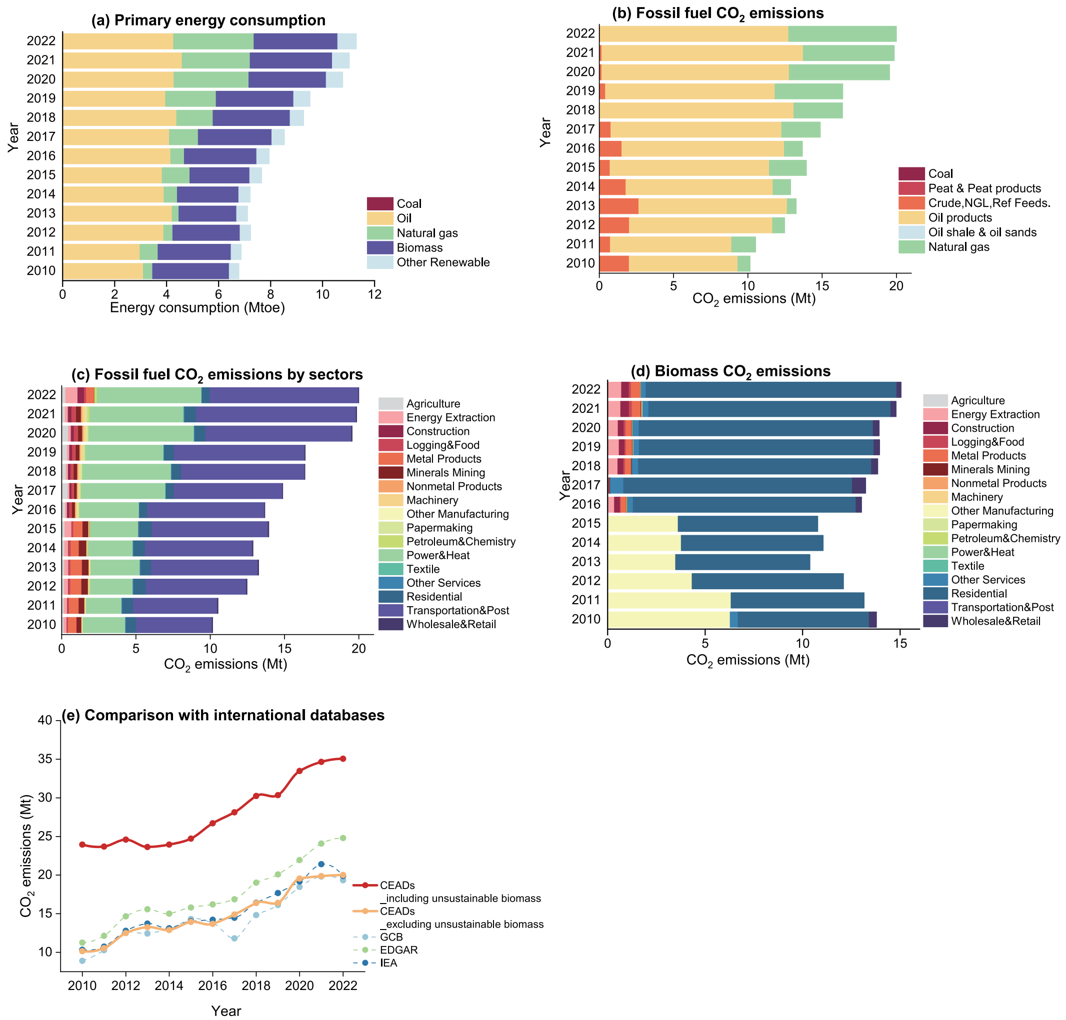


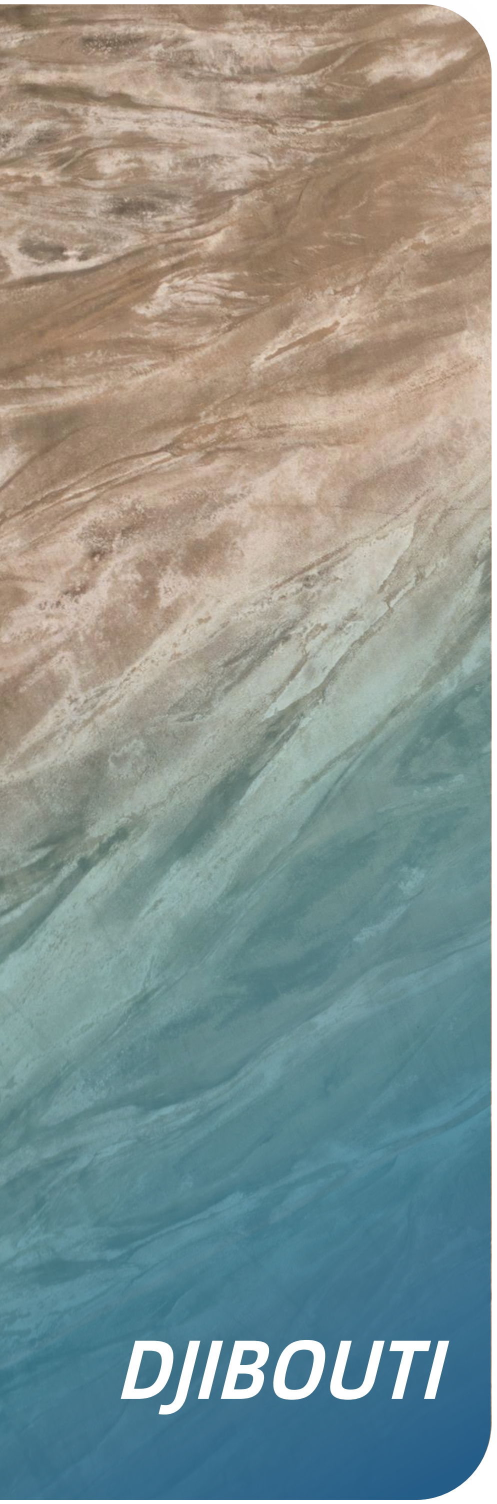
Figure 3.16: Ghana's energy consumption and CO_2 emissions from 2010 to 2022 (a) Primary energy consumption; (b) Fossil fuel CO_2 emissions; (c) Fossil fuel CO_2 emissions by sectors; (d) Biomass CO_2 emissions; (e) Comparison with international databases

Brief description of data sources:

The energy data used in this report is taken from the energy balance sheets provided by the Ghana Ministry of Energy for 2010-2022. The balance sheets contain primary and secondary energy processing and conversion data from 7 main types of fossil fuels consumed in Ghana, and energy consumption data from 6 major economic sectors. In terms of sub-sector matching, we used the UN data - value added by industries and export data in the UN Comtrade database to conduct downscaling matching of sectors and allocate them to 47 sectors.

Table 3.16: Data sources for Ghana's emission accounting

Data type	Source	Website
Energy balance sheet	Ghana Ministry of Energy	http://www.energycom.gov.gh/files
	AFREC	https://au-afrec.org/
Emission factor	IPCC	https://www.ipcc-nggip.iges.or.jp/efdb/
Sectoral mapping indicator	UN data - Value added by industries	http://data.un.org/Explorer.aspx#marts
	UN Comtrade data	https://comtradeplus.un.org/



Background

Strategically located at the mouth of the Red Sea in eastern Africa, Djibouti borders Eritrea, Ethiopia and Somalia by land and Yemen by sea. It is one of the smallest countries in Africa, and has a population of under 1 million. The country lacks natural resources and has little industrial activity; its economy is heavily dependent on logistics services and trade through its international ports. In 2022, Djibouti's GDP was US$3.7 billion at current prices, with the services sector accounting for approximately 77% of GDP.

Djibouti is poor in natural resources and has a weak industrial and agricultural foundation. More than 95% of agricultural products and industrial products rely on imports. Transportation, commerce and services (mainly port services) dominate the economy. In recent years, Djibouti has actively adjusted its economic policies, strived for foreign aid and foreign investment, focused on the development of the tertiary industry, stepped up infrastructure construction, and actively participated in the regional integration process. Djibouti makes full use of its strategic location, and port transit trade accounts for a large proportion. It has become Ethiopia's main maritime trade channel. In 2020, Djibouti handled more than 90% of Ethiopia's exports and imports. Djibouti's main exports include salt, fish, leather, spices, etc., and its main imports are oil, food, machinery and equipment, etc. Djibouti is still heavily dependent on electricity imported from Ethiopia, accounting for about 70% of its supply.

Djibouti is heavily dependent on electricity imports from Ethiopia, which account for 70% of its supply and thus pose an energy security risk for its economic and social development. In 2013, Djibouti embarked on an ambitious Vision 2035 plan to aggressively transition its electricity production to fully domestic renewable energy by 2035, in order to achieve an abundant, cheap and fully autonomous electricity supply. Since 2013, the country has actively partnered with countries such as Morocco, Spain, the United States and France to develop renewable energy sources such as geothermal, wind and solar energy to meet the growing demand for residential and industrial electricity, reduce external energy dependency and promote economic development and a clean energy transition[189]. In addition, the Djibouti government has committed to reducing its greenhouse gas emissions by 40% by 2030 compared to the baseline scenario, approximately 2 Mt CO_2.

Primary energy consumption

Djibouti's primary energy is dominated by biomass. In 2022, Djibouti's fossil energy consumption accounted for 38.0% of its primary energy consumption. The relatively homogeneous energy mix was dominated by oil; there was no consumption of coal or natural gas. In addition, the foundation of renewable energy is weak. Biomass accounted for 62.0% of the primary energy consumed.

Characteristics of fossil fuel emissions

Djibouti's fossil energy consumption is limited to petroleum products, and its carbon emissions from fossil energy consumption fell sharply in 2017, due to a sharp drop in oil consumption. Between 2010 and 2022, carbon emissions remained stable and then fell, and then continued to decline slowly, with a total of 0.5 Mt of carbon emissions in 2022, with an average annual growth rate of -2.0%.

Sectoral emission contribution

The sectors with the highest carbon emissions from fossil energy consumption in Djibouti are transportation, warehousing and postal services. Its carbon emissions from fossil energy consumption in 2022 were 0.32 Mt, accounting for 66.5% of total fossil energy carbon emissions; followed by the production of electricity, heat, gas and water, with fossil energy carbon emissions of 0.06 Mt in 2022. As Djibouti's total fossil energy consumption continues to decline, its fossil energy carbon emissions in various industries have continued to decline.

Biomass emissions

In 2022, Djibouti's biomass consumption accounted for 62.0% of the primary energy consumption, mainly used for household consumption. The main type of biomass in Djibouti is firewood, and excessive logging has led to reduced forest cover and forest degradation. Due to the long cycle of forest recovery, this way of biomass utilization is not renewable and sustainable within a certain period of time. Therefore, the country's biomass does not have a "zero carbon" attribute, and it should be included in the overall carbon emissions together with fossil energy consumption in the national and regional carbon emission accounting. The carbon emissions of biomass have generally maintained a steady growth, generating 1.2 Mt of carbon emissions in 2022.

Emission trends

Djibouti's emissions from fossil energy consumption decreased by 21.1% from 0.6 Mt to 0.5 Mt over the period 2010 and 2022. During this period, emissions from biomass consumption increased from 0.8 Mt to 1.2 Mt, continuing to rise.

Comparison with international databases

In terms of trends, the accounting results are broadly similar across agencies (especially after 2017), while differences in accounting methods and underlying data led to different results. The differences in accounting methods and basic data make the results different. The fossil energy carbon emissions calculated by CEADs are close to the GCB data, and the error after 2019 is within 7%. From 2010 to 2018, CEADs' emissions were slightly higher than GCB's results, with a difference of about 0.2 Mt.

In addition, when the carbon emission generated by biomass consumption is included, in 2022, CEADs' data is 1.7 Mt.

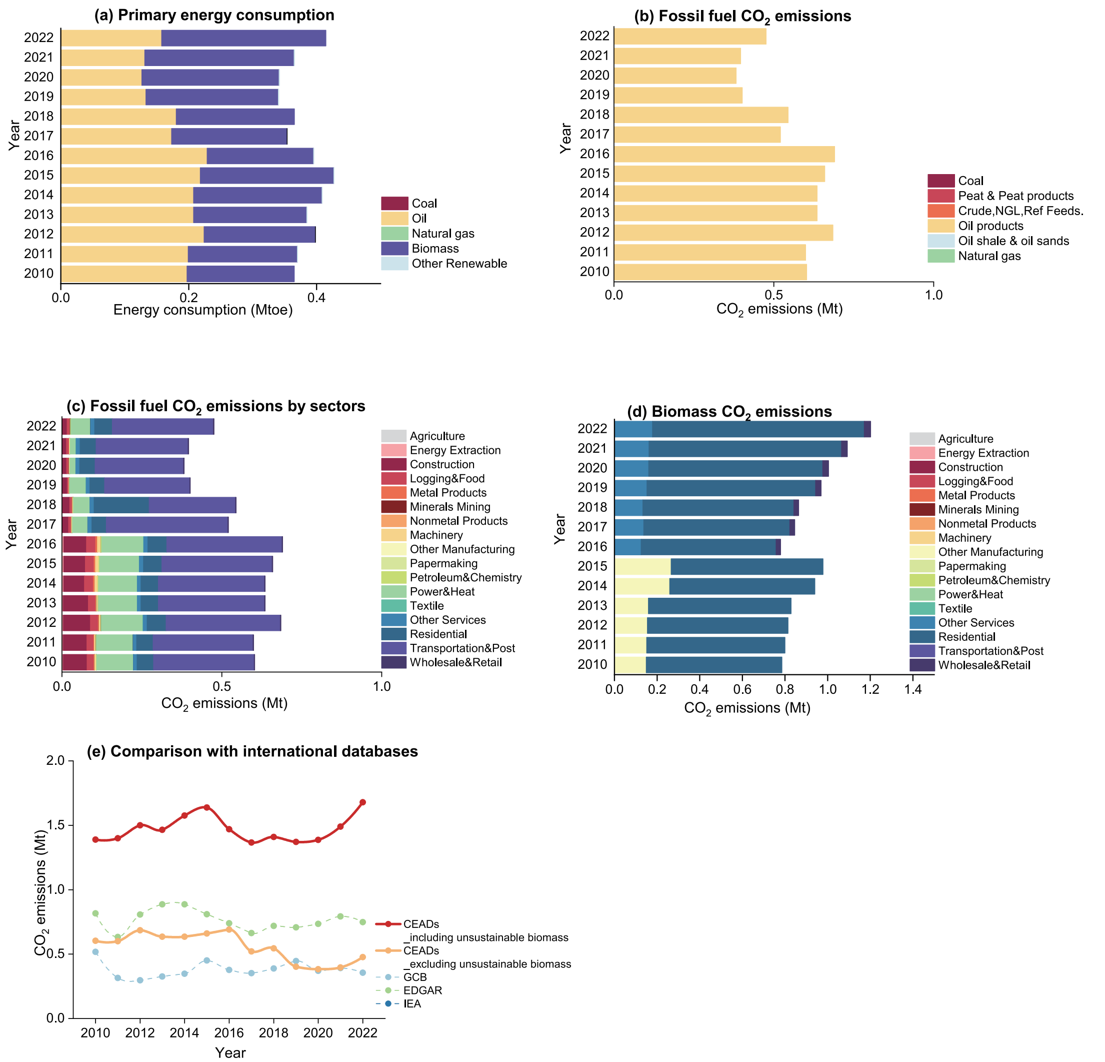


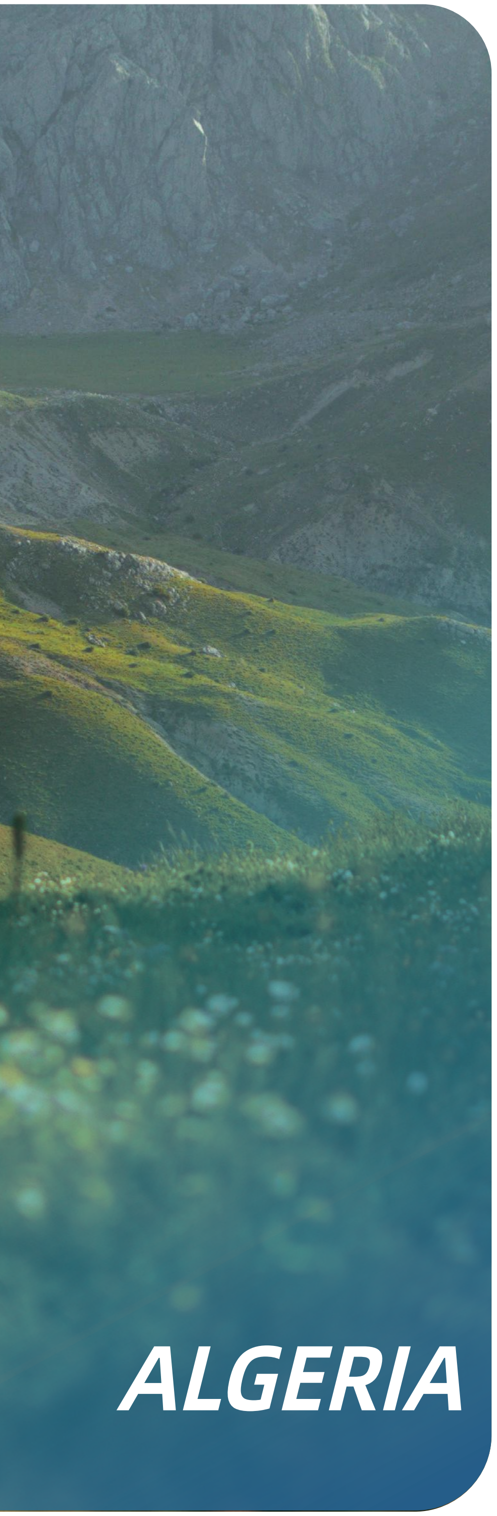
Figure 3.17: Djibouti's energy consumption and CO_2 emissions from 2010 to 2022 (a) Primary energy consumption; (b) Fossil fuel CO_2 emissions; (c) Fossil fuel CO_2 emissions by sectors; (d) Biomass CO_2 emissions; (e) Comparison with international databases.

Brief description of data sources:

The Djibouti energy balance sheet was obtained from the African Energy Commission website, which contains data on energy processing and conversion of nine primary and secondary energy types in Djibouti, as well as energy consumption data for seven major economic sectors.

Table 3.17: Data sources for Djibouti's emission accounting

Data type	Source	Website
Energy balance sheet	AFREC	https://au-afrec.org/en/energy-balances
Emission factor	IPCC	https://www.ipcc-nggip.iges.or.jp/EFDB/
Sectoral mapping indicator	UN Comtrade	https://comtrade.un.org/
	Djibouti National Accounts	http://www.insd.dj/accueil.php



Background

Algeria is sited in North Africa, bordering the Mediterranean Sea, along with Libya, Tunisia, Morocco and other countries. It is the largest country in Africa in terms of land area[190]. It is also one of the continent's largest economies, with a total GDP (at current rates) of $225.6 billion in 2022[191], Its population is currently 45.48 million[2].

Algeria is rich in natural gas and oil resources, with natural gas reserves ranking 10th in the world and oil reserves ranking 15th in the world. The natural gas and oil industries are the pillars of Algeria's national economy, accounting for 45.1% of the country's GDP in 2022, and their exports account for more than 90% of the country's total exports[190]. Algeria exports primarily to countries in the European Union and the United States. In addition to the natural gas and oil industries, the country's steel, metallurgy, machinery, electricity and other industrial sectors are underdeveloped, and the contribution of manufacturing to GDP in 2022 was only 5.2%. Algeria's agricultural scale is large, accounting for about 12% of the country's GDP in 2022, but the grain self-sufficiency rate is low, and grain, milk, oil, sugar, etc. rely on imports. The main importing countries are France, Germany, the United States, etc.

Since 86% of the country's land area is taken up by part of the Sahara Desert, Algeria is rich in solar and wind energy resources. According to the United Nations Framework Convention on Climate Change (UNFCCC), Algeria has committed in its Intended Nationally Determined Contributions (INDC) to reduce national greenhouse gas emissions by 7% to 22% compared with 2010 by 2030, and to generate 27% of its electricity from renewable energy sources.

Primary energy consumption

Algeria's primary energy structure is dominated by natural gas and oil. In 2022, natural gas accounted for 64.8% of primary energy consumption, and oil for 35.0%. In addition, renewable energy such as solar energy accounted for 0.1% of primary energy consumption; the proportion of biomass energy in the primary energy structure was very small.

Characteristics of fossil fuel emissions

Among all emissions from fossil fuel consumption, those from natural gas and oil dominate. Natural gas, as Algeria's main fossil energy source, produced a total of 86.7 Mt of carbon emissions in 2022. Petroleum produced a total of 57.1 Mt of carbon emissions in 2022. Since 2010, the share of emissions from natural gas products in the total emissions from fossil fuels has gradually increased, from 46.3% in 2010 to 59.4% in 2022, while those from petroleum products has gradually decreased over that period, from 50.5% to 39.1%.

Sectoral emission contribution

The largest carbon emissions in Algeria come from the transportation, warehousing and postal sectors. In 2022, carbon emissions generated by this sector were 46.1 Mt, accounting for 31.5% of Algeria's total fossil energy carbon emissions. Following closely is the production of electricity, heat, gas and water, which is the second largest fossil energy carbon emission sector in Algeria in recent years, generating a total of 42.5 Mt of carbon emissions in 2022, accounting for 29.1% of the total fossil energy carbon emissions. The third largest fossil energy carbon emission sector is residential sector, which generated carbon emissions of up to 26.3 Mt in 2022 from the consumption of fossil energy.

Biomass emissions

In 2022, biomass energy accounted for far less than 0.02% of Algeria's primary energy consumption. The main types of biomass in Algeria are firewood and charcoal, which has led to over-logging of forests, resulting in reduced forest cover and forest degradation. The cycle of forest recovery is long, and this way of using biomass is not renewable and sustainable within a certain period of time. Therefore, the country's biomass does not have a "zero carbon" attribute, and biomass and fossil energy consumption should be included in the overall carbon emissions in national and regional carbon emission accounting. Carbon emissions from biomass are generally on a downward trend, from 0.0431 Mt in 2010 to 0.004 Mt in 2022.

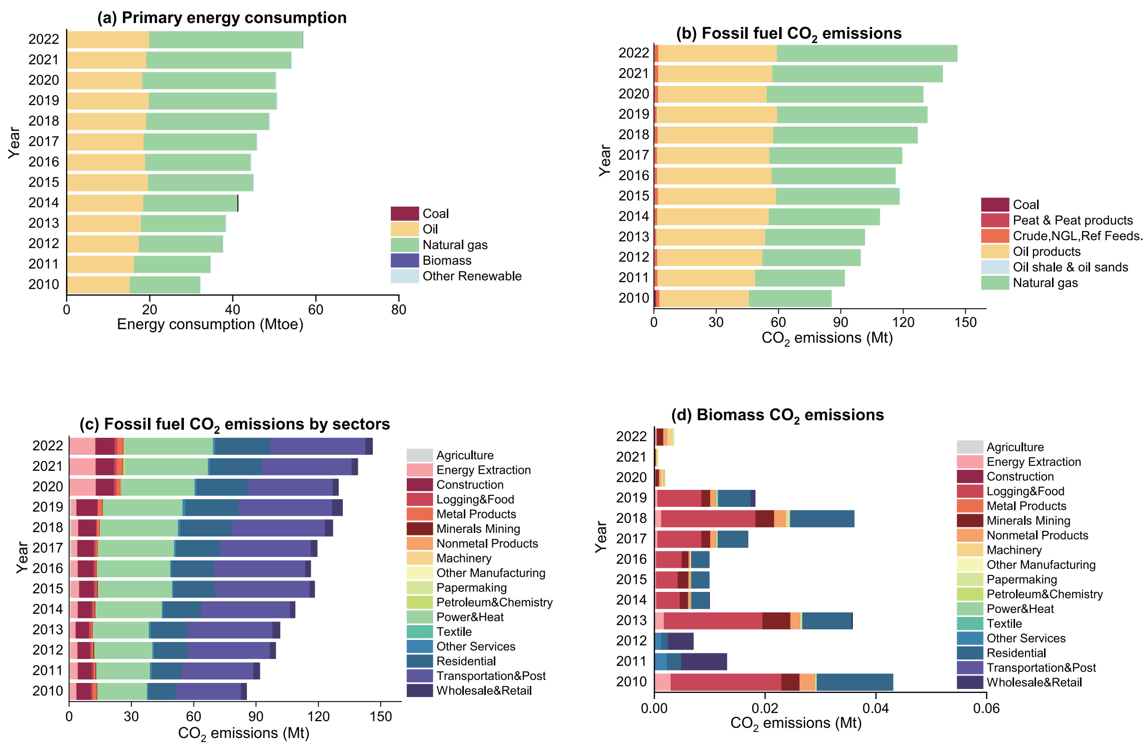
Emission trends

Carbon emissions from fossil fuel consumption increased by 70.9% from 85.4 Mt to 146.1 Mt between 2010 and 2022. During this period, carbon emissions from biomass consumption decreased from 0.0431 Mt to 0.004 Mt.

Comparison with international databases

Under the unified accounting caliber, when biomass carbon emissions are not included, the fossil energy carbon emissions calculated by CEADs are roughly similar to the results released by GCB, EDGAR and IEA. The differences in accounting methods and basic data make the results different every year. Among them, EDGAR has the highest fossil energy carbon emissions; the fossil energy carbon emissions of IEA and GCB are close, and the difference with CEADs data is about 15%. When comparing the fossil energy carbon emissions of CEADs and IEA by industry, there are differences in the results. For example, in 2013, the fossil energy carbon emissions of CEADs were 101.5 Mt, while the data of IEA was 115.8 Mt, a gap of 14.2%. One of the main reasons for this difference lies in the emission factors. CEADs has a more detailed energy classification, while IEA's statistical caliber for energy varieties is relatively rough. The second reason is the energy consumption data for each sector. For example, IEA statistics lack the energy use data of the agricultural sector, and the data of other unclassified industries are different from those in the official energy balance sheets, thus resulting in different accounting results.

In addition, when emission produced by biomass consumption is included, the CEADs accounting data is 146.1 Mt in 2022.



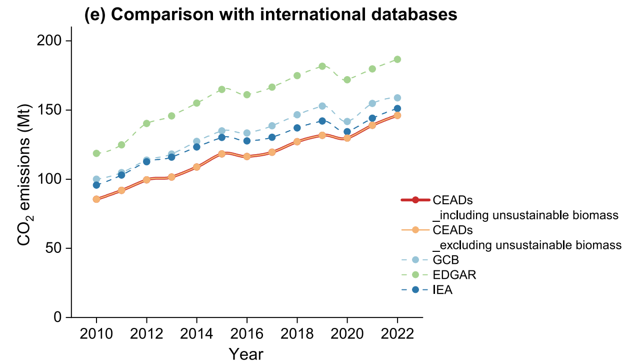


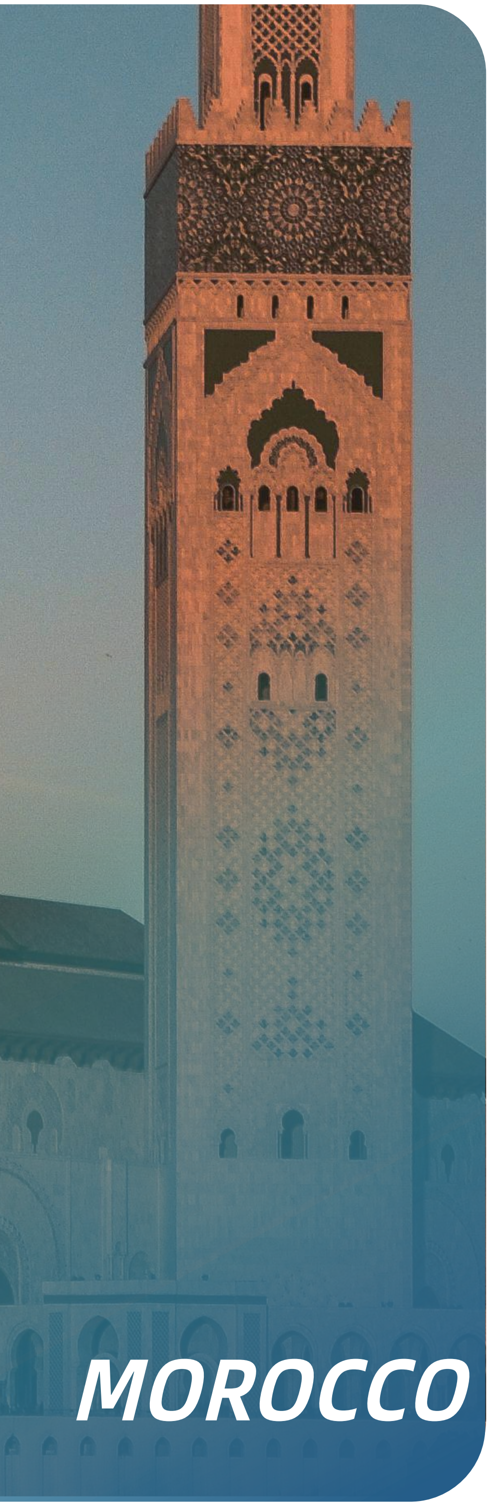
Figure 3.18: Algeria's energy consumption and CO_2 emissions from 2010 to 2022 (a) Primary energy consumption; (b) Fossil fuel CO_2 emissions; (c) Fossil fuel CO_2 emissions by sectors; (d) Biomass CO_2 emissions; (e) Comparison with international databases.

Brief description of data sources:

Algeria's energy balance sheets are all from the Ministry of Energy and Mines, covering 2010-2022 data, and involving 22 energy types and 16 sectors. Among them, for sub-sector matching, we use export data from the UN Comtrade and Algeria's own sectoral data as the basis for distribution, to downscale the sectors and assign to 47 departments.

Table 3.18: Data sources for Algeria's emission accounting

Data type	Source	Website
Energy balance sheet	Ministry of Energy and Mines	http://www.energy.gov.dz/
Emission factor	IPCC	https://www.ipcc-nggip.iges.or.jp/EFDB/
Sectoral mapping indicator	Algeria Bureau of Statistics	https://www.ons.dz/
	UN Comtrade，export data	https://comtradeplus.un.org/



Background

Morocco is located in the northwestern tip of Africa, bordering Algeria in the east and southeast, Western Sahara in the south, the Atlantic Ocean in the west, and the Strait of Gibraltar in the north. Its coastline is more than 1,700 kilometres long, and its land area is some 459,000 square kilometres. In 2022, its population was 36.67 million [192]. Morocco's economic aggregate (2022) ranks it fifth in Africa (after Nigeria, Egypt, South Africa and Algeria) and third in North Africa[193]. In 2022 GDP (at current rates) was some US$131.0 billion[194].

Phosphate exports, tourism and remittances are the pillars of Morocco's economy. Agriculture accounted for about 9.3% of total GDP in 2022, but the country is not self-sufficient in food. Fishery resources are rich and the output ranks first in Africa, but the overall value of fisheries accounts only for about 0.5% of total GDP. The services sector is more developed, accounting for 54.6% of GDP in 2022, with a high output of automotive trade and maintenance.

Phosphate is Morocco's main resource, with an estimated reserve of 110 billion tonnes, accounting for 75% of the world's reserves. The country's other mineral resources are iron, lead, zinc, cobalt, manganese, barium, copper, salt, magnetite, anthracite and oil shale. Moroccan oil shale reserves stand at more than 100 billion tons and contain 6 billion tons of crude oil. However, energy resources are relatively scarce and currently, more than 95% of basic energy is imported.

Morocco trades with more than 90 countries and regions, and primarily with European countries, which account for about 70% of total imports and exports. Spain and France are Morocco's most important trading partners. Its export products are primarily electrical, transportation equipment, non-knitted clothing, fertilizers, inorganic chemicals and building materials. Morocco exports mainly to Spain, France and Italy. Its key imports are mineral fuels, mechanical and electrical products, machinery and equipment, transportation equipment and grain. It imports mainly from Spain, France and China[193].

Morocco is rich in wind energy and solar energy resources. The government is actively developing renewable energy, has formulated a renewable energy development strategy, and it further aims to increase this to 52% by 2030, and achieve the goal that 100% of the total installed capacity of new energy by 2050. The Noor Ouarzazate Solar Complex now under construction is the largest project in the country and the largest solar power plant under construction with the largest installed capacity in the world[193]. According to the United Nations Framework Convention on Climate Change (UNFCCC), Morocco has set a goal of meeting 42% of its energy needs from renewable resources by 2020, and formally submitted its Intended Nationally Determined Contributions (INDC) in 2015.

In 2021, the Moroccan government emphasized at the Middle East Green Initiative (MGI) summit held in Saudi Arabia that it will actively implement its commitments in the Paris Agreement, and formulated a comprehensive strategy to achieve low-carbon economic development by 2050. The new government of Morocco has committed to renewable energy accounting for more than 52% of the national energy structure by 2025, five years earlier than before.

Primary energy consumption

Morocco's primary energy consumption is dominated by petroleum products. In 2022, consumption of petroleum products accounted for 58.5% of total energy consumption, coal for 30.9% and natural gas for 0.9%, for a total share of 90.3%. In addition, biomass accounts for 5.6% of primary energy consumption, and other renewable energy sources such as wind and solar energy account for 4.1% of the primary energy consumption structure.

Characteristics of fossil fuel emissions

The CO_2 emissions generated by fossil fuel consumption in Morocco in 2022 stood at about 63.7Mt. Emissions from the consumption of petroleum products are around 37.0 Mt, accounting for 58.1% of total CO_2 emissions from fossil energy. These were followed by the CO_2 emissions from the consumption of coal and natural gas, which accounted for roughly 41.2% and 0.7%, respectively. Overall, CO_2 from fossil energy consumption in Morocco increased year by year from 2010 to 2022, from 8.5 million tonnes in 2010 to 26.3 million tonnes in 2022.

Sectoral emission contribution

The production of electricity, heat, gas, and water sector is Morocco's largest in terms of CO_2 emissions. In 2022, the CO_2 emissions generated by the consumption of fossil fuels in this sector were close to 29.9 Mt, or 46.9% of Morocco's overall emissions from fossil energy. This is an increase from 35.7% in 2010. Secondly, Morocco's fossil energy CO_2 emissions come from the transportation, warehousing, and postal sector In 2022, the CO_2 emissions generated by the consumption of fossil fuels in this industry were close to 17.4 Mt, accounting for 27.3% of Morocco's total CO_2 emissions from fossil fuels. Next, fossil fuel CO_2 emissions from the residential sector are much smaller: among them, CO_2 emissions generated through fossil fuel consumption by the residential sector in 2022 were about 7.7 Mt, or 12.1% of the total.

Biomass emissions

Moroccan biomass, which is primarily used for home use, made up 5.6% of the country's primary energy consumption structure in 2022. Wood and charcoal, which primarily come from woods, make up the majority of Morocco's biomass species. Deforestation and reduced forest cover are results of excessive logging. This biomass utilization method is not renewable and sustainable beyond a given amount of time due to the lengthy cycle of forest restoration. As a result, throughout the accounting period, the country's biomass did not have a "zero-carbon" attribute, and the country's and region's CO_2 emission accounting should account for the combustion of biomass and fossil fuels in total CO_2 emissions. The consumption of biomass results in an increase in CO_2 emissions overall, from 2 Mt in 2010 to 5.6 Mt in 2022.

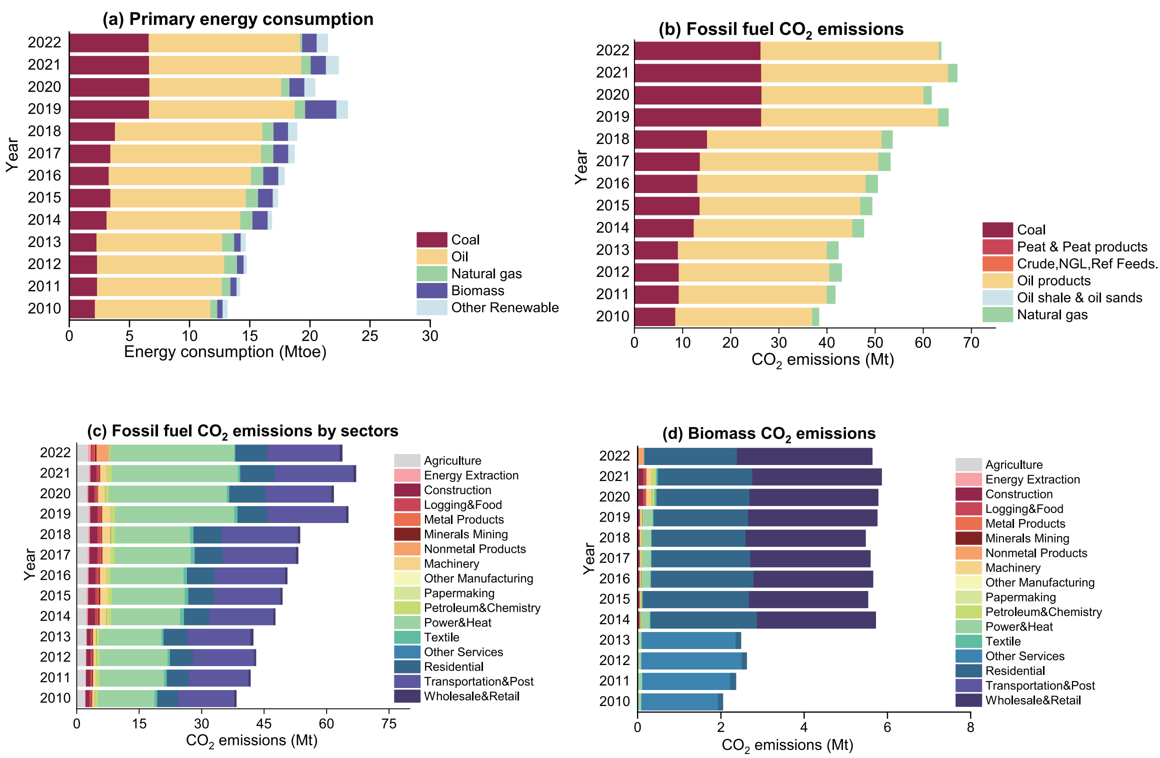
Emission trends

Morocco's CO_2 emissions are on a clear upward trend. Between 2010 and 2022, CO_2 emissions from fossil fuel consumption increased from 38.3 Mt to 63.7 Mt in 2022. During this period, CO_2 emissions from biomass consumption increased from 2.0 Mt in 2010 to 5.6 Mt in 2022.

Comparison with international databases

Under the same accounting caliber (excluding emissions from biomass), CEADs' calculation of total CO_2 emissions in 2022 was 63.7 Mt; IEA's was 66.8 Mt, EDGAR's 70.3 Mt and GCB's 64.4 Mt. The trend changes of CEADs' fossil energy carbon emissions data are similar to the trends of IEA, GCP and EDGAR. The value is similar to that of IEA and GCB, while the value of EDGAR is generally higher than the value calculated by the GCB, IEA, and CEADs teams. Additionally, the difference between CEADs and IEA has shrunk as of 2019 and the accounting findings are essentially consistent. The disparity in the overall quantity of outcomes is relatively insignificant, approximately 5% or lower. The main cause of the discrepancy is the quality of the statistical data. For instance, CEADs uses the energy balance sheets from the African Energy Commission's statistical yearbook, but the IEA uses information from the annual energy questionnaire.

In addition, when CO_2 emissions from biomass consumption are included, the CO_2 emission data calculated by CEADs in 2022 is 69.4 Mt.



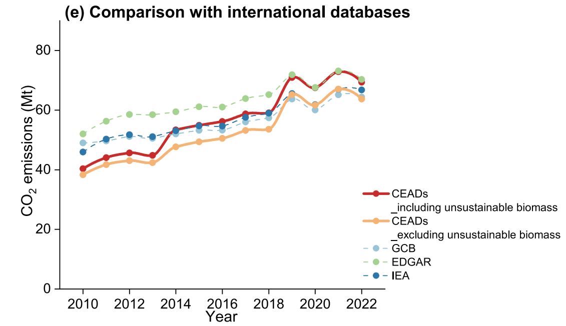


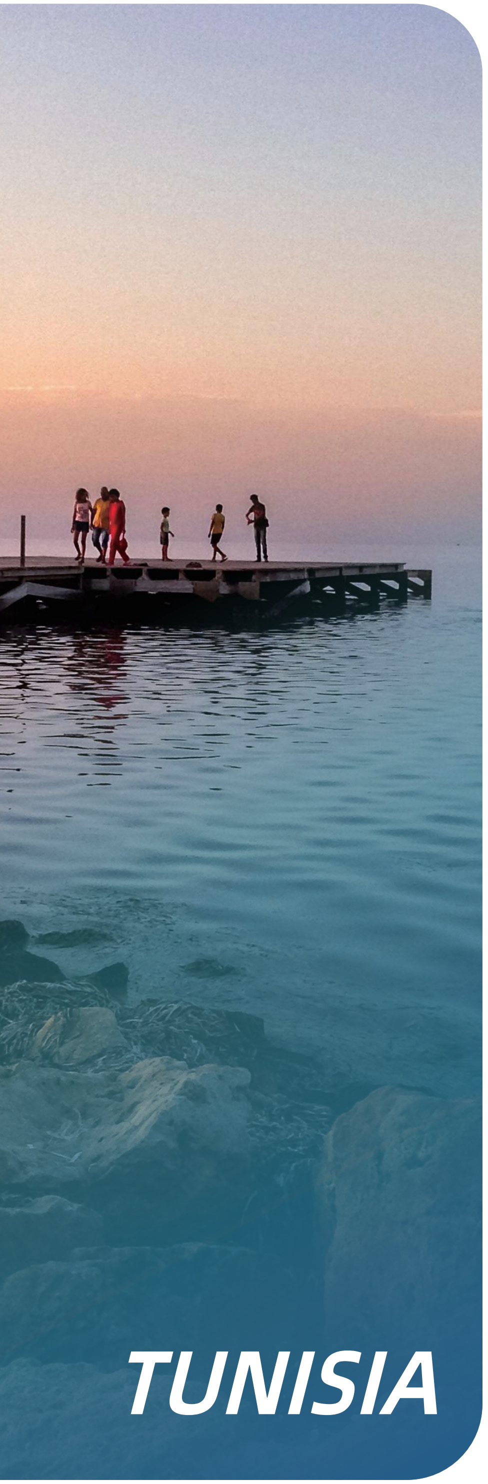
Figure 3.19: Morocco's energy consumption and CO_2 emissions from 2010 to 2022 (a) Primary energy consumption; (b) Fossil fuel CO_2 emissions; (c) Fossil fuel CO_2 emissions by sectors; (d) Biomass CO_2 emissions; (e) Comparison with international databases.

Brief description of data sources:

African Energy Commission (AFREC) energy balances for Morocco cover 2010–2022. For subsector matching, we use export data from the UN Comtrade and Morocco's own subsectoral data as the basis for distribution, allocating it to 47 sectors through downscaling.

Table 3.19: Data sources for Morocco's emission accounting

Data type	Source	Website
Energy balance sheet	AFREC	https://au-afrec.org/publication/african-energy-balance-and-indicators-2021
Emission factor	IPCC	https://www.ipcc-nggip.iges.or.jp/EFDB/
Sectoral mapping indicator	Statistical Office of Morocco	https://www.hcp.ma/
	UN Comtrade，export data	https://comtradeplus.un.org/



Background

Tunisia is located in northern Africa, bordering Algeria and Libya, with the Mediterranean Sea to the north and east. It lies in the middle of the Mediterranean Sea Route, a prime route for oil shipments from the Middle East to western Europe and the United States. Tunisia has a land area of 160,000 square kilometres and a population (in 2022) of about 12.2 million[195]. Its development has been limited to some degree due to its location, sandwiched between two regional powers, Libya and Algeria. In recent years, civil strife and social unrest have hit Tunisia and a number of its industries have collapsed. Its level of economic development has left it lagging behind other Arab countries. In 2022, its total GDP at current prices was US$48.5 billion.

Olive cultivation is key to Tunisia: it is one of the major olive oil producers and exporters in the world. Its mineral resources are also relatively rich, and include phosphate, oil, natural gas, iron, aluminum and zinc. Industry, agriculture and services form the three pillars of the Tunisia economy[196].

Industry is dominated by phosphate mining, processing and textiles, while agriculture is inevitably dominated by olive cultivation. In terms of the service industry, tourism plays an important role in Tunisia. In terms of international trade, olive oil is Tunisia's main export agricultural product, although electronic machinery and textiles are also key exports. France, Italy and Germany are its top three export markets. Tunisia imports primarily energy, electromechanical equipment, automobiles, cotton, and agricultural and food processing products. It imports mainly from Italy, France and China[197].

Tunisia is rich in solar and wind energy. To reduce external energy dependence and mitigate the socioeconomic impact of climate change on the country, the Tunisian government plans to increase the ratio of renewable energy generation to 30% by 2030. In 2017, the government completed the first round of 70 MW photovoltaic bidding, and in December 2019, the state completed the first 500 MW photovoltaic bidding plan. In 2019, Tunisia launched the construction of 10 photovoltaic power station projects, each with a power generation capacity of 10 MW, and a single power station investment of 30 million dinars, which will be completed in 2020 to generate electricity[198, 199].

Primary energy consumption

Tunisia's primary energy consumption is dominated by natural gas. In 2022, it accounted for 52.5% of primary energy consumption, and oil for 37.8%, making the contribution of fossil fuel as a whole 90.3% of the total. Biomass meanwhile accounted for 8.5%, with other renewable energy sources such as solar and wind contributing 1.2%.

Characteristics of fossil fuel emissions

The consumption of petroleum and natural gas are the main sources of CO_2 emissions from fossil fuels in Tunisia. Petroleum products generated a total of 11.4 Mt of CO_2 emissions in 2022, accounting for 47.7% of the total from fossil fuels. Natural gas generated 12.5 Mt of CO_2 emissions in 2022, accounting for 52.3%. In terms of trends, CO_2 emissions from natural gas consumption increased from 11.4 Mt in 2010 to 12.5 Mt in 2022, at a stable rate of growth.

Sectoral emission contribution

The utility sector is the largest CO_2-emitting sector in Tunisia. In 2022, CO_2 emissions from the consumption of fossil fuels in this sector were 8.6 Mt, accounting for 36.1% of the total of such emissions in Tunisia. In 2022, CO_2 emissions from the consumption of the transport, storage and postal sector generated 8.1 Mt of carbon emissions, accounting for 34.0% of such emissions. The third is the residential sector, which accounted for 9.7% of CO_2 emissions from fossil fuel consumption.

Biomass emissions

Biomass in Tunisia accounted for 8.5% of primary energy consumption in 2022 and is mainly used in the residential sector and in wholesale, retail and other service industries. Biomass types mainly include agricultural residues (from grain, fruit and vegetables), charcoal and fuelwood, accounting for 16.4%, 18.9% and 64.7% of the biomass energy structure, respectively. By cutting fuelwood, burning charcoal for home cooking and heating, and using wood in the commercial service industry, locals use wood-based biomass unsustainably; so, CO_2 emissions should be included in the overall carbon accounting process. Agricultural residues, however, originate on local plantations and are regarded as sustainable renewable resources with a "zero carbon" life cycle. These should not be included in the emissions system during the overall carbon accounting process. From 2010 to 2022, in terms of the overall time trend, carbon emissions from fuelwood and charcoal consumption remained stable at 3.1-3.9 Mt.

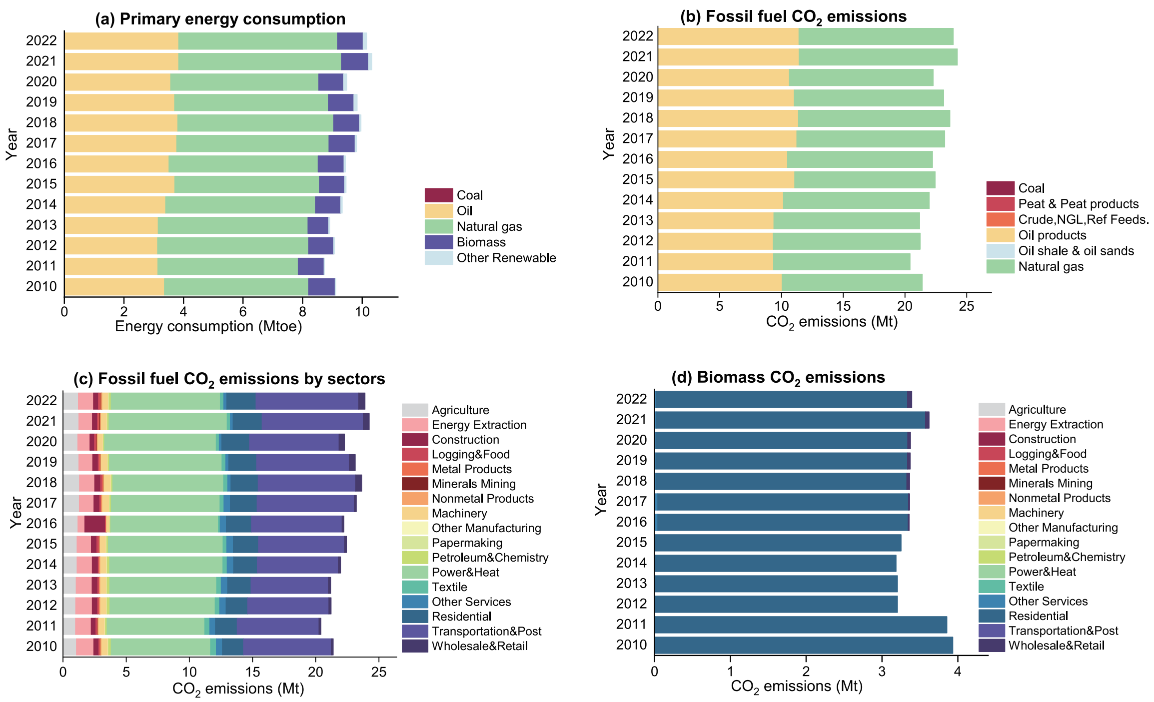
Emission trends

Tunisia's CO_2 emissions fluctuate from year to year, but the overall trend is a gentle upward trend, mainly from the increase in carbon emissions from fossil fuels. Between 2010 and 2022, carbon emissions from fossil fuel consumption remained basically flat, from 20.4 Mt to 24.2 Mt in 2022. In 2010 and 2022, CO_2 emissions from biomass consumption in Tunisia were 3.9 Mt and 3.4 Mt.

Comparison with international databases

Under the same accounting caliber (excluding emissions from biomass), CEADs' calculations for CO_2 emissions in Tunisia show almost the same annual emission trends as those from other agencies. Differences in accounting methods and basis render results different. The IEA estimate of Tunisia's 2022 total fossil fuel carbon emissions was 26.4 Mt, compared to CEADs' 23.9 Mt estimate; this represents a discrepancy of roughly 9.5%. The GCB database shows 27.2 Mt, while the EDGAR database shows 30.5 Mt, also slightly off. According to the findings, the primary causes of the discrepancies are, first, variations in the statistical quality and, second, variations in certain EDGAR energy consumption data when compared to the energy balance table made public by the African Energy Commission, which leads to disparate accounting outcomes.

In addition, when the CO_2 generated by biomass consumption is included, the CO_2 emissions data calculated by CEADs in 2022 is 27.3Mt.



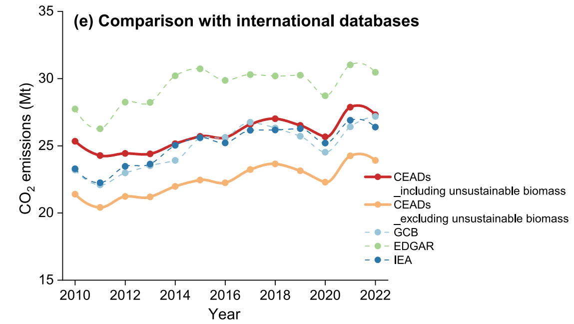


Figure 3.20: Tunisia's energy consumption and CO_2 emissions from 2010 to 2022 (a) Primary energy consumption; (b) Fossil fuel CO_2 emissions; (c) Fossil fuel CO_2 emissions by sectors; (d) Biomass CO_2 emissions; (e) Comparison with international databases.

Brief description of data sources:

Tunisia's energy balance sheets are all from the African Energy Commission (AFREC), covering 2010-2022 data and involving a total of 17 energy varieties and 6 sectors, extrapolation based on economic indicators in 2020. Among them, in terms of sub-sector matching, CEADs used the output data of various industrial, agricultural, service and construction sectors published by the National Bureau of Statistics and export data from the UN Comtrade as the allocation basis, and allocated them to 47 departments.

Table 3.20: Data sources for Tunisia's emission accounting

Data type	Source	Website
Energy balance sheet	AFREC	https://au-afrec.org/en/energy-balances
Emission factor	IPCC	https://www.ipcc-nggip.iges.or.jp/EFDB/
Sectoral mapping indicator	Tunisia Bureau of Statistics (GDP statistics by industry)	http://www.ins.tn/en/statistiques/75
	UN Comtrade	https://comtradeplus.un.org/

Background

Egypt, in the northeast of Africa, sits at the hub of three continents — Europe, Asia and Africa. It borders Sudan to the south; Libya to the west; the Red Sea, with Palestine and Israel, to the east; and the Mediterranean Sea to the north. With a population of 109 million, Egypt is the most populous country in North Africa and the Arab world, and is one of the few middle-power countries on the African continent, with particularly extensive influence in the Mediterranean and Middle East. The country's GDP (at current rates) in 2022 was US$476.7 billion.

Egypt's economy is mainly dependent on agriculture, oil exports, tourism and labour exports. The service industry in Egypt is relatively developed, accounting for about 54% of total GDP in 2022; agriculture accounts for 12%; and industrial output value accounts for 35%. Egypt's key natural resources include oil, natural gas, iron ore and phosphates. In terms of international trade, its export products are mainly coffee, tea, leather and tin, and its main exporting countries are the United Arab Emirates, Kenya and Switzerland. Its prime imports are food, machinery and equipment, steel, petrochemical products, cement and building materials, and are mainly imported from China, Uganda and India[200].

Egypt has relatively abundant hydropower resources; the Nile River, for instance, is an impressive source of hydroelectric power. The Aswan High Dam Power Station, completed and put into operation in 1970, has an installed capacity of 2,000 MW. But Egypt's booming population and growing demand for energy have forced the government to build more thermal power plants. Many of them are fueled by the country's rich natural gas reserves, which in 2018 supplied about four-fifths of the country's electricity.

To mitigate the socioeconomic impact of climate change in the country, Egypt plans to increase the supply of electricity from renewable energy sources to 20% by 2022 and 42% by 2035, of which 14% will be from wind, 2% from hydro, and 22% from photovoltaics electricity generation (PV) and concentrated solar power (CSP) accounts for 3%, with the private sector expected to provide most of the capacity[201]. Egypt has not given clear and quantified emission reduction goals in its Intended Nationally Determined Contributions (INDC), but has only committed to low-carbon policies such as the transition to clean energy.

Primary energy consumption

The primary energy structure of Egypt is dominated by natural gas and oil. In 2022, coal accounted for 4.7% of primary energy consumption, oil for 34.2% and natural gas for 58.6%; the total consumption of fossil fuel accounted for about 97.6%. In addition, wind energy, solar energy and other renewable energy accounted for 2.4% of primary energy supply.

Characteristics of fossil fuel emissions

Among all CO_2 emissions from fossil fuel consumption, those from petroleum products and natural gas dominate in Egypt. The country's most important fossil fuel, natural gas, produced 124.8 Mt of CO_2 emissions in 2022, accounting for 52.6% of fossil fuel emissions. CO_2 emissions from petroleum products consumption decreased, from 97.7 Mt in 2010 to 95.3 Mt in 2022.

Sectoral emission contribution

The utility sector is responsible for most CO_2 emissions from fossil fuel consumption in Egypt. In 2022 the sector accounted for 88.1 Mt CO_2 emissions, accounting for 37.2% of the country's total. The proportion gradually increased from 2010, but decreased slightly and remained stable after 2015. In 2022, the transport, storage and postal sector meanwhile accounted for 24.4% of total fossil fuel carbon emissions, mainly through its use of diesel, gasoline and fuel oil. Furthermore, the process of extracting energy is a significant contributor to carbon emissions from fossil fuels, amounting to 13.2% of total emissions.

Emission trends

Egypt's CO_2 emissions are growing rapidly. Between 2010 and 2022, CO_2 emissions from fossil fuel consumption increased by 49.2%, from 159.0 Mt to 237.2 Mt.

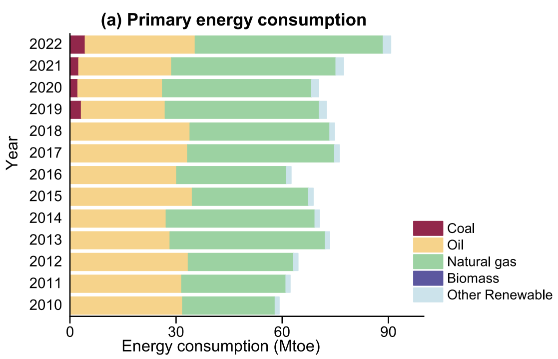
Comparison with international databases

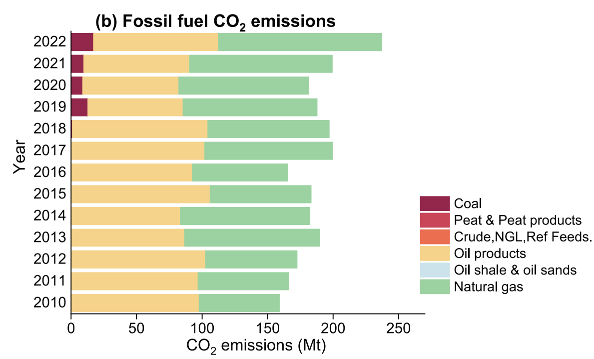
In terms of trends, the accounting results are broadly similar across agencies (especially after 2017), while differences in accounting methods and underlying data led to different results. The differences in accounting methods and basic data make the results different. The fossil energy carbon emissions calculated by CEADs are close to the GCB data, and the error after 2019 is within 7%. From 2010 to 2018Under the same accounting caliber (excluding emissions from biomass), CEADs' carbon accounting result is 237.2 Mt, which is about 8.9% higher than IEA's (217.8 Mt), 4.0% lower than EDGAR's (247.2 Mt) and 4.7% lower than GCB's (248.9Mt).

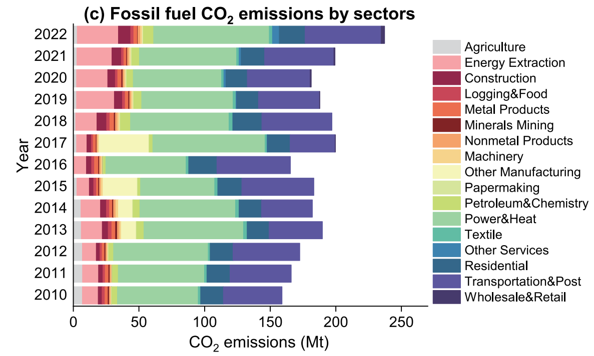
When comparing the carbon emissions of CEADs and IEA by energy type, the results are different. The central reason for the difference lies in the different sources of energy consumption data used. CEADs uses the energy consumption data of the African Energy Commission, while IEA uses multiple data sources, including the Egypt Central Bureau of Statistics, Egypt Gas Holding Company and Egypt Electricity Statistical Annual Report.

There are subtle differences between the agencies' energy consumption statistics. For example, in 2016, IEA estimated that the total final consumption of coal products in Egypt was 84 kilotonnes of oil equivalent. The data from the Egypt Central Bureau of Statistics used by CEADs, however, showed the figure as 136 kilotonnes. Another reason for such differences lies in emission factors. CEADs have a more detailed energy classification, listing hard coal, lignite and coke under the coal category, while the IEA has a rough statistical caliber of energy types. Therefore, the emission factors adopted by IEA are different from those used by CEADs and lead to differences in emission data., CEADs' emissions were slightly higher than GCB's results, with a difference of about 0.2 Mt.

In addition, when the carbon emission generated by biomass consumption is included, in 2022, CEADs' data is 1.7 Mt.







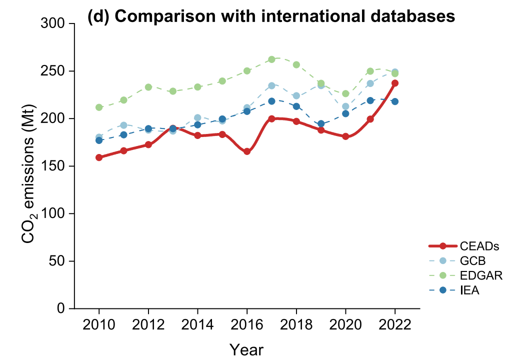


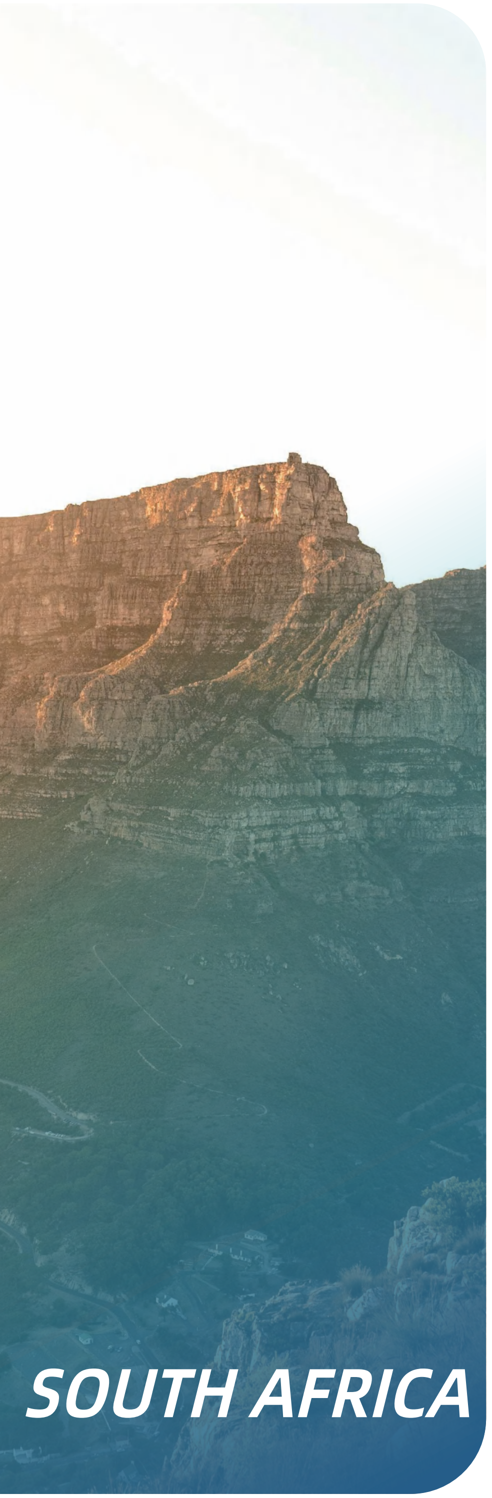
Figure 3.21: Egypt's energy consumption and CO_2 emissions from 2010 to 2022 (a) Primary energy consumption; (b) Fossil fuel CO_2 emissions; (c) Fossil fuel CO_2 emissions by sector; (d) Comparison with international databases.

Brief description of data sources:

Egypt's energy balance sheets come from the African Energy Commission, involving 8 energy types and 6 sectors. For the rest of the sectors, we utilise the value added and export data of the sector obtained from the UN data and UN Comtrade, and downscales the sectors and assigns to 47 sectors.

Table 3.21: Data sources for Egypt's emission accounting

Data type	Source	Website
Energy balance sheet	AFREC	https://au-afrec.org/data-statistics-energy-balances
Emission factor	IPCC	https://www.ipcc-nggip.iges.or.jp/EFDB/
Sectoral mapping indicator	UN data - Value added by industries	http://data.un.org/Explorer.aspx#marts
	UN Comtrade	https://comtradeplus.un.org/



Background

South Africa is located at the southernmost tip of Africa, at the intersection of the South Atlantic and the South Indian Ocean, bordering Namibia, and with Botswana and Zimbabwe to the north, and Mozambique and Swaziland to the northeast. According to World Bank data, South Africa's population in 2022 was 62.37 million and its GDP is US$40.69 billion [202].

South Africa has comparative advantages in agriculture, mining and production of related products. The country's economic focus has shifted to services, which account for 65% of GDP and are valued at an estimated $230 billion. Mining has been the central economic activity in South Africa's history and development, and the country remains a world leader in mining and processing minerals. Although the mining industry's share of GDP fell from 21% in 1970 to 6% in 2011, it still accounts for nearly 60% of total exports. The country's primary exports are corn, diamonds, fruits, gold, metals, minerals, sugar and wool. Meanwhile, machinery and transportation equipment accounted for more than a third of the country's import value, along with other imports such as chemicals, manufactured goods and petroleum[203].

Renewable energy such as wind and solar has great development potential in South Africa. In terms of climate policy, the European Union (EU) and South Africa have maintained a strategic partnership since 2007, adopting an action plan on the partnership that year. At the annual EU-South Africa summit and at the consultation meetings of the United Nations Climate Conferences, climate issues are discussed at the highest political level. As the chairman of the Group of 77 and China (G77+China) — the intergovernmental organization of developing countries — South Africa played a key role in passing the historic 2015 Paris Agreement.

Primary energy consumption

In 2022, South Africa's fossil fuel consumption accounted for 86.3% of primary energy consumption, and was dominated by coal. In 2022, coal accounted for 67.7% of primary energy consumption, oil for 17.1% and natural gas for 1.6%. Renewable energy sources such as solar and wind meanwhile accounted for 4.3%. Biomass energy sources accounted for 9.5%.

Characteristics of fossil fuel emissions

Among all CO_2 emissions from fossil fuel consumption, these from coal and petroleum products dominate. As the most important fossil fuel consumed in South Africa, coal produced 281.7 Mt of CO_2 emissions in 2022, accounting for 78.5% of fossil fuel emissions. The CO_2 emissions generated by the consumption of petroleum products are 73.3 Mt, accounting for 20.4% of the carbon emissions from fossil fuels, CO_2 emissions from coal have decreased year on year.

Sectoral emission contribution

CO_2 emissions from fossil fuel consumption in South Africa are linked mainly to the Utility sector and the transportation, storage and postal services sector. In 2022, the utility sector generated 217.5 Mt of CO_2 emissions, accounting for 60.6% of the total CO_2 emissions from fossil fuels. The Transportation, Storage, Post and Telecommunication Services sector are also the main fossil energy CO_2 emission industries in South Africa. This sector's CO_2 emissions have dropped from 72.2 Mt in 2010 to 45.1 Mt, and there has been a discernible downward trend in the percentage of fossil energy-related CO_2 emissions, which has also decreased from 18.5% in 2010 to 12.6% in 2022.

Biomass emissions

In South Africa, biomass made up 9.5% of the country's primary energy consumption structure in 2022. Since sustainable renewable resources are the primary source of biomass in South Africa, biomass has a "zero carbon" attribute throughout its whole life cycle and shouldn't be included in the overall carbon accounting process.

Emission trends

Between 2010 and 2022, CO_2 emissions from fossil fuel combustion in South Africa decreased by 8.3%, from 391.3 Mt to 358.8 Mt. In 2013, fossil fuel carbon emissions reached a peak of 418.8 Mt, and from 2015 to 2016, carbon emissions from fossil fuels rebounded, followed by a continuous decline. This is intricately linked to the modification of South Africa's energy framework.

Comparison with international databases

CO_2 emissions in South Africa calculated by CEADs (excluding emissions from biomass) show almost the same annual emission trends as the equivalent statistics of other agencies, but the annual values of each differ somewhat. In 2022, the accounting results of CEADs was 358.8 Mt, and the accounting results of GCB, EDGAR and IEA were 400.0 Mt, 409.4 Mt and 394.1 Mt, respectively. Compared with EDGAR's and IEA's statistics, CEADs' as a whole are lower.

The primary cause for the higher values of IEA compared to CEADs is the inconsistency between the statistical caliber and energy consumption statistics. From a statistical point of view, the CEADs data are more detailed in terms of energy classification. For example, petroleum products are subdivided into automotive gasoline, diesel, fuel oil and other products, each with a corresponding emission factor. IEA, however, does not subdivide petroleum products by type. The emission factors used by IEA are therefore different from those used by CEADs, which leads to discrepancies in emission data.

Another reason for the differences is that the energy consumption data of the two institutions are different. CEADs uses data from Statistics South Africa, the country's national statistical service; the IEA uses multiple data sources, such as the International Renewable Energy Agency (IRENA). And there is a stark gap between the energy consumption statistics of these agencies. Therefore, due to these factors, the IEA and CEADs report different amounts of industry emission.

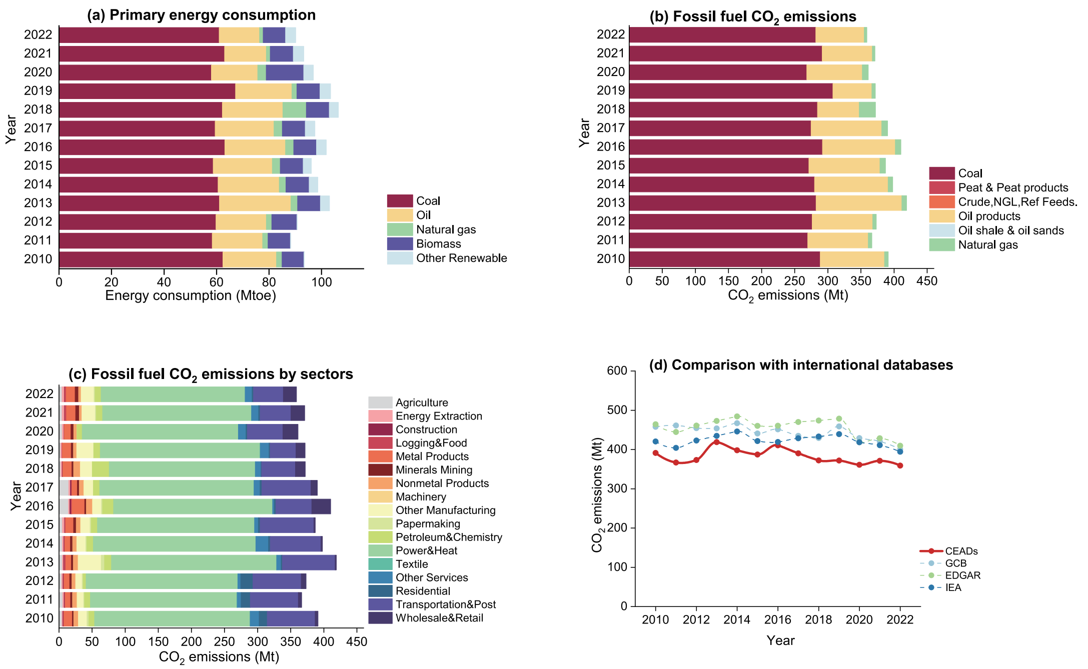


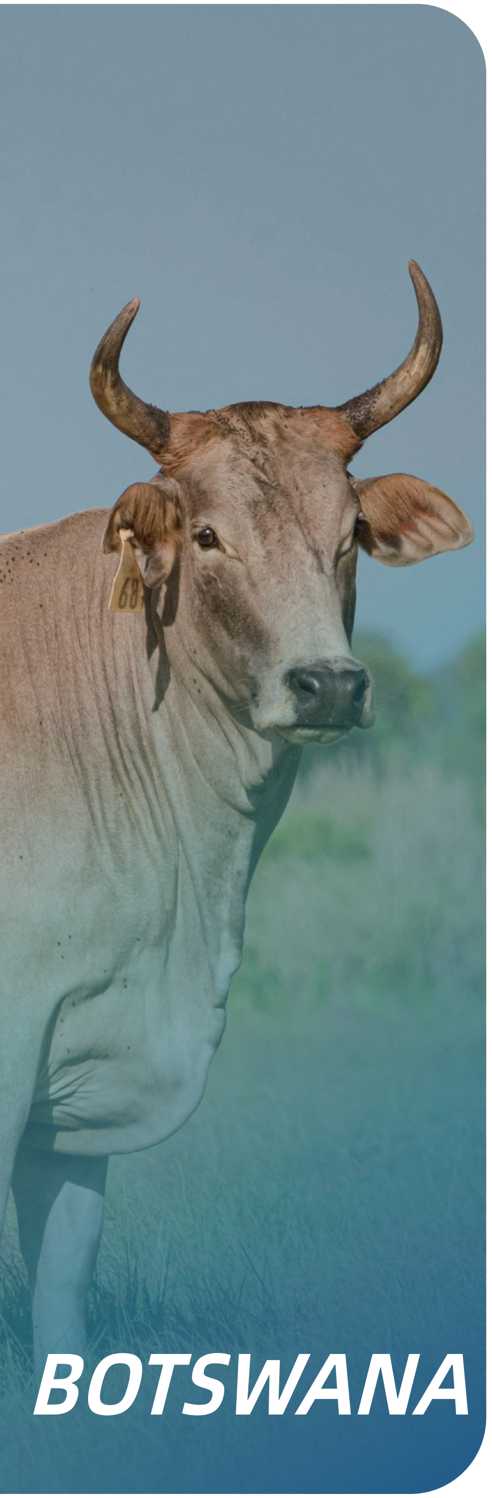
Figure 3.22: South Africa's energy consumption and CO_2 emissions from 2010 to 2022 (a) Primary energy consumption; (b) Fossil fuel CO_2 emissions; (c) Fossil fuel CO_2 emissions by sectors; (d) Comparison with international databases.

Brief description of data sources:

The energy balance sheets from Statistics South Africa are divided into coal, crude oil, oil, gas core, hydro, geothermal, renewable energy, electricity and heat. Due to data unavailability in 2022, South Africa's carbon emissions were extrapolated based on 2021 data. For sectoral downscaling, South Africa's national GDP data from the national statistics agency and export data from the UN Comtrade are used as allocation indicators for mapping to 47 sectors.

Table 3.22: Data sources for South Africa's emission accounting

Data type	Source	Website
Energy balance sheet	Statistics South Africa	http://www.energy.gov.za/files/media/Energy_Balances.html
Emission factor	IEA	https://www.iea.org/areas-of-work/global-engagement/china?language=zh
Sectoral mapping indicator	Statistics South Africa	https://www.statssa.gov.za/?page_id=1854&PPN=P0441
	UN Comtrade	https://comtradeplus.un.org/



Background

Botswana is a landlocked nation. The elevation is roughly 1000 meters on average. Botswana is adjacent to South Africa in the south, Namibia in the west, Zambia in the north, and Zimbabwe in the east . There are 58,730 square kilometers of national territory, and Gaborone is the capital city. The country is made up of 10 administrative regions and is home to 2.346 million people in 2022[204]. In Botswana, 90% of the people living there are Tswanas and speak the Bantu language. In addition, Botswana is one of the countries with rapid economic development and good economic conditions in Africa. With diamond industry, cattle raising industry and emerging manufacturing industry as pillar industries, its GDP was about US$20.32 billion in 2022 and per capita GDP reached US$7726.1[205].

Since the middle of the 1970s, mining has taken the place of animal husbandry as the primary economic sector in Botswana. Affected by global commodity prices as well as other variables, the share of mining in Botswana's GDP fell from roughly 24.0% a decade ago to 11.5% in 2020. The main export commodities include rough diamonds, gold, soda ash, salt and copper. One of the main sectors of Botswana's economy and a significant source of both foreign exchange earnings and government revenue is the diamond industry. However, diamond industry chain in Botswana is incomplete due to limitations imposed by geography, technology, human resources, and other factors. While the upstream diamond mining sector has reached a mature state, downstream industries with high value added, like jewelry design and diamond processing, are still developing at a slower pace. Furthermore, Debswana, Diamond Trading Company, and Okavango Diamond Company are the primary diamond mining and sale companies in Botswana.

The government of Botswana has actively pursued the strategy of economic diversification, issued relevant supporting policies, set up a special economic zone, and vigorously attracted investment in order to develop the manufacturing industry and get rid of dependence on the single diamond economy. Nevertheless, Botswana develops slowly and accounts for a small proportion of the national economy because of the weak market, raw materials and industrial foundation. In 2021, increased diamond production has led to the mining industry returning to its pre-pandemic levels, contributing to 19.2% of the country's GDP via industrial output.

Primary energy consumption

Botswana consumed 80.8% of its primary energy from fossil fuels in 2022, mostly petroleum. They consumed 41.3% oil and 39.5% coal for primary energy. Additionally, 19.2% of primary energy came from biomass.

Characteristics of fossil fuel emissions

Petroleum dominated fossil fuel CO_2 emissions. Petroleum products emitted 3.0 Mt of CO_2 in 2022, 44.3% of fossil energy emissions. The remaining CO_2 emissions came from coal, up from 19.8% in 2010 to 55.7% in 2022.

Sectoral emission contribution

The largest fossil fuel carbon-emitting sector in Botswana is the utility sector. This sector saw an increase in CO_2 emissions from 16% in 2010 to 54.2% in 2022. The transport, storage, and postal industry emits the second most fossil fuel carbon in Botswana. This sector emitted 2.3 Mt of CO_2 in 2022. From 60.6% in 2010 to 33.3% in 2022, their share of fossil energy carbon emissions has decreased.

Biomass emissions

In 2022, 19.2% of Botswana's primary energy consumption was biomass, mostly used in the Utility sector, living consumption, and Other Manufacturing and Waste sectors. Rice husk, bagasse, agricultural waste, firewood, black liquor and residual gas from firewood processing are biomass in Botswana. The whole life cycle of rice husk, bagasse, agricultural waste, and the secondary energy produced from their processing, such as biogas, bioethanol, and biodiesel, is "zero-carbon". Total carbon emissions should not be counted. Firewood, black liquor and residual gas from firewood processing are unsustainable, so carbon emissions should be included in the carbon accounting process. Overall, biomass consumption carbon emissions rose from 0.83 Mt in 2010 to 1.1 Mt in 2022.

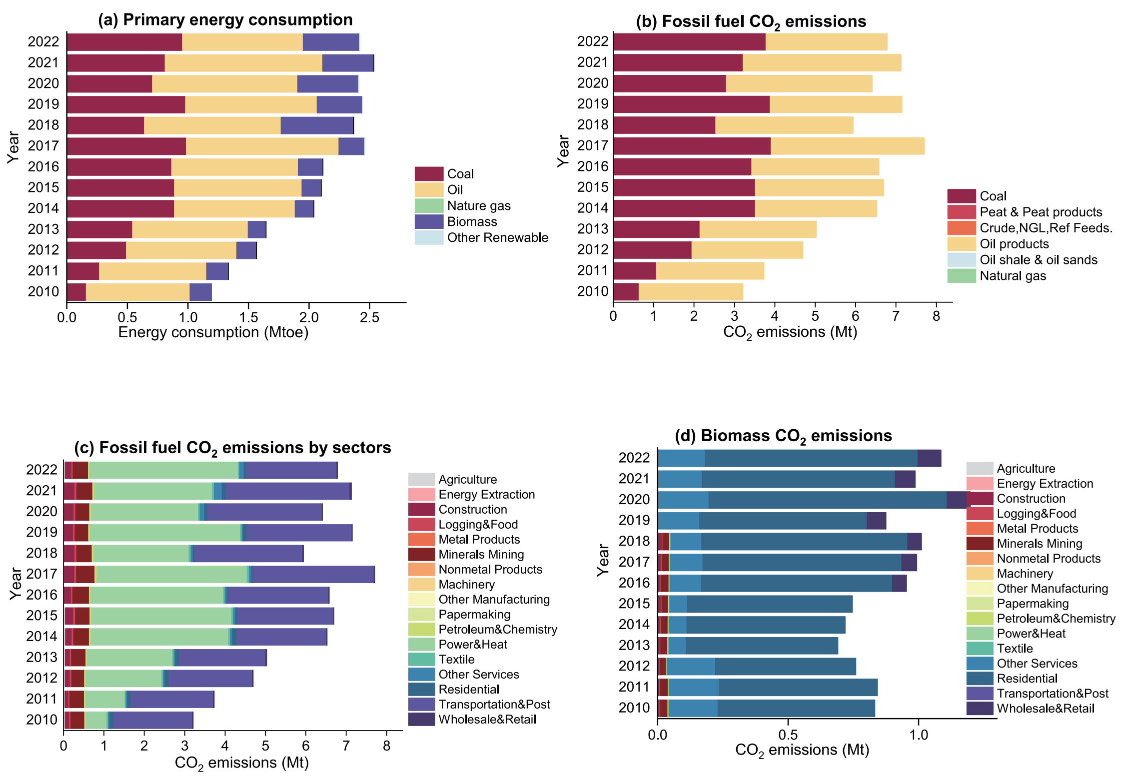
Emission trends

From 2010 to 2022, fossil energy consumption CO_2 emissions rose 111.1%, from 3.2 million tonnes to 6.8 million tonnes, or 6.4% per year. This period saw biomass consumption CO_2 emissions rise from 0.8 to 1.1 Mt.

Comparison with international databases

Botswana's fossil energy CO_2 emissions calculated by CEADs have similar trends to other agencies' statistical data (excluding biomass emissions), but their values differ. International databases estimate 2022 CO_2 emissions at 6.6 Mt for GCB, 7.3 Mt for EDGAR, 6.5 Mt for IEA, and 6.8 Mt for CEADs. There is little difference in the data. From 2010 to 2017, Botswana's CO_2 emission value calculated by CEADs was close to IEA and EDGAR, while GCB's 2017 statistical value was much lower.

When including CO_2 from biomass consumption, the CEADs figure for 2022 is 7.9 Mt.



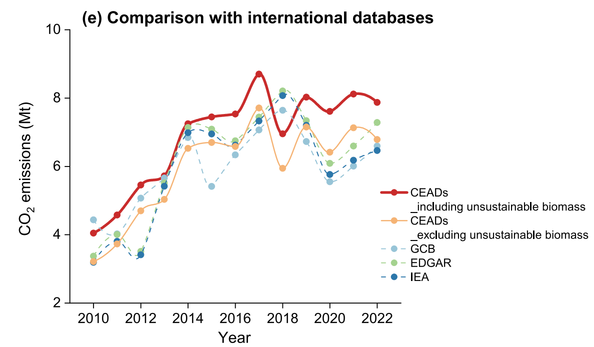


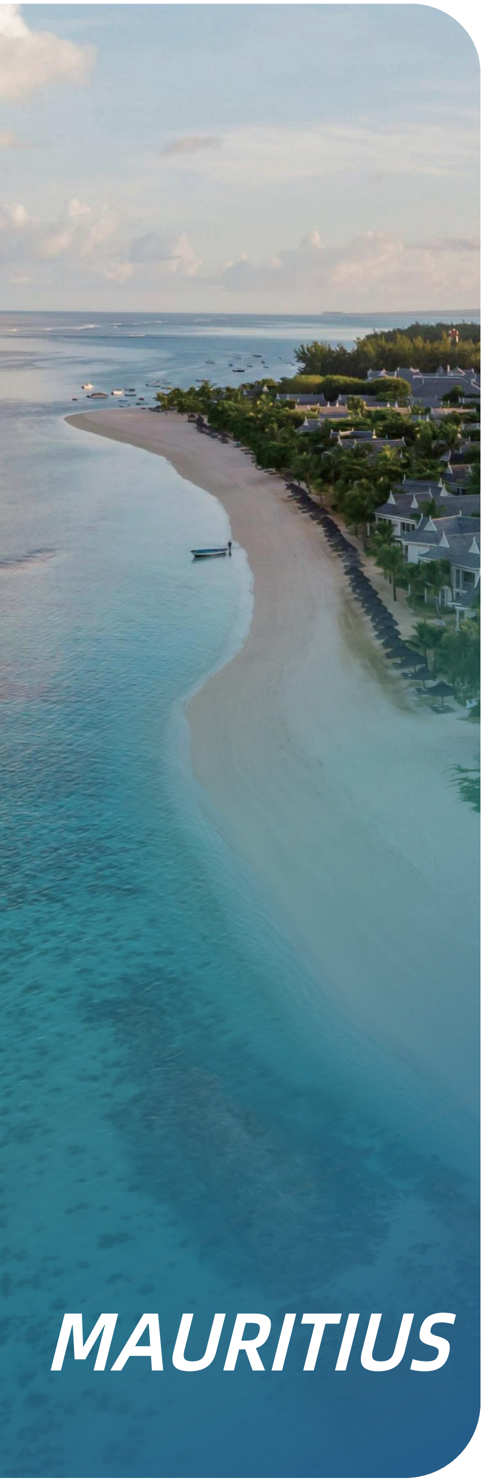
Figure 3.23: Botswana's energy consumption and CO_2 emissions from 2010 to 2022 (a) Primary energy consumption; (b) Fossil fuel CO_2 emissions; (c) Fossil fuel CO_2 emissions by sectors; (d) Biomass CO_2 emissions; (e) Comparison with international databases.

Brief description of data sources:

The energy balance of Botswana comes from the 2010-2022 energy balance provided by the African Energy Commission. According to statistics, there are 47 types of energy consumption, including 40 types of fossil fuels. The main types of fossil fuels include coal, crude oil and NGLs, petroleum products and biomass. These energies are consumed in 7 major industries, namely agriculture, mining, manufacturing, construction, residential, commercial and transportation. To further disaggregate the seven major industries into unified sectors, GDP data from the Botswana Bureau of Statistics were used.

Table 3.23: Data sources for Botswana's emission accounting

Data type	Source	Website
Energy balance sheet	AFREC	https://www.statsbots.org.bw/
Emission factor	IPCC	https://www.ipcc-nggip.iges.or.jp/EFDB/
Sectoral mapping indicator	Statistics Botswana	https://www.ipcc-nggip.iges.or.jp/EFDB/



Background

The island nation of Mauritius is located in the southwestern Indian Ocean some 2,200 kilometres from the African continent, and about 800 km from Madagascar. As a volcanic island, Mauritius is surrounded by coral reefs and features many mountains and isolated peaks. Mauritius is one of the few rich countries in Africa: in 2022, the GDP of Mauritius was US$12.93 billion at current rates, a 8.9% increase compared to the previous year. And its population stood at 1.2 million, and GDP per capita (current price) reached $10000. It is a relatively developed economy[206].

Mauritius is one of the countries with better economic development in Africa. In the 2019 Global Competitiveness Report of the World Economic Forum, Mauritius ranked 52nd and ranked first among African countries. Mauritius's four economic pillars are manufacturing, financial services, tourism and information and communication. In 2022, the tourism industry in Mauritius has gradually recovered from the impact of the pandemic. The industry is mainly dominated by sugar refining and export processing, accounting for 12.1% of total GDP in 2022[207]. The country is deficient in mineral resources and completely dependent on imports of oil and natural gas, and its water resources are also limited. External trade is key to the Mauritian national economy. It mainly exports cane sugar and export processed products, and imports grain and other foodstuffs, cotton, wool and other raw materials, machinery and equipment, and petroleum products. Its primary trading partners are France, the United Kingdom, the United States, India and China.

As an island nation, the challenge of climate change in Mauritius is even more urgent. In its third NDC, Mauritius indicated that it would increase the contribution of renewable energy to 28% by 2020 and 35% by 2025[208]. In 2023, the Central Electricity Authority (CEA) of Mauritius launched the Carbon Neutral Industrial Sector Renewable Energy Programme (CNIREP), aimed at investing in renewable energy generation, particularly solar and wind, for industrial enterprises. The programme is in line with its green energy transition and its goal of achieving a 60 per cent share of renewable energy in the local electricity mix by 2030[209].

Primary energy consumption

The primary energy structure of Mauritius is dominated by oil. In 2022, coal accounted for 24.2% of primary energy consumption, and oil for 65.8%; the total consumption of fossil fuel accounted for nearly 90.0%. Biomass meanwhile accounted for 8.3% of primary energy consumption, and renewable energy such as wind and solar power accounted for 1.7%.

Characteristics of fossil fuel emissions

Among all CO_2 emissions from fossil fuel consumption, those from petroleum dominate. Petroleum products, as the main fossil energy source in Mauritius, have shown an upward trend in CO_2 emissions from 2010 to 2019. The pandemic and other causes reduced oil consumption-related carbon emissions by 24.1% in 2020, and the trend has remained constant since then, generating approximately 3.0 Mt of CO_2 emissions in 2022. 1.2 Mt (29.0%) of CO_2 emissions in 2022 were caused by the use of coal.

Sectoral emission contribution

The largest fossil fuel carbon emissions in Mauritius come from the utility sector. In 2022 this sector produced 2.1 Mt CO2 emissions from fossil fuels, accounting for 50.5% of fossil fuel emissions that year. The transport, storage and postal industry is the second largest fossil fuel carbon-emitting sector in Mauritius, accounting for 26.4% of the total in 2022. Emissions from the Residential sector sector meanwhile accounted for 4.0% of total fossil fuel carbon emissions in 2022.

Biomass emissions

In 2022, biomass consumption in Mauritius accounted for 8.3% of primary energy consumption, and was consumed primarily in the domestic and manufacturing sectors. The forms of biomass most commonly used in Mauritius are fuelwood, charcoal and bagasse or plant fibre. Locals obtain fuelwood and charcoal, generally for home cooking and heating, mainly through deforestation, which has a great impact on the environment. As this comprises unsustainable use, the overall CO_2 emissions from it should be included in the overall carbon accounting process. Bagasse, by contrast, is a product of local plantations and can be replanted. It is considered a sustainable resource, has a "zero-carbon" lifetime and should therefore not be included in the emissions system in the overall CO_2 accounting process. The amount of CO_2 emissions produced by burning charcoal and fuel wood fell from 0.03 million metric tonnes in 2010 to 0.02 million metric tonnes in 2022.

Emission trends

CO_2 emissions in Mauritius show an upward trend. Between 2010 and 2019, CO_2 emissions from fossil fuel consumption increased from 3.8 Mt to 4.4 Mt. Due to the epidemic, CO_2 emissions fell by 16.7% year over year in 2022 to 4.2 Mt. Emissions from the consumption of biomass fell during this time, from 0.03 Mt to 0.02 Mt.

Comparison with international databases

Under the same accounting caliber (excluding emissions from biomass), the accounting results of each dataset share a similar trend. Differences in accounting methods and basic data do lead to differences in results, but these are still relatively close. The fossil energy carbon emissions calculated by CEADs are closest to the GCB data. The average difference is about 3.14%. The main difference between the two is down to the sourced energy consumption by sector. These data, however, were not included in the energy balance sheets published by Statistics Mauritius and used by CEADs; thus, figure of CEADs is lower. Compare to the emission results of IEA and GCB, CEADs has a difference with them about 4.05% and 3.51%.

When including CO_2 from biomass consumption, the CEADs figure for 2022 is 4.2 Mt.

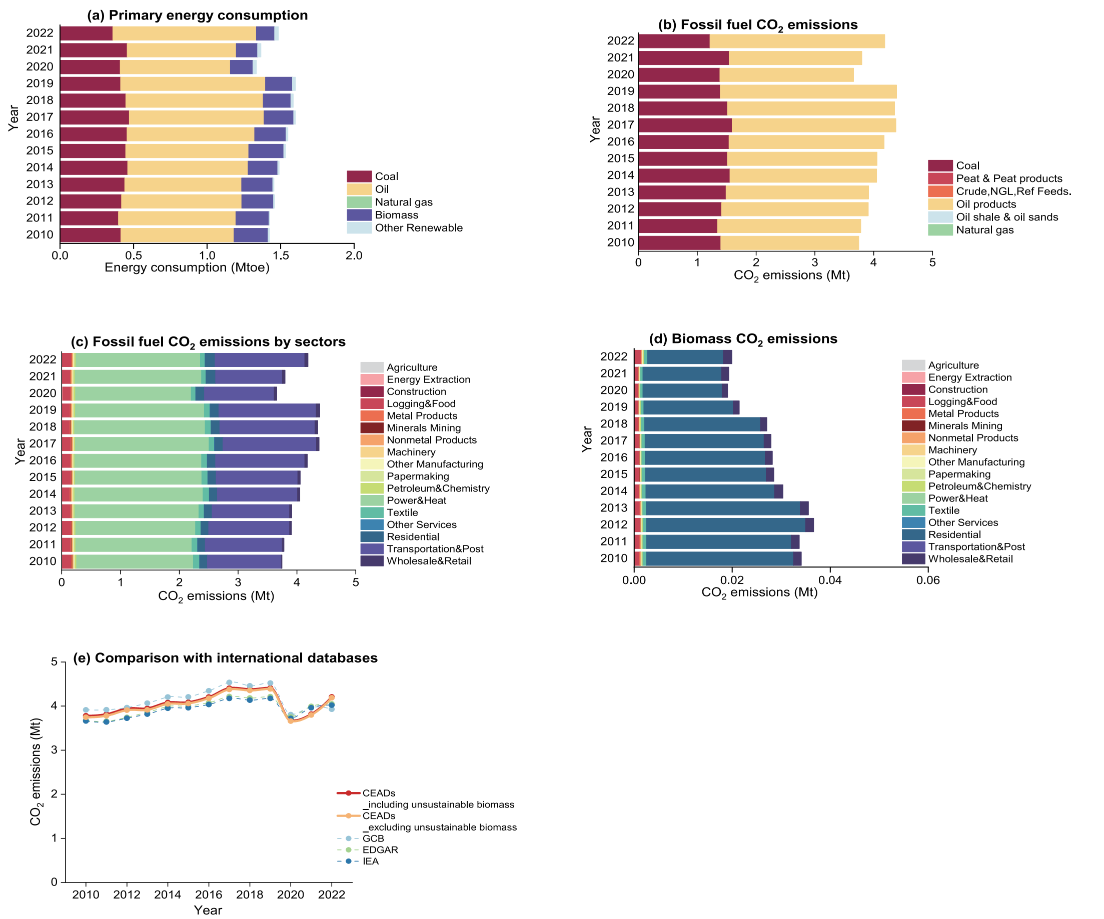


Figure 3.24: Mauritius's energy consumption and CO_2 emissions from 2010 to 2022 (a) Primary energy consumption; (b) Fossil fuel CO_2 emissions; (c) Fossil fuel CO_2 emissions by sectors; (d) Biomass CO_2 emissions; (e) Comparison with international databases.

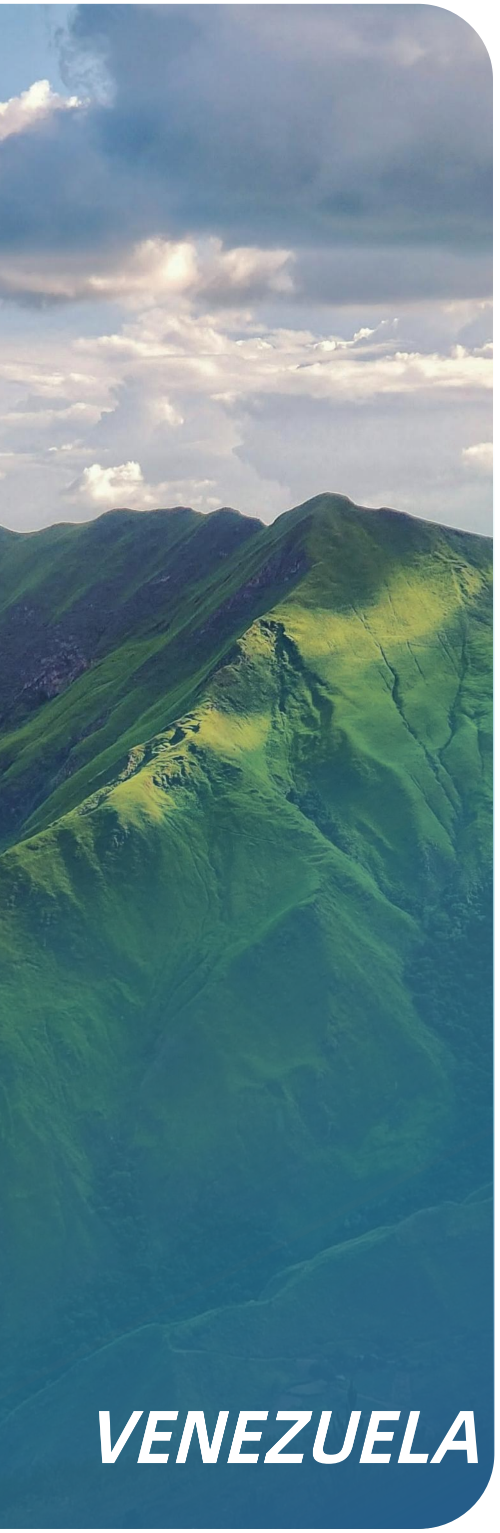
Brief description of data sources:

The energy balance sheets of Mauritius are all from the Ministry of Energy and Mines, covering the data from 2010 to 2022, and involving a total of 15 energy types and 6 sectors. Of these, for sub-sector matching, we used output data from the industrial sectors published by Statistics Mauritius, as well as GDP from agriculture, services and construction as the basis for the distribution to downscale the sectors and assign to 47 sectors.

Table 3.24: Data sources for Mauritius's emission accounting

Data type	Source	Website
Energy balance sheet	Statistics Mauritius	https://statsmauritius.govmu.org/Pages/Statistics/By_Subject/Energy_Water/Arch_Energy-Water.aspx
Emission factor	IPCC	https://www.ipcc-nggip.iges.or.jp/EFDB/
Sectoral mapping indicator	Statistics Mauritius	https://statsmauritius.govmu.org/Pages/Statistics/By_Subject/Manufacturing/SB_Manufacturing.aspx

LATIN AMERICA and the Caribbean



Background

Venezuela, located in the northern part of the South American continent, shares its borders with Guyana to the east, Brazil to the south, and Colombia to the west, while its northern coastline lies along the Caribbean Sea. As one of the significant nations in South America, Venezuela had a total population of approximately 28.2 million in 2022, accounting for 67.4% of the continent's total population. In the same year, Venezuela's Gross Domestic Product (GDP) at current prices was recorded at 9.21billion USD[210].

The cornerstone of Venezuela's economy is its petroleum industry. The country possesses proven oil reserves, including heavy oil, amounting to 300 billion barrels, ranking first in the world. Venezuela also holds the fourth-largest natural gas reserves globally. The principal industrial sectors include petroleum, iron mining, construction, steelmaking, aluminum refining, electricity, automobile assembly, food processing, and textiles. The petroleum industry is the lifeblood of Venezuela's national economy.

Venezuela has a total of 80 million hectares of land suitable for the development of agriculture, forestry, animal husbandry, and aquaculture, of which 30.07 million hectares are arable land and 13.79 million hectares are natural and artificial pasturelands. However, agricultural development has been slow, and the country remains unable to achieve self-sufficiency in food production.

In September 1990, Venezuela joined the General Agreement on Tariffs and Trade (GATT) and currently maintains trade relations with over 100 countries and regions worldwide. The country's main exports include crude oil, petrochemical products, aluminum ingots, steel, iron ore, and metal products, while it imports electromechanical equipment, chemical and hardware products, automobile parts, construction materials, and agricultural products. In recent years, the Venezuelan economy has been severely impacted by the decline in international oil prices and the imposition of sanctions[211].

Venezuela is one of the world's leading producers of hydroelectric power, ranking ninth globally in terms of hydroelectric generation, which constitutes 1.9% of the total global output. In addition to its significant hydroelectric capacity, Venezuela also possesses substantial renewable energy resources derived from wind and solar power. The potential for photovoltaic energy development in the country is particularly promising. According to data from the Global Solar Atlas, Venezuela's theoretical solar energy generation capacity is 5.35 kilowatts per square meter, making it one of the highest in South America[212]. According to data from the International Renewable Energy Agency (IRENA), Venezuela's photovoltaic power generation amounted to approximately 50 GWh in 2020. As of the end of 2019, the country's installed wind power capacity was 71.28 MW[213]. With the continuous

energy resources derived from wind and solar power. The potential for photovoltaic energy development in the country is particularly promising. According to data from the Global Solar Atlas, Venezuela's theoretical solar energy generation capacity is 5.35 kilowatts per square meter, making it one of the highest in South America[212]. According to data from the International Renewable Energy Agency (IRENA), Venezuela's photovoltaic power generation amounted to approximately 50 GWh in 2020. As of the end of 2019, the country's installed wind power capacity was 71.28 MW[213]. With the continuous development of renewable energy, green power is expected to transform Venezuela's electricity supply structure and alleviate its power shortages. To further promote the development of the renewable energy sector, the Venezuelan government has set specific development targets for wind and solar energy. Venezuela plans to establish wind farms with a total installed capacity of 10,000 MW over the next 15 years. At the beginning of 2023, the Ministry of Electric Power of Venezuela announced a new plan to add 2,000 MW of installed solar power capacity within the next three years.

Primary energy consumption

Venezuela's primary energy consumption is dominated by fossil fuels. In 2022, consumption of coal accounted for 0.7% of total energy consumption, oil for 39.7% and natural gas for 32.5%, for a total share of 72.9%. In addition, biomass accounts for 1% of primary energy consumption, and other renewable energy sources such as wind and solar energy account for 26.04% of the primary energy consumption structure.

Characteristics of fossil fuel emissions

Among all CO_2 emissions from fossil fuel consumption, those from natural gas and oil dominate. As Venezuela's most important fossil fuel, oil products accounted for 26.4 Mt of CO_2 emissions in 2022, which accounted for 56.9% of carbon emissions from fossil fuels. Overall, CO_2 from fossil energy consumption in Venezuela decreased year by year from 219.3Mt in 2010 to 46.4 Mt 2022.

Sectoral emission contribution

The largest fossil fuel carbon emissions in Venezuela come from the transport, storage and postal industry. In 2022 this sector produced 16.8 Mt CO_2 emissions from fossil fuels, accounting for 36.2 % of fossil fuel emissions that year. Next sector is petroleum processing, raw chemical, and medical, which is the second largest emission sector in 2022. This sector is also the sector with the fastest growth in fossil fuel emissions that years, it accounted for 15.2% of the total fossil fuel emissions, mainly using diesel, gasoline and fuel oil. The third is energy extraction, which accounted for 11% of the total fossil fuel emissions in 2022.

Biomass emissions

In 2022, biomass accounted for 1% of Venezuela's primary energy consumption structure, and was mainly used in the household consumption. In general biomass carbon emissions have decreased from 1.7 Mt in 2010 to 0.6 Mt in 2022, rebounded in 2021 and rose to 1 Mt by 2022. The economic slump and falling oil prices may have contributed to the2018–2020 biomass carbon emissions decrease. In addition, the Venezuelan government is also actively encouraging renewable energy, which has reduced biomass energy's carbon emissions.

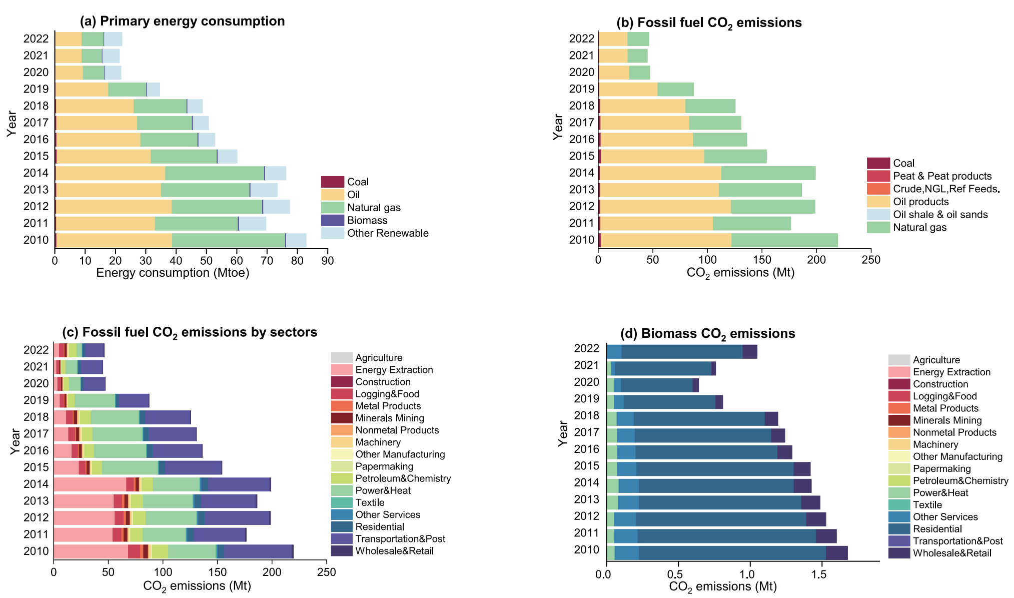
Emission trends

Venezuela's fossil fuel CO_2 emissions show a downward trend. In 2022, fossil fuels accounted for 72.9% of Venezuela's CO_2 emissions. Between 2018 and 2021, emissions from fossil fuel combustion decreased by 73.1%, from 21.9 Mt to 59.0 Mt in 2021. The average annual decline rate was 11.2%. In this period, emissions from biomass consumption decreased from 1.7 Mt to 0.6Mt in 2020. Biomass use increased emissions by 1Mt in 2022 after the epidemic broke out, and had a 63.5% growth in two year.

Comparison with international databases

Under the same accounting caliber (excluding emissions from biomass), the accounting results of each dataset share a similar trend. Differences in accounting methods and basic data do lead to differences in results. International databases estimate 2022 CO_2 emissions at 70.3 Mt for GCB, 77.8 Mt for EDGAR, 63.6 Mt for IEA, and 46.4 Mt for CEADs. Comparing energy balance sheets shows a 3% difference in total energy production between CEADs and IEA, which is not much; After analysing the data sources, it is found that the statistical process of IEA has errors in the data of energy processing and conversion and aviation use, resulting in rough statistics, while CEADs' statistics are more detailed and comprehensive, resulting in different accounting results.

When including CO_2 from biomass consumption, the CEADs figure for 2022 is 47.4 Mt.



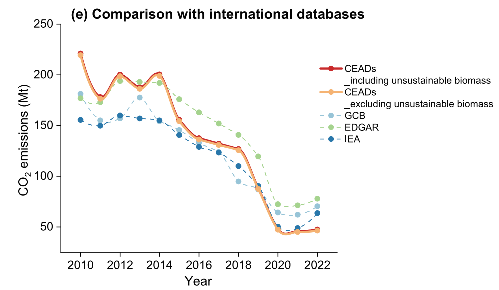


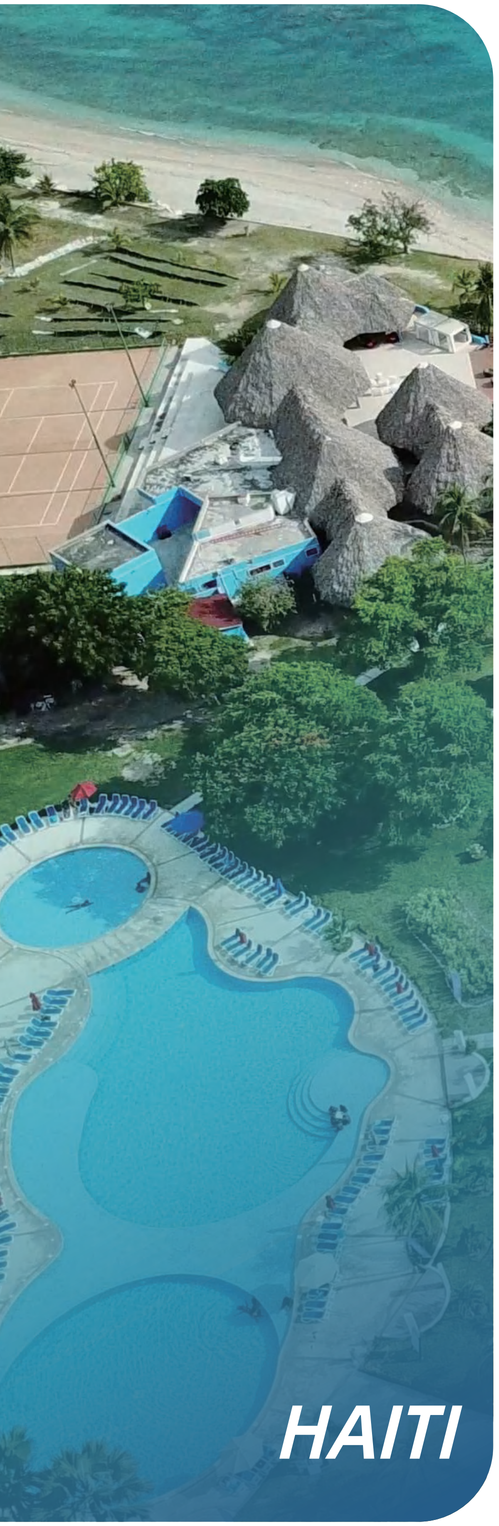
Figure 4.1: Venezuela's energy consumption and CO_2 emissions from 2010 to 2022 (a) Primary energy consumption; (b) Fossil fuel CO_2 emissions; (c) Fossil fuel CO_2 emissions by sectors; (d) Biomass CO_2 emissions; (e) Comparison with international databases.

Brief description of data sources:

Venezuela's energy balance sheets come from the Energy Information System of Latin America and the Caribbean, involving 20 energy types and 7 sectors. The subsector matching uses data from the official statistics website of Venezuela to downscale the sectoral allocation to 47 sectors based on the gross product of industrial sector output, agriculture, construction, transportation, etc., as well as the proportion of urban dwellers.

Table 4.1: Data sources for Venezuela's emission accounting

Data type	Source	Website
Energy balance sheet	Energy Information System of Latin America and the Caribbean	https://sielac.olade.org/WebForms/Reportes/ReporteBalanceEnergetico.aspx?or=600&ss=2&v=1
Emission factor	IPCC	https://www.ipcc-nggip.iges.or.jp/EFDB/
Sectoral mapping indicator	Statistics Venezuela	https://web.archive.org/web/20150409232349/http:/www.ine.gov.ve/index.php?option=com_content&view=category&id=108&Itemid=62



Background

Haiti, officially known as the Republic of Haiti, is located in the northern Caribbean, occupying the western portion of the island of Hispaniola (also referred to as Haiti Island). To the east, it shares a border with the Dominican Republic; to the south, it faces the Caribbean Sea; to the north, it borders the Atlantic Ocean; and to the west, it is separated from Cuba and Jamaica by sea. The total land area of Haiti is approximately 27,800 square kilometers. Administratively, Haiti is divided into 10 provinces, which are further subdivided into 42 districts. The capital city is Port-au-Prince[214]. In 2022, Haiti had a total population of 11.5 million, with a population growth rate of 1.1%[215].

Haiti is one of the least developed countries in Latin America, with an economy primarily based on agriculture and heavily reliant on foreign aid. The country's economic development has been significantly impacted by political instability, the COVID-19 pandemic, and frequent natural disasters. These challenges have led to sharp increases in prices, rising unemployment, and deteriorating living conditions for the population. In 2022, Haiti's gross domestic product (GDP) was valued at 20.3 billion USD (current prices), with a per capita GDP of 1760.6 USD (current prices). The GDP growth rate for the year was -3.0% [216].

Haiti's industrial base is extremely underdeveloped. Despite the government's efforts to strongly encourage foreign and private investment, the country's unstable security situation and severely lagging infrastructure, including water, electricity, and telecommunications, have deterred potential investors. Haiti's foreign trade mainly involves the export of products such as coffee, cocoa, mangoes, essential oils, and processed goods, while imports primarily consist of food, fuel (refined oil), industrial goods, machinery, transportation equipment, and consumer products. The United States and the European Union are Haiti's major trading partners. Haiti does not have diplomatic relations with China, but it is a member of the World Bank, the International Monetary Fund, the World Trade Organization, the Community of Latin American and Caribbean States, the Inter-American Development Bank, and the Caribbean Community. More than 30 international and regional organizations have permanent offices in Haiti. The international community has provided long-term economic assistance to the country[214].

Primary energy consumption

In 2022, fossil fuel consumption in Haiti accounted for 27.4% of the total energy mix, with no reported consumption of coal or natural gas. Biomass represented a significant share, comprising 72.1% of the country's primary energy consumption. Other renewable energy sources, such as solar and hydropower, contributed only 0.5% to the overall primary energy consumption.

Characteristics of fossil fuel emissions

Due to the lack of data on coal and natural gas carbon emissions in Haiti for 2022, the carbon emissions from fossil fuel consumption are represented solely by those from petroleum. As the primary fossil fuel in Haiti, petroleum consumption has resulted in carbon emissions increasing from 2.1 Mt in 2010 to 2.9 Mt in 2022, marking a 38.1% increase.

Sectoral emission contribution

Transportation, storage and postal services is Haiti's highest-emitting sector. In 2022, this sector's fossil fuel emissions amounted to 1.4 Mt, accounting for 49.1% of Haiti's total fossil fuel emissions. Secondly, Haiti's fossil energy CO_2 emissions come from the Utility sector. In 2022, the CO_2 emissions generated by the consumption of fossil fuels in this sector were close to 0.6 Mt, or 21.9% of Haiti's total CO_2 emissions from fossil energy.

Biomass emissions

In 2022, biomass energy accounted for 72.1% of Haiti's primary energy consumption, primarily utilized in the residential sector. The biomass sources mainly include wood, charcoal, and other commonly used materials for household purposes. A significant proportion of Haiti's carbon emissions is attributed to traditional biomass energy. Local residents primarily obtain firewood by deforesting areas, which is used for household cooking and heating, leading to substantial environmental impacts and unsustainable resource utilization. In the overall carbon accounting process, these emissions should be included in the total carbon emissions. From a temporal perspective, Haiti's biomass carbon emissions have generally shown an upward trend, rising from 10.4 Mt in 2010 to 11.6 Mt in 2022, with slight declines in 2014 and 2020, followed by a rebound in 2021 and a continued rise in 2022.

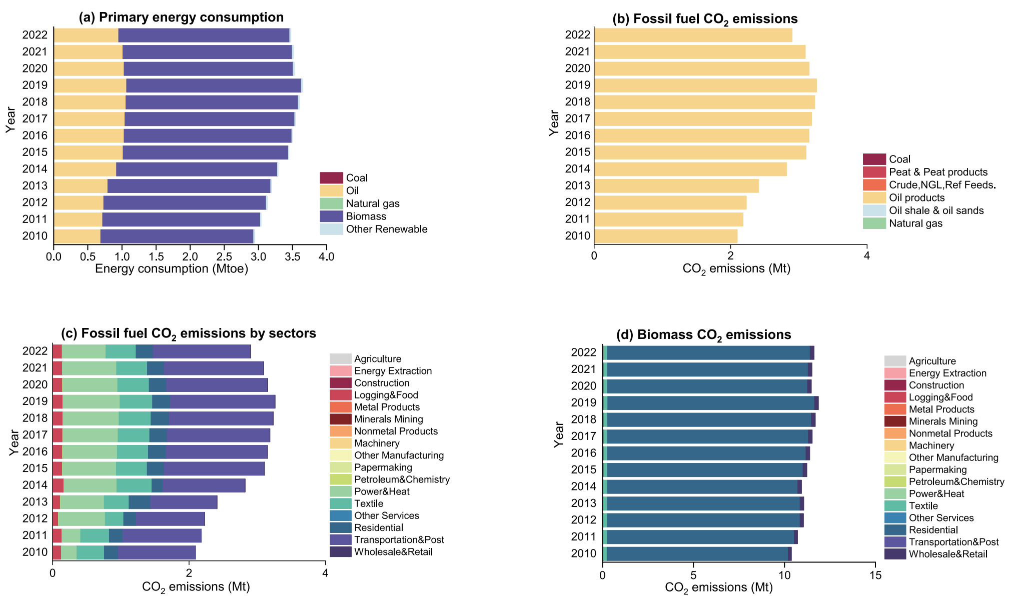
Emission trends

The total CO_2 emissions in Haiti exhibited a consistent upward trajectory from 2010 to 2019, experienced a slight decline in 2020, rebounded in 2021, and then showed another minor decrease in 2022. Haiti's total CO_2 emissions increased from 12.5 Mt in 2010 to 14.5 Mt in 2022, representing a 16% rise. Specifically, carbon emissions from fossil fuel combustion rose from 2.1 Mt in 2010 to 3.0 Mt in 2022, an increase of 38.4%. Meanwhile, carbon emissions from biomass combustion increased from 10.4 Mt in 2010 to 11.6 Mt in 2022, reflecting a 11.9% growth.

Comparison with international databases

Under the same accounting caliber (excluding emissions from biomass), the accounting results of each dataset share a similar trend. Differences in accounting methods and basic data do lead to differences in results. International databases estimate 2022 CO2 emissions at 3.3 Mt for GCB, 3.4 Mt for EDGAR, 3.04 Mt for IEA, and 2.9 Mt for CEADs. It can be observed that there is a 17.2% and 13.8% difference in the total carbon emissions from fossil fuels reported by CEADs compared to EDGAR and GCB, respectively, while the total carbon emissions from fossil fuels reported by CEADs and IEA are largely consistent. Notably, the IEA's carbon emission data is estimated by the Secretariat of the International Energy Agency based on secondary information from multiple sources. In contrast, CEADs calculates emissions directly based on the official energy balance sheets published by the national authorities of Haiti, as part of the Latin American Energy Organization, resulting in more accurate data.

When including CO_2 from biomass consumption, the CEADs figure for 2022 is 14.5 Mt.



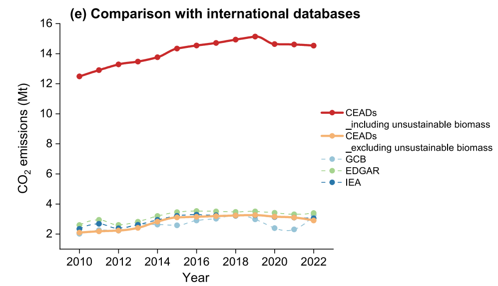


Figure 4.2: Haiti's energy consumption and CO_2 emissions from 2010 to 2022 (a) Primary energy consumption; (b) Fossil fuel CO_2 emissions; (c) Fossil fuel CO_2 emissions by sectors; (d) Biomass CO_2 emissions; (e) Comparison with international databases.

Brief description of data sources:

Haiti's energy balance sheets of 2010-2022 come from the Energy Information System of Latin America and the Caribbean, involving 20 energy types and 6 sectors. The sectoral matching was conducted using data from Global EDGE and the World Bank. Based on the GDP share of industrial sectors and the proportion of urban residents, the sectoral data was downscaled and allocated across 47 sectors.

Table 4.2: Data sources for Haiti's emission accounting

Data type	Source	Website
Energy balance sheet	Energy Information System of Latin America and Caribbean	https://sielac.olade.org/WebForms/Reportes/ReporteBalanceEnergetico.aspx?or=600&ss=2&v=2
Emission factor	IPCC	https://www.ipcc-nggip.iges.or.jp/EFDB/
Sectoral mapping indicator	Global EDGE	https://globaledge.msu.edu/countries/haiti/economy
	World Bank	https://data.worldbank.org/indicator/SP.URB.TOTL.IN.ZS

Background

Nicaragua is located in Central America, bordered by Honduras to the northwest, the Caribbean to the east, Costa Rica to the south, and the Pacific Ocean to the southwest. While the north of the country is mostly highlands, the east levels out to a coastal plain with jungles and swamps. The country covers an area of 130,400 square kilometres. In 2022, the population of Nicaragua reached 6.7 million, with a total GDP of US$15.7 billion (at current rates), representing a real GDP decrease of 10.7% year-on-year; GDP per capita is $2325.2[217].

Nicaragua's economy remains relatively underdeveloped. Agriculture and livestock continue to be significant components of the Nicaraguan economy, with major products including cotton, coffee, sugarcane, bananas, and meat. In 2022, the agricultural sector accounted for 16.8% of the country's GDP. Additionally, the industrial base is relatively weak, with the manufacturing sector contributing 26.09% to GDP in 2022[3]. At the same time, Nicaragua is one of the major gold producers in Latin America, and holds other mineral deposits including silver, antimony, zinc, copper and lead. Geothermal resources in Nicaragua are abundant, and there are two oil deposits. Its forests are also significant, covering 43%[218]of the country. Nicaragua’s primary exports are coffee, meat, gold, dairy products, sugar and peanuts, and it exports primarily to the United States, EI Salvador, Costa Rica and Venezuela. Its main imports are raw materials, consumer goods, petroleum, fuel and lubricants, and it imports primarily from the United States, Mexico, Costa Rica and Venezuela[219].

Since 2007, Nicaragua has vigorously developed clean energy. Over the past seven years, its total investment in renewable power generation has reached $1.5 billion. In 2010, Nicaragua released its 2010-2017 National Energy Plan, which established the ambitious goal of developing renewable energy — specifically, aiming for 597.7 MW of hydroelectric capacity, 100 MW of geothermal energy and 100 MW of wind capacity. At the same time, it is expected that by 2018, Nicaraguan Ministry of Energy and Mines will invest another $2.5 billion in the field of renewable energy to adjust the country's energy structure[220].Nicaragua has further committed in its Nationally Determined Contribution (NDC) to reducing greenhouse gas emissions resulting from land use, land-use change, and energy consumption and production[220].

Primary energy consumption

The primary energy structure of Nicaragua is dominated by petroleum and biomass. In 2022, Nicaragua's oil consumption was 1.6 Mt of oil equivalent, accounting for 51.6% of primary energy consumption. Biomass accounted for 41.7%, and renewable energy such as hydropower and wind power accounted for 6.7%.

Characteristics of fossil fuel emissions

All of Nicaragua's fossil fuel CO_2 emissions are generated by petroleum products. As the most important fossil energy in Nicaragua, petroleum products generated a total of 5.0 Mt of CO_2 emissions in 2022, an increase of 23.2% compared to 2010.

Sectoral emission contribution

Two sectors — transportation, storage and postal services, and electricity, heat, gas and water production — are responsible for most of Nicaragua’s CO_2 emissions. In 2022, carbon emissions from the consumption of fossil energy in the transportation, storage and postal services sectors were 2.6 Mt, accounting for 51.8% of Nicaragua’s total emissions from fossil energy. The electricity, heat, gas and water production sector meanwhile was 1.1 Mt, accounting for 21.1%, although its proportion has declined since 2012 because of Nicaragua’s continued investment in renewable power generation.

Biomass emissions

In 2022, biomass accounted for 41.7% of Nicaragua’s primary energy consumption structure, and was mainly used in the household sector and commercial consumption. Prime sources of biomass in the country are firewood and crop wastes such as bagasse and rice, coffee and peanut husks. Firewood is primarily obtained through deforestation, and used for home cooking and heating. As this exerts pressure on the environment, firewood should be considered an unsustainable resource and carbon emissions linked to it should be included in the overall carbon accounting process. Bagasse and other crop wastes, by contrast, come from local plantations and can be replanted repeatedly, and so are regarded as a sustainable, renewable resource with a "zero carbon" life cycle; their emissions should therefore not be included in the carbon accounting process. Between 2010 and 2022, CO_2 emissions from firewood consumption increased from 5.1 Mt to 6.0 Mt.

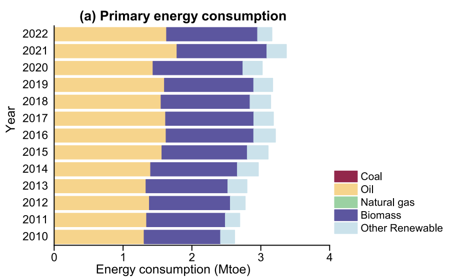
Emission trends

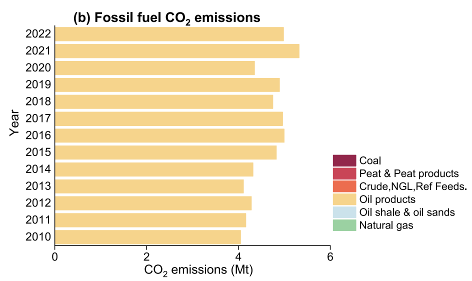
Nicaragua's CO_2 emissions are growing relatively quickly. Between 2010 and 2022, carbon emissions from fossil energy consumption increased from 4.0 Mt to 5.0 Mt, with an average annual growth rate of 1.8%. During this period, carbon emissions from biomass consumption increased 0.9 Mt.

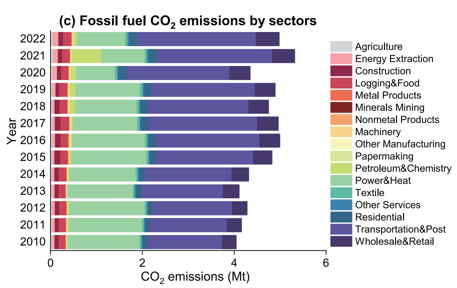
Comparison with international databases

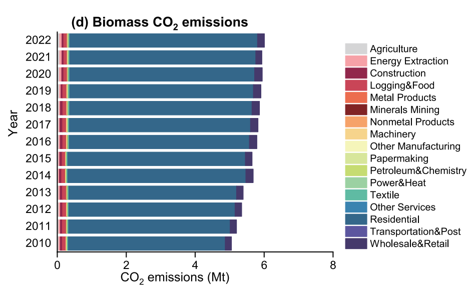
Under the same accounting caliber (excluding emissions from biomass), the carbon emissions from fossil energy in Nicaragua calculated by CEADs are slightly lower than the results of IEA, EDGAR and GCB. Differences in accounting methods and data render the results slightly different. Among them, the results of CEADs accounting are closest to those of IEA and GCB, and has the biggest difference with EDGAR. The average discrepancy between the CEADs and IEA results is less than 2%, while the average difference with EDGAR results reaches 8%.

When including CO_2 from biomass consumption, the CEADs figure for 2022 is 11.0 Mt.









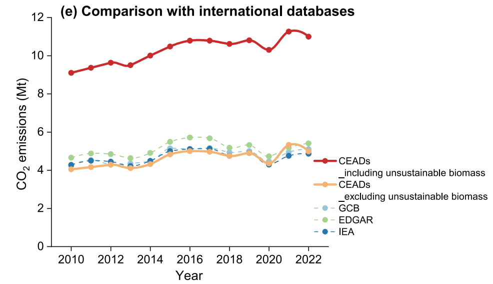


Figure 4.3: Nicaragua's energy consumption and CO_2 emissions from 2010 to 2022 (a) Primary energy consumption; (b) Fossil fuel CO_2 emissions; (c) Fossil fuel CO_2 emissions by sectors; (d) Biomass CO_2 emissions; (e) Comparison with international databases.

Brief description of data sources:

The energy balance sheet of Nicaragua is provided by its Ministry of Energy and Mineral Resources, covering the data for 2010 to 2022, which includes 22 categories of energy and 6 sectors. For subsector matching, we used the GDP of agriculture, services and construction from their National Institute for Information Development (NII) and export data from the United Nations Commodity Trade Statistics Database (UN Comtrade) as the basis for allocation, and downscaled the sectoral matching to 47 sectors.

Table 4.3: Data sources for Nicaragua's emission accounting

Data type	Source	Website
Energy balance sheet	Ministry of Energy and Mineral Resources	http://www.mem.gob.ni/
Emission factor	IPCC	https://www.ipcc-nggip.iges.or.jp/EFDB/
Sectoral mapping indicator	Nicaragua's Institute National of Information Development	https://www.inide.gob.ni/
	UN Comtrade	https://comtrada.un.org

Background

Bolivia is a landlocked country in the west-central part of South America. The country is divided into nine departments, with the legal capital being Sucre and the actual government and administrative capital being La Paz. According to data released by the National Bureau of Statistics, the total population of Bolivia in 2022 was 12.08 million, with a GDP (current price) of 44.0 billion US dollars[221]. Although Bolivia has experienced rapid development in the past few decades, it is still the second poorest country in South America and a developing country.

In 2022, the added value of agriculture, industry, and service industries accounted for 12.5%, 37.9%, and 49.6% of GDP, respectively[222]. Its main economic sectors include agriculture, forestry, fisheries, mining, textiles and clothing, and refined petroleum. Despite Bolivia's developed agriculture, a large-scale and industrialized development model has not yet been formed in the processing of agricultural products. Agricultural residues such as sugarcane, soybeans, corn, and sunflower residues are widely present and not fully utilized[223]. Bolivia has abundant mineral resources, including tin, silver, lithium, and copper, but key mineral extraction and processing technologies still rely on imports. Bolivia's main exporting countries are Brazil, Argentina, and the United States, with the main export products being natural gas, silver, zinc, lead, tin, gold, quinoa, soybeans, and soy products; The main importing countries are China, Brazil, and Argentina, with imported products including machinery, petroleum products, vehicles, steel, plastics, etc.

In promoting sustainable energy development, Bolivia actively takes measures to mitigate climate change, is committed to improving the utilization rate of renewable energy[224], and promotes clean energy technologies. The main actions taken by the Bolivian government include the construction of hydropower stations (small and medium-sized hydropower stations, large-scale hydropower, and multi-purpose hydropower) and the promotion of renewable energy development (wind, geothermal, and solar) to change the fossil energy consumption structure dominated by oil and natural gas. To address global climate change, Bolivia's National Autonomous Contribution (INDC) has prioritized linking mitigation and adaptation actions in the fields of water, energy, forests, and agriculture.

Primary energy consumption

Bolivia's fossil energy consumption accounts for nearly 87.3% of the primary energy consumption structure, mainly consisting of petroleum products and natural gas, with almost no consumption of coal. In 2022, oil product consumption accounted for 50.6% and natural gas consumption accounted for 36.7%. In addition, renewable energy consumption dominated by hydropower accounts for 2.8% of primary energy consumption; The proportion of biomass consumption in primary energy consumption is 9.9%.

Characteristics of fossil fuel emissions

Consumption of natural gas and petroleum products is the main source of fossil fuel emissions in Bolivia. In 2010, CO_2 emissions from natural gas consumption stood at 6.6 Mt, accounting for 41.3% of carbon emissions from fossil fuels, and showed a continuous growth trend through to 2018. Between 2019 to 2020, the CO_2 emissions generated by natural gas consumption had slightly decreased to 6.8 Mt, before bouncing back to 7.8 Mt in 2022 As for petroleum, the CO_2 emissions from petroleum products in 2022 were 13.6 Mt, accounting for 62.8% of the carbon emissions from fossil fuels. Among them, gasoline and diesel are the main petroleum products used in Bolivia.

Sectoral emission contribution

Two sectors — transportation, storage and postal services, and electricity, heat, gas and water production — are responsible for most of Bolivia's CO_2 emissions. The carbon emissions generated by the consumption of fossil fuels in transportation, warehousing, and postal services have been on the rise since 2010, increasing from 7.01 Mt in 2010 to 11.5 Mt in 2018, accounting for 43.9% to 50.8% of the total carbon emissions from fossil fuels. Then it decreased to 8.9 Mt in 2020. In 2022, it rose to 12.6 Mt. In 2022, emissions from the consumption of fossil energy in the electricity, heat, gas and water production sector was 3.9 Mt, accounting for 18.0% of Bolivia's total emissions from fossil energy.

Biomass emissions

In 2022, biomass consumption accounted for approximately 9.9% of the primary energy consumption structure, mainly used for household consumption, logging, and food industries. The main types of biomass in Bolivia include feces and green residues[225], Due to the fact that Bolivian biomass mainly comes from sustainable renewable resources and has a "zero carbon" attribute throughout its lifecycle, it should not be included in the overall CO_2 accounting process.

Emission trends

From 2010 to 2018, the growth of CO_2 emissions from fossil energy consumption in Bolivia was relatively flat, increasing from 16.0 Mt to 22.6 Mt, with an average annual growth rate of 4.5%. In 2019, there was a slight decrease, and in 2020, due to the impact of the global epidemic, emissions decreased to 18.0 Mt. Carbon emissions rebounded to 21.6 Mt in 2022, with an average annual growth rate of 2.9% from 2010 to 2022.

Comparison with international databases

Under the unified accounting standard, which does not include biomass carbon emissions, the CO_2 emissions of Bolivia's fossil fuels calculated by CEADs are basically consistent with the data of EDGAR and GCB before 2017, but overall slightly higher than the IEA data, with an overall trend error of around 8%. Due to the fact that the Bolivian energy balance tables used by CEADs and IEA are both sourced from the Bolivian Ministry of Hydrocarbons, it can be inferred that the error is caused by different fossil energy carbon emission factors used. After 2017, the CO_2 emissions from fossil fuels accounted for by CEADs have grown relatively fast compared to EDGAR data; The growth trend of CEADs and IEA data is relatively consistent. The results for 2022 are relatively close to IEA data.

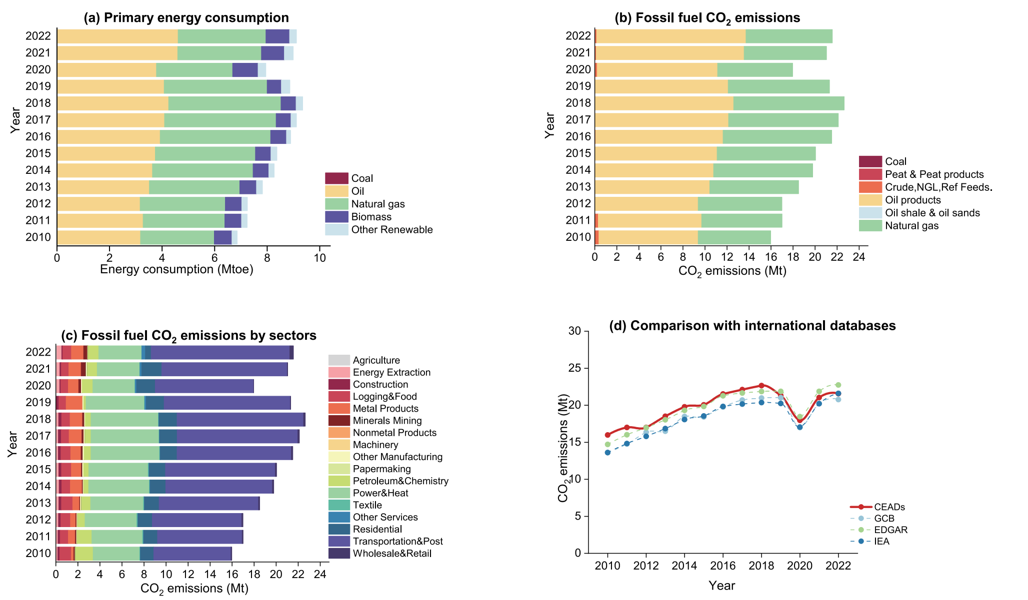


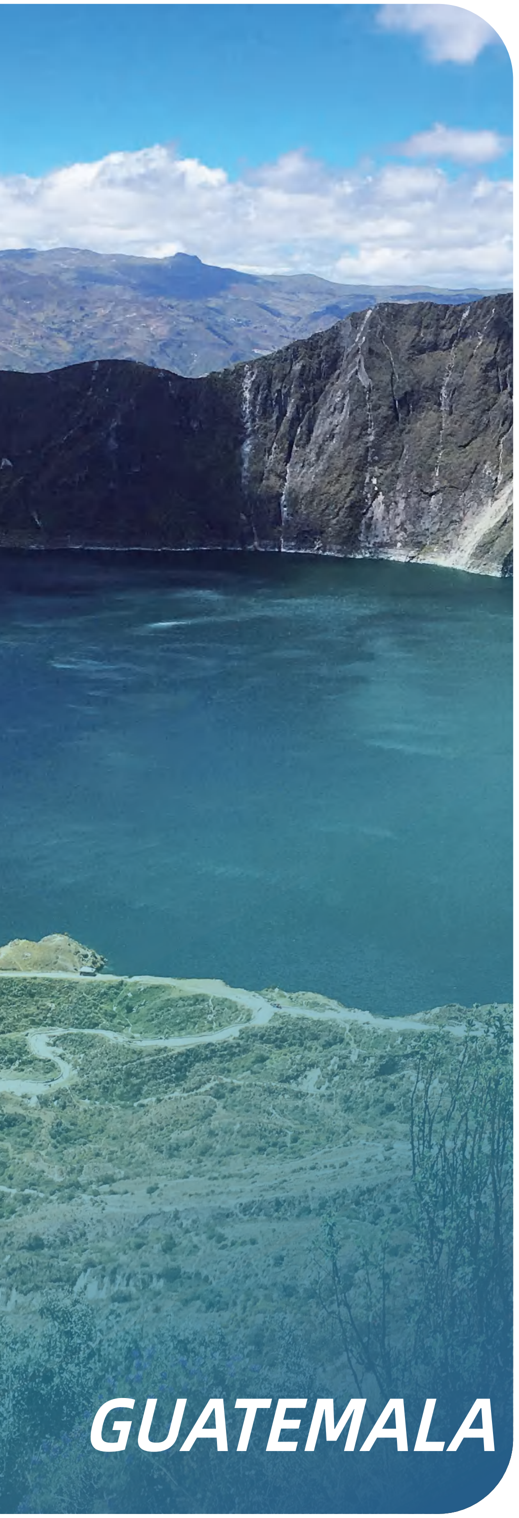
Figure 4.4: Bolivia's energy consumption and CO_2 emissions from 2010 to 2022 (a) Primary energy consumption; (b) Fossil fuel CO_2 emissions; (c) Fossil fuel CO_2 emissions by sectors; (d) Comparison with international databases.

Brief description of data sources:

The energy balance table for Bolivia from 2010 to 2022 was obtained from the website of the Bolivian Energy Agency, which includes energy processing and conversion data for 25 primary and secondary energy varieties in Bolivia, as well as energy consumption data for 7 major economic sectors. Calculate CO_2 emissions by industry based on GDP from Bolivia National Institute of Statistics and export data from the United Nations Commodity Trade Statistics.

Table 4.4: Data sources for Bolivia's emission accounting

Data type	Source	Website
Energy balance sheet	Bolivian Ministry of Hydrocarbons	https://www.hidrocarburos.gob.bo/
Emission factor	Intergovernmental Panel on Climate Change (IPCC)	https://www.ipcc-nggip.iges.or.jp/EFDB/
Sectoral mapping indicator	United Nations Commodity Trade Statistics Database (UN Comtrade), Export Data	https://comtradeplus.un.org/
	GDP from Bolivia National Institute of Statistics	https://www.ine.gob.bo/



Background

Guatemala is a presidential republic country in the northwest of Central America, bordering countries such as Mexico, Belize, and Honduras. It is bordered to the east by the Caribbean Sea and to the south by the Pacific Ocean. The country is divided into 22 departments, with a land area of 108900 square kilometers and a population of 18.125 million in 2023, with a GDP of 104.45 billion US dollars (current price in 2023). Guatemala was affected by the civil war and its economy remained stagnant for a long time. After the Final Peace Agreement came into effect in 1996, Guatemala's economy resumed growth. From 2003 to 2008, the average annual growth rate of GDP reached 4%. It is the country with the largest population in Central America, and also the country with the highest poverty rate and income inequality in Central America and even Latin America. The unemployment rate in 2023 was 2.3%[226].

Guatemala's economy is dominated by the service industry[227]. Agriculture mainly produces cash crops such as coffee, sugarcane, bananas, and cardamom, and exports them to North America, Central America, Europe, and other regions. However, due to 65% of the land being controlled by 2.5% of farms[228], the distribution of land use rights is very uneven, resulting in lower income and higher poverty rates for the population engaged in agricultural production. In addition, Guatemala's industrial foundation is weak, and industrial raw materials and main consumer goods rely on imports. In 2019, industrial added value accounted for about a quarter of GDP.

It is worth noting that agriculture, livestock, fuelwood, illegal logging, and forest fires have brought enormous pressure to Guatemala's sustainable development. The country is currently strengthening its national plan and actively cooperating with international organizations to better manage its natural resources, reduce deforestation and forest degradation caused by agricultural development and residents' livelihoods, and improve livelihoods. In addition, Guatemala submitted its nationally owned contribution in 2015, proposing to reduce greenhouse gas emissions by 11.2% (53.85 Mt of CO_2 emissions) by 2030 compared to the baseline scenario. And with the support of international resources, this goal can be raised to 22.6%[224].

Primary energy consumption

Fossil fuel consumption accounted for 35.7% of primary energy consumption in Guatemala in 2022, and it is mainly composed of coal and petroleum products, with almost no consumption of natural gas. Coal consumption accounted for 6.1% and petroleum product consumption accounted for 29.6%. In addition, other renewable energy sources, mainly water energy, account for 6.6% of primary energy consumption; Biomass accounts for 57.7% of the total primary energy consumption.

Characteristics of fossil fuel emissions

The consumption of petroleum products and coal is the main source of carbon emissions from Guatemala's fossil fuels. Among them, petroleum product consumption is its largest source of carbon emissions. In 2022, the CO_2 emissions generated by petroleum product consumption were 15.2 Mt, accounting for 77.5% of the country's fossil energy carbon emissions. Among its petroleum products, diesel and gasoline are the main types. Other petroleum products, such as fuel oil, liquefied petroleum gas, kerosene, and turbines, are also used in Guatemala and contribute to certain CO_2 emissions. The carbon emissions generated by coal consumption in 2010 were 2.1 Mt, accounting for 17.3% of fossil energy carbon emissions; In 2022, 4.4 Mt of carbon emissions were generated, accounting for 2.5% of fossil energy carbon emissions, with a significant growth rate.

Sectoral emission contribution

The transportation, storage and postal services sector is the biggest contributor to fossil fuel CO_2 emissions in Guatemala. In 2022, the CO_2 emissions generated by the consumption of fossil fuels in transportation, warehousing, and postal services are 12.2 Mt, accounting for 62.0% of the total carbon emissions from fossil fuels. The production industries of electricity, heat, gas, and water were Guatemala's second fossil energy carbon emissions industries, changing from 3.2 Mt (25.8%) in 2010 to 1.9 Mt (9.8%) in 2022.

Biomass emissions

In 2022, Guatemala's biomass consumption accounted for 57.7% of the primary energy consumption structure, mainly used for daily consumption. The main types of biomass in Guatemala include firewood and bagasse. Local residents mainly obtain firewood through deforestation for household cooking and heating, which has a significant impact on the environment. Therefore, in the overall carbon accounting process, it should be included in the overall carbon emissions due to the unsustainable use of resources. However, crops such as sugarcane bagasse come from repeatedly planted farmland and are sustainable renewable resources. They have a "zero carbon" attribute throughout their entire life cycle, and should not be included in the overall carbon accounting process.

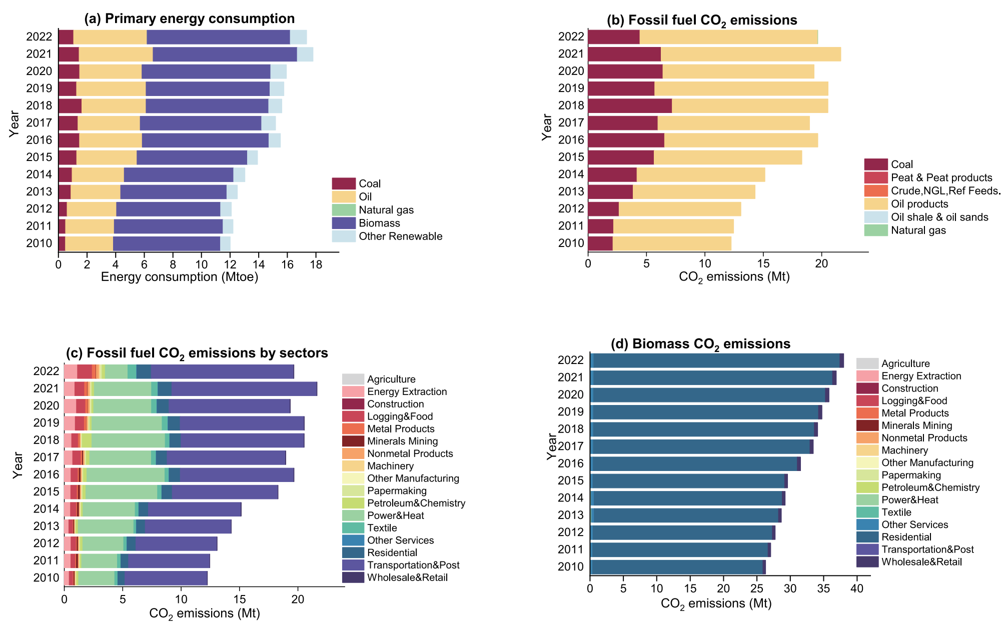
Emission trends

From 2010 to 2022, Guatemala's CO_2 emissions from fossil fuels showed a certain growth trend, increasing from 12.2 million tons to 19.7 million tons. During this period, the carbon emissions generated by biomass consumption increased from 26.3 million tons to 38.0 million tons, an increase of 44.5%.

Comparison with international databases

Under the unified accounting framework, which does not include biomass carbon emissions, the CO_2 emissions from Guatemala's fossil fuels calculated by CEADs are basically consistent with the results published by IEA and EDGAR. The data calculated by CEADs is slightly higher than the results published by GCB. The main difference lies in the accounting results for 2014 and 2020. EDGAR data shows that Guatemala's fossil energy CO_2 emissions decreased from 2014 to 2015, while data released by CEADs shows that fossil energy CO_2 emissions did not decrease during this period. According to the Guatemalan Energy Balance Table collected by CEADs from the Guatemalan Ministry of Energy and Mines, from 2014 to 2015, Guatemala's energy consumption increased from 73712 kilotons of oil equivalent to 77989 kilotons of oil equivalent, with energy consumption increasing by about 6%. Therefore, we believe that CO_2 emissions from fossil fuels should not decrease during the period of 2014 to 2015.

In addition, when emissions generated from biomass consumption is included, the CO_2 emissions calculated by CEADs in 2022 were 57.6 million tons.



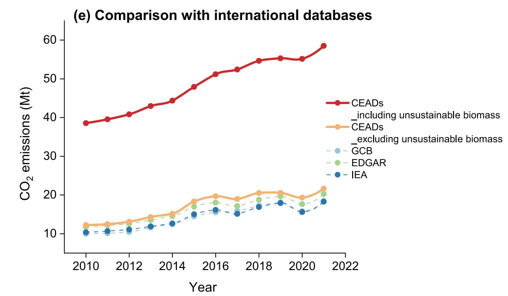


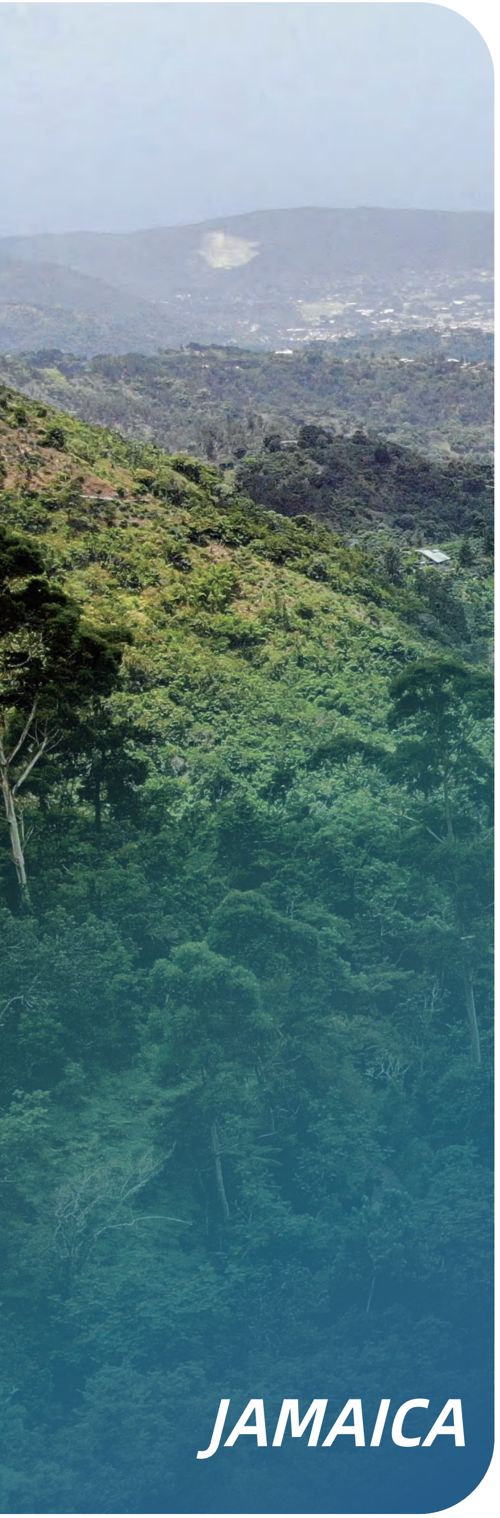
Figure 4.5: Guatemala's energy consumption and CO2 emissions from 2010 to 2022; (a) Primary energy consumption; (b) Fossil fuel CO_2 emissions; (c) Fossil fuel CO_2 emissions by sectors; (d) Biomass CO_2 emissions; (e) Comparison with international databases.

Brief description of data sources:

CEADs used energy balance sheets for 2010-2022 from the Guatemalan Ministry of Energy and Mines, which contained data on the energy processing and conversion of 17 primary and secondary energy types in Guatemala. The country's energy balance sheet contains energy consumption data for four economic sectors: transportation, industry, commercial, services, and residential. UN Comtrade export data is used to break down the four sectors.

Table 4.5: Data sources for Guatemala's emission accounting

Data type	Source	Website
Energy balance sheet	Guatemalan Ministry of Energy and Mines	https://mem.gob.gt/
Emission factor	IPCC	https://www.ipcc-nggip.iges.or.jp/EFDB/
Sectoral mapping indicator	UN Comtrade: export data	https://comtradeplus.un.org/



Background

Jamaica is an island nation in the Caribbean Sea. With an area of 10,990 square kilometers, it is the third largest island in the Greater Antilles and the Caribbean. According to the Statistical Institute of Jamaica, the country's total population in 2022 was 2,839,000[229]. It is the third most populous Anglophone country in the Americas and the fourth most populous in the Caribbean, with 60% of its population under the age of 29. Its GDP in 2022 was US$17.10 billion (at current prices), an increase of 16.6%, and an increase of $1.44 billion over the GDP in 2010.

Jamaica's economy is highly dependent on the service sector, which accounted for 64.8% of GDP in 2022[230]. Thus, tourism and finance are vital components of the country's economy. Agriculture and industry also play an important role, accounting for 8.9% and 21.1% of GDP in 2021, respectively. Jamaica is rich in natural resources including bauxite, copper, iron, lead, zinc and gypsum; its bauxite reserve, of approximately 2.5 billion tons, is the fourth largest in the world. Trade accounts for about a quarter of Jamaica's GDP. Its main export destinations include the United States, the Netherlands and Canada, and its key exports are aluminum oxide, bauxite, chemicals, coffee, mineral fuels and scrap metal. The country's main importers include the United States, Colombia and Japan, and its primary imports are food and other consumer goods, industrial supplies, fuel, parts and accessories for capital goods, machinery and transport equipment, and construction materials.

In terms of the development of renewable energy, the government of Jamaica adopted a National Energy Policy in 2010, which established goals of 20% renewables in the energy mix, and 33% of electricity generated from renewable sources, by 2030[231]. According to the United Nations Framework Convention on Climate Change (UNFCCC), Jamaica's Intended National Determined Contributions (INDC) outline a reduction in CO_2 emissions by 1.1 million tons per year by 2030, which represents a 7.8% reduction in CO_2 emissions compared to business as usual (BAU).

Primary energy consumption

Fossil fuels are dominated by petroleum products in Jamaica's primary energy consumption. In 2022, these products accounted for 94.2% of primary energy consumption: petroleum products for 71.2%, natural gas for 20.8% and coal for 2.1%. In addition to fossil fuels, biomass accounted for 4.3% of primary energy consumption.

Characteristics of fossil fuel emissions

In 2022, Jamaica's carbon emissions from fossil energy consumption were approximately 7.9 Mt. Consumption of petroleum products is the main source of CO_2 emissions from fossil fuels in Jamaica, generating 6.0 Mt of these emissions in 2022 — that is, 76.9% of total fossil fuel carbon emissions. Secondly, the CO_2 emissions resulting from coal and natural gas consumption account for approximately 3.1% and 20.1%, respectively. In contrast, coal's contribution is relatively small and shows little change, increasing slightly from 1.3% in 2010 to 3.1% in 2022.

Sectoral emission contribution

CO_2 emissions from fossil fuel consumption in Jamaica mainly come from transportation, storage and postal services sector, which generated 3.3 Mt of such emissions in 2022, accounting for 42.1% in 2022. In addition, Jamaica's the electricity, heat, gas and water production sector saw a sharp increase in fossil fuel CO_2 emissions. In 2022, the carbon emissions generated by the consumption of fossil fuels in this sector were close to 2.3 Mt, accounting for 29.6% of the total carbon emissions from fossil fuels. The Metal Smelting, Pressing and Products sector follows behind, with carbon emissions from fossil fuels significantly lower than those of the electricity, heat, gas, and water production sectors. In 2022, the Metal Smelting, Pressing and Products sector generated 0.8 million tons of carbon emissions, accounting for 10.4% of the total carbon emissions from fossil fuels.

Biomass emissions

In 2022, biomass accounted for 4.3% of primary energy consumption in Jamaica, dominated by the domestic sector and service industries. The prime types of biomass used include bagasse or sugarcane pulp, wood and municipal waste. Forest timber is overharvested in Jamaica for household cooking and heating, a practice that has significant environmental impacts and is not sustainable. Wood consumption should therefore be counted in the overall carbon accounting process. Sugarcane pulp and municipal solid waste, however, are considered to be sustainable, renewable resources and carbon neutral over their life cycle, and thus should not be included in the overall carbon accounting process. CO_2 emissions from wood consumption showed an upward, then downward trend, rising from 0.6 Mt in 2011 to 0.8 Mt in 2014 and falling to 0.4 Mt in 2022. Due to a change in the statistical caliber, biomass fuel consumption - which before 2013 was classified as belonging to the agriculture sector - has since 2014 been included in the "other consumption" sector in energy balance sheets. This inventory uses sector matching indicators, and the biomass carbon emissions from the "other consumption" sector are allocated to agriculture. As a result, agriculture has shown lower biomass emissions and "other consumption" has shown higher ones after 2014.

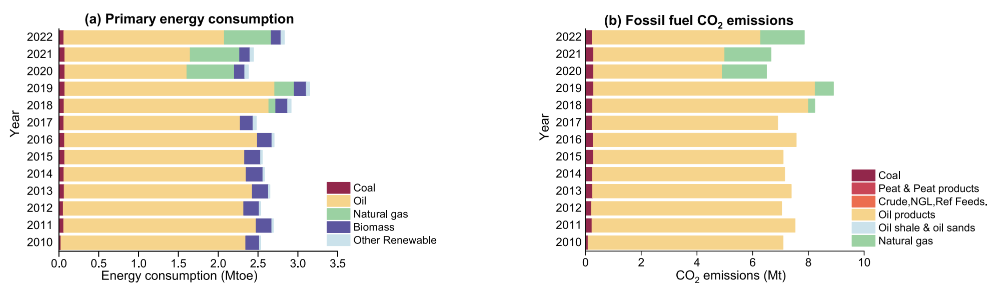
Emission trends

Jamaica's fossil fuel CO_2 emissions showed a rising trend from 7.1 Mt in 2010 to 8.9 Mt in 2019, with a growth rate of 25.5%; it then slightly dropped by 2.2 Mt in 2021. And in 2022, Jamaica's fossil energy CO_2 emissions reach 7.9 Mt, up 18.0% year-on-year. CO_2 emissions from biomass consumption decreased from 0.5 Mt in 2010 to 0.4 Mt in 2021 over the same period.

Comparison with international databases

Under the same accounting caliber (excluding emissions from biomass), CO_2 emissions in Jamaica calculated by CEADs show almost the same annual trend as other agencies' statistics. Specifically, CEADs' calculation for CO_2 emissions in 2018 and 2019 are higher than GCB's, but in other year, CEADs' calculation for CO_2 emissions are lower than GCB's. As for IEA statistics, from 2010 to 2016, CEADs' calculation for CO_2 emissions is higher sightly, in 2017 and 2018, CEADs' statistics were almost the same with IEA's, but since 2018, the data of IEA and CEADs started to overlap. When comparing data sources used by CEADs and the IEA, CEADs data has a more detailed breakdown of energy sources; petroleum products are divided into motor gasoline, diesel, fuel oil and other types, with corresponding emission factors for each. According to IEA's statistical caliber, however, the category of petroleum products is not subdivided further. Therefore, emission factors adopted by CEADs are different from those used by IEA, leading to differences in carbon emission data. Another reason for the discrepancy is the difference in energy consumption data used by CEADs and by IEA. CEADs' are from the Statistical Institute of Jamaica while IEA uses data from multiple sources, including the International Renewable Energy Agency (IRENA). The energy consumption statistics of these agencies differ significantly.

When including CO_2 from biomass consumption, CEADs' calculation for CO_2 emissions in 2022 was 8.3 Mt.



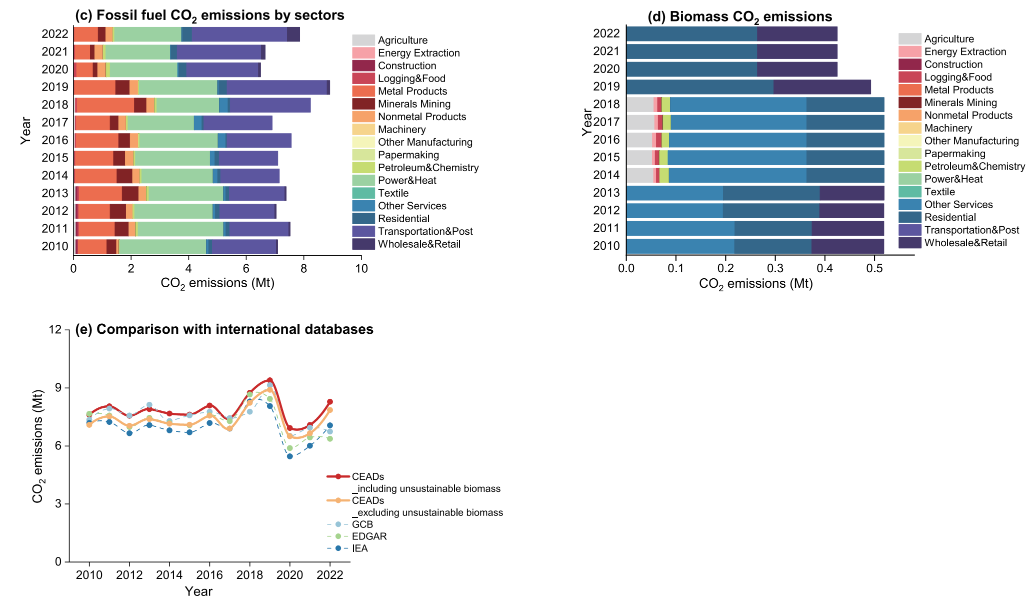


Figure 4.6: Jamaica's energy consumption and CO_2 emissions from 2010 to 2022(a) Primary energy consumption; (b) Fossil fuel CO_2 emissions; (c) Fossil fuel CO_2 emissions by sectors; (d) Biomass CO_2 emissions; (e) Comparison with international databases.

Brief description of data sources:

Energy sources in Jamaica's energy balance sheet are divided into coal, crude oil, gasoline, diesel, turbine, aviation, aviation paraffin, fuel oil, liquefied petroleum gas, raw materials, other non-energy products, firewood, charcoal, sugarcane pulp, hydropower, wind, solar (PV) and electricity. The sectors are divided into manufacturing, agriculture, mining/bauxite, households, services, construction, electricity and heat. The downscaling indicator is from Statistical Institute of Jamaica and export data from UN Comtrade, and the data years are 2010-2022.

Table 4.6: Data sources for Jamaica's emission accounting

Data type	Source	Website
Energy balance sheet	Statistical Institute of Jamaica	https://www.mset.gov.jm/document-category/energy-balances/
Emission factor	IEA	https://www.iea.org/areas-of-work/global-engagement/china?language=zh
Sectoral mapping indicator	Statistical Institute of Jamaica	https://statinja.gov.jm/NationalAccounting/Quarterly/NewQuarterlyGDP.aspx
	UN Comtrade	https://comtrada.un.org

Background

Paraguay, a landlocked country in central South America, is bordered by Argentina, Brazil and Bolivia. The capital of Paraguay is Asuncion. Paraguay covers an area of approximately 406000 square kilometers and ranks 60th in the world. According to World Bank data, the population of Paraguay in 2023 was approximately 6.844 million[232], with a per capita GDP of $6276.4.

Paraguay is one of the most backward countries in Latin America. Agriculture is the main pillar of Paraguay's economy. The main agricultural products include soybeans, cotton, tobacco, wheat, and corn. The proportion of agricultural added value to GDP in 2023 was 11.4%[233]. Paraguay has a weak industrial foundation, mainly consisting of light industry and agricultural and animal husbandry product processing industry. Its main products include canned meat, flour, beverages, tobacco, diesel, naphtha, etc. Paraguay's natural resources mainly include minerals such as iron, gold, magnesium, and limestone. The forest coverage is relatively high, with 70% of forest resources concentrated in the Granchaco region. In terms of international trade, its export products mainly include beans, wood products, cotton, etc. The main export countries are Uruguay, Brazil, Argentina, etc; Its imported products mainly include automobiles, daily necessities, tobacco, petrochemical products, etc., mainly imported from countries such as China, Brazil, and the United States.

According to the analysis by the International Energy Agency[234], Paraguay has been striving to promote natural gas consumption in order to reduce the use of firewood and charcoal. The national development plan for 2014 to 2030 has set a renewable energy target, which is to account for 60% of total energy consumption by 2030 and reduce the share of fossil fuels in energy consumption by 20%. Paraguay has recently approved a commitment to reduce CO_2 emissions by 20% by 2030 in its updated national contribution, emphasizing the use of renewable energy as the main driving force.

Primary energy consumption

Paraguay's fossil energy consumption accounts for nearly 29.9% of its primary energy structure, with petroleum products as the main source. In 2022, petroleum product consumption accounted for 27.7% and natural gas consumption accounted for 2.2%. The primary energy structure is mainly composed of renewable energy sources such as hydropower. Other renewable energy sources, mainly water energy, accounted for 42.9% in 2022. In addition, biomass accounts for 27.2% of the total primary energy consumption.

Characteristics of fossil fuel emissions

The consumption of petroleum products is the main source of carbon emissions from fossil fuels in Paraguay. As Paraguay's main fossil energy source, petroleum products generated 7.4 Mt of CO_2 emissions in 2022, accounting for 93.7% of fossil energy carbon emissions. The CO_2 emissions generated by natural gas consumption have increased from 0.2 Mt in 2010 to 0.5 Mt in 2022, with relatively stable emissions. Paraguay also uses a small amount of coal, and the CO_2 emissions caused by coal consumption in 2022 only accounted for 0.02% of fossil energy carbon emissions.

Sectoral emission contribution

Transportation, storage and postal services is Paraguay's highest-emitting sector. The CO_2 emissions generated by fossil energy consumption in this industry increased from 4.5 Mt in 2010 to 7.5 Mt in 2022, accounting for 94.7% of the total carbon emissions from fossil energy, with an average growth rate of 5.5%. The residential sector is the second-largest fossil fuel carbon emissions industry in Paraguay. In 2022, fossil fuel consumption in this sector generated 0.2 Mt of CO_2 emissions, accounted for 2.6% of the total fossil fuel carbon emissions. Logging and food is the third largest fossil energy carbon emission industry in Paraguay, with 0.07 Mt in 2022, accounting for 0.9% of the total fossil energy carbon emissions.

Biomass emissions

In 2022, Paraguay's biomass consumption accounted for 27.2% of the primary energy consumption structure, mainly used for residential consumption. Paraguay's biomass mainly consists of firewood and sugarcane bagasse, which accounted for 74% and 26% of the biomass energy structure in 2021, respectively. For the acquisition of firewood, only a small portion has been certified as a sustainable source, with the vast majority coming from deforestation. Local residents collect firewood by cutting down trees without permission and use it for household cooking and heating, which has a significant impact on the environment. Therefore, for unsustainable use, it should be included in the overall carbon accounting process and included in the overall emission system. Paraguay also uses biomass waste such as sugarcane bagasse and corn, which come from local plantations and can be repeatedly planted. As a sustainable renewable resource, it has a "zero carbon" attribute throughout its entire life cycle and should not be included in the emission system in the overall carbon accounting process. From 2010 to 2022, the CO_2 emissions generated by firewood consumption increased rapidly from 6.2 Mt in 2010 to 7.9 Mt in 2021.

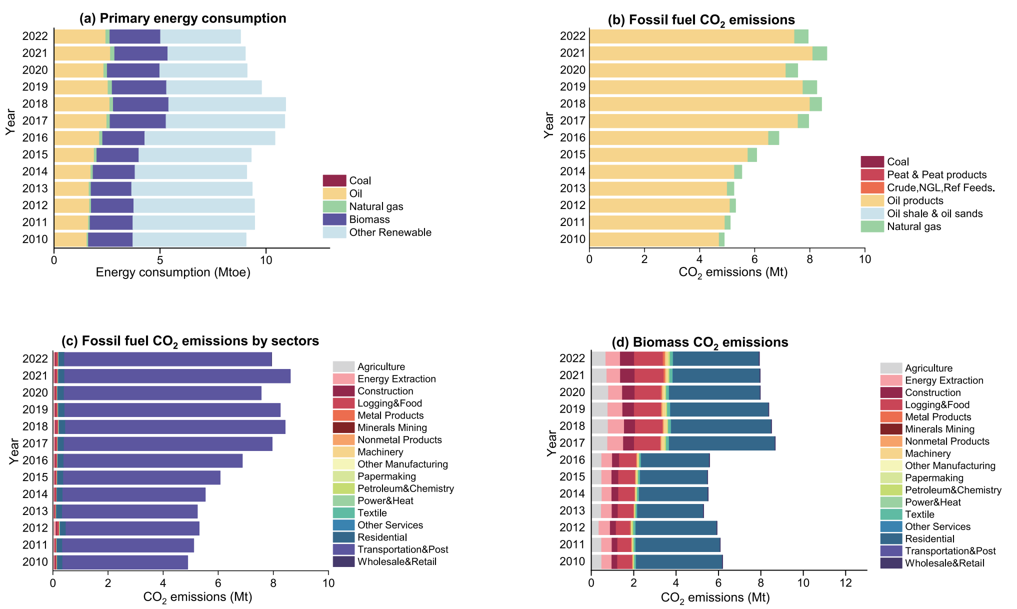
Emission trends

Between 2010 and 2022, Paraguay's CO_2 emissions from fossil fuels showed a rapid growth trend, with an average annual growth rate of 4.1%, increasing from 4.9 Mt to 7.9 Mt in 2022. During this period, the CO_2 emissions generated by biomass consumption increased from 6.2 Mt in 2010 to 7.9 Mt in 2022, showing rapid growth.

Comparison with international databases

Under the same accounting scope (excluding emissions from biomass), the difference between the fossil fuel CO_2 emissions in Paraguay calculated by CEADs and those released by IEA, EDGAR, and GCB is relatively small. The main reasons for the differences are: firstly, there are differences in the selection of emission factors between CEADs, IEA, and EDGAR. Secondly, CEADs data have more detailed energy classifications, while other institutions have relatively vague statistical criteria for energy varieties.

In addition, when CO_2 generated from biomass consumption is included, the CO_2 emissions calculated by CEADs in 2022 were 15.9 Mt.



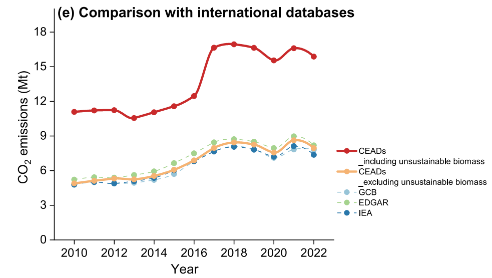


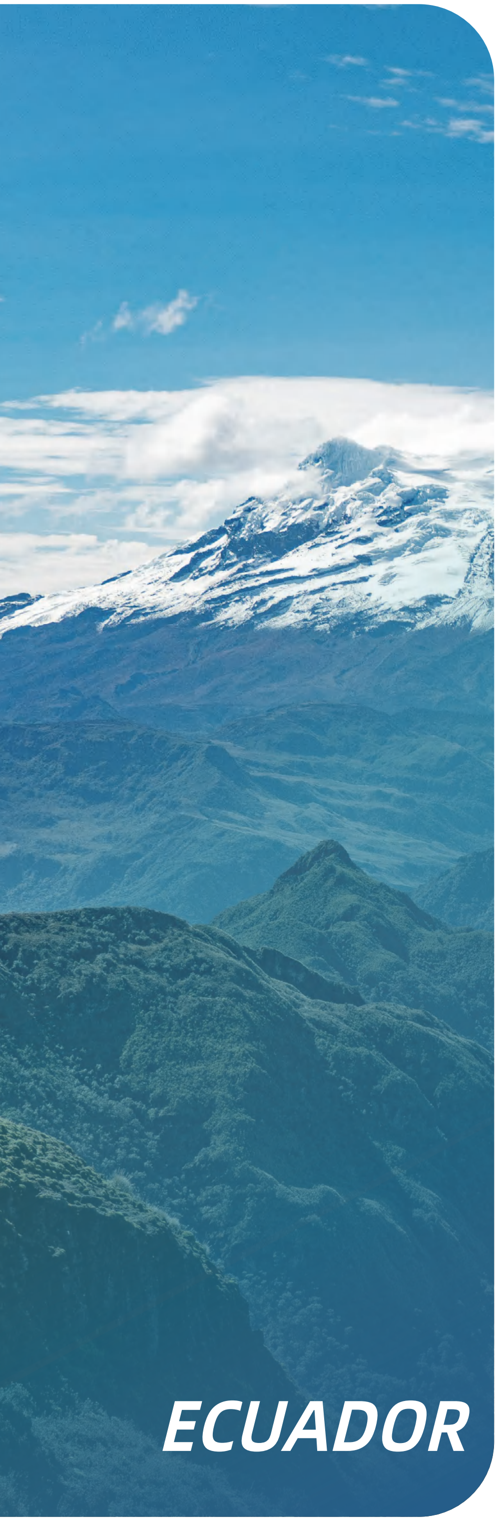
Figure 4.7: Paraguay's energy consumption and CO_2 emissions from 2010 to 2022 (a) Primary energy consumption; (b) Fossil fuel CO_2 emissions; (c) Fossil fuel CO_2 emissions by sectors; (d) Biomass CO_2 emissions; (e) Comparison with international databases.

Brief description of data sources:

The energy balance sheets of Paraguay contain data on the energy processing and conversion of 15 energy types, with gasoline, diesel and firewood being the most-used sources. The country's energy balance sheet contains energy consumption data for four economic sectors: residential, transportation, industry and others. For subsector matching, we use value added by industries from UNdata and export data from the United Nations Commodity Trade Statistics Database (UN Comtrade) to downscale the sectoral matching and assign to 47 sectors.

Table 4.7: Data sources for Paraguay's emission accounting

Data type	Source	Website
Energy balance sheet	Paraguay Bureau of Statistics	http://www.dgeec.gov.py/
Emission factor	Intergovernmental Panel on Climate Change（IPCC）	https://www.ipcc-nggip.iges.or.jp/EFDB/
Sectoral mapping indicator	United Nations Commodity Trade Statistics Database（UN Comtrade）, Export Data	https://comtrada.un.org
	UNdata - Value added by industries	http://data.un.org/Explorer.aspx#marts



Background

Ecuador is located in the northwest part of South America, bordered by Colombia and Peru. It also includes the Galapagos Islands, located about 1000 kilometers west of the mainland in the Pacific Ocean. As of 2022, Ecuador had a population of approximately 17.8 million and a GDP of $116.6 billion (current prices)[235] , with a per capita GDP of around $6541. About 64% of the population lives in urban areas, categorizing it as a middle-income developing country.

Ecuador's agricultural development is relatively slow, with its main agricultural products including bananas, coffee, cocoa, and flowers, making it the world's largest exporter of bananas[236]. The industrial base is relatively weak, with the oil industry serving as Ecuador's largest economic pillar. Despite the country's abundant oil and natural gas reserves, due to a lack of appropriate refining equipment, crude oil exports remain the focus. More than 80% of its energy supply comes from oil and its derivatives[237]. Currently, the Ecuadorian government is striving to diversify its primary energy supply by increasing the provision of renewable energy or natural gas.

Since 2010, the share of hydropower has rapidly increased, now becoming one of the significant sources of power generation in Ecuador. Ecuador is a signatory to the United Nations Framework Convention on Climate Change and has made mitigating climate change one of its national goals, developing the National Climate Change Strategy for 2012-2025. In its commitment to Nationally Determined Contributions, Ecuador aims to increase the proportion of hydropower in renewable energy generation to 90% or higher by 2025 and reduce CO_2 emissions from energy consumption by 20.4%-25% compared to the baseline scenario. With international support, this emission reduction could be further increased to between 37.5% and 45.8%[224].

Primary energy consumption

In 2022, fossil energy consumption accounted for approximately 83.5% of Ecuador's primary energy, dominated by petroleum products, with almost no consumption of coal until 2021, and 1.3% of coal consumption in 2022. Petroleum products accounted for 80.9% of consumption, natural gas 1.4%, and coal 1.3%. In addition, other renewable energy sources, primarily hydro, accounted for 14.1% of primary energy consumption, while biomass made up 2.4%.

Characteristics of fossil fuel emissions

Petroleum product consumption is the main source of carbon emissions from Ecuador's fossil energy. In 2022, petroleum product consumption generated 35.7 Mt of carbon dioxide, accounting for 96.4% of fossil energy carbon emissions. Natural gas is also an important source of fossil energy in Ecuador, with CO_2 emissions from natural gas consumption showing a downward trend since 2016, reaching 0.47 Mt in 2022. Ecuador began consuming coal in 2022 and generated 0.86 Mt of CO_2 emissions.

Sectoral emission contribution

CO_2 emissions from fossil energy consumption in Ecuador mainly come from the transportation, storage, and postal sectors, which increased from 13.3 Mt (42.7%) in 2010 to 21.6 Mt (58.3%) in 2022; the sector primarily uses gasoline and diesel. The logging and food industry is the second-largest sources of fossil energy carbon emissions in Ecuador. Their emissions increased from 1.7 Mt in 2010 to 3.3 Mt in 2022, accounting for 8.9% of total fossil energy carbon emissions. Natural gas, fuel oil, diesel, and other petroleum products are commonly used as fuels for thermal power generation, resulting in significant carbon emissions.

Biomass emissions

In 2022, biomass consumption accounted for 2.4% of Ecuador's primary energy consumption, primarily used for residential purposes. The main sources of biomass in Ecuador include firewood and crop residues such as bagasse. Local residents primarily obtain firewood through deforestation and use it for household cooking and heating, which significantly impacts the environment and is considered unsustainable. Thus, it should be included in the overall carbon accounting process. Meanwhile, the use of crop residues like bagasse is rapidly increasing, and this biomass is considered a sustainable renewable resource that should not be included in the overall carbon accounting process.

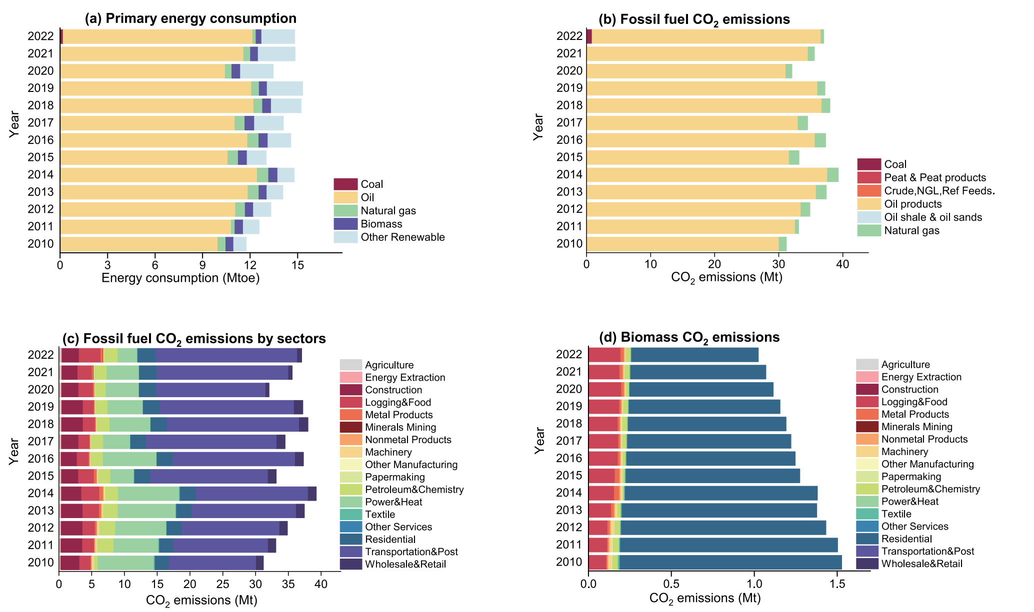
Emission trends

From 2010 to 2014, CO_2 emissions from fossil energy consumption in Ecuador showed an increasing trend, rising from 31.2 Mt in 2010 to 39.3 Mt in 2014. In 2015, emissions from fossil fuels decreased, followed by a fluctuating growth trend, and in 2022, Ecuador's fossil energy CO_2 emissions totaled 37.1 Mt. During this period, emissions from biomass consumption slightly decreased from 1.5 Mt in 2010 to 1.0 Mt in 2022.

Comparison with international databases

Under the unified accounting standards (excluding biomass carbon emissions), the CO_2 emissions from Ecuador's fossil fuels accounted for by CEADs totaled 37.1 Mt in 2022, generally lower than the data released by EDGAR (42.3 Mt), and closer to the data from IEA (38.3 Mt) and GCB (36.0 Mt). Prior to 2014, the growth trends were similar. After 2014, the figures began to diverge, but the difference remained within 3%. The discrepancies in the raw data, where CEADs' data is sourced from Ecuador's Ministry of Energy and Non-Renewable Natural Resources and IEA's from Ecuador's Geological Survey, may account for the differences in the calculated CO_2 emissions.

Additionally, when including CO_2 emissions from biomass consumption, CEADs' calculated emissions for 2022 were 38.1 Mt.



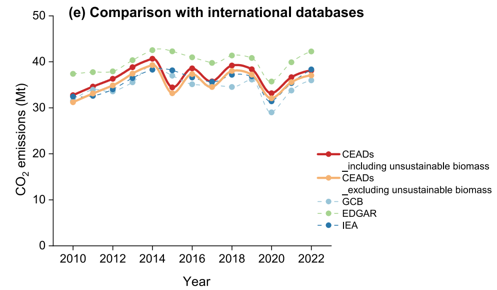


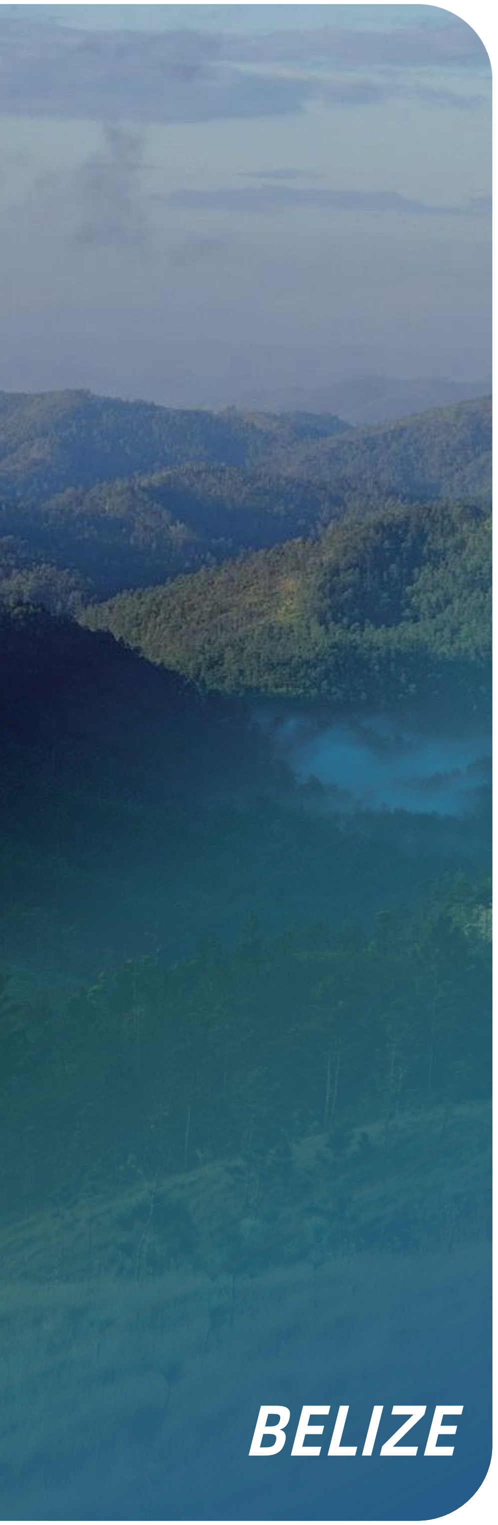
Figure 4.8: Ecuador's energy consumption and CO_2 emissions from 2010 to 2022 (a) Primary energy consumption; (b) Fossil fuel CO_2 emissions; (c) Fossil fuel CO_2 emissions by sectors; (d) Biomass CO_2 emissions; (e) Comparison with international databases.

Brief description of data sources:

CEADs use Ecuador's energy balance sheets for 2010-2022 from the Ministry of Energy and Non-renewable Natural Resource of Ecuador, which contain data on energy processing and conversion of 22 primary and secondary energy types in the country, as well as the energy consumption data for 7 broad economic sectors. CEADs refined the four sectors into 47 sectors using data from Statistical Institute of Ecuador and export data from UN Comtrade.

Table 4.8: Data sources for Ecuador's emission accounting

Data type	Source	Website
Energy balance sheet	Ministry of Energy and Non Renewable Natural Resources	https://www.recursosyenergia. gob.ec/
Emission factor	Intergovernmental Panel on Climate Change（IPCC）	https://www.ipcc-nggip.iges.or.jp/EFDB/
Sectoral mapping indicator	United Nations Commodity Trade Statistics Database（UN Comtrade）， Export Data	https://comtradeplus.un.org/
	Statistical Institute of Ecuador	https://www.ecuadorencifras.gob.ec/



Background

Belize is located in the northeastern part of Central America, bordered by Mexico to the north, Guatemala to the west and south, and the Caribbean Sea to the east. The country spans an area of 22,966 square kilometers with a coastline approximately 386 kilometers long[238]. According to the World Bank, Belize had a total population of about 403,000 in 2022, with a relatively high population growth rate attributed to immigration and a youthful demographic structure, where approximately 28% are under 15 years old and about 5% are aged 65 and above[239]. In 2022, the GDP at current prices was USD 2.85 billion, marking a 19.2% increase compared to the pre-pandemic period; compared to 2010, the GDP grew by USD 1100 million[240].

Historically, Belize's economy has been dominated by agriculture with a weak industrial base. In 2022, the agricultural and industrial sectors contributed approximately 7.7% and 15.4% to the GDP, respectively. In recent years, tourism has become a pillar of the Belizean economy, with offshore financial services, fisheries, light industry, and construction also developing rapidly, with the service sector accounting for about 61.7% of the GDP in 2022[241]. In terms of international trade, Belizeans heavily rely on imports for consumer goods, machinery, and transport equipment, with major exports including sugar, bananas, garments, timber, and seafood, mainly traded with the United States, the United Kingdom, the EU, Mexico, Canada, and Caribbean Community countries. Belize is rich in forest and fishery resources, with approximately 70% forest cover, producing valuable timber and seafood such as lobsters and marlin. The northwestern region of Belize contains mineral resources such as petroleum, barite, cassiterite, and gold, with proven oil reserves of 6.7 million barrels. The Belize government imposed a ban on domestic oil development at the end of 2017 and now relies mainly on imports[238, 242].

In terms of renewable energy development, the Belizean government has heavily invested in domestic biomass power generation, solar energy, and hydropower over the past 20 years, setting a target to source 85% of the country's electricity from renewable energies by 2027, predominantly from hydropower[242]. The "2012-2033 National Sustainable Energy Strategy" aims for Belize to become a net exporter of electricity and biofuels by 2033, increase the energy intensity of GDP by 30%, double the energy recovery from waste streams, and reduce fossil energy imports by 50%[243]. The Belizean government is actively integrating the principles of the "2030 Agenda for Sustainable Development" and its Sustainable Development Goals into the current "Belize Medium-Term Development Strategy 2022-2026," promoting the extensive development of renewable energies to support its strategic implementation[244].

Primary energy consumption

In 2022, fossil energy consumption accounted for approximately 63.9% of Belize's primary energy structure, entirely from petroleum consumption. Biomass accounted for 35.3% of primary energy consumption, while hydropower, solar energy, and other renewable energies made up 4.8%.

Characteristics of fossil fuel emissions

In 2022, Belize's fossil energy carbon emissions totaled 0.8 Mt, all arising from petroleum product consumption. Carbon emissions from petroleum product consumption in 2022 increased by 0.3 Mt compared to 2010, consistently accounting for nearly 100% of fossil energy carbon emissions. In contrast, natural gas contributed minimally to fossil energy carbon emissions with its share decreased.

Sectoral emission contribution

Belize's fossil energy carbon emissions mainly stem from the transportation, storage, and postal services, and residential consumption sectors. Since 2010, these sectors have shown fluctuating carbon emissions from fossil energy consumption, reaching 0.6 Mt in 2022, accounting for 71.2% of fossil energy carbon emissions. Residential consumption is the second largest sector for fossil energy carbon emissions, with emissions totaling 0.1 Mt in 2022, accounting for 9.5% of the total.

Biomass emissions

In 2022, biomass accounted for about 31.3% of Belize's primary energy consumption, generating carbon emissions that decreased from 0.09 Mt in 2010 to 0.07 Mt. The primary sources of biomass consumption are residential use, with carbon emissions decreasing from 0.06 Mt in 2010 to 0.05 Mt in 2022. Belize's biomass primarily includes firewood and crop residues such as bagasse, representing 11.2% and 88.8% of the biomass energy structure, respectively. Due to the lack of traditional energy sources, locals obtain firewood by deforestation for household cooking and heating, which significantly impacts the environment and is considered unsustainable. Thus, it should be included in the overall carbon accounting process. Meanwhile, biomass wastes like bagasse, sourced from local agricultural plantations, are considered sustainable renewable resources with a "zero carbon" attribute throughout their lifecycle and should not be included in the emission system.

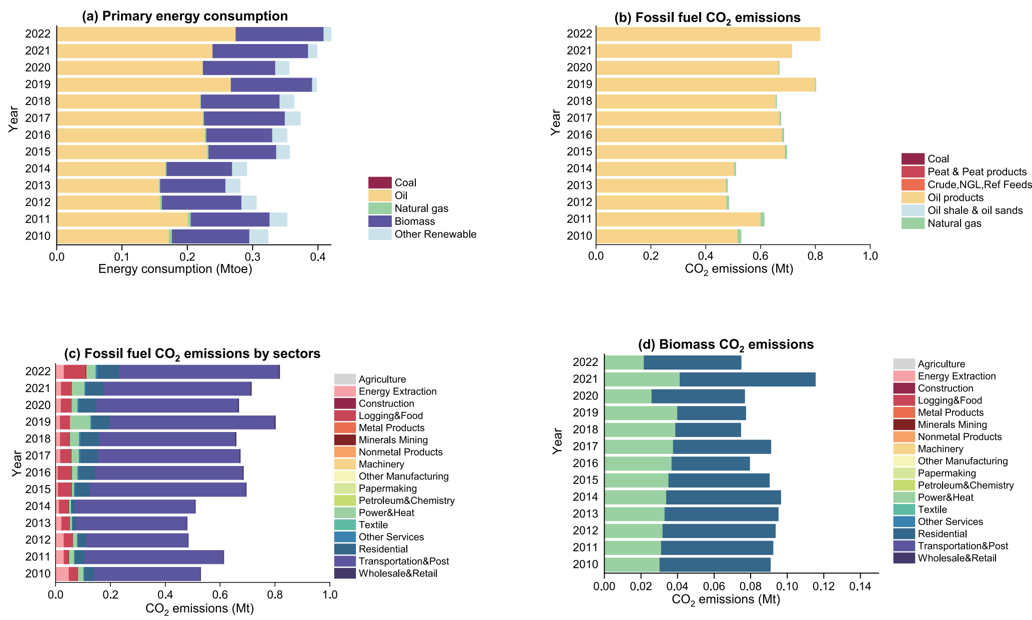
Emission trends

From 2010 to 2022, Belize's fossil energy carbon emissions showed an increasing trend, rising from 0.5 Mt in 2010 to 0.8 Mt in 2021, with an average annual growth rate of 3.7%. During this period, emissions from biomass burning decreased from 0.09 Mt to 0.07 Mt.

Comparison with international databases

Under the same accounting standards (excluding biomass carbon emissions), CEADs' data on Belize's fossil energy carbon emissions almost align with the annual trends of other international institutions, but CEADs' annual figures are consistently higher. The gaps with IEA and GCB are approximately 3.3% and 6.4%, respectively. The difference arises because CEADs has more detailed energy classification, with each type of oil having a corresponding emission factor, whereas other institutions like the IEA categorize energy simply as petroleum products. Therefore, the emission factors used by CEADs differ from those used by the IEA, leading to differences in carbon emission data. Another reason for the discrepancy is the different sources of energy consumption data used; CEADs uses data from the Latin American and Caribbean Energy Information System (Olade), while other institutions like the IEA use multiple sources, including the International Renewable Energy Agency (IRENA), leading to significant differences in energy consumption statistics and further discrepancies in CO_2 emissions data between CEADs and other institutions.

Additionally, when including carbon dioxide from biomass consumption, the accounting data for CEADs in 2022 is 0.9 Mt.



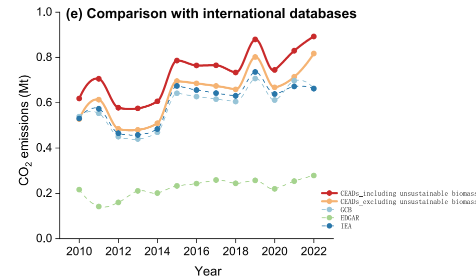


Figure 4.9: Belize's energy consumption and CO_2 emissions from 2010 to 2022 (a) Primary energy consumption; (b) Fossil fuel CO_2 emissions; (c) Fossil fuel CO_2 emissions by sectors; (d) Biomass CO_2 emissions; (e) Comparison with international databases.

Brief description of data sources:

Belize's energy balance tables are sourced from the Energy Information System of Latin America and the Caribbean (Olade), covering data from 2010 to 2022 across 19 types of energy and 6 sectors. In the allocation to sectors, data on the output of commercial and public sectors published by the national statistics office, along with industrial product export data from UN Comtrade are used as the basis for disaggregating and allocating to 47 sectors.

Table 4.9: Data sources for Belize's emission accounting

Data type	Source	Website
Energy balance sheet	Energy Information System of Latin America and Caribbean	https://sielac.olade.org/WebForms/Reportes/ReporteBalanceEnergetico.aspx?or=600&ss=2&v=3
Emission factor	Intergovernmental Panel on Climate Change（IPCC）	https://www.ipccnggip.iges.or.jp/EFDB/
Sectoral mapping indicator	Belize Statistical Institute, Statistical Yearbook (GDP data)	https://sib.org.bz/publications/annual-reports/
	United Nations Comtrade database (UN Comtrade), export data	https://comtradeplus.un.org/
	World Bank (Urbanization rate data)	https://data.worldbank.org.cn/indicator/SP.URB.TOTL.IN.ZS

Background

Colombia, spanning the continents of South and North America, is primarily located in northwestern South America, consisting of 32 provinces and its largest city, Bogotá Capital Region, and is bordered by Venezuela and Brazil. In 2022, Colombia's population was 51.73 million, and its GDP was $345,3 billion (current price)[245].

Industry is a pillar of the national economy, with industrial added value accounting for about 26.15% of the GDP in 2022[246]. The country is rich in natural resources, with nearly 60 million hectares of forest, accounting for 59% of the national territory, and key minerals including coal, oil, and emeralds. Colombia has the world's largest emerald reserves and consistently accounts for half of the global emerald market. It is Latin America's fourth-largest oil producer and the world's fourth-largest coal producer, as well as the third largest coffee exporter[247], primarily trading with the United States, China, Mexico, and Japan.

Renewable energy is rapidly developing in Colombia, with hydropower accounting for over 70% of installed capacity[248]. This growth is due to proactive government policies and actions, such as the Renewable Energy Law introduced in 2014, which aims to promote the development and use of renewables through incentives like tax reductions or exemptions. Additionally, Colombia has committed to reducing domestic deforestation to protect vital ecosystems, especially in the Amazon region[224], and has pledged to reduce greenhouse gas emissions by 20% by 2030 compared to the baseline scenario, with a 30% reduction achievable with international support. This equates to a reduction of 67 Mt to 100.5 Mt of emissions by 2030.

Primary energy consumption

Fossil fuels, dominated by petroleum products, accounted for 74.8% of Colombia's primary energy consumption in 2022. Coal consumption made up 7.5%, petroleum products 46.8%, and natural gas 20.4%. Additionally, renewable energy sources, primarily hydropower, represented 13.8% of primary energy consumption, while biomass accounted for 11.5%.

Characteristics of fossil fuel emissions

Petroleum product consumption is the primary source of CO_2 emissions from fossil fuels in Colombia. Emissions from this source increased from 36.9 Mt in 2010 to 54.9 Mt in 2022, accounting for 56.1% of that year's fossil fuel CO_2 emissions. Diesel and gasoline are the main types of energy consumption, with other petroleum products like fuel oil, liquefied petroleum gas, paraffin, and jet fuel also contributing to emissions. In 2022, natural gas consumption resulted in 20 Mt of CO_2 emissions, representing 22.5% of all fossil fuel CO_2 emissions. Meanwhile, coal consumption accounted for 14% of the fossil fuel CO_2 emissions.

Sectoral emission contribution

The transportation, storage, and postal sector is the largest contributor to CO_2 emissions from fossil fuel consumption in Colombia. In 2022, this sector was responsible for 45.9 Mt of CO_2 emissions, representing 51.7% of total fossil fuel emissions. The utility sector, producing electricity, heat, gas, and water, is the second-largest emitting sector, with its fossil energy consumption resulting in 13.1 Mt of CO_2 emissions in 2022.

Biomass emissions

In 2022, biomass consumption in Colombia accounted for 11.5% of primary energy consumption, primarily used for residential purposes. Biomass mainly includes wood, biodiesel, and crop waste such as sugarcane pulp. Wood is primarily obtained through deforestation and used for household cooking and heating, significantly impacting the environment and thus considered unsustainable. It should be included in the overall carbon accounting process. Biodiesel and crop waste, on the other hand, come from local plantations and can be repeatedly planted, making them sustainable renewable resources with a "zero carbon" attribute throughout their life cycle and should not be included in the emission accounting system. From 2010 to 2022, CO_2 emissions from wood consumption decreased from 17.6 Mt to 13.4 Mt.

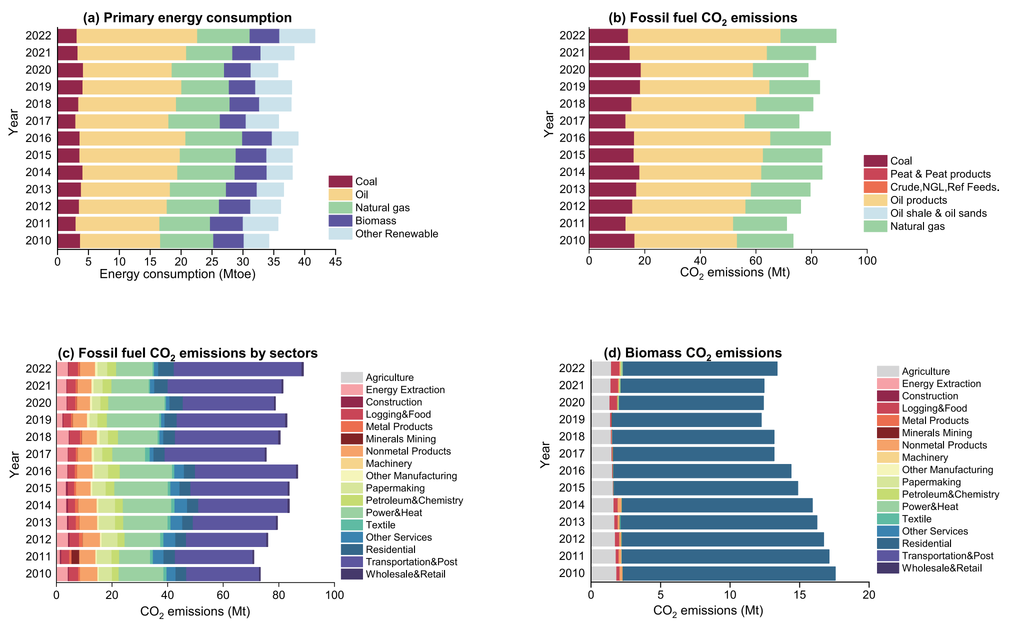
Emission trends

From 2010 to 2022, Colombia's fossil fuel CO_2 emissions grew at an average annual rate of 1.8%, increasing from 73.4 Mt to 88.9 Mt. During this period, CO_2 emissions from biomass consumption decreased from 17.6 Mt to 13.4 Mt.

Comparison with international databases

Under the same accounting standards (excluding emissions from biomass), fossil fuel CO_2 emissions in Colombia calculated by CEADs closely align with those reported by EDGAR, with an average difference of no more than 3% between 2010 and 2022. The trends are consistent with those reported by GCB, and figures published by CEA n those of the IEA. Differences in original energy data sources are a primary cause of these discrepancies. CEADs obtained energy balance sheets directly from the official website of the Colombian Mining and Energy Planning Unit, while the IEA obtained data through communications with the unit.

Additionally, when including biomass consumption, the CO_2 emissions in 2022 calculated by CEADs stood at 102.3 Mt.



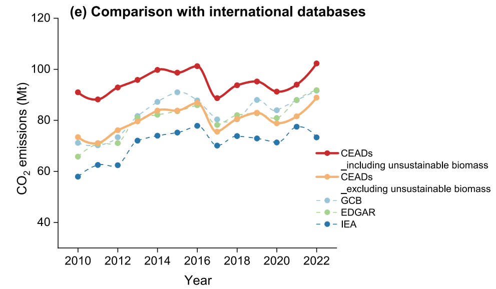


Figure 4.10: Colombia's energy consumption and CO_2 emissions from 2010 to 2022 (a) Primary energy consumption; (b) Fossil fuel CO_2 emissions; (c) Fossil fuel CO_2 emissions by sectors; (d) Biomass CO_2 emissions; (e) Comparison with international databases.

Brief description of data sources:

CEADs relied on Colombia's energy balance sheets for 2010-2022 from the Colombian Mining and Energy Planning Unit, which contain data on energy processing and conversions for 19 primary and secondary energy types, including biomass, raw coal, petroleum products and natural gas, among others. These energy balance sheets also contain detailed energy consumption data for nearly 40 economic sectors. For subsector matching, we use export data from the UN Comtrade to downscale the sectoral matching and assign to 47 sectors.

Table 4.10: Data sources for Colombia's emission accounting

Data type	Source	Website
Energy balance sheet	Colombian Ministry of Mines and Energy	https://www1.upme.gov.co/InformacionCifras/Paginas/BECOCONSULTA.aspx
Emission factor	Intergovernmental Panel on Climate Change（IPCC）	https://www.ipcc-nggip.iges.or.jp/EFDB/
Sectoral mapping indicator	United Nations Commodity Trade Statistics Database（UN Comtrade）， Export Data	https://comtrada.un.org

Background

Peru, located in the western part of South America, borders countries such as Ecuador, Colombia, and Brazil. Peru is a developing country with a moderate human development index. As of 20223, Peru's total population was approximately 33.85 million, with approximately 20.2% of the population in poverty[249], especially in rural areas where 53.0% of the rural population was identified as poor, and 16.6% of the urban population was identified as poor. In 2023, Peru's GDP was $267.6 billion (current price), with a per capita GDP of approximately $7906.6 (current price)[250].

Peru's economy mainly relies on mining, agriculture, and light industry. Mining is the main economic pillar of Peru, which is one of the world's largest producers of silver, tin, and gold, as well as one of the main producers of metals such as copper, zinc, lead, and antimony. In terms of agriculture, Peru is one of the world's largest producers of cocoa beans and Himalayan quinoa, as well as one of the main producers of agricultural products such as coffee, cotton, corn, potatoes, and fruits. In terms of light industry, Peru's textile, clothing, leather products, and food processing industries have also developed to some extent[251]. In 2023, the proportion of Peru's primary, secondary, and tertiary industries to GDP was 7.2%, 33.9%, and 51.3%, respectively[252]. Peru has a forest area of 78 million hectares and a forest coverage rate of 58%, second only to Brazil in South America. Fishery resources are abundant, and fish meal production ranks among the top in the world. Peru implements a free trade policy, mainly exporting mineral products and petroleum, agricultural and animal husbandry products, textiles, and fishing products. In recent years, Peru's participation in international trade has continuously increased, mainly exporting metals such as copper, gold, and zinc to the United States, China, Brazil, and the European Union.

Peru is committed to addressing global change. Peru's energy development strategy plans to double the share of renewable energy by 2030[253]. Meanwhile, as mentioned in Peru's national independent contribution, it is expected to reduce greenhouse gas emissions by 30% compared to the baseline scenario by 2030[224].

Primary energy consumption

Fossil fuel consumption, dominated by petroleum products and natural gas, accounted for 75.2% of primary energy consumption in Peru. In 2022, coal accounted for 2.7%, oil for 44.6%, and natural gas for 27.8%. In addition, wind, solar, hydropower, and other renewable energy sources accounted for 11.6%; biomass accounted for 13.2% of primary energy consumption.

Characteristics of fossil fuel emissions

Consumption of petroleum products is the biggest source of CO_2 emissions from fossil fuels in Peru. In 2022, CO_2 emissions from this source were 29.1 Mt, accounting for 52.8% of fossil fuel emissions. CO_2 emissions from natural gas consumption showed an overall increasing trend from 11.5 Mt in 2010 to 17.2 Mt in 2022. Additionally, coal consumption accounted for less than 10% of CO_2 emissions.

Sectoral emission contribution

The transportation, storage, and postal services sector is the highest emitter of carbon dioxide from fossil fuel consumption in Peru. CO_2 emissions from this sector increased from 18.8 Mt in 2010 to 26.6 Mt in 2017, with an average annual growth rate of 5.07%, then slightly decreased in 2018 to 25.3 Mt, accounting for 50.7% of total fossil fuel emissions, rebounded to 26.5 Mt in 2019, decreased again to 20.8 Mt in 2020 due to the global pandemic, and then significantly increased again in 2022 to 28.1 Mt. The utility sector, producing electricity, heat, gas, and water, is Peru's second-largest sectoral emitter, with CO_2 emissions from fossil energy consumption decreasing from 11.5 Mt in 2010 to 12.1 Mt in 2022, accounting for 25.7% and 21.9% of that year's total fossil fuel emissions, respectively. The manufacture of metal products is the third-largest sector emiter in Peru. In 2022, the CO_2 emissions from fossil energy consumption in this industry were about 4.3 Mt, accounting for 7.9% of the total CO_2 emissions from fossil energy.

Biomass emissions

In 2022, Peru's biomass consumption accounted for about 13.2% of the primary energy consumption structure, mainly used for daily consumption. Biomass in Peru mainly includes firewood, animal manure, and crop waste represented by sugarcane bagasse. Local residents mainly obtain firewood through deforestation and use it for household cooking and heating, which has a significant impact on the environment and thus is considered unsustainable. It should be included in the overall carbon accounting process. Peru also uses biomass waste such as sugarcane bagasse, which comes from local plantations and can be repeatedly planted, being considered a sustainable renewable resource with a "zero carbon" attribute throughout its entire life cycle and should not be included in the emission system in the overall carbon accounting process. CO_2 emissions from biomass consumption increased from 9.1 Mt in 2010 to 12 Mt in 2022.

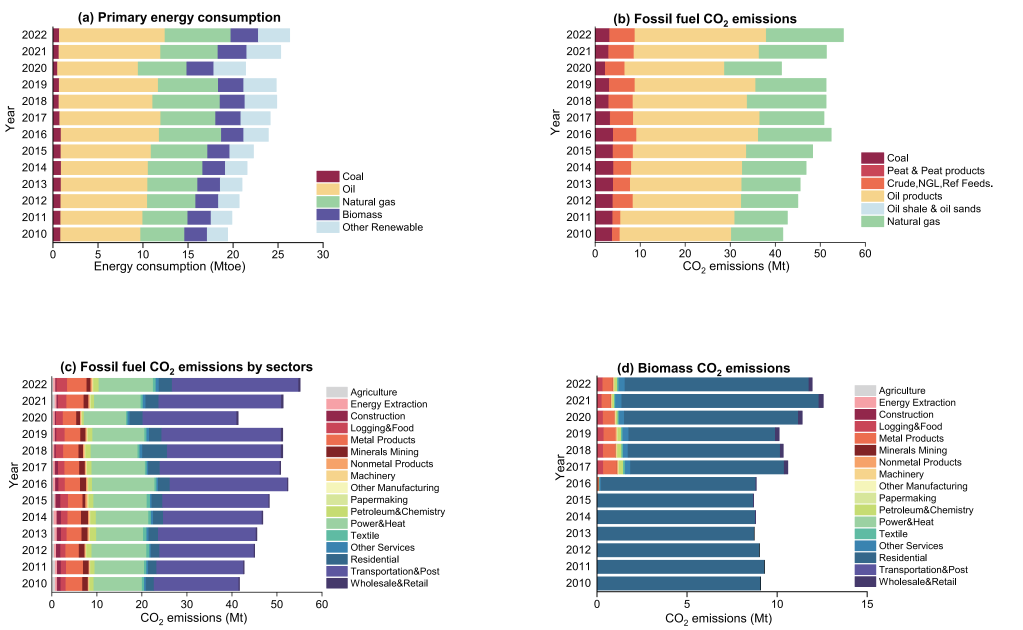
Emission trends

From 2010 to 2019, Peru's fossil energy CO_2 emissions showed a stable growth trend, increasing from 41.7 Mt in 2010 to 51.3 Mt in 2019; in 2020, due to the impact of the global pandemic, the total emissions decreased to 41.4 Mt, and in 2022, emissions returned to 55.2 Mt. During this period, CO_2 emissions from biomass consumption increased from 9.1 Mt in 2010 to 12 Mt in 2022.

Comparison with international databases

Under the unified accounting framework, which does not include biomass CO_2 emissions, the CO_2 emissions from fossil fuels in Peru calculated by CEADs are relatively low compared to the data released by EDGAR, about 10% lower; The data is basically consistent with that of IEA and GCB, with an average difference of less than 1.7%.

Additionally, when CO_2 generated from biomass consumption is included, the CO_2 emissions calculated by CEADs in 2022 were 67.1 Mt.



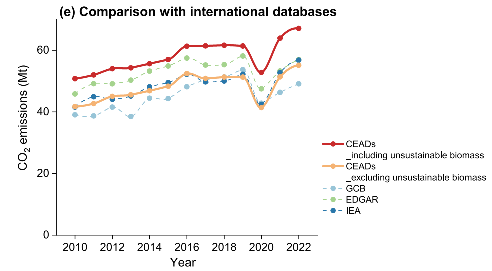


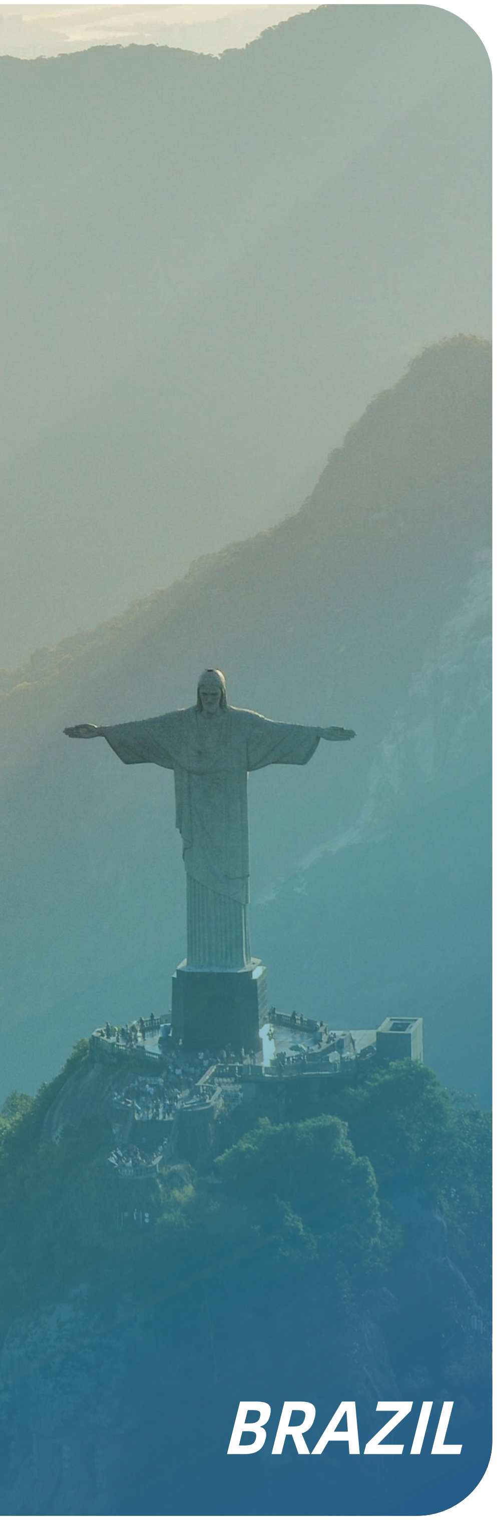
Figure 4.11: Peru's energy consumption and CO_2 emissions from 2010 to 2022 (a) Primary energy consumption; (b) Fossil fuel CO_2 emissions; (c) Fossil fuel CO_2 emissions by sectors; (d) Biomass CO_2 emissions; (e) Comparison with international databases.

Brief description of data sources:

CEADs obtained energy balance sheets from the Peruvian National Environmental Information System, which contains process and conversion data for 26 energy sources, as well as energy consumption data for 8 economic sectors. We refined the 4 sectors into 47 sectors using value added by industries from UNdata and UN Comtrade export data.

Table 4.11: Data sources for Peru's emission accounting

Data type	Source	Website
Energy balance sheet	Peru Environmental Information System	https://sinia.minam.gob.pe/
Emission factor	Intergovernmental Panel on Climate Change（IPCC）	https://www.ipcc-nggip.iges.or.jp/EFDB/
Sectoral mapping indicator	UN Comtrade，Export Data	https://comtrada.un.org
	UNdata - Value added by industries	http://data.un.org/Explorer.aspx#marts



Background

Brazil, the largest country in Latin America, is located in the eastern part of South America, mainly between the Equator and the Tropic of Capricorn, bordering the Atlantic Ocean and countries including Uruguay, Argentina, and Paraguay. According to World Bank official data, in 2022 Brazil had a population of 215 million, and its GDP was US$1,901.461 billion (constant 2015 prices).

The pillars of Brazil's national economy are industry and agriculture. In 2022, industry accounted for 20.7% of the country's GDP[254]. Brazilian industries are diverse, ranging from automobiles, steel, and petrochemicals to computers, aircraft, and consumer goods[255]. Additionally, Brazil is the world's largest producer of coffee, sugar cane, and oranges, and one of the largest producers of soybeans. Half of Brazil's territory is forested, including the Amazon, the world's largest rainforest; Brazil is also the fourth largest exporter of timber. In international trade, its primary exports are soybeans, iron ore, oil, and pulp, mainly to China, the United States, and the Netherlands. Its key imports include refined petroleum products, crude oil, communication equipment, and auto parts, mostly from China, the United States, Argentina, and Germany.

The Brazilian government is actively developing new public policies to address climate change. By implementing climate change adaptation policies and measures, Brazil aims to reduce vulnerability and enhance ecosystem services, improving the resilience of ecosystems, infrastructure, and production systems. Meanwhile, the involvement of various stakeholders will help in the planning and implementation of Brazil's strategies. In 2021, Brazil committed to achieving carbon neutrality by 2050, with one of its key strategies being to reduce net CO_2 emissions by 37% by 2025 and 43% by 2030[256]. In 2022, Brazil updated its National Independent Contribution (NDC), adding a commitment to end illegal deforestation by 2028[257]. In 2023, Brazil reiterated its goal of achieving carbon neutrality by 2050 in its updated NDC[258]. Additionally, the Brazilian Supreme Court reactivated the Climate Fund and became the first country to recognize the Paris Agreement as a human rights treaty[259].

Primary energy consumption

Fossil fuel consumption accounted for 54.5% of Brazil's primary energy consumption, dominated by petroleum products. In 2022, coal consumption accounted for 5.3%, petroleum products for 39.9%, and natural gas for 9.4%. In addition, hydropower, wind energy, and other renewable energy sources accounted for 14.4%; biomass accounted for 31.1% of primary energy consumption.

Characteristics of fossil fuel emissions

Consumption of petroleum products is the largest source of CO_2 emissions from fossil fuels in Brazil. In 2022, CO_2 emissions from this source exceeded 291.4 Mt, accounting for 69.5% of fossil fuel emissions. Since 2017, CO_2 emissions from coal consumption have decreased annually, from 65.5 Mt to 56.2 Mt in 2020, and then rose to 68.9 Mt in 2021, returning to pre-2015 emission levels, and reduced to 56.7 Mt in 2022. Additionally, the consumption of natural gas is a major source of fossil fuel CO_2 emissions in Brazil. From 2010 to 2015, its CO_2 emissions increased rapidly, peaking at over 90 Mt, while from 2016 to 2020, its emissions fell back and fluctuated around 80 Mt. However, after the pandemic, CO_2 emissions from natural gas consumption rapidly increased to 89.8 Mt in 2021, and then decrease to 70.9 Mt in 2022.

Sectoral emission contribution

The transportation, storage, and postal services sector is the largest source of CO_2 emissions from fossil fuel consumption in Brazil, fluctuating between 173.9 Mt and 213.2 Mt. In 2022, this sector's CO_2 emissions from fossil fuel consumption were 211.1 Mt, accounting for 50.4% of total fossil fuel emissions. The utility sector and the mineral extraction industry are also major sources of CO_2 emissions from the consumption of fossil energy in Brazil, emitting 40.8 Mt and 32.9 Mt respectively in 2022, both showing decreases compared to 2020.

Biomass emissions

In 2022, biomass consumption accounted for 31.1% of Brazil's primary energy consumption, mainly used in the electricity, heat, gas, water production industries, the paper industry, and residential consumption. The main types of biomass in Brazil include crop waste such as sugarcane and wood. Local residents primarily obtain wood through deforestation and use it for household cooking and heating, which has a significant environmental impact and is considered unsustainable. It should be included in the overall carbon accounting process. Brazil also uses biomass waste such as sugarcane bagasse, which comes from local plantations and can be repeatedly planted, being considered a sustainable renewable resource with a "zero carbon" attribute throughout its entire life cycle and should not be included in the emission system in the overall carbon accounting process. From 2010 to 2022, CO_2 emissions from wood and other biomass consumption increased from 138.3 Mt to 216.6 Mt, with an average annual growth rate of 3.8%.

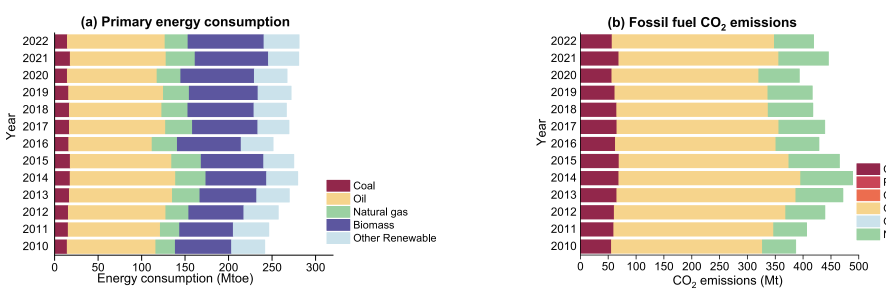
Emission trends

Brazil's fossil energy CO_2 emissions displayed a trend of initial growth, subsequent decline, and then rapid increase and rapid decrease. Between 2010 and 2014, CO_2 emissions from fossil energy consumption increased by 26.4%, rising annually from 387.0 Mt to 488.9 Mt. Subsequently, from 2014, CO_2 emissions from fossil energy consumption showed a declining trend, decreasing at an average annual rate of 3.7% to 393.6 Mt in 2020. After the pandemic, CO_2 emissions from fossil energy consumption rapidly increased in 2021 to 445.7 Mt, a single-year increase of 13.3%, and then reduced to 419.1 Mt in 2022. During this period, CO_2 emissions from biomass consumption increased from 138.3 Mt to 216.6 Mt, with an average annual growth rate of 3.8%.

Comparison with international databases

Under the unified accounting framework, which does not include biomass CO_2 emissions, the annual emission trend of Brazil's fossil energy CO_2 emissions calculated by CEADs is almost the same as that of other institutions' carbon dioxide statistical data, but there is a certain gap in the annual values. Specifically, compared to the statistical data of EDGAR and GCB, CEADs' statistical data is slightly lower; compared to the IEA's statistical data, CEADs' statistical data is slightly higher than the IEA's. From the perspective of statistical caliber, CEADs data has more detailed energy classification. For example, petroleum products are divided into automotive gasoline, diesel, fuel oil, etc., each type of oil has a corresponding emission factor, while according to the IEA's statistical caliber, energy varieties are only classified as petroleum products. Therefore, the emission factors used by CEADs are different from those used by IEA, which also leads to differences in carbon dioxide emission data. Another reason for the difference is that CEADs and IEA use different energy consumption data. CEADs use energy consumption data from the Brazilian Bureau of Statistics, while IEA data comes from multiple sources such as the International Renewable Energy Agency (IRENA). There is a significant gap between the energy consumption statistics of these institutions, which in turn leads to differences in CO_2 emissions data between CEADs and IEA.

Additionally, when CO_2 emissions generated from biomass consumption is included, the CO_2 emissions calculated by CEADs in 2022 were 635.7 Mt.



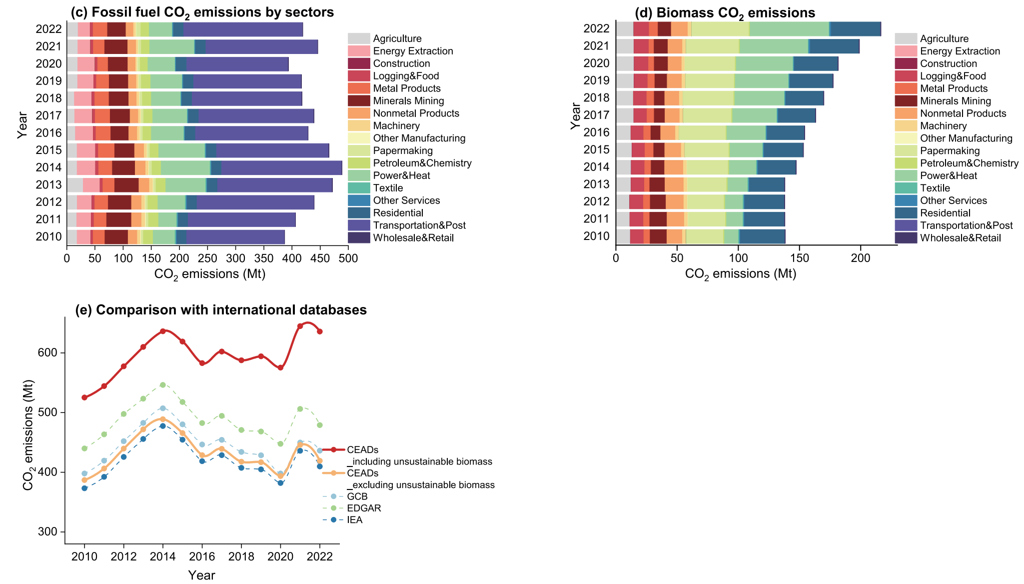


Figure 4.12: Brazil's energy consumption and CO_2 emissions from 2010 to 2022 (a) Primary energy consumption; (b) Fossil fuel CO_2 emissions; (c) Fossil fuel CO_2 emissions by sectors; (d) Biomass CO_2 emissions; (e) Comparison with international databases.

Brief description of data sources:

The energy types in the energy balance table include oil, natural gas, thermal coal, metallurgical coal, firewood, sugarcane products, other primary energy, biodiesel, diesel, fuel oil, gasoline, liquefied petroleum gas, naphtha, kerosene, coke oven gas, coking coal, charcoal, ethanol, other secondary energy, other petroleum products, other petroleum secondary energy, and tar. The industries are divided into energy sector, consumer goods, commerce, public sector, agriculture and animal husbandry, transportation, cement production, pig iron and steel production, steel alloy production, mining, non-ferrous metal production, chemical industry, food and beverage production, textile industry, paper making industry, ceramic production, and other industries. For subsector matching, we use export data from the UN Comtrade and GDP by industry published by Brazilian Bureau of Statistics.

Table 4.12: Data sources for Brazil's emission accounting

Data type	Source	Website
Energy balance sheet	Brazilian Bureau of Statistics	https://www.epe.gov.br/sites-en/publicacoes-dados-abertos/publicacoes/Paginas/Brazilian-Energy-Balance-2023.aspx
Emission factor	IPCC	https://www.ipcc-nggip.iges.or.jp/EFDB/
Sectoral mapping indicator	Brazilian Bureau of Statistics	https://www.ibge.gov.br/en/statistics/economic/national-accounts/17173-system-of-national-accounts-brazil.html?edicao=41775&t=resultados
	UN Comtrade	https://comtrada.un.org

Background

Grenada is an island nation in the eastern Caribbean Sea, part of the Windward Islands in the Lesser Antilles. It lies to the south of Saint Vincent and the Grenadines and approximately 100 miles (160 kilometers) from Trinidad and Tobago and the South American mainland. In 2022, Grenada had a population of approximately 117,000 with a GDP of $1.22billion (current price) and a per capita GDP of about $10474.3[260]. Approximately 37% of the population lived in urban areas, classifying it as a middle-income developing country.

Tourism is a pillar of Grenada's economy. The country's main agricultural exports are nutmeg and mace, making Grenada the world's second-largest exporter of nutmeg. Currently, nearly all of the country's electricity is generated from fossil fuels, specifically diesel[261]. In 2022, 92.6% of the energy supply came from fossil fuels.

Primary energy consumption

Fossil fuel consumption accounted for about 92.6% of Grenada's primary energy consumption in 2022, almost entirely from petroleum products. Petroleum product consumption accounted for 92.6%, and biomass consumption accounted for 7.1%. Renewable energy only accounted for 0.3%.

Characteristics of fossil fuel emissions

In 2022, the consumption of petroleum products was the main source of CO_2 emissions from fossil fuel consumption in Grenada, generating 0.4 Mt of CO_2 emissions, accounting for 100% of fossil fuel carbon emissions.

Sectoral emission contribution

The CO_2 emissions from fossil fuel consumption in Grenada are primarily generated by the production of electricity, heat, gas, and water. These industries generated CO_2 emissions from fossil fuel consumption increasing from 0.13 Mt (49.2%) in 2010 to 0.17 Mt (46.7%) in 2022. The transportation, storage, and postal services are the second largest source of fossil fuel carbon emissions in Grenada, with emissions remaining steady at about 0.1 Mt from 2010 to 2022, accounting for 36.0% of total fossil fuel carbon emissions in 2022.

Biomass emissions

In 2022, biomass consumption accounted for 7.1% of Grenada's primary energy consumption, mainly used for residential purposes and in the industries producing electricity, heat, gas, and water. From 2010 to 2022, Grenada's biomass carbon emissions were stable at about 0.04 Mt.

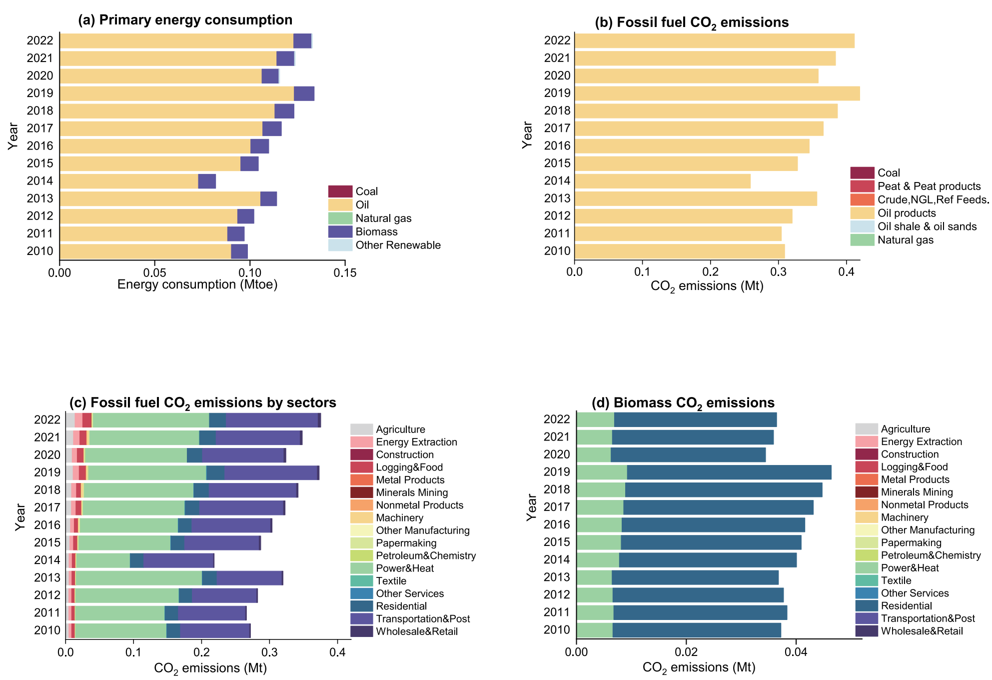
Emission trends

From 2010 to 2019, CO_2 emissions from fossil fuel consumption in Grenada showed a fluctuating increase, rising from 0.3Mt in 2010 to 0.4 Mt in 2019. In 2020, emissions decreased to 0.32 Mt due to the pandemic, rising to 0.38 Mt in 2022.

Comparison with international databases

Under the unified accounting standards (excluding biomass carbon emissions), CEADs' calculations of Grenada's fossil fuel CO_2 emissions were 0.35 Mt, close to the GCB and IEA's data (both are 0.34 Mt) and higher than EDGAR's 0.12 Mt.

Additionally, including CO_2 emissions from biomass consumption, CEADs' calculated Grenada's total CO_2 emissions in 2022 at 0.4 Mt.



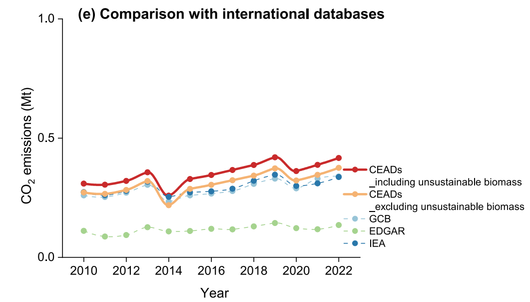


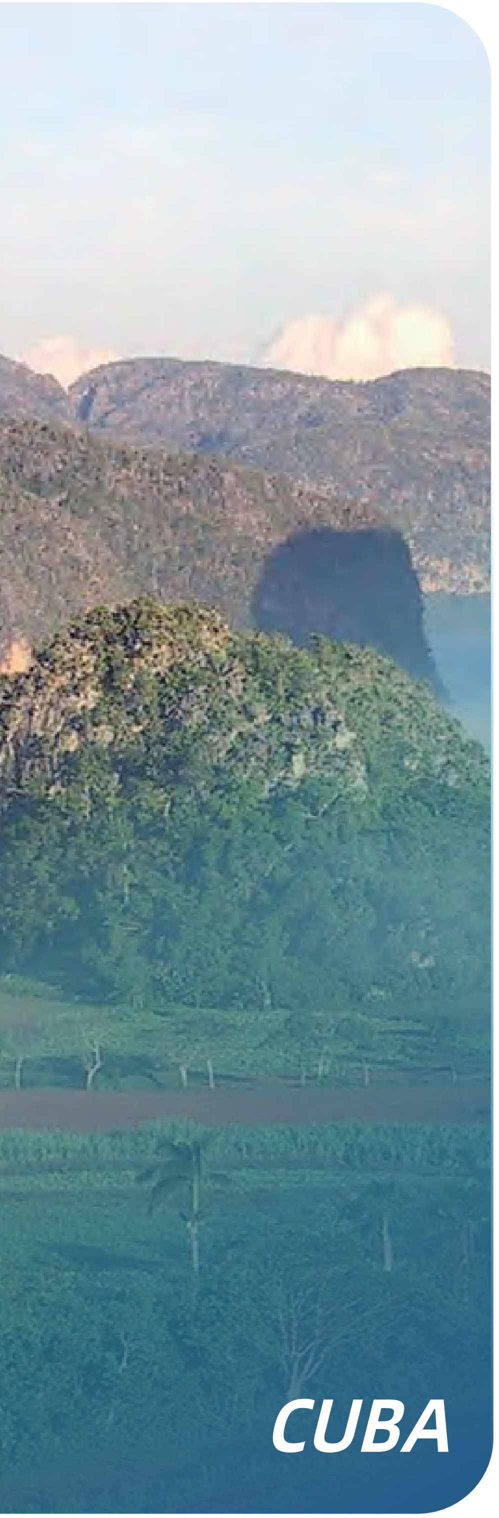
Figure 4.13: Grenada's energy consumption and CO_2 emissions from 2010 to 2022 (a) Primary energy consumption; (b) Fossil fuel CO_2 emissions; (c) Fossil fuel CO_2 emissions by sectors; (d) Biomass CO_2 emissions; (e) Comparison with international databases.

Brief description of data sources:

The energy data for 2010-2022 comes from the energy balance sheets provided by the Energy Information System of Latin America and the Caribbean (Olade), covering six sectors. Export data from the UN Comtrade is used as the basis for allocation, where the six sectors are disaggregated and matched to 47 sectors at a downscaled level.

Table 4.13: Data sources for Grenada's emission accounting

Data type	Source	Website
Energy balance sheet	Energy Information System of Latin America and Caribbean	https://sielac.olade.org/WebForms/Reportes/ReporteBalanceEnergetico.aspx?or=600&ss=2&v=1
Emission factor	Intergovernmental Panel on Climate Change (IPCC)	https://www.ipcc-nggip.iges.or.jp/EFDB/
Sectoral mapping indicator	United Nations Commodity Trade Statistics Database (UN Comtrade), Export Data	https://comtradeplus.un.org/



Background

The Republic of Cuba is an island country in the northern Caribbean Sea of North America, with a total area of 109,884 square kilometers. From 2010 to 2022, the population of the Republic of Cuba remained basically stable, fluctuating between 11.1 million and 11.3 million people. The total population of the Republic of Cuba in 2021 was 11.1 million, with 77.4% of the urban population[262]. From 2010 to 2022, the GDP of the Republic of Cuba continued to grow at an annual growth rate of 1.0%, reaching $126.69 billion in 2020 at current prices. The per capita GDP increased from $5275.5 in 2010 to $11,255 in 2020[263].

Cuba has long implemented a planned economic system. The sugar industry, tourism, and nickel exports are important economic pillars. The main agricultural products are sugarcane, tobacco, tropical fruits, coffee, cocoa, rice, etc. Industrial manufactured products mainly rely on imports. The sugar industry accounts for over 7% of the world's sugar production, with per capita sugar production ranking first in the world. The annual output value of sucrose accounts for approximately 40% of national income. Agriculture mainly grows sugarcane, which accounts for 55% of the country's arable land. The mining resources are mainly nickel, cobalt, chromium, and also manganese, copper, etc. The cobalt ore reserves are 800,000 tons, nickel reserves are 14.6Mt, and chromium reserves are 2Mt. The forest coverage rate is about 21%. Rich in precious hardwood. Labor export, tourism, and overseas remittance income are important sources of foreign exchange.

Cuba is the largest country in the Caribbean region, with abundant natural resources such as solar and wind energy. However, due to the lower level of economic and technological development, its traditional energy extraction and new energy development and utilization are relatively slow. Currently, it can only meet its energy needs through a large amount of imports. In 2012, only 3.8% of the electricity consumed in Cuba was generated through renewable energy. At present, there are a total of 34,658 different types of renewable energy installations in Cuba, including 9,476 solar panels, 4 wind experimental power plants (20 wind turbines), 827 biogas power plants, 187 hydroelectric power plants, 10,595 solar water heaters, 9,343 windmills, 79 biomass turbine generators (114 boilers), and 647 biomass brick kilns. The Cuban government is urgently formulating new energy development policies, encouraging foreign investment in new energy projects, and increasing financial investment to vigorously build solar, wind, and biomass power plants. It plans to increase the proportion of renewable energy in total electricity generation from 3.8% to 20% within the next 8 years[264].

Primary energy consumption

In 2022, fossil energy consumption in the Republic of Cuba accounted for 89.6% of the primary energy consumption structure, mainly dominated by oil. In addition, biomass accounts for 9.9% of primary energy consumption, with sugarcane products being the main source of biomass energy. Other renewable energy sources accounted for 0.5%.

Characteristics of fossil fuel emissions

Among the CO_2 emissions generated by fossil energy consumption, petroleum products have always been the largest source of fossil energy CO_2 emissions in the Republic of Cuba, with CO_2 emissions significantly decreasing from 30.5 Mt in 2010 to 15.7 Mt in 2022. In addition, in the Republic of Cuba, natural gas and coal consumption also generate a certain amount of CO_2 emissions, but the emissions are relatively small.

Sectoral emission contribution

From 2010 to 2022, the electricity, heat, gas, and water production industries have been the industries in the Republic of Cuba that generate the most CO_2 emissions from fossil fuels. For example, in 2022, the CO_2 emissions generated by the use of fossil fuels in the industry accounted for over 45.2% of the total CO_2 emissions from fossil fuels. The machinery sector followed closely, accounting for 13.3% of the country's total fossil fuel CO_2 emissions in 2021.

Biomass emissions

In 2022, Cuba's biomass consumption accounted for 9.9% of its primary energy consumption, mainly from the construction sector and the electricity, heat, gas, and water production industries. These two industries accounted for 37.0% and 27.0% of the total biomass CO_2 emissions in 2022, respectively. The main types of biomass in the country are firewood, sugarcane products, biogas, charcoal, and ethanol. Since sugarcane products in the Republic of Cuba come from plantations and are sustainable energy sources, overall CO_2 emissions should not be included in the overall carbon accounting process. The black liquor and residual gases generated during the processing of firewood are unsustainable resource utilization; therefore, in the overall carbon accounting process, they should be included in the overall CO_2 emissions. From 2010 to 2022, CO_2 emissions generated by consumption of wood and other materials decreased from 0.9 Mt in 2010 to 0.6 Mt in 2022.

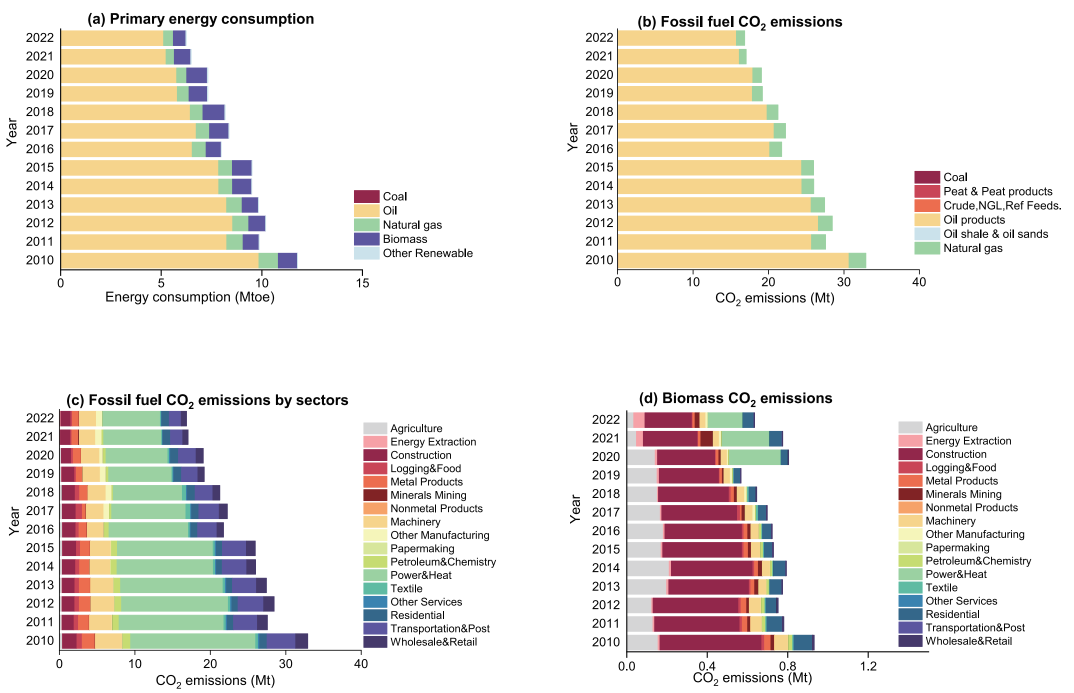
Emission trends

From 2010 to 2022, the CO_2 emissions generated by fossil energy consumption in the Republic of Cuba decreased from 32.9 Mt to 16.9 Mt. CO_2 emissions from biomass consumption decline from 0.9 Mt in 2010 to 0.6 Mt in 2022.

Comparison with international databases

Under the unified accounting framework, which does not include biomass CO_2 emissions, the fossil energy CO_2 emissions data of CEADs are close to those of GCB, EDGAR, and IEA for the periods 2010-2015 and 2019-2022. However, from 2016 to 2018, CEADs reported lower fossil energy CO_2 emissions, likely due to differences in emission factor data.

Additionally, when emissions generated from biomass consumption is included, the CO_2 emissions calculated by CEADs in 2022 were 17.5 Mt.



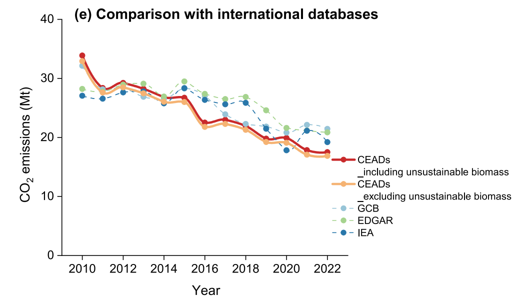


Figure 4.14: Cuba's energy consumption and CO_2 emissions from 2010 to 2022 (a) Primary energy consumption; (b) Fossil fuel CO_2 emissions; (c) Fossil fuel CO_2 emissions by sectors; (d) Biomass CO_2 emissions; (e) Comparison with international databases.

Brief description of data sources:

We obtained energy consumption data for 2010-2022 from the Latin American Energy Organization (OLADE). By using GDP by sector data from the National Bureau of Statistics of the Republic of Cuba and export data from the UN Comtrade from different sectors, the national level data was downscaled to calculate the CO_2 emissions of the Republic of Cuba by industry.

Table 4.14: Data sources for Cuba's emission accounting

Data type	Source	Website
Energy balance sheet	The Latin American Energy Organization (OLADE)	https://www.olade.org/en/
Emission factor	Intergovernmental Panel on Climate Change（IPCC）	https://www.ipcc-nggip.iges.or.jp/EFDB/
Sectoral mapping indicator	UN Comtrade	https://comtrada.un.org
	National Bureau of Statistics of the Republic of Cuba - National GDP by sector	http://www.onei.gob.cu/publicaciones-tipo/Anuario

Background

The Co-operative Republic of Guyana, commonly known as Guyana, is located in northern South America, bordered by Venezuela to the northwest, Brazil to the south, Suriname to the east, and the Atlantic Ocean to the northeast. Guyana covers a land area of 197,000 square kilometers and a water area of 18,000 square kilometers. As of 2022, Guyana had a total population of 790,000, a GDP of $14.72 billion, and a per capita GDP of $18632.9, making it the only country in the Caribbean region with positive economic growth[265].

Guyana possesses abundant mineral resources. The annual production of gold exceeds 500,000 ounces. Bauxite reserves are about 360Mt, known for their high quality and few impurities. Additionally, Guyana has substantial fossil fuel resources, with proven recoverable natural gas reserves exceeding 10 billion barrels of oil equivalent (with an oil-gas ratio of approximately 3:1).

In terms of international trade, Guyana primarily exports crude oil, gold, rice, bauxite, and sugar. The top five export destinations are the United States, Canada, Jamaica, the United Arab Emirates, and Barbados. Major imports include fuel, lubricants, machinery, and cement, with key importing countries being the United States, Portugal, Trinidad and Tobago, China, and Japan.

Guyana has made significant efforts to combat global climate change. The country plans to achieve 100% use of clean and renewable energy in the electricity sector by 2025. It is expected to construct two medium-sized hydroelectric power stations, contributing 150-350 megawatts to the national grid, with Guyana's hydroelectric power potential estimated at 7,000 megawatts[266]. Additionally, Guyana has implemented a low-carbon development strategy and formulated the "2030 Low Carbon Development Strategy," expressing full support for global decarbonization efforts and committing to a 70% reduction in emissions by 2030.

Primary energy consumption

In 2022, fossil energy consumption accounted for 93.9% of Guyana's primary energy structure, predominantly oil. Additionally, biomass accounted for 5.8% of primary energy consumption, with wind, solar, and other renewable energy sources making up a negligible 0.1%.

Characteristics of fossil fuel emissions

Petroleum products dominate fossil fuel carbon emissions in Guyana. In 2022, these products were responsible for carbon emissions of 3.2 Mt, up from 1.2 Mt in 2010, an increase of 61.9%.

Sectoral emission contribution

The production of electricity, heat, gas and tap water sector is the largest source of CO_2 emissions from fossil energy consumption in Guyana. In 2022, this sector accounted for total carbon emissions of 1.2 Mt, representing 36.5% of Guyana's total fossil energy emissions. The transportation, warehousing, and postal services sector was the second largest sector, with carbon emissions of approximately 1.1 Mt, making up 33.9% of the total fossil energy emissions.

Biomass emissions

In 2022, biomass consumption in Guyana accounted for 5.8% of primary energy consumption, mainly used in the electricity production sector and residential consumption. The primary biomass used is charcoal, derived from excessive deforestation, and thus considered a non-renewable resource. Therefore, biomass combustion should be included in the overall carbon accounting process, as it does not possess a "zero carbon" attribute.

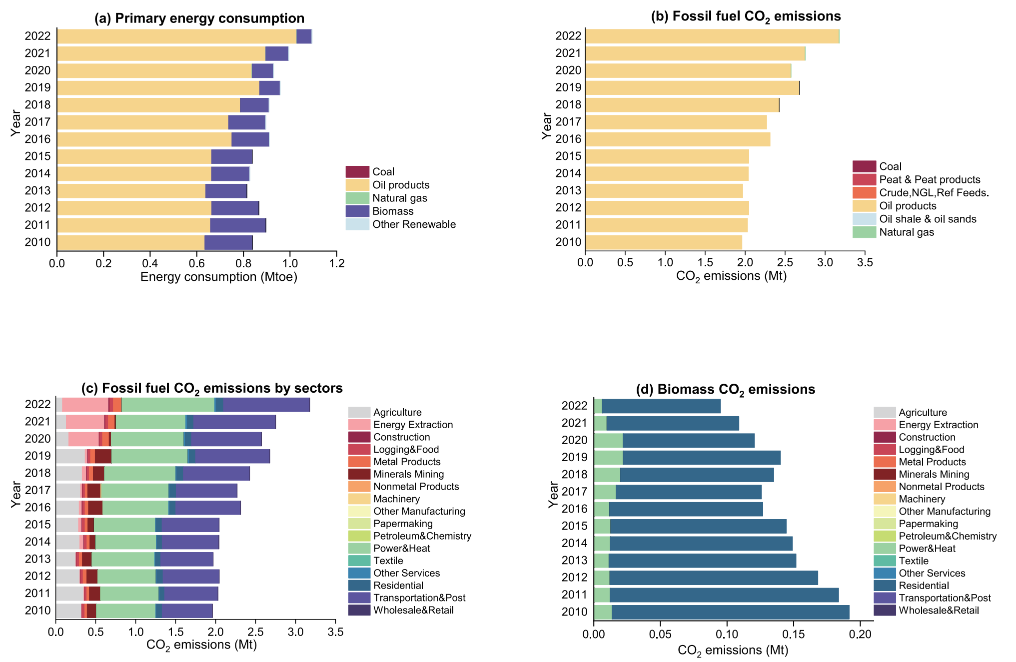
Emission trends

From 2010 to 2022, fossil energy consumption in Guyana showed a rapid growth trend, with carbon emissions increasing by 62.1% from 2.0 Mt to 3.2 Mt. During this period, carbon emissions from biomass consumption decreased from 0.2 Mt to 0.1 Mt.

Comparison with international databases

Under the same accounting standards (excluding biomass carbon emissions), the fossil energy carbon emissions calculated by CEADs are consistently lower than those reported by other institutions, with a difference of about 30%. This discrepancy is primarily due to inconsistencies in the source of energy consumption data. CEADs uses data from the Latin American and Caribbean Energy Information System, which provides original data such as processing, conversion volumes, and consumption of energy varieties, differing from the IEA database.

Additionally, when CO_2 emissions from biomass consumption are included, the CEADs data for 2022 amounted to 3.3 Mt.



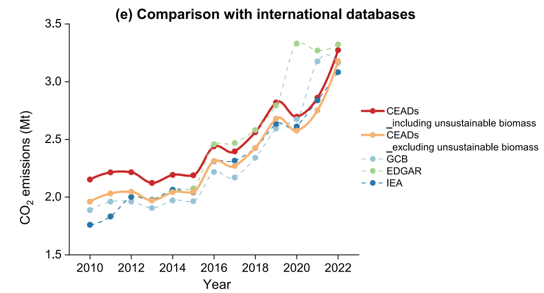


Figure 4.15: Guyana's energy consumption and CO_2 emissions from 2010 to 2022 (a) Primary energy consumption; (b) Fossil fuel CO_2 emissions; (c) Fossil fuel CO_2 emissions by sectors; (d) Biomass CO_2 emissions; (e) Comparison with international databases.

Brief description of data sources:

The energy data used in this report comes from the energy balance table provided by the Latin American and Caribbean Energy Information System from 2010 to 2022, covering a total of 6 departments. In sub sector matching, we use national sectoral economic data and export data from UN Comtrade as the allocation basis and perform downscaling matching on departments, assigning them to 47 departments.

Table 4.15: Data sources for Guyana's emission accounting

Data type	Source	Website
Energy balance sheet	Latin American and Caribbean Energy Information System（Energy Information System of Latin America and Caribbean）	https://sielac.olade.org/default.aspx
Emission factor	Intergovernmental Panel on Climate Change (IPCC)	https://www.ipcc-nggip.iges.or.jp/efdb/
Sectoral mapping indicator	Guyana Bureau of Statistics（Bureau of Statistics）	https://statisticsguyana.gov.gy/
	UN Comtrade	https://comtrada.un.org

ARGENTINA

Background

Argentina, located in southern South America, is the second-largest country in Latin America after Brazil. It consists of 23 provinces and one federal capital district, Buenos Aires. As of the end of 2022, Argentina's total population reached 46.235 million. Since 2018, Argentina's economic and financial situation has experienced several dramatic fluctuations, compounded by the impact of the COVID-19 pandemic, which increased economic downturn pressures. However, starting in 2021, the GDP began to recover, reaching US$ 631.13 billion in 2022[267], a year-on-year increase of 29.4%.

Furthermore, Argentina's agriculture and livestock sectors are well-developed, making it one of the world's leading agricultural producers. Industrially, Argentina relies on food processing, beverages, chemicals and pharmaceuticals, oil refining, motor vehicles, and auto parts. In 2021, the shares of Argentina's primary, secondary, and tertiary sectors in GDP were 6.9%, 22.9%, and 52.0%, respectively [268]. The country is rich in natural resources such as gold, copper, silver, and lithium and has the richest renewable energy resources in Latin America, including wind energy in southern Patagonia and solar energy in the northwest[269]. In international trade, Argentina's main trading partners are Brazil, China, and the United States, with key exports including soy and derivatives, oil and gas, vehicles, corn, and wheat, and main imports including machinery, automobiles, oil and gas, organic chemicals, and plastics.

To diversify its energy sources, reduce dependence on imported fossil fuels, and decrease CO_2 emissions, Argentina has initiated an innovative program called RenovAr. The goal is to have 20% of Argentina's electricity sourced from renewable energies by 2025[269]. Under the United Nations Framework Convention on Climate Change (UNFCCC), Argentina's Nationally Determined Contributions (INDC) aim to reduce greenhouse gas emissions by 15% by 2030. The action guidelines under this target include promoting sustainable forest management, energy efficiency, and the transformation of transportation modes, and using domestically developed technologies to capture greenhouse gases wherever possible[270].

Primary energy consumption

In 2022, fossil energy consumption in Argentina accounted for 87.0% of the primary energy consumption, predominantly from natural gas. Coal consumption accounted for 2.2%, petroleum products for 39.2%, and natural gas for 45.5%. Affected by energy conservation and emission reduction policies, natural gas consumption has been on a rising trend, although it decreased since 2019. Petroleum consumption has been decreasing annually but rebounded in 2021. Additionally, in 2022, wind and other renewable energies accounted for 8.7% of primary energy consumption; biomass accounted for 4.4%.

Characteristics of fossil fuel emissions

In 2022, natural gas consumption was the dominant source of CO_2 emissions from fossil energy consumption in Argentina, mainly used as fuel for supply and power generation, accounting for 46.3% of fossil energy carbon emissions and showing a rapidly increasing trend. The country holds the world's fourth-largest shale oil reserves and the second-largest shale gas reserves. CO_2 emissions from petroleum product consumption increased from 71.8 Mt in 2010 to 87.2 Mt in 2022, displaying a trend of initially increasing, then decreasing, and then increasing again, accounting for 50.8% of the country's fossil energy carbon emissions in 2022.

Sectoral emission contribution

The largest sources of CO_2 emissions from fossil energy consumption in Argentina are the electricity, heat, gas, and water production sector, and other services. In 2022, the electricity, heat, gas, and water production sector produced 58.8 Mt of CO_2 emissions from fossil energy consumption, accounting for 34.3% of total fossil energy emissions. The other services sector emitted 50.2 Mt of carbon dioxide, accounting for 29.2% of its fossil energy carbon emissions. In 2022, the sector of Residential produced 25.8 Mt of CO_2 emissions, making it the third-largest source of fossil energy emissions.

Biomass emissions

In 2022, biomass accounted for approximately 4.4% of Argentina's primary energy consumption, mainly used in the production of electricity, heat, gas, water, and residential consumption. The types of biomass in Argentina mainly include firewood and bagasse. For firewood, locals primarily obtain it through deforestation for home cooking and heating, which has a significant environmental impact and is considered unsustainable. Therefore, it should be included in the overall carbon accounting process. Bagasse and other crop residues, sourced from repeatedly planted farmlands, are considered sustainable renewable resources with a "zero carbon" attribute throughout their lifecycle and should not be included in the overall carbon accounting process. CO_2 emissions from biomass consumption were 3.2 Mt in 2010 and 5.2 Mt in 2022.

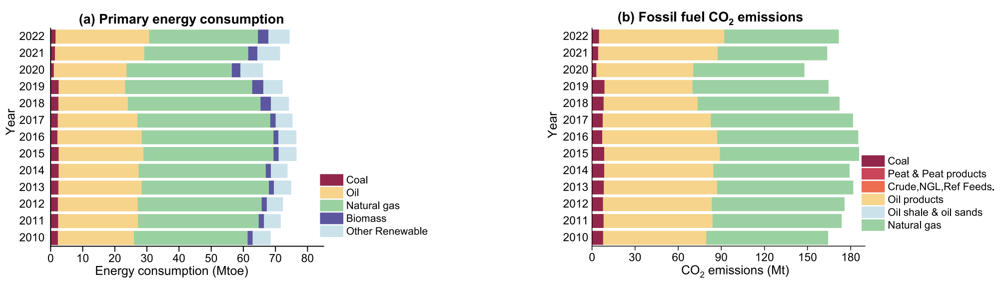
Emission trends

Between 2010 and 2015, CO_2 emissions from fossil energy consumption in Argentina increased from 164.2 Mt to 185.8Mt, an increase of 21.6 Mt. From 2015 to 2021, CO_2 emissions from fossil energy consumption showed a slow decline, from 185.8 Mt to 171.6 Mt, indicating that Argentina's emission reduction policies were somewhat effective. In 2022, CO_2 emissions from biomass consumption were 5.2 Mt.

Comparison with international databases

Under the same accounting standards (excluding biomass CO_2 emissions), the CO_2 emissions from fossil energy in Argentina calculated by CEADs are almost the same as the annual emission trends of CO_2 statistics from other institutions, but there are some differences in annual values. According to international databases, the total fossil energy CO_2 emissions in 2021 were as follows: GCB 196.8 Mt, EDGAR 193.5 Mt, IEA 174.3 Mt, CEADs 171.6 Mt. Specifically, compared to GCB and EDGAR, CEADs' data were consistently lower from 2010 to 2022. CEADs' results are very close to those of the IEA. From a statistical standpoint, CEADs data features more detailed energy classification. For example, petroleum products are subdivided into categories such as motor gasoline, diesel, and fuel oil, each with a corresponding emission factor, while according to the IEA's classification, energy varieties are only categorized as petroleum products. Therefore, the emission factors used by CEADs differ from those used by the IEA, which also leads to differences in CO_2 emission data. Another reason for the discrepancy is that CEADs and IEA use different energy consumption data. CEADs uses data from Argentina's National Institute of Statistics and Censuses, while IEA data comes from multiple sources such as the International Renewable Energy Agency (IRENA). There is a clear disparity between the energy consumption statistics of these agencies, which in turn leads to discrepancies in the CEADs and IEA CO_2 emissions data.

Additionally, when CO_2 emissions from biomass consumption are included, the CO_2 emissions accounted for by CEADs in 2022 were 176.9 Mt.



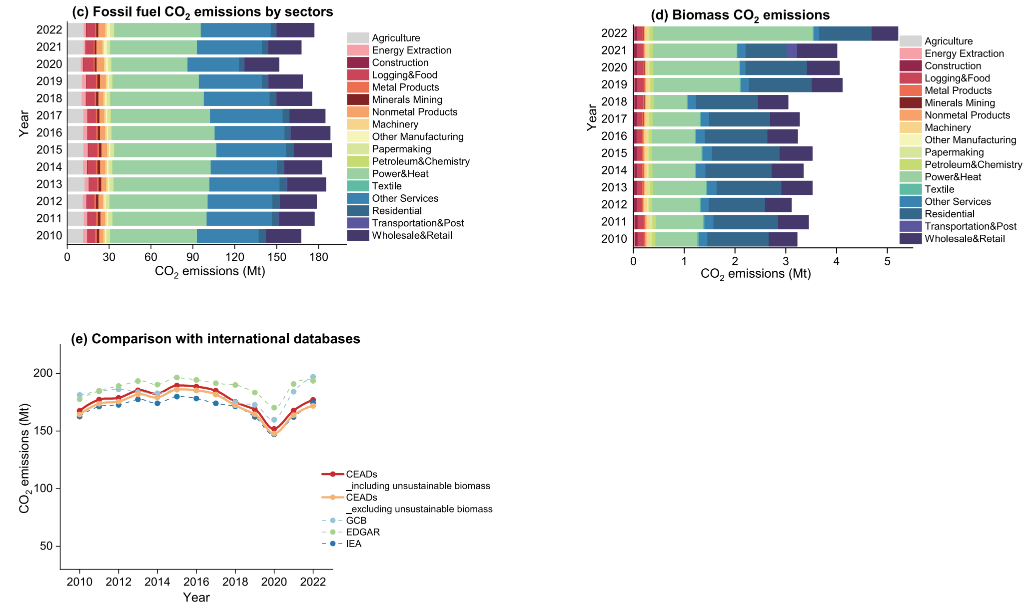


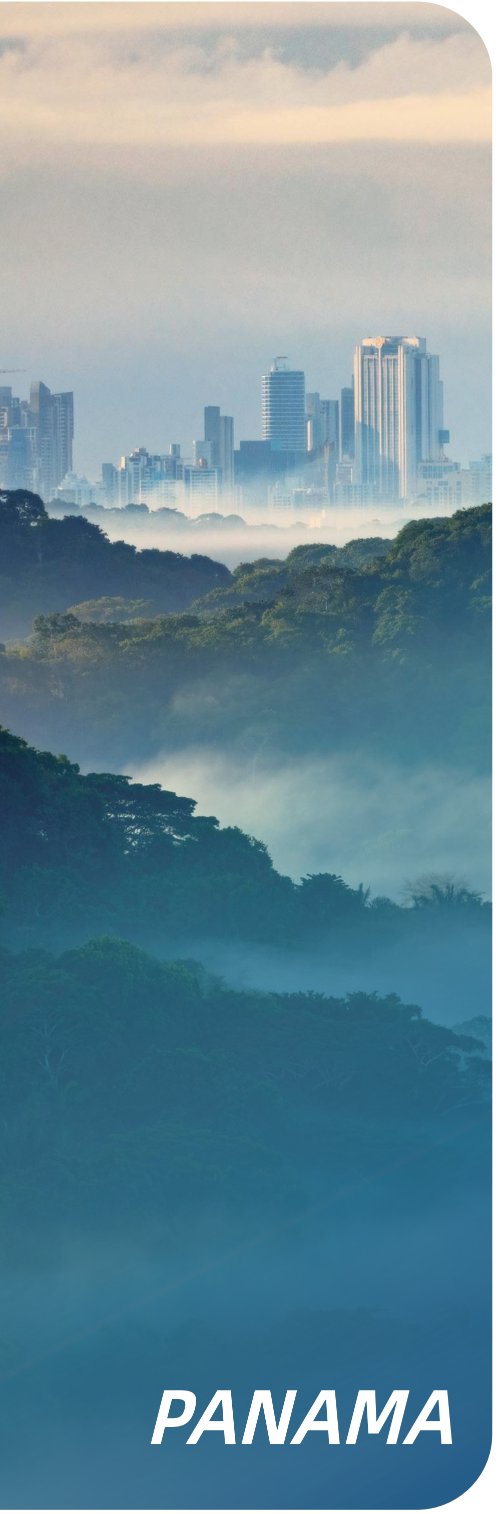
Figure 4.16: Argentina's energy consumption and CO_2 emissions from 2010 to 2022 (a) Primary energy consumption; (b) Fossil fuel CO_2 emissions; (c) Fossil fuel CO_2 emissions by sectors; (d) Biomass CO_2 emissions; (e) Comparison with international databases.

Brief description of data sources:

The energy balances are taken from the Argentinean Institute of Statistics (INEGI) and the data years are 2010-2022. The types of energy are categorized as natural gas, oil, mineral carbon, firewood, bagasse vegetable oil, wind, solar, refinery gas, liquefied gas, diesel + gas oil, fuel oil, residual coal, non-high-energy coke oven gas, blast furnace gas, coke, charcoal, bioethanol, and biodiesel. Sectors are categorized as residential, commercial and public, transport, agriculture, industrial, electricity and heat.

Table 4.16: Data sources for Argentina's emission accounting

Data type	Source	Website
Energy balance sheet	Argentine Bureau of Statistics	https://www.argentina.gob.ar/economia /energia/hidrocarburos/balances-energeticos
Emission factor	International Energy Agency（IEA）	https://www.iea.org/areas-of-work/global-engagement/ china?language=zh
Sectoral mapping indicator	Argentine Bureau of Statistics	https://www.indec.gob.ar/indec/web/Nivel3-Tema-3-9



Background

The Republic of Panama is the southernmost country in Central America, covering a total area of 75,517 square kilometers. From 2010 to 2022, Panama experienced steady population growth, with an average annual growth rate of about 1.7%. By 2022, Panama's total population reached 4.4 million, with 69.1% living in urban areas. From 2010 to 2022, Panama's GDP grew rapidly at an annual rate of 7.2%, with the GDP per capita increasing from $8,124 in 2010 to $17332.4 in 2022 [271].

Panama is one of the most important countries in Central America and the Caribbean. The nation enjoys a stable political climate and strong economic development momentum. The Panama Canal, regional financial centers, the Colón Free Trade Zone, and tourism are four pillars of Panama's economy. The service sector, including finance, trade, and tourism, plays a crucial role in the national economy. The industrial base is weak with no heavy industry, focusing primarily on light industries such as processing agricultural products and consumer goods, including some low-tech home appliances. Due to Panama's significant ties with the United States, the country has used the US dollar as its currency since 1907, making it the first country outside the US to use the dollar as legal tender.

Panama has significant potential for developing renewable energy, particularly in hydropower, solar energy, and wind energy. Currently, about 60% of the installed capacity of Panama's national grid is renewable, with 54% of that coming from hydropower. Panama also hosts the largest wind farm in Central America and the Caribbean. While solar energy comprises a smaller portion of Panama's renewable resources, it grew from 2 megawatts in 2011 to 198 megawatts by 2020, now capable of powering approximately 300,000 homes annually. To address climate change, Panama's national energy plan aims to achieve over 70% renewable energy consumption by 2050[272]. Additionally, Panama has committed to becoming carbon-neutral by 2050. According to the NDC Partnership, Panama plans to restore 50,000 hectares of national forests, which will help absorb about 2.6 Mt of carbon dioxide by 2050[272].

Primary energy consumption

In 2022, fossil energy consumption in Panama accounted for over 74.2% of the primary energy consumption, primarily from oil and natural gas. Oil consumption accounted for 68.4%, and natural gas for 5.8%. Additionally, biomass made up 5.9% of the primary energy consumption, with hydro, wind, and solar energy collectively comprising 19.9%.

Characteristics of fossil fuel emissions

Petroleum products have been Panama's primary source of carbon emissions from fossil energy consumption, accounting for 90.9% in 2022. Since 2018, natural gas consumption began contributing to emissions, accounting for 6.1% of fossil energy carbon emissions in 2022.

Sectoral emission contribution

From 2010 to 2022, the transportation, storage, and postal services sector consistently produced the most carbon emissions from fossil energy in Panama. In 2022, this sector's fossil energy carbon emissions accounted for over 62.1%. The electricity, heat, gas, and water production, and the construction sectors followed, accounting for 13.4% and 7.3% of the country's total fossil energy carbon emissions in 2022, respectively.

Biomass emissions

In 2022, biomass accounted for about 5.9% of primary energy consumption, primarily used in the residential and construction sectors. The main types of biomass used in Panama include firewood, bagasse, biogas, charcoal, and ethanol. Due to the unsustainable sourcing of biomass from deforestation, biomass carbon emissions should be included in the overall carbon accounting process. In 2022, biomass use in Panama resulted in carbon emissions of 0.9 Mt, mainly from the residential and construction sectors, accounting for 81.5% and 6.8% of biomass carbon emissions, respectively.

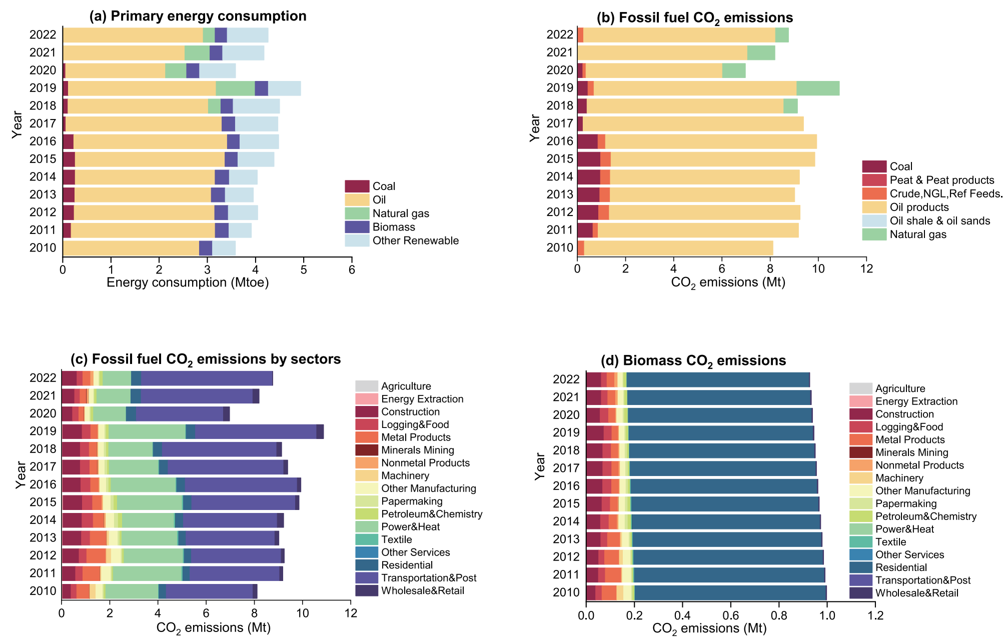
Emission trends

From 2010 to 2012, carbon emissions from fossil energy consumption in Panama showed an increasing trend, rising from 8.1Mt to 9.2 Mt. Between 2012 and 2013, there was a slight decrease in fossil energy carbon emissions; however, from 2013 to 2016, emissions increased from 9.0Mt to 9.9Mt. There were minor fluctuations from 2017 to 2019, showing a trend of initial decline followed by growth, peaking at 10.9Mt in 2019. In 2020, there was a significant decrease to 7.0Mt, and in 2021, it rose again to 8.8Mt. Between 2010 and 2022, carbon emissions from biomass consumption decreased from 1.0Mt to 0.9 Mt.

Comparison with international databases

Under the same accounting standards (excluding biomass emissions), CEADs' data closely aligns with other institutions' emission trends. Numerically, CEADs' data are closest to IEA's results, being almost identical in 2010-2018, as both CEADs' and IEA's data sources come from the Energy Policy Commission of the Republic of Panama. CEADs' data for 2019-2022 are slightly lower than IEA's. GCB and CEADs data largely match in 2010-2018, with relatively slightly higher data gaps in other years. When comparing CEADs with EDGAR, the numerical gap was large, with an average difference of more than 1.4 Mt.

In 2022, including carbon emissions from biomass consumption, CEADs accounted for carbon emissions of 9.7 Mt.



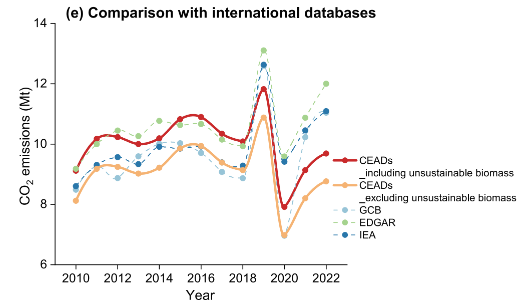


Figure 4.17: Panama's energy consumption and CO_2 emissions from 2010 to 2022 (a) Primary energy consumption; (b) Fossil fuel CO_2 emissions; (c) Fossil fuel CO_2 emissions by sectors; (d) Biomass CO_2 emissions; (e) Comparison with international databases.

Brief description of data sources:

The energy balance sheet of Panama from 2010 to 2022 was obtained from the website of the Energy Commission of the Republic of Panama, which contains the energy processing and conversion data of 27 primary and secondary energy types in Panama, as well as 5 major economic categories. The country-level data was downscaled using GDP by sector from the National Statistical Office of the Republic of Panama and export data from the UN Comtrade to calculate CO_2 emissions for each sub-sector in Panama.

Table 4.17: Data sources for Panama's emission accounting

Data type	Source	Website
Energy balance sheet	Energy Commission of the Republic of Panama	https://www.energia.gob.pa/mdocs-posts/balance-energetico-serie-1970-2020/
Emission factor	IIntergovernmental Panel on Climate Change (IPCC)	https://www.ipcc-nggip.iges.or.jp/EFDB/
Sectoral mapping indicator	National Statistical Office of the Republic of Panama - National GDP by sector	https://www.inec.gob.pa/publicaciones/Default2.aspx?ID_CATEGORIA=4&ID_SUBCATEGORIA=26
	UN Comtrade	https://comtrada.un.org

Background

Trinidad and Tobago is located at the southeastern end of the Lesser Antilles in the Caribbean, directly north of Venezuela. The nation comprises two main islands: Trinidad, covering 4,828 square kilometers, and Tobago, spanning 300 square kilometers[273]. According to the World Bank, the population in 2022 was approximately 1.366 million, with an urbanization rate of 53.3%[274], with most people living in urban areas of Trinidad, especially in the capital, Port of Spain, and other major cities. Tobago is known for its rural and natural landscapes. In 2022, the GDP at current prices was $30.05 billion, marking a 26.4% growth compared to pre-pandemic levels, and a $7.89 billion increase compared to 2010[275].

For many years, the economic structure of Trinidad and Tobago has been primarily based on energy development and processing. In recent years, manufacturing, construction, tourism, and finance and insurance industries have developed rapidly. In 2022, agriculture, industry, and services contributed approximately 3.3%, 48.9%, and 47.8% to the GDP, respectively[276]. Internationally, Trinidad and Tobago mainly export petroleum, natural gas, chemical products, manufactured goods, and raw materials, and import steel products, construction machinery, fuels, transportation equipment, and food. Major trading partners include the United States, China, Mexico, Guyana, Brazil, and Canada. Trinidad and Tobago are rich in natural gas and petroleum resources, making it the largest oil and natural gas producer and exporter in the Caribbean region. As of the end of 2019, the proven and potential natural gas reserves were estimated at 10.2 trillion cubic feet, and oil reserves were about 240 million barrels. Trinidad and Tobago also possess the world's largest natural asphalt lake, covering an area of about 41 hectares, with proven reserves exceeding 6 million tons[277].

As an island nation, Trinidad and Tobago have excellent solar radiation levels and conditions for deploying offshore and onshore wind energy. The energy sector is currently focusing on solar photovoltaic and wind energy power generation, with a target to achieve 30% of electricity from renewable sources by 2030[278]. In their Nationally Determined Contributions (NDC), Trinidad and Tobago have committed to reducing emissions by 15% from the "business as usual" development path in the power generation, industrial, and transportation sectors by 2030; and a 30% unconditional reduction in public transportation emissions compared to 2013 by the same year[279].

Primary energy consumption

In 2022, fossil energy consumption accounted for 100% of Trinidad and Tobago's primary energy consumption structure, with oil consumption at 13.1% and natural gas consumption at 86.9%. In addition, hydropower, solar energy, and other renewable energy sources account for an extremely small proportion of primary energy consumption, nearly 0%.

Characteristics of fossil fuel emissions

In 2022, Trinidad and Tobago's fossil energy carbon emissions totaled 20.6 Mt, stemming from the consumption of petroleum products and natural gas. The carbon emissions from petroleum product consumption decreased by 0.7 Mt compared to 2010, accounting for 16.2% of fossil energy carbon emissions. Carbon emissions from natural gas consumption decreased by 1.7 Mt compared to 2010, making up 83.8% of fossil energy carbon emissions.

Sectoral emission contribution

CO_2 emissions from fossil energy consumption in Trinidad and Tobago primarily originate from energy extraction and the production of electricity, heat, gas, and water. The energy extraction industry is the largest fossil fuel carbon emission sector in Trinidad and Tobago. In 2022, fossil fuel consumption generated 6.8 million tons of CO_2 emissions—0.9 million tons lower than in 2010—and accounted for 33.1% of the total fossil fuel carbon emissions in 2022. The production of electricity, heat, gas, and water is the second largest fossil fuel carbon emission sector in Trinidad and Tobago. Since 2010, CO_2 emissions from the production of electricity, heat, gas, and water have shown a fluctuating downward trend, decreasing from 6.3 Mt in 2010 to 5.3 Mt in 2023, accounting for 25.7% of the 2022 fossil energy carbon emissions. In addition, the fossil fuel carbon emissions from Trinidad and Tobago's non-metallic products manufacturing industry have experienced the largest growth since 2010, increasing from 0.03 million tons in 2010 to 0.07 million tons in 2022, accounting for 0.3% of the fossil fuel carbon emissions in 2022.

Emission trends

From 2010 to 2022, fossil energy carbon emissions in Trinidad and Tobago showed a decreasing trend, from 23.0 Mt in 2010 to 20.6 Mt in 2022, with an annual average decrease of 0.9%.

Comparison with international databases

Under the unified accounting standards that exclude biomass carbon emissions, CEADs' calculations of Trinidad and Tobago's fossil fuel carbon emissions closely align with the annual change trends reported by other institutions. Compared to IEA data, CEADs' figures are consistently higher by about 15% each year. In contrast, compared to GCB and EDGAR, CEADs' figures are consistently lower. The differences arise because CEADs uses a more detailed energy classification, with each type of oil having a corresponding emission factor, whereas other institutions like the IEA categorize energy varieties only as petroleum products. Therefore, the emission factors used by CEADs differ from those used by the IEA, leading to discrepancies in carbon emission data. Another reason for the discrepancy is that CEADs and the IEA use different sources of energy consumption data. CEADs uses data from the Energy Information System of Latin America and the Caribbean (Olade), while other institutions like the IEA source their data from multiple sources, such as the International Renewable Energy Agency (IRENA), leading to significant differences in energy consumption statistics and further discrepancies in CO_2 emissions data between CEADs and other institutions.

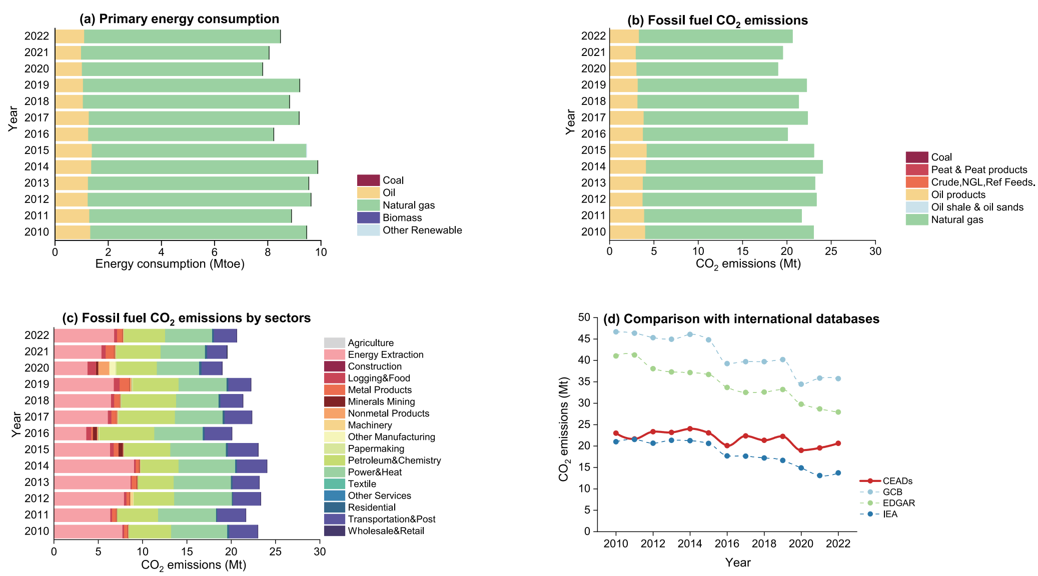


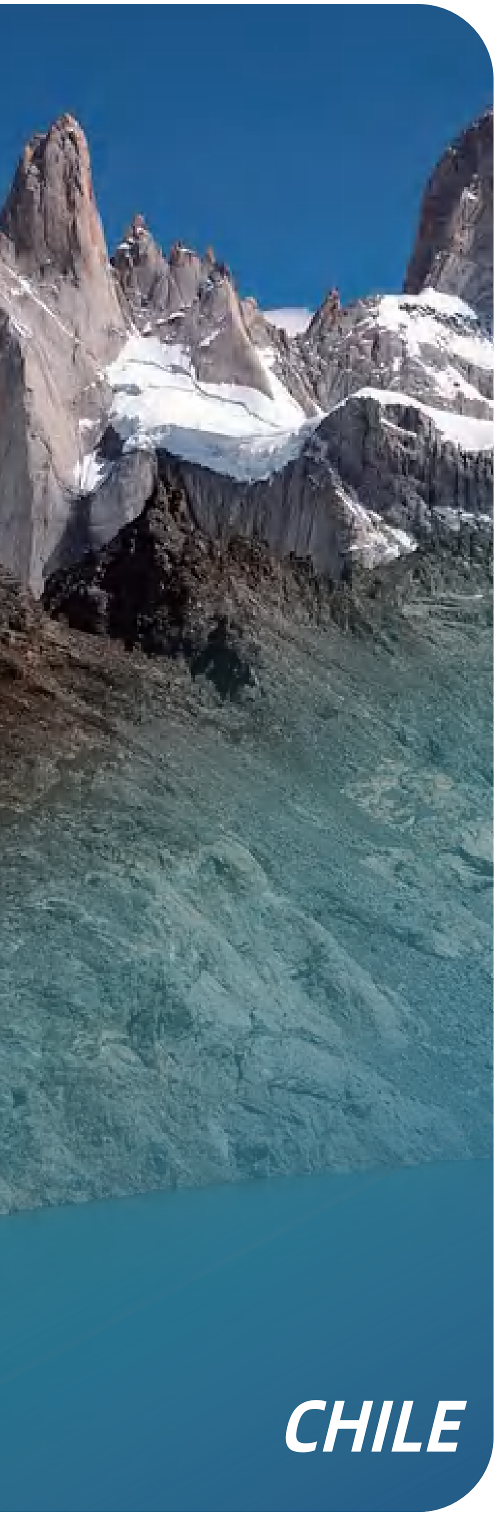
Figure 4.18: Trinidad and Tobago's energy consumption and CO_2 emissions from 2010 to 2022 (a) Primary energy consumption; (b) Fossil fuel CO_2 emissions; (c) Fossil fuel CO_2 emissions by sectors; (d) Comparison with international databases.

Brief description of data sources:

Trinidad and Tobago's energy balance sheets come from the Energy Information System of Latin America and the Caribbean (Olade), covering the period from 2010 to 2022. This data encompasses 19 types of energy across six sectors. In terms of sectoral matching, GDP data published by the national statistical office is used as a basis for allocation refined by export data published by UN Comtrade, with the data being downscaled and distributed across 47 sectors.

Table 4.18: Data sources for Trinidad and Tobago's emission accounting

Data type	Source	Website
Energy balance sheet	Energy Information System of Latin America and Caribbean	https://www.energia.gob.pa/mdocs-posts/balance-energetico-serie-1970-2020/
Emission factor	Intergovernmental Panel on Climate Change (IPCC)	https://www.ipcc-nggip.iges.or.jp/EFDB/
Sectoral mapping indicator	Central Statistical Office of Trinidad and Tobago (Sectoral GDP Statistics)	https://www.inec.gob.pa/publicaciones/Default2.aspx?ID_CATEGORIA=4&ID_SUBCATEGORIA=26
	World Bank (Urbanization Rate Data)	https://comtrada.un.org
	United Nations Comtrade database (UN Comtrade), export data	https://comtradeplus.un.org/



Background

Chile is located in western South America, running between the Andes and the Pacific Ocean and bordering Peru, Bolivia and Argentina. Due to its large latitudinal span, its climate is diverse, ranging from the world's driest desert, the Atacama, in the north, through a Mediterranean climate in the center, a subtropical humid climate on Easter Island, and a maritime climate in the east and south. As of 2022, Chile had a population of 19.5 million and a GDP of US$ 302.1billion, and the second-highest nominal GDP per capita in Latin America (after Uruguay and Panama) [280].

Chile is rich in non-ferrous resources. Copper mining accounts for 20% of its GDP and 60% of exports [281]; it produces a third of the world's copper [282]. Chile is deficient in fossil fuels, however, and relies for these on imports such as oil, natural gas and coal. The country has abundant renewable energy, with rich solar energy resources in the north [283]. Chile is traversed by many rivers, giving it potential for the supply of hydro in the south. In addition, the development of agriculture and forestry offers great potential for biomass supply. In terms of international trade, Chile exports mainly mineral products, base metals and plant products, primarily to China, the United States, Brazil and Japan. It imports mainly machinery and appliances, mineral products, transportation equipment and chemical products. The key importing countries are China, the United States, Brazil, Argentina and Germany, among others.

Chile has made a number of efforts to combat climate change. The country has pledged to reduce CO_2 emissions per unit of GDP by 30% from 2007 levels by 2030. With funding from the International Monetary Fund, it may achieve a 35% to 45% reduction. The Chilean government also proposes that by 2025, 20% of the country's energy supply will be renewable, and between 2014 and 2025, that 45% of the country's electricity production will use cleaner energy. At the same time, Chile also plans to use the carbon trading market as a tool to mitigate greenhouse gas emissions[224].

Primary energy consumption

Chile's fossil energy consumption accounts for about 72.1% of the primary energy structure, mainly coal. In 2022, coal consumption accounted for 14.5%, petroleum product consumption for 43.1%, and natural gas consumption for 14.5%. In addition, hydro, solar and other renewable energy accounted for 11.1% of primary energy consumption; and biomass, for 16.8%.

Characteristics of fossil fuel emissions

In Chile, the primary sources of CO_2 from fossil fuel consumption are derived from coal and petroleum products. Among petroleum products, diesel and gasoline represent the most significant types of consumption. In 2022, CO_2 emissions from petroleum products consumption amounted to over 50.2 million tons, accounting for 58.4% of the total fossil fuel-related CO_2 emissions. In comparison, emissions from coal consumption reached 22.5 million tons, contributing to 26.3% of fossil fuel CO_2 emissions. Additionally, CO_2 emissions resulting from natural gas consumption in Chile totaled 13.1 million tons, representing 15.3% of the country's fossil fuel CO_2 emissions. The emissions from natural gas consumption exhibited a year-on-year increase from 9.6 million tons in 2014 to 13.1 million tons in 2022.

Sectoral emission contribution

The largest source of carbon dioxide emissions in Chile comes from the transportation, storage, and postal services sector. In 2022, this sector accounted for 38.7% of the country's total fossil fuel-related CO_2 emissions. Between 2010 and 2022, CO_2 emissions from fossil fuel consumption in this sector showed an overall increasing trend, rising from 25.5 million tons in 2010 to 33.2 million tons in 2022. The production of electricity, heat, gas, and water is the second largest industry in terms of fossil energy CO_2 emissions in Chile. In 2022, this sector generated approximately 32.4 million tons of CO_2 emissions from fossil fuel consumption, representing 37.7% of the total fossil fuel CO_2 emissions.

Biomass emissions

In 2022, Chile's biomass consumption accounted for 16.8% of the primary energy consumption structure, which was mainly used for the production of electricity, heat, gas, water and residential sector. Biomass in Chile is mainly crop waste, which comes from local plantations and is a sustainable renewable resource, "zero carbon" throughout its life cycle; thus, it should not be included in CO_2 emissions during the overall carbon accounting process.

Emission trends

Between 2010 and 2022, CO_2 emissions from fossil energy consumption in Chile increased by 15.9%, from 74.1 Mt to 85.8 Mt.

Comparison with international databases

Under the same accounting caliber (excluding emissions from biomass), the fossil energy CO_2 emissions calculated by CEADs are relatively high compared with the results released by GCB, BP, EDAG and IEA, with a difference of between 2.8% to 8.2%. This is mainly because the information on various energy varieties in Chile used by the IEA is collected from the consumption, import and export data of various industries; CEADs meanwhile directly use the energy balance sheet issued by the Chilean National Energy Commission, from which various industries and energy sources are obtained. The difference in the original data, such as the processing and transformation volume and consumption volume of varieties, leads to a certain difference between the CEADs accounting data and that of IEA.

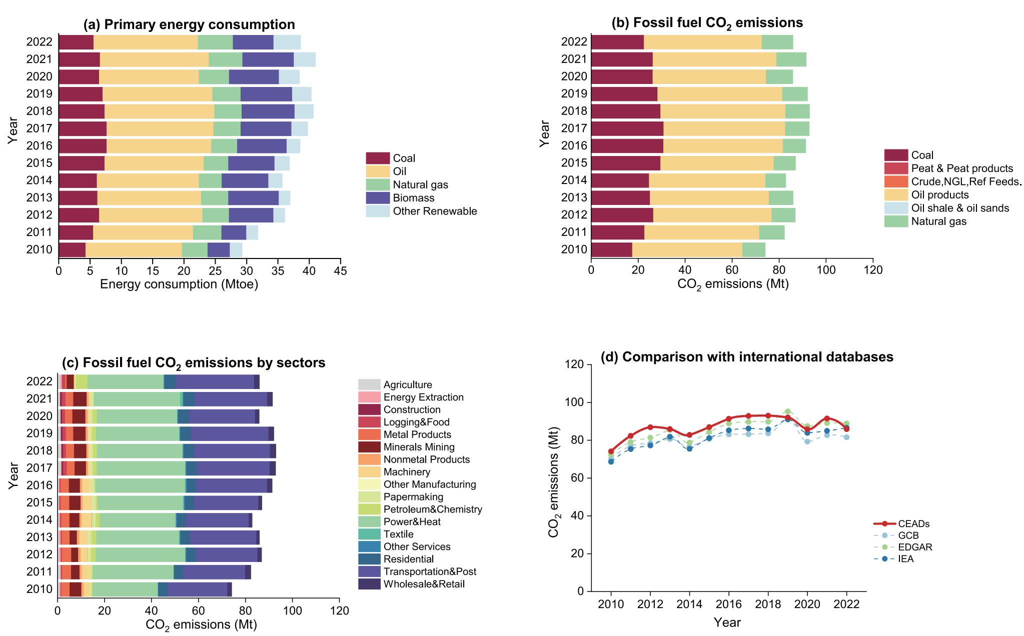


Figure 4.19: Chile's energy consumption and CO_2 emissions from 2010 to 2022 (a) Primary energy consumption; (b) Fossil fuel CO_2 emissions; (c) Fossil fuel CO_2 emissions by sectors; (d) Comparison with international databases.

Brief description of data sources:

CEADs obtained Chile's 2010-2022 energy balance from the Chilean National Energy Commission website. Chile's energy balance table includes energy processing and conversion data for 27 primary and secondary energy types, as well as energy consumption data for 22 economic sectors. CO_2 emissions by sector are calculated using export data from UN Comtrade.

Table 4.19: Data sources for Chile's emission accounting

Data type	Source	Website
Energy balance sheet	National Energy Commission	http://energiaabierta.cl/visualizaciones/balance-de-energia/
Emission factor	Intergovernmental Panel on Climate Change (IPCC)	https://www.ipcc-nggip.iges.or.jp/EFDB/
Sectoral mapping indicator	UN Comtrade, export data	https://comtrada.un.org

Background

Uruguay, located in southeastern South America, is bordered by Argentina, Brazil, the La Plata River and the South Atlantic Ocean. The country's population is 3.4 million, of whom nearly 1.8 million live in its capital and largest city, metropolitan Montevideo. With an area of about 176,000 square kilometers, Uruguay is the second smallest country in South America. The World Economic Outlook[284] report shows that the country has long had the highest GDP per capita in Latin America: it was US$ 22,798 in 2023. The United Nations classifies Uruguay as a high-income country.

Agriculture and industry are key sectors in Uruguay. In 2015, Uruguay's agricultural output value accounted for 6.5% of GDP, while its industrial output value accounted for 12.3%. Tourism is also an important part of the Uruguayan economy, accounting for 17.4% of total GDP in 2019[285]. In terms of international trade, Uruguay's primary export products are beef, pulp, soybeans and dairy products, exported mainly to China, Brazil and the United States. Key imports include automobiles, clothing and plastic products; the main importing countries are Brazil, China and Argentina, among other countries.

Following the Paris Agreement, Uruguay pledged to become carbon neutral by 2030. In 2019, Uruguay's share of electricity generation from hydro, wind and solar power rose to 98.0%. It is worth noting the explosive growth of wind power, with a 68-fold increase in installed wind power capacity between 2010 and 2019, and Uruguay going from having almost no wind power to having the highest per capita wind power generation in the world in less than a decade.

Primary energy consumption

In 2022, Uruguay's fossil energy consumption accounted for 42.3% of the primary energy consumption structure. Among sources of fossil energy, oil consumption accounted for 40.6%, and natural gas for 1.7%. In addition, hydro, solar and other renewable energy sources accounted for 18.7% of primary energy consumption. Finally, biomass accounted for 39.0% of primary energy consumption.

Characteristics of fossil fuel emissions

Among the CO_2 emissions from fossil energy consumption, those from oil and natural gas consumption dominate. Petroleum products, the most important fossil fuel in Uruguay, produced 6.7 Mt of CO_2 emissions in 2022, accounting for 96.5% of CO_2 emissions from fossil energy. CO_2 emissions from natural gas consumption increased from 0.17 Mt in 2010 to 0.25 Mt in 2022, at a relatively slow rate of growth.

Sectoral emission contribution

The sector with the largest CO_2 emissions from fossil energy consumption in Uruguay is transportation, storage and postal services. In 2010, its CO_2 emissions from the consumption of fossil energy amounted to 3.1 Mt, at a rate increasing by 3.1% per year. In 2017, emissions reached 3.9 Mt; in 2020, they decreased slightly to 3.7 Mt; in 2022 they rose to 4.3 Mt， accounting for 61.5% of the total CO_2 emissions from fossil energy. The production and supply of electric power, heat, gas, and water also constitutes a major source of fossil energy CO_2 emissions in Uruguay. In 2022, the CO_2 emissions from fossil energy consumption in this sector were about 0.79 Mt, which represents a decrease of 10.2% compared to the CO_2 emissions from fossil energy consumption in this industry in 2010. Additionally, in 2022, the logging and video sector's CO_2 emissions from fossil energy consumption were about 0.53 Mt, accounting for 7.6% of the total CO_2 emissions from fossil energy.

Biomass emissions

In 2022, Uruguay's biomass consumption accounted for 39.0% of the primary energy consumption structure, and was used mainly in the logging and residential sectors. Locals gather firewood through deforestation for use in home cooking and heating, all of which has a great impact on the environment. As the practice is not considered sustainable, the CO_2 emissions linked to biomass should be included in the overall carbon accounting process. Wood waste, by contrast, is sourced mainly from local plantations and is a sustainable and renewable resource with a "zero carbon" life cycle; thus it should not be included in the emissions reportage in the overall carbon accounting process. Between 2010 and 2022, CO_2 emissions from firewood consumption in Uruguay rose from 2.5 Mt to 3.4 Mt in 2018, after which they fell to 2.2 Mt in 2022.

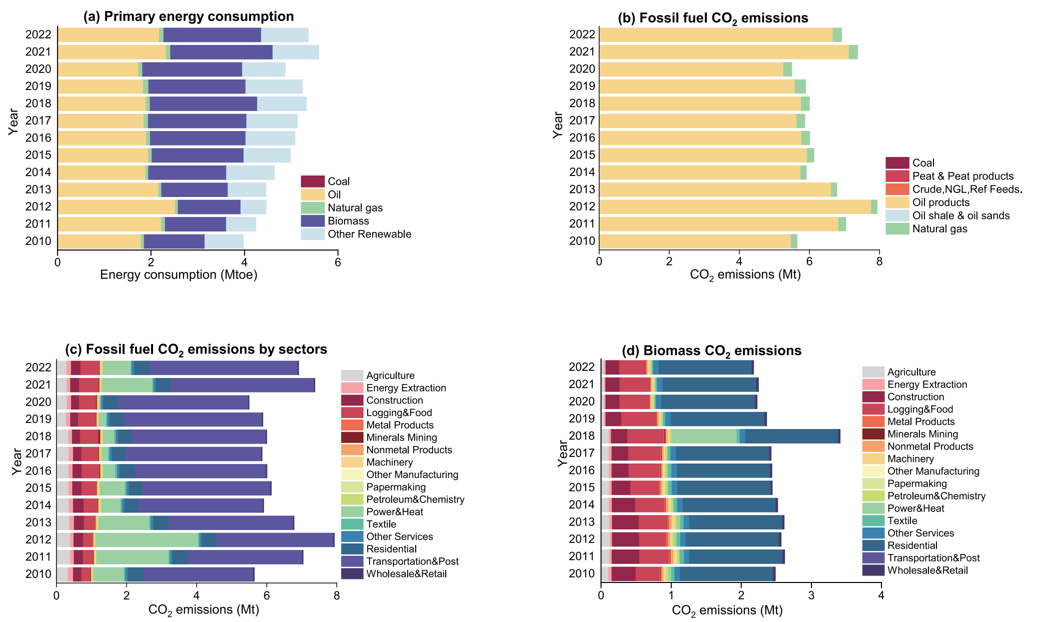
Emission trends

From 2010 to 2022, CO_2 emissions from fossil energy consumption in Uruguay increased at an average annual rate of 1.57%, from 5.6 Mt to 6.9 Mt. In 2012, Uruguay's fossil energy CO_2 emissions hit a peak, at 7.9 Mt. During this period, emissions from biomass consumption increased rapidly from 2.5 Mt in 2010 to 3.4 Mt in 2018, before falling to 2.2 Mt in 2022.

Comparison with international databases

Under the same accounting calibre (excluding emissions from biomass), the differences between calculations by CEADs and data results released by IEA, EDGAR, and GCB are small. The main reasons for the differences are as follows: first, the emission factor selection of CEADs is different from that of IEA and EDGAR; second, CEADs data have more detailed energy classification, while other institutions have vague statistical standards for energy varieties.

When the CO_2 generated by biomass consumption is included, CEADs' figure for 2022 is 9.1 Mt.



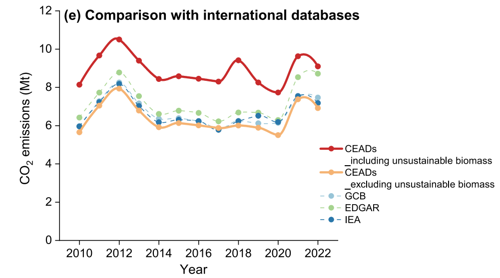


Figure 4.20: Uruguay's energy consumption and CO_2 emissions from 2010 to 2022 (a) Primary energy consumption; (b) Fossil fuel CO_2 emissions; (c) Fossil fuel CO_2 emissions by sectors; (d) Biomass CO_2 emissions; (e) Comparison with international databases.

Brief description of data sources:

Uruguay's energy balance sheet is sourced from the country's National Institute of Statistics and covers data from 2010 to 2022. Uruguay's energy balance table lists 22 kinds of energy varieties, of which the main energy varieties are gasoline and firewood. Uruguay's energy balance table divides emitting industries into five categories, namely household consumption, transportation, industry, agriculture and business services. For subsector matching, we use value added by industries from UN and export data from the United Nations Commodity Trade Statistics Database (UN Comtrade) to downscale the sectoral matching and assign to 47 sectors.

Table 4.20: Data sources for Uruguay's emission accounting

Data type	Source	Website
Energy balance sheet	National Institute of Statistics	https://www.ine.gub.uy/inicio
Emission factor	IPCC	https://www.ipcc-nggip.iges.or.jp/EFDB/
Sectoral mapping indicator	UN Comtrade, export data	https://comtrada.un.org
	UNdata - Value added by industries	http://data.un.org/Explorer.aspx#marts

Background

Barbados, located at the eastern end of the Lesser Antilles Islands in the eastern Caribbean Sea, is a coral limestone island. Surrounded by the sea, it is bordered by Saint Lucia, Saint Vincent and the Grenadines, and Grenada. Barbados spans around 431 square kilometres. In 2022, the population is approximately 282,000, of which more than 90% are of black heritage and 2% are of European immigrant descent. Bridgetown, the capital, is divided into 11 districts[286]. From 2010 and 2019, Barbados experienced consistent growth in its GDP, increasing from $490 million to $530 million. However, in 2020, there was a decline, with the GDP dropping to $470 million. The GDP for the 2022 amounted to $530 million. The GDP per capita increased from $16,903 in 2010 to $22,164in 2022[287].

Barbados is rich in mineral and natural resources. The oil reserves amount to around 2 million barrels, while the gas reserves reach 110 million cubic meters. Additionally, there are limestone reserves of around 30 billion tonnes and pumice reserves totaling 1.32 billion tonnes. Barbados mostly relies on artificial agriculture for its plant resources, which include figs, cotton, sugar cane, banana trees, mango trees, baobab, coconut trees, and palm trees. The region boasts a rich abundance of animal resources, including pelicans, geckos, frogs, vervet monkeys, as well as other marine species such as tuna, swordfish, dolphins, and flying fish. Furthermore, Barbados harbors numerous indigenous species, such as the blind snake, gooseberry, cherry, Curacao aloe vera, and others. These species are important to the country's ecosystem and biodiversity.

Barbados' traditional economy was historically centered around the sugar industry, but in recent years, it has diversified into tourism, offshore finance, light manufacturing, and information services. However, the 2020 pandemic severely impacted the tourism sector, delivering a significant blow to the economy. The economy has shown signs of recovery recently. In agriculture, the government is promoting the cultivation of fruits and vegetables to alleviate the pressure on food imports. The manufacturing sector primarily produces sugar, beverages, rum, clothing, and other goods.Tourism remains a crucial pillar of the economy, especially attracting visitors from Europe, the United States, and Canada. In 2022, the total value of foreign trade reached $2.31 billion, with exports mainly comprising rum, processed foods, and chemicals, while imports were dominated by fuel, food, and beverages.

Primary energy consumption

Barbados' primary energy consumption structure is dominated by fossil fuels. In 2022, oil consumption accounted for 97.9%, while biomass made up 2.1% of the primary energy consumption, a reduction of 0.3 Mt compared to 2010.

Characteristics of fossil fuel emissions

Petroleum products have consistently been the primary source of CO_2 emissions from fossil fuel consumption. In 2022, the consumption of petroleum products produced1.4 Mt of CO_2 emissions.

Sectoral emission contribution

From 2010 to 2022, the transportation, storage, post and telecommunication services has been the largest contributor to fossil fuel CO_2 emissions in Barbados. CO_2 emissions from fossil fuels used in the transportation, storage, post and telecommunication services accounted for 48.2% of the total fossil fuel CO_2 emissions in 2022. Additionally, the production of electricity, heat, gas, and water sector contributed 39.9% of the total fossil fuel CO_2 emissions.

Biomass emissions

In 2022, biomass accounted for about 2.1% of the primary energy consumption. The main biomass in the country is sugar cane, which is considered a sustainable biomass energy source and should not be included in the overall CO_2 emissions during carbon accounting.

Emission trends

Between 2010 and 2022, CO_2 emissions from fossil fuel consumption have shown a downward trend, decreasing from 1.8 Mt in 2010 to 1.4 Mt in 2022, the annual change rate is -1.9%.

Comparison with international databases

Under the same accounting caliber (excluding emissions from biomass), in 2022, the CO_2 emissions data published by EDGAR, IEA, and GCB are 0.76 Mt, 1.1 Mt, and 1.03 Mt, respectively. The fossil energy CO_2 emissions for Barbados calculated by CEADs is 1,4 Mt, show a smaller margin of error compared to the data published by IEA and GCB, with a high degree of consistency in the overall trend. However, there is a relatively larger margin of error compared to EDGAR's results, mainly due to differences in data sources and versions. The Barbados energy balance table used by CEADs comes from the APEC Energy Working Group.

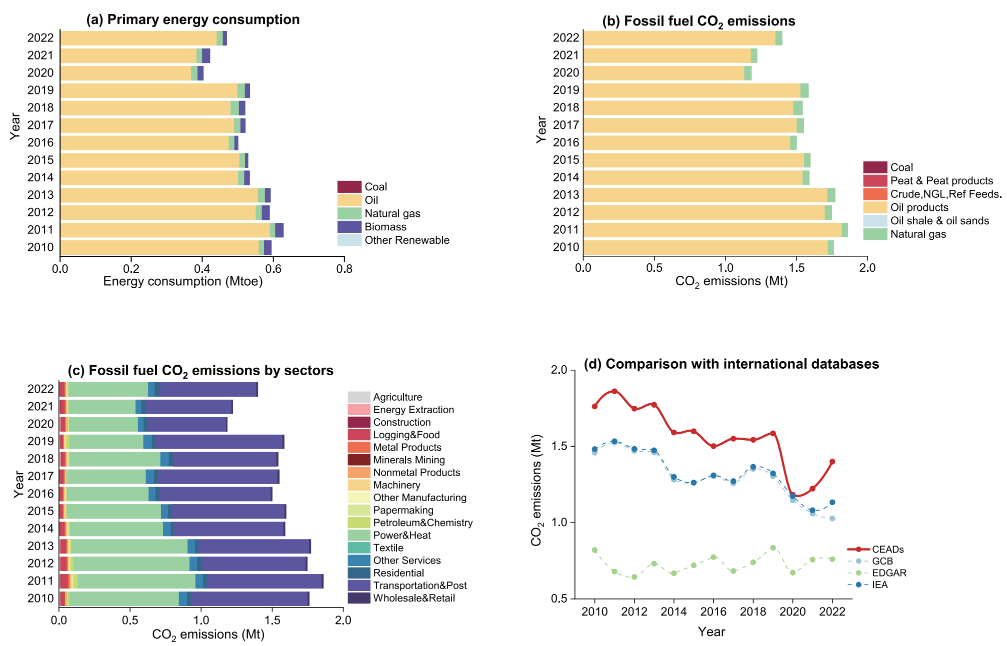


Figure 4.21: Barbados' energy consumption and CO_2 emissions from 2010 to 2022 (a) Primary energy consumption; (b) Fossil fuel CO_2 emissions; (c) Fossil fuel CO_2 emissions by sectors; (d) Comparison with international databases.

Brief description of data sources:

The energy balance sheet for Barbados, provided by the APEC Energy Working Group, includes data for 13 years from 2010 to 2022 and covers 18 types of primary and secondary energy sources. For industry disaggregation, we use the total output value from the Emerging Input-Output Table and export data from UN Comtrade as the allocation indicator corresponding to unified sectors.

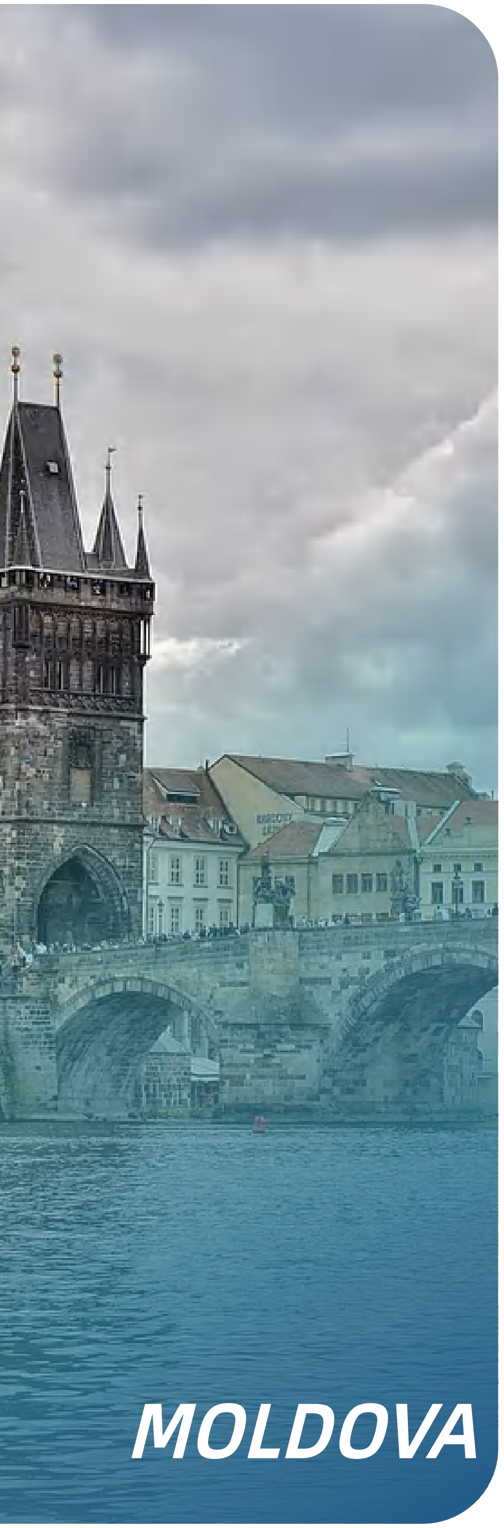
Table 4.21 Data sources for Barbados' emission accounting

Data type	Source	Website
Energy balance sheet	East Asia-ASEAN Economic Research Center (ERIA)	https://sielac.olade.org/WebForms/Reportes/ReporteBalanceEnergetico.aspx?or=600&ss=2&v=1
Emission factor	IIntergovernmental Panel on Climate Change (IPCC)	https://www.ipcc-nggip.iges.or.jp/EFDB/
Sectoral mapping indicator	Emerging MRIO table	https://www.ceads.net.cn/
	UN Comtrade export data	https://comtrade.un.org

CEADs

Chapter 5

EUROPE



Background

Moldova is located in eastern Europe, bordered by Romania to the west and Ukraine to the north, east and south, with most of its territory lying between the Prut and Dniester rivers. In June 2003, Moldova was restructured into 32 districts, 3 municipalities and 2 local special administrative regions. The political situation in Moldova is stable, and social security is guaranteed. According to data published by its national statistics bureau, Moldova's GDP at current prices in 2022 was approximately \$16.5 billion[288], with a population of 2.5 million[289], of which 24.5% lived below the poverty line.

Moldova's economy is primarily based on agriculture, with 80% of its land consisting of fertile black soil suitable for crop production. The country is known for its production of grapes, sugar, edible oil, and tobacco. In 2022, the agricultural value added accounted for approximately 7.6% of the country's GDP[290]. The industry is primarily focused on traditional manufacturing sectors such as food processing, textiles, clothing, and footwear. In recent years, Moldova's GDP structure has been gradually shifting towards the service sector, with the tertiary industry accounting for 61.1% of GDP in 2022[291]. In terms of foreign trade, Moldova's main trade partners are EU member states and CIS countries, with key exports including vegetables, fruits, agricultural products, and industrial goods. Additionally, Moldova lacks fossil fuels and currently relies heavily on Russian natural gas, importing 97% of its energy needs[292].

Moldova has abundant solar and wind energy resources, which can help reduce its dependence on external energy sources and mitigate the impacts of climate change on the country's socio-economic conditions. The government has set a target for renewable energy to account for 20% of the energy mix by 2030. This includes biofuels making up 10% of transportation energy, and renewable energy sources contributing 10% to electricity generation and 27% to heating. Regarding greenhouse gas emissions, the goal is to achieve a 64%-67% reduction from 1990 levels by 2030, with efforts focused on reducing CO_2 emissions by up to 67%.

Primary energy consumption

In 2022, fossil fuel consumption in Moldova accounted for 75.5% of primary energy consumption, primarily from natural gas and petroleum products. Specifically, petroleum products made up 36.6% of energy consumption, while natural gas accounted for 35.6%. Additionally, hydropower, solar energy, and other renewable sources represented 1.5% of primary energy consumption, and biomass constituted 22.9%.

Characteristics of fossil fuel emissions

Among all CO_2 emissions from fossil fuel consumption, those from petroleum products and natural gas dominate. In 2022, petroleum products were responsible for 3.1 Mt CO_2 emissions, accounting for 54.5% of total fossil fuel emissions. Emissions from natural gas reached 2.2 Mt in 2021 and accounted for 39.3% of total emissions from fossil fuels.

Sectoral emission contribution

The transportation, storage and postal services sector is the highest emitter of CO_2 from fossil fuel consumption. Its emissions rose from 1.8 Mt in 2010 (38.2% of fossil fuel emissions) to 2.4 Mt in 2022 (42.3% of fossil fuel emissions), at an average annual growth rate of 2.5%. The fossil fuels used by this sector are mainly gasoline and diesel. The residential sector is the second largest in terms of fossil fuel emissions, generating 1.2 Mt in 2021, which accounted for 21.9% of total fossil fuel CO_2 emissions. The third largest sector for fossil fuel CO_2 emissions is the production of electricity, heat, gas, and water, which primarily relies on natural gas for power generation and accounts for 16.0% of fossil fuel CO_2 emissions. Moldova has a very small proportion of domestic electricity generation. Currently, the electricity supplied by domestic power plants meets less than 30% of the country's total electricity demand. This is because these thermal power plants use natural gas, which, due to its low efficiency and high marginal costs, results in Moldova lacking efficient power generation capacity.

Biomass emissions

In 2022, Moldova's biomass consumption accounted for 22.9% of primary energy consumption, and was confined primarily to the residential sector. Moldova's biomass energy mainly includes agricultural residues, such as plant roots, stems, leaves, straw, and grapevines. Additionally, the use of agricultural residues is rapidly increasing. Since Moldova's biomass sources are primarily sustainable and renewable resources with a "zero carbon" attribute throughout their lifecycle, they should not be included in the overall CO_2 emissions accounting process.

Emission trends

Moldova's fossil fuel CO_2 emissions show an upward trend. Between 2010 and 2022, they grow at an annual rate of 1.3%, rising from 4.7 Mt to 5.6 Mt.

Comparison with international databases

Under the same accounting caliber (excluding emissions from biomass), CO_2 emissions calculated by CEADs are slightly lower than those of EDGAR, IEA and GCB, but show almost the same annual emission trend. Among these, EDGAR reports the highest emissions, with the gap between its data and CEADs' figures widening each year. Since 2014, the CO_2 emissions data and trends reported by CEADs and GCB have been relatively close, with CEADs reporting 5.6 Mt of fossil fuel emissions for Moldova in 2022, compared to GCB's 5.2 Mt. The main difference between CEADs and the data from IEA and EDGAR lies in the energy statistics for the Transnistrian region. CEADs' energy balance data is based on official energy statistics from the Moldovan National Statistics Bureau, which does not include data from the Transnistrian region, whereas IEA and EDGAR's data includes CO_2 emissions from this area, leading to discrepancies in the reported emissions. When accounting for Moldova's administrative boundaries as defined by our Ministry of Foreign Affairs (including the Transnistrian region), CEADs' fossil fuel CO_2 emissions data aligns closely with the figures reported by IEA and EDGAR.

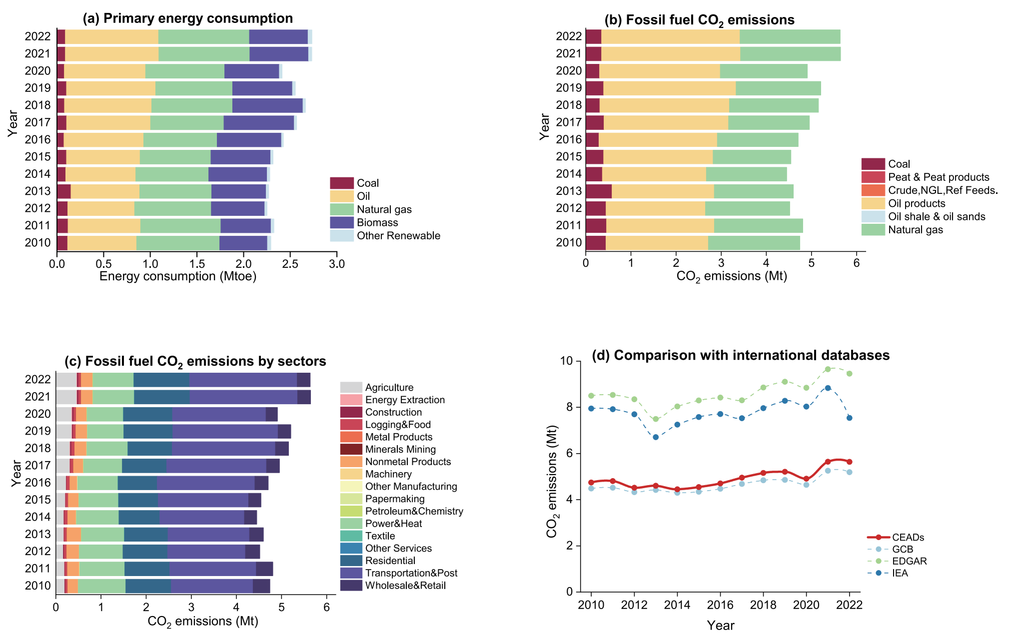


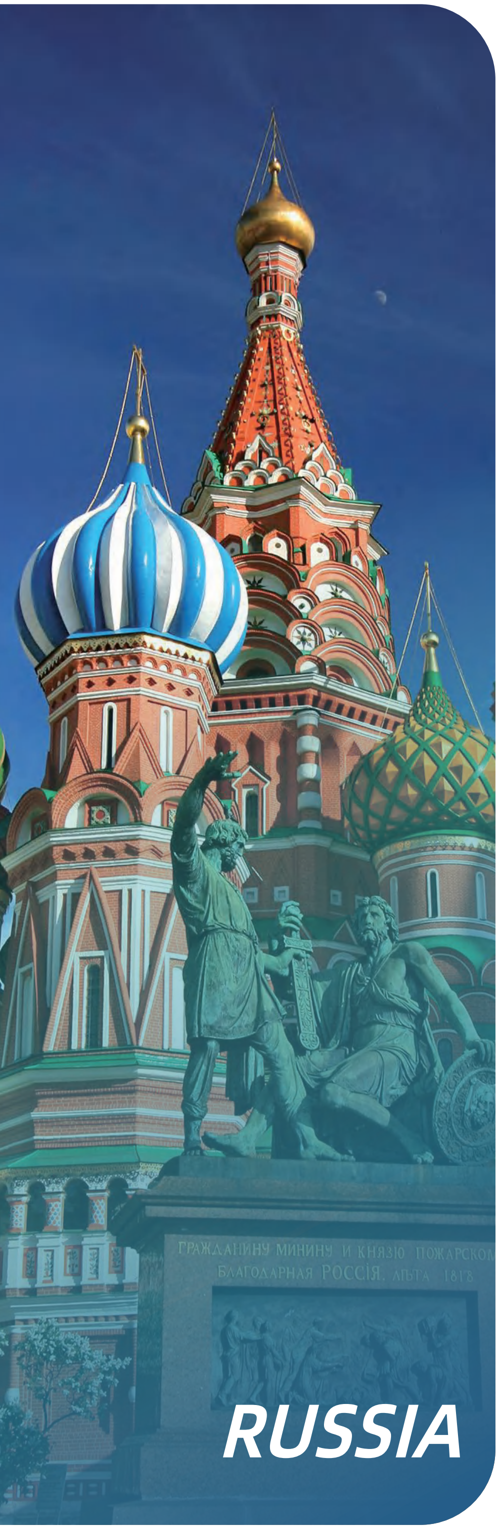
Figure 5.1: Moldova's energy consumption and CO_2 emissions from 2010 to 2022 (a) Primary energy consumption; (b) Fossil fuel CO_2 emissions; (c) Fossil fuel CO_2 emissions by sectors; (d) Comparison with international databases

Brief description of data sources:

The energy data used in this report is from the energy balance sheets provided by Moldova's National Bureau of Statistics for 2010-2022. The balance sheets contain primary and secondary energy processing and conversion data from 4 main types of fossil fuels consumed, and energy consumption data from 6 major economic sectors. To further downscale the national data into 47 sectors, total output data of industry and total output value of the agriculture, commerce, transportation and service sectors and export data from the UN Comtrade is used, among which 2010-2013 data are missing; CEADs thus used 2014 output value as the indicator for mapping.

Table 5.1: Data sources for Moldova's emission accounting

Data type	Source	Website
Energy balance sheet	National Bureau of Statistics	https://statbank.statistica.md/PxWeb/pxweb/ro/40%20Statistica%20economica/40%20Statistica%20economica__15%20ENE__serii%20anuale/ENE020100.px/?rxid=b2ff27d7-0b96-43c9-934b-42e1a2a9a774
Emission factor	IPCC	https://www.ipcc-nggip.iges.or.jp/EFDB/
Sectoral mapping indicator	National Bureau of Statistics	https://statbank.statistica.md/PxWeb/pxweb/ro/40%20Statistica%20economica/40%20Statistica%20economica__14%20IND__IND020/IND020100.px/table/tableViewLayout1/?rxid=b2ff27d7-0b96-43c9-934b-42e1a2a9a774
	UN Comtrade	https://comtradeplus.un.org/



Background

Russia straddles the continents of North Asia and Eastern Europe. Its capital, Moscow, is the largest city in Europe. Russia has one of the world's lowest population densities and highest degrees of urbanization. According to data from the Federal State Statistics Service, Russia's total population reached 144 million, and its GDP at current prices amounted to $2.27 trillion, with a year-on-year growth rate of -2.1%. Additionally, Russia's GDP per capita at current prices also reached $15,000[293].

Russia is rich in natural resources, and its energy-related industries are well-developed. In 2022, the energy extraction sector accounted for 16.7% of GDP. Additionally, Russia has a highly advanced industrial sector, with its nuclear and aerospace industries holding significant positions globally. In agriculture, Russia has favourable conditions and ranks among the top in the world for grain production; however, the agricultural sector's share of the economy has traditionally been low. In 2021, agriculture accounted for 3.8% of Russia's GDP[294]. Furthermore, Russia possesses the largest mineral resource reserves in the world and is a major exporter of oil and natural gas, with the world's largest forest reserves. The ongoing Russia-Ukraine conflict has posed numerous challenges and significantly impacted Russia's international trade. For instance, Asian regions like India are gradually replacing Europe as the primary destination for Russian oil and gas exports.

Russia has begun to promote the use of renewable energy, especially for power generation. According to current policies, it is estimated that by 2030, renewable energy (excluding nuclear and water energy) will account for nearly 5% of the total final energy consumption. Achieving this goal will necessitate investing US$ 300 billion in renewable energy before 2030[295]. In response to climate change, in 2019 Russia joined the Paris Agreement, which aims to strengthen international cooperation and mitigate global climate change. In its 2020 Intended National Determined Contributions (INDC), Russia proposed a goal of limiting greenhouse gas emissions to 70% of 1990 levels by 2030[296].

Primary energy consumption

Fossil energy accounted for 88.2% of Russia's primary energy consumption. In 2022, natural gas accounted for 56.9% of the primary energy consumption, and oil for 22.6%. Nuclear, hydropower, thermal power and other renewable energy accounted for 9.4% of its primary energy consumption; meanwhile, biomass accounted for less than 0.1% of the primary energy supply.

Characteristics of fossil fuel emissions

Among all CO_2 emissions from fossil fuel consumption, those from natural gas and coal dominate in Russia. In 2022, they accounted for 517.3 Mt and 499.7 Mt CO_2 emissions, respectively, or 37.3% and 36.0% of the country's total emissions from fossil fuels. Compared to 2010, this represents a decrease of 27.9 Mt for natural gas and an increase of 43.2 Mt for coal. Additionally, petroleum products are also a significant source of fossil fuel CO_2 emissions in Russia. In 2022, emissions from petroleum product consumption accounted for 21.7% of the total.

Sectoral emission contribution

The electricity, heat, gas and water production sectors emit the most CO_2 emissions from fossil fuel consumption in Russia. From 2017 to 2020, its emissions dropped from 616.1 Mt to 566.3 Mt. In 2022, they accounted for 41.8% of the total CO_2 emissions from fossil energy. The metal products manufacturing industry is the second largest source of fossil fuel CO_2 emissions in Russia, with emissions in 2022 representing 22.9% of the total. The transportation, storage and postal services sector is the third largest contributor, with 128.6Mt emissions in 2022, or 9.3% of the total fossil fuel emissions.

Biomass emissions

In 2022, Russia's biomass consumption accounted for less than 0.1% of primary energy consumption, primarily used in the pulp and paper industry, lumber, food industry, and metal products manufacturing. Russian biomass mainly includes wood pellets and wood waste, with the utilization of these resources rapidly increasing. Since Russia's biomass sources are primarily sustainable and renewable resources with a "zero carbon" attribute throughout their lifecycle, they should not be included in the overall CO_2 accounting process.

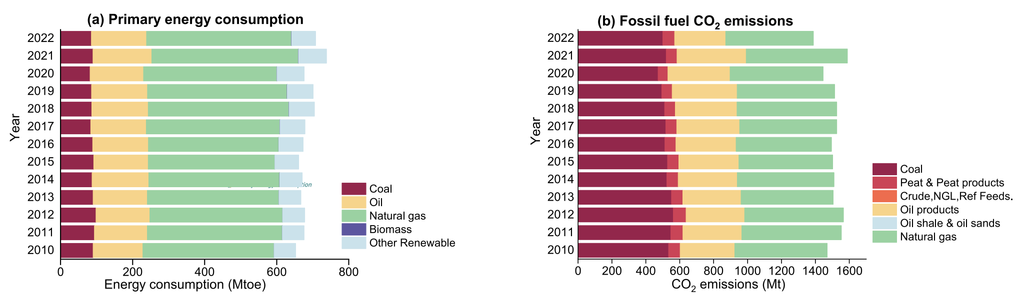
Emission trends

From 2010 to 2018, Russia's fossil fuel emissions generally showed an upward trend, increasing from 1,470.1 Mt to 1,526.4 Mt, an approximate increase of 3.8%. However, since then, Russia's CO_2 emissions have exhibited a slow decline. In 2022, Russia's CO_2 emissions reach to 1,388.8 Mt.

Comparison with international databases

Under the same accounting calibre (excluding emissions from biomass), the CO_2 emissions calculated by CEADs show a growth trend consistent with those calculated by EDGAR, GCB and IEA, but are slightly lower than their statistics. CEADs' data is more closely aligned with IEA's, showing a similar overall growth trend, with an average difference of only 0.78%. Although the gap between CEADs and IEA data began to widen in 2017, it narrowed again in 2022. Specifically, CEADs reported 1388.8 Mt of emissions, while IEA data indicated 1577.2 Mt, resulting in a 2.1% difference. The main reasons for these discrepancies are the sources of the original data and the energy consumption data for various sectors.

From the point of use of the original data, CEADs' data source is the Unified Interdepartmental Statistical Information System (UISIS); the emission factors are provided by Ministry of Natural Resources and Environment (MNRE). However, the IEA's energy balance sheet data are from the National Bureau of Statistics, Russia, but the economic sectors and energy varieties published by the National Bureau of Statistics are rough. IEA's emission factor data are from the 2006 IPCC National Greenhouse Gas Inventories guidelines. There are thus differences in the original data, which may be the reason for the different CO_2 emission data.



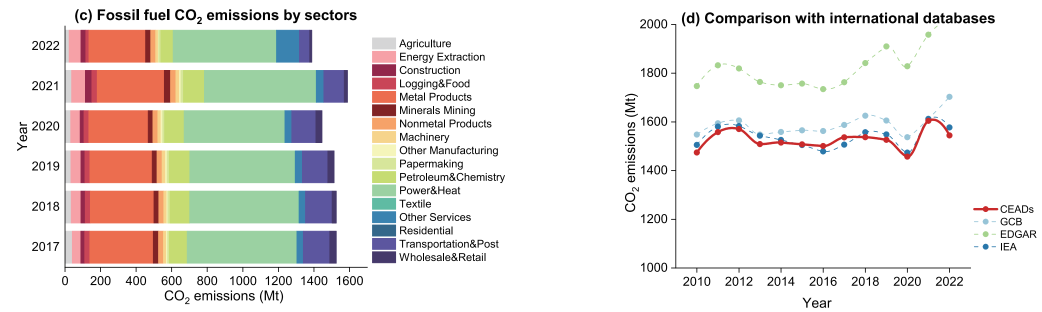


Figure 5.2: Russia's energy consumption and CO_2 emissions from 2010 to 2022 (a) Primary energy consumption; (b) Fossil fuel CO_2 emissions; (c) Fossil fuel CO_2 emissions by sectors; (d) Comparison with international databases. Due to the problem of data availability, data are provided for fossil fuel CO_2 emissions by sectors only from 2017 to 2022.

Brief description of data sources:

The compilation of CO_2 inventory in Russia is based on the compilation method of Intergovernmental Panel on Climate Change (IPCC), and the CO_2 inventory of CEADs with unified format and unified statistical caliber is taken as the template. These are combined with the fossil energy consumption data of the Unified Interdepartmental Statistical Information System (UISIS) of Russia and the emission factors of more than 100 kinds of energy released by the Ministry of Natural Resources and Environment (MNRE) of Russia in 2015 to calculate the CO_2 emissions sourced from fossil fuel consumption in Russia.

Table 5.2: Data sources for Russia's emission accounting

Data type	Source	Website
Energy balance sheet	The Unified Interdepartmental Statistical Information System (UISIS)	https://fedstat.ru/indicator
Emission factor	The Unified Interdepartmental Statistical Information System (UISIS)	https://fedstat.ru/indicator
Sectoral mapping indicator	The Unified Interdepartmental Statistical Information System (UISIS)	https://fedstat.ru/indicator

Background

Estonia is a northern European country bordered by the Baltic Sea to the west, the Gulf of Finland to the north, Latvia to the south and Russia to the east. Since the country's administrative reform in 2017, Estonia now has 79 local governments, including 15 towns and 64 rural municipalities. As of 1 January 2022, the country's total population is approximately 1.3 million. Since it joined the European Union in 2004, its economy has developed rapidly, leading Europe to dub it the "Baltic Tiger". It is listed as a high-income country by the World Bank. In 2022, its GDP (at the current price) reached US$ 38.4 billion, with a per capita GDP of US$ 28,451[115].

From an industrial perspective, Estonia has a well-developed service sector. In 2022, services accounted for 70.8% of the country's economic value added. This is followed by manufacturing and construction, which contributed 13.77% and 6.4%, respectively[297]. Estonia is rich in fossil resources and non-metallic minerals, including oil shale, peat, and limestone. Additionally, the country has abundant forest resources, with a forest cover rate of 54%. In terms of international trade, Estonia's major export partners are Finland, Latvia, and Sweden, while its main import partners are Finland, Lithuania, and Germany. The four main categories of goods in Estonia's trade are electronics and communication products, mineral products, machinery and equipment, and wood and wood products.

Estonia is rich in wind, solar, and hydropower resources and has long encouraged the development of renewable energy by providing state subsidies to businesses that utilize these resources. To advance the use of renewable energy, Estonia has signed agreements with Latvia to jointly develop offshore wind farms. Furthermore, Estonia has set a target for 2030 to achieve a 50%[298] share of renewable energy in both final energy consumption and electricity generation. According to the United Nations Framework Convention on Climate Change (UNFCCC), Estonia's Intended National Determined Contributions (INDC) aim to reduce domestic greenhouse gas emissions by at least 40% before 2030 compared with 1990 levels[299].

Primary energy consumption

Fossil fuels dominate Estonia's primary energy consumption. In 2022, fossil fuel consumption accounted for 67.3% of total primary energy consumption, with oil making up 54.0% and natural gas 7.1%. Biomass constituted 30.1% of primary energy consumption, while wind, solar, and other renewable energies accounted for 2.7%.

Characteristics of fossil fuel emissions

CO_2 emissions from the consumption of fossil fuels are primarily attributed to petroleum products, which in 2022, were responsible for 3.0 Mt of CO_2 emissions, making up 37.1% of the total CO_2 emissions from fossil fuels. There has been a notable trend in CO_2 emissions from shale oil consumption since 2010, with emissions increasing from 9.4 Mt in 2010 to 10.9 Mt in 2013, followed by a sharp decrease to 3.9 Mt in 2022, at which point they constituted 48.5% of CO_2 emissions from fossil energy. Additionally, CO_2 emissions from natural gas and coal contributed to about 8.3% and 5.7% of the total fossil fuel emissions, respectively.

Sectoral emission contribution

CO_2 emissions from fossil fuel consumption in Estonia mainly come from two sectors: the electricity, heat, gas and water production sector, and transportation, storage and postal services. The utility sector is the highest-emitting in Estonia, accounting for 4.8 Mt of CO_2 emissions and contributing 58.7% of fossil fuel emissions in 2022. The transportation, storage and postal services sector is the second largest contributor, responsible for 2.5Mt of CO_2 emissions, which accounted for 30.4% of total fossil fuel emissions.

Biomass emissions

In 2022, biomass accounted for 30% of primary energy consumption, and was mainly used in the electricity, heat, gas and water production sector. The primary types of biomass include wood and wood pulp, agricultural residues and municipal waste[300]. Since Estonia's biomass sources are predominantly sustainable and renewable resources with a "zero carbon" attribute throughout their lifecycle, they should not be included in the overall CO_2 accounting process.

Emission trends

Between 2010 and 2017, CO_2 emissions from fossil fuel combustion were relatively stable but declined rapidly thereafter. Due to the outbreak of COVID-19, CO_2 emissions dropped to their lowest point in history in 2020. However, in 2022, emissions rebounded to 8.1 Mt.

Comparison with international databases

Under the same accounting caliber (excluding emissions from biomass), the CO_2 emissions calculated by CEADs between 2005 to 2018 show a growth trend consistent with those calculated by EDGAR and IEA, but are slightly lower than their statistics. The reason for the difference is that CEADs used emission factors from the official government agency Statistics Estonia, which are smaller than those used by other agencies. The United Nations Framework Convention on Climate Change, which is published by Statistics Estonia, was the new source for the emission factor used by CEADs in 2019–2020 as a result of modifications to the data compilation process. Overall, the CEADs results show the greatest discrepancy from the EDGAR results and are closest to the IEA results.

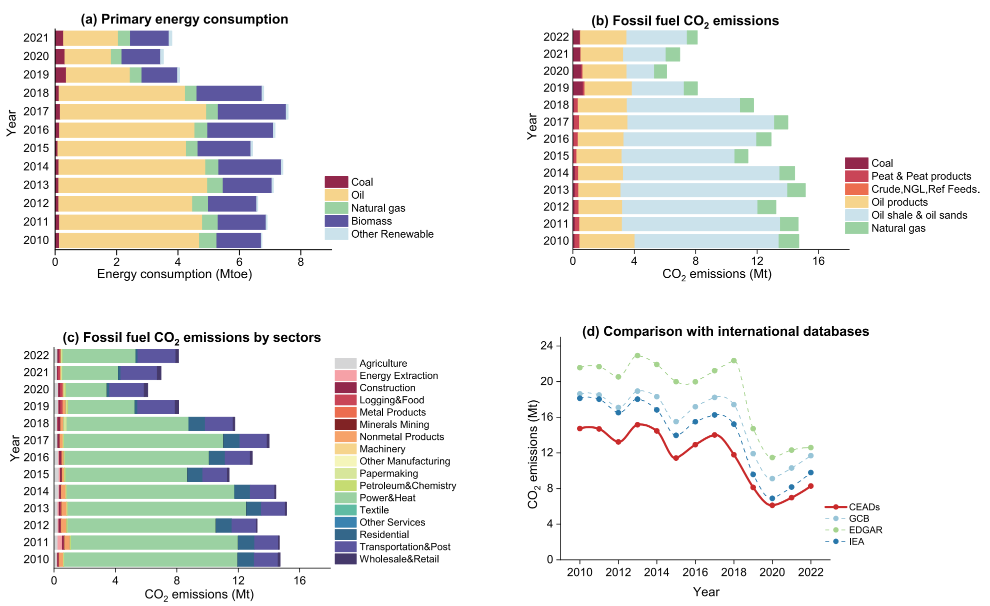


Figure 5.3: Estonia's energy consumption and CO_2 emissions from 2010 to 2022 (a) Primary energy consumption; (b) Fossil fuel CO_2 emissions; (c) Fossil fuel CO_2 emissions by sectors; (d) Comparison with international databases .

Brief description of data sources:

The energy balance sheet contains statistics of 27 energy types and 19 sectors. The energy of the 2019-2022 energy balance sheet has 30 kinds of energy varieties and 18 industries, the sub-sectoral indicators come from industrial output value of the particular industry. All these data of CEADs come mainly from Statistics Estonia.

Table 5.3: Data sources for Estonia's emission accounting

Data type	Source	Website
Energy balance sheet	Statistics Estonia	https://andmed.stat.ee/en/stat
Emission factor	UNFCCC	https://unfccc.int/process/transparency-and-reporting/reporting-and-review-under-the-convention/greenhouse-gas-inventories-annex-i-parties/national-inventory-submissions-2018
Sectoral mapping indicator	Statistics Estonia	https://andmed.stat.ee/en/stat

Chapter 6

OCEANIA

Background

Located in the Southern Pacific region, Papua New Guinea is bordered by Indonesia to the west and Australia to the south, with a land area of 463,000 square kilometres From 2010 to 2022[301], the population of Papua New Guinea increased from 7.6 million in 2010 to 9.9 million in 2021. In 2021, the urban population accounted for 13.5%. Papua New Guinea is one of the least developed countries in the world. Between 2010 and 2022, the country's GDP continued to grow at an annual rate of 4.1%, reaching $26.1 billion in current prices in 2022. Per capita GDP increased from $1,879.2 in 2010 to $2,624.6 in 2021[302].

Papua New Guinea is rich in natural resources. Minerals, petroleum and agricultural cash crops are the three pillars of the economy. The nation abounds in gold, chromium, nickel, bauxite, undersea natural gas and oil resources and is rich in forests. The land area is made up of 86.4% tropical primary forests. Coffee, cocoa beans, natural rubber, palm oil, and copra are the principal agricultural products. In the Pacific Island area, Papua New Guinea is the biggest producer of copra and coconut oil.

Papua New Guinea's economic development is highly uneven. In recent years, economic growth has slowed due to the impact of the COVID-19 pandemic and fluctuations in international markets, leading to increased fiscal difficulties for the government. At the same time, many residents in mountainous areas still live a subsistence lifestyle in traditional tribal communities. Nearly 37% of the country's population lives below the international poverty line ($1.25 per person per day). According to the 2021 Human Development Index released by the United Nations Development Programme, Papua New Guinea ranked 156th out of 191 countries. The country has experienced rapid population growth, with a significant migration of rural populations to urban areas. Unemployment remains high, and social security needs improvement. Currently, the Papua New Guinea government has concentrated on developing strategic development plans like the 2010–2030 Development Plan, the 2050 Vision Plan, and "Connecting Papua New Guinea”These plans have allowed the country's economy to grow positively for many years in a row and have provided a relatively stable external policy environment. The administration has increased its efforts and seen some success in luring in foreign capital. Significant advancements have been made in investment initiatives like the Ruimu Nickel Mine and liquefied natural gas projects, both of which have been crucial in fostering long-term economic growth..

Primary energy consumption

In 2022, fossil fuel consumption accounted for over 53.5% of Papua New Guinea's primary energy consumption, primarily driven by oil. Additionally, biomass made up 42.4% of primary energy consumption, while other renewable energy sources accounted for 4.1%.

Characteristics of fossil fuel emissions

Petroleum products have been the largest CO_2 emissions from fossil fuels in Papua New Guinea, with CO_2 emissions of 6.2 Mt in 2022.

Sectoral emission contribution

From 2010 to 2023, the sector producing the highest volume of CO_2 emissions from fossil fuels in Papua New Guinea was the electricity, heat, gas and water production sector. In 2022, emissions from the utility sector accounted for 42.4% of total fossil fuel energy CO_2 emissions. CO_2 emissions from fossil fuel consumption in the transportation, storage and postal services sector increased from 1.4 Mt in 2010 to 1.8 Mt in 2022.

Biomass emissions

In 2022, biomass accounted for 42.4% of Papua New Guinea's primary energy consumption, primarily sourced from residential sector. The types of biomasses in the country include firewood, wood waste, and charcoal, with firewood and wood waste being the main sources of biomass energy. These are classified as unsustainable biomass energy and should be included in overall CO_2 emissions during the carbon accounting process. Between 2010 and 2022, emissions from firewood combustion increased from 7.4 Mt to 8.1 Mt.

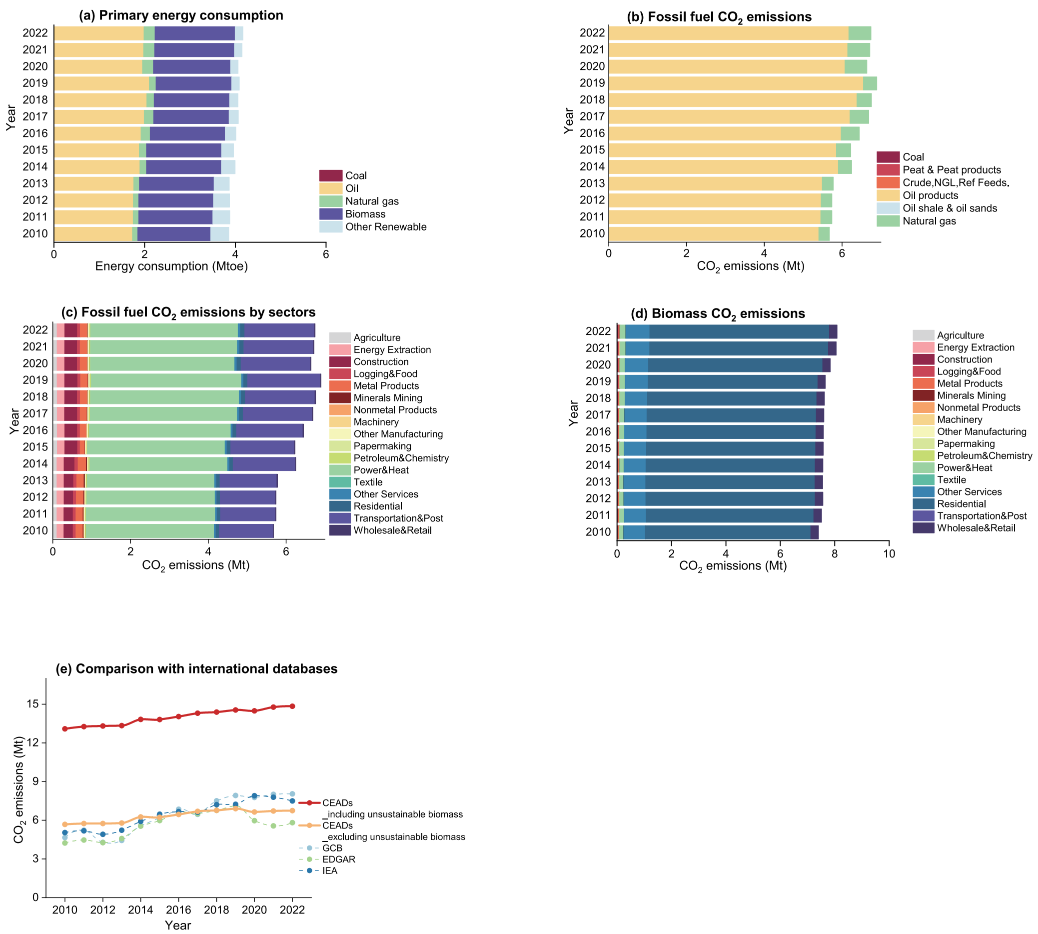
Emission trends

Papua New Guinea's fossil fuel CO_2 emissions show an upward trend, increasing from 5.7 Mt in 2010 to 6.7 Mt in 2022, with an annual growth rate of 1.5%. Biomass CO_2 emissions in Papua New Guinea have also exhibited a gradual increase, rising from 7.4 Mt in 2010 to 8.1 Mt in 2022.

Comparison with international databases

Under the same accounting caliber (excluding emissions from biomass), CEADs' CO_2 emissions data from fossil fuel consumption is significantly higher than EDGAR's data and is more closely aligned with the IEA and GCB data. The discrepancies between different organizations' statistics may be due to variations in data sources; for example, the IEA uses the United Nations Energy Statistics Database, while CEADs utilizes the latest data format from the APEC Energy Working Group.

When including CO_2 emissions from biomass consumption, CEADs calculated total CO_2 emissions for 2022 to be 14.8 Mt.



FFigure 6.1: Papua New Guinea's energy consumption and CO_2 emissions from 2010 to 2022 (a) Primary energy consumption; (b) Fossil fuel CO_2 emissions; (c) Fossil fuel CO_2 emissions by sectors; (d) Biomass CO_2 emissions; (e) Comparison with international databases

Brief description of data sources:

The energy data used in this report from the APEC Energy Working Group, covers 62 primary and secondary energy varieties. In terms of industry downscaling, we use the input-output data of the Carbon Emission Accounts and Datasets for industry and the total output value of agriculture, commerce, transportation and services as distribution indicators corresponding to unified sectors.

Table 6.1: Data sources for Papua New Guinea's emission accounting

Data type	Source	Website
Energy balance sheet	APEC Energy Working Group	https://www.egeda.ewg.apec.org/egeda/database_info/newbalance_select_form2.html
Emission factor	Intergovernmental Panel on Climate Change (IPCC)	https://www.ipcc-nggip.iges.or.jp/EFDB/
Sectoral mapping indicator	Carbon Emission Accounts and Datasets	https://www.ceads.net/

Background

Located in the Central Pacific region, the Federated States of Micronesia is part of the Caroline Islands archipelago, with a land area of 702 square kilometres and a marine economic zone of 2.98 million square kilometres. The country consists of four states (Yap, Chuuk, Pohnpei and Kosrae) and 600 islands. In 2022, Micronesia had a total population of 112,630. Between 2010 and 2022, Micronesia's GDP grew at an annual rate of 1.6%, reaching US$ 430 million at current prices in 2022. GDP per capita rose from US$ 2,760 in 2010 to US$ 3,535 in 2022[303].

Micronesia is a lower middle-income country and economic development is slow. The vast majority of its population lives in villages. Agriculture, fishing and tourism are the three pillars of the economy. The nation abounds in coconut, pepper, taro, breadfruit and other agricultural products and is rich in fishery resources; it is especially famous for its tuna. It imports much of its food and daily necessities, however, and is heavily dependent on foreign aid.

Currently, Micronesia relies primarily on diesel for electricity generation. According to the International Renewable Energy Agency (IRENA), as of the end of 2019, Micronesia had 2 MW of solar installed and 18 MW of total power installed[304]. In 2020, the government launched a tender to build multiple photovoltaic plants equipped with energy storage systems.

Primary energy consumption

In 2022, fossil energy consumption in Micronesia is dominated by petroleum, which accounts for 100% of primary energy consumption.

Characteristics of fossil fuel emissions

Petroleum products have been the largest and only source of CO_2 emissions from fossil fuels in Micronesia, with CO_2 emissions hovering between 0.14 Mt and 0.18 Mt between 2010 and 2022.

Sectoral emission contribution

From 2010 to 2022, the agriculture sector produced the highest volume of CO_2 emissions from fossil fuels in Micronesia. In 2022, emissions from fossil energy use in the industry accounted for 42.2% of total fossil energy CO_2 emissions. The wholesale and retail and paper industries followed, accounting for 19.2% and 17.3%, respectively.

Emission trends

CO_2 emissions from fossil energy consumption in Micronesia showed a relatively stable trend between 2010 and 2022, declining from 0.15 Mt in 2010 to 0.14 Mt in 2011, then rising to 0.18 Mt in 2022.

Comparison with international databases

nder the same accounting caliber (excluding emissions from biomass), the CO_2 emissions calculated by CEADs after 2015 are almost exactly consistent with GCB's emission trend. However, when comparing the statistics of CEADs and GCB, there was a large difference in value. CEADs' stated emissions were higher than IEA's over the period. This may be due to different data sources. For example, the IEA does not use publicly available data sources, while CEADs use the official statistics of Micronesia.

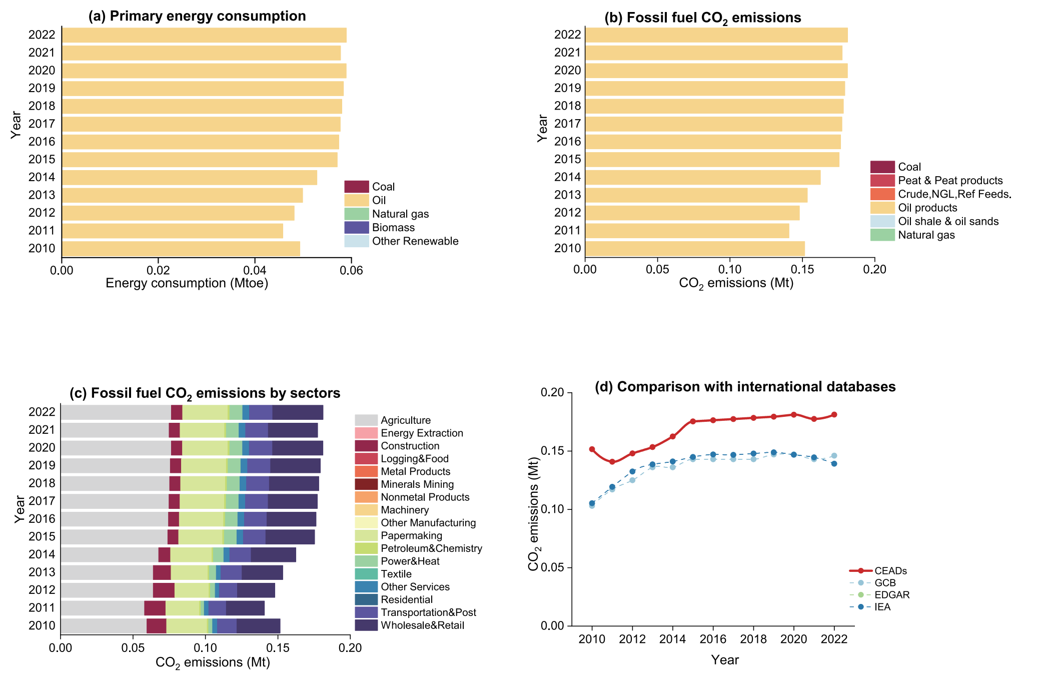


Figure 6.2: Micronesia's energy consumption and CO_2 emissions from 2010 to 2022 (a) Primary energy consumption; (b) Fossil fuel CO_2 emissions; (c) Fossil fuel CO_2 emissions by sectors; (d) Comparison with international databases

Brief description of data sources:

The energy balance for Micronesia is derived from the FSM National Statistical Office (NSO) and contains energy consumption data for the FSM in 2015 for the three secondary energy varieties, as well as output values by energy type from 2010 to 2014. For the sectoral downscaling, we used the national GDP from the FSM National Statistics Office as the allocation indicator.

Table 6.2: Data sources for Micronesia's emission accounting

Data type	Source	Website
Energy balance sheet	FSM Statistics: Secondary Energy consumption	https://www.fsmstatistics.fm/environment/seea-experimental-energy-accounts/
Emission factor	The Intergovernmental Panel on Climate Change (IPCC)	https://www.ipcc-nggip.iges.or.jp/EFDB/
Sectoral mapping indicator	FSM Statistics: National Gross Domestic Product	https://www.fsmstatistics.fm/wp-content/uploads/2019/02/FSM-Experimental-Energy-Accounts.pdf

Chapter 7

Regional Observations

Regional Observations—Analysis of Emission Patterns in Typical East African Countries

East Africa, one of the most economically dynamic regions in the world today, remains underdeveloped but is poised to become a key battleground for global emission reduction efforts[305]. The countries in this region share commonalities and differences in economic, social, and ecological dimensions. In terms of economic and urban development, most East African countries rely heavily on agriculture, with primary products such as coffee and tea, as well as mineral resources, serving as major export commodities. However, industrialization levels are generally low, and economic structures are relatively homogeneous, making these economies vulnerable to fluctuations in international markets. For example, countries like Burundi and Rwanda are heavily dependent on coffee exports, and fluctuations in global coffee prices significantly impact their economies[306]. Outside major cities such as Nairobi in Kenya, Addis Ababa in Ethiopia, and Dar es Salaam in Tanzania, urbanization levels remain low, and infrastructure and service sector development are underdeveloped. On the social front, poverty, inequality, and social conflicts are major challenges facing East African countries. For instance, Kenya and Uganda have seen heightened social tensions in recent years due to election disputes and political governance issues. Ecologically, East Africa is renowned for its rich biodiversity, with numerous wildlife reserves and unique ecosystems. However, the region also faces environmental challenges such as deforestation, climate change, and resource depletion. In terms of energy supply and demand, although these countries are advancing renewable energy projects—such as Ethiopia's Grand Ethiopian Renaissance Dam hydroelectric project[307] and Kenya's newly constructed Garissa solar power project—energy demand and energy poverty remain significant issues[308], particularly in rural areas severely affected by uneven electricity distribution. Additionally, the impact of climate change is particularly pronounced in East African countries[309], not only increasing the frequency and intensity of extreme weather events, such as droughts and flooding, but also threatening agriculture and food security, and further destabilizing economic development and social stability. For example, Zambia and Madagascar have frequently experienced droughts and cyclones in recent years, leading to reduced crop yields and volatile food prices[310]. Meanwhile, the lake and wetland ecosystems in Tanzania and Uganda are degrading due to climate change and human activities, affecting fisheries and water resources.

In summary, as industrialization and urbanization progress in East Africa, emissions driven by energy use are expected to rise further. While pursuing economic growth, these countries face numerous challenges in achieving sustainable development, including a homogeneous economic structure, inadequate infrastructure, social conflicts, energy transitions, and climate change. Balancing energy demand with environmental protection remains a critical challenge for the region.

Temporal and Spatial Evolution Trends of Carbon Dioxide Emissions in East African Countries

Among the East African countries, from 2010 to 2022, the top three countries in terms of total fossil fuel carbon emissions were Kenya, Tanzania, and Ethiopia, with annual growth rates of 4.3%, 6.7%, and 8.5%, respectively. Kenya, as one of the largest economies in East Africa, leads the region in economic scale and is a core member of the East African Community (EAC). It also serves as the trade and financial hub of East Africa. In terms of energy resources, Kenya is a pioneer in renewable energy development in the region. Despite its leading position in geothermal and solar energy, the importance of its oil industry keeps carbon emissions high. In 2022, carbon emissions from petroleum products accounted for 83.3% of the total fossil fuel carbon emissions. Zambia experienced the fastest annual growth rate in fossil fuel emissions at 14.8%, increasing from 1.6 million tons of CO_2 in 2010 to 8.6 million tons in 2022. This is attributed to Zambia's rapid economic growth, which has driven up energy demand for production and daily life, leading to a rise in carbon dioxide emissions. In particular, the rapid development of Zambia's transportation sector and the increase in vehicle ownership have boosted fuel demand. In 2022, the transportation sector contributed 31.5% of the country's fossil fuel carbon emissions. Additionally, despite Zambia's abundant hydropower resources, unstable electricity supply due to droughts and other extreme weather events has forced the country to rely heavily on oil and coal to meet its energy needs.

Across East African countries, the growth patterns of fossil fuel carbon emissions show significant similarities across sectors. In 2022, except for Zimbabwe, Madagascar, and Mauritius, where the highest carbon emissions from fossil fuels came from the electricity, heat, gas, and water production and supply sectors, the highest emissions in other East African countries were from the transportation, storage, and postal sectors. However, due to differences in economic foundations and energy structures, the specific contributions of industrial sectors to carbon dioxide emissions vary. For example, in Kenya, apart from the transportation sector, the manufacturing sector also contributed significantly, producing 3.9 million tons of CO_2 in 2022, accounting for 22.8% of the total. This is due to Kenya's relatively well-developed transportation, communication, and energy infrastructure, as well as a stable political environment and abundant labor resources, which provide a solid foundation for manufacturing development. In contrast, Zambia's mining sector contributes a higher proportion of total carbon emissions compared to other East African countries. This is attributed to Zambia's rich copper and other mineral resources, making mining a vital component of its economy[311].

Challenges and Contradictions in the Future Emission Reduction Pathways of East African Countries

Against the backdrop of climate change and the urgent pressure to reduce carbon emissions, East African countries face numerous challenges and difficulties. These challenges are closely related to economic structure, industrial development, energy dependency, financial and technological limitations, and the international environment.

Firstly, there is the contradiction between rapid urbanization and growing energy demand. East African countries are undergoing rapid urbanization, with increasing urban populations driving a surge in energy demand. For example, Rwanda and Uganda have seen accelerated urbanization in recent years, leading to rapid growth in electricity demand and emissions from the transportation sector[312]. Balancing the growth in energy demand with emission reduction goals during urbanization is a significant challenge for East African countries. Secondly, there is the tension between economic development and low-carbon transition. The industrial development levels in East African countries are generally low, but in countries like Kenya and Zambia, manufacturing and mining industries are gradually emerging. The development of these sectors will result in substantial carbon emissions. Therefore, achieving a balance between economic development needs and emission reduction targets through technological upgrades and transitioning to cleaner, low-carbon production methods is a bottleneck for many East African nations. Thirdly, there is the trade-off between energy structure transformation and energy supply stability. The energy structures of East African countries have historically relied heavily on fossil fuels and traditional biomass[313]. Many countries face insufficient power supply, outdated energy infrastructure, and prominent energy poverty issues. For instance, Tanzania still heavily depends on biomass energy, which not only exacerbates deforestation and land degradation but also negatively impacts public health and the environment[314]. Thus, reducing reliance on fossil fuels and biomass while ensuring stable energy supply and security during the energy transition is a challenging issue in the emission reduction process. Fourthly, there is the contradiction between emission reduction investments and financial and technological constraints. East African countries generally face severe limitations in emission reduction technologies and funding. On one hand, many countries lack the financial and technical support needed to develop renewable energy, leaving the utilization of clean energy sources like solar and wind power in its infancy. On the other hand, the introduction and application of advanced technologies such as carbon capture, utilization, and storage (CCUS) require significant investments, which are beyond the fiscal capacity of most East African countries. Fifthly, there is the conflict between climate change and food security. Agriculture in East African countries is highly sensitive to climate change, with extreme weather events like droughts and floods severely affecting food security and agricultural productivity[315]. For example, Burundi's agricultural sector faces the risk of reduced yields due to climate change, which could exacerbate economic and social instability. Therefore, emission reduction actions need to be integrated with food security and sustainable agricultural development, making it a complex challenge to achieve emission reduction goals with limited resources. Additionally, there is the tension between international commitments and national conditions. East African countries typically participate in international climate negotiations through regional cooperation platforms such as the African Union (AU) and the East African Community (EAC). However, due to differing national conditions, priorities in emission reduction targets and policies may vary among countries. If international commitments and domestic development needs are not well-balanced, it could lead to contradictions in policy formulation and implementation[316].

In summary, East African countries face numerous challenges in their future emission reduction pathways. To address climate change and achieve sustainable development goals, these countries need to strengthen carbon emission monitoring and management, promote the development of renewable energy, improve energy efficiency, and enhance natural resource protection. Furthermore, with support from the international community, it is essential to unite efforts from governments, businesses, and various sectors of society to explore emission reduction pathways tailored to national conditions, formulate differentiated policies and measures, and drive low-carbon transitions and sustainable development. This will help achieve a win-win situation of economic growth and carbon emission reduction.

CEADs

APPENDIX

CO_2 Emission Accounts

1) National emission accounts

According to the Intergovernmental Panel on Climate Change (IPCC) guidelines, national CO_2 emissions can be calculated as follows:

$$CE = \sum_{ij} CE_{iJ} = \sum_{ij} AD_{iJ} \times EF_{iJ}$$

where is the CO_2 emissions from the activity type of the industry (such as the energy type for energy-related emissions accounting, industrial process-related emissions accounting, etc.), is activity data (such as energy consumption), and is the emission factor, which can measure the CO_2 emissions released per unit of activity.

For any years in which the underlying statistics are temporarily missing, or when there is a significant anomaly in the statistics compared with the preceding and subsequent years, but for which there is no basis for explanation, the carbon emissions are corrected by:

$$CE_{t1} = CE_{t0} \times (1 + agr)^{t1-t0}$$

where CE_{t1} are the carbon emissions in the revision year, CE_{t0} are the emissions in the reference year, and agr is the annual growth rate of carbon emissions. Thus, the carbon emissions in the revision year are calculated based on the emissions in the reference year, assuming that the growth rate of carbon emissions remains unchanged. The specific revision year is shown in the following table.

Appendix Table 1: Countries and years for data correction

Countries	Countries
Myanmar	2018, 2019, 2020, 2021, 2022
Pakistan	2022
Cambodia	2020, 2021, 2022
Laos	2019, 2020, 2021, 2022
Sri Lanka	2011, 2022
Iran	2019, 2020, 2021, 2022
Armenia	2010, 2011, 2012, 2013, 2014
Thailand	2010, 2011, 2012
Kazakhstan	2010, 2011, 2012, 2013
Malaysia	2022
Brunei	2022
Israel	2010, 2011, 2012
Uganda	2012, 2013, 2014, 2015
Tanzania	2022
Guinea	2016
Kenya	2010, 2011, 2020
South Africa	2022
Nicaragua	2010, 2011
Peru	2010
Cuba	2010
Russia	2020
Papua New Guinea	2022
Micronesia	2015, 2016, 2017, 2018, 2019, 2020, 2021, 2022

2) Sectoral emission accounts

The number of sectors accounted for by different countries or agencies varies due to different statistical caliber. The established CEADs database (https://ceads.net) includes 47 industries, and so was used to match the industries. According to the emission accounts and industry matching indicators of the above countries, the corresponding CO_2 emissions matched to the sector are as follows:

$$CE_{ij} = CE_{iJ} \times \frac{SI_{ij}}{SI_{iJ}}$$

where SI represents sector-mapping indicators, including sectoral energy consumption, industry energy intensity, industry added value, industry output, etc. J is the sector defined by the country's official statistics, and is the matching industry in the list of 47 industries.

Data Sources

1) Energy balance sheets

Energy balance sheets contain detailed data on energy types, supply, processing and conversion, and consumption by sector. CO_2 emissions are calculated based on energy combustion and conversion, such as electricity and heat production; and final consumption, such as that by industry and transport. The energy balance sheet data used in this report were obtained from national statistical offices and regional research centres (detailed data sources are listed in the analysis of results by country).

2) Emission factors

An emission factor is defined as the amount of CO_2 emitted per unit (calorific value or physical amount) of energy burned. This database prefers nationally published emission factors. For countries without national emission factors, IPCC recommends that emission factors are used for calculation. Detailed data sources are listed in the analysis of results by country.

3) Industry matching indicators

Since each country's energy consumption statistics are in a different mix of industries, we standardized each country's industries into 47 consistent with the System of National Accounts in China. Carbon emissions generated from the original industry are distributed among the 47 industries using the industry matching index. The industry matching indicators include data on, for instance, energy consumption, output and sales, which are comparable among similar industries (for example, ferrous metal smelting and non-ferrous metal smelting from the same initial industry, metal smelting). The industry matching indicators are collected from national statistical offices, economic reports, industrial reports and other sources; detailed data sources are described in the description of data sources for each country in the analysis of results.

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Hailong Zhao	North China University of Science and Technology	Xiuyi Zheng	Guangdong University of Technology

NAME	SCHOOL	NAME	SCHOOL
Jun Yan	China University of Petroleum (Beijing)	Jiaqi Chen	East China Normal University
Wenjuan Yang	North China University of Water Resources and Hydropower	Cunxue Zhao	Hohai University
Shaojian Huang	Hunan Agricultural University	Tong Fang	Tongji University
Qianling Zhou	Peking university	Zhi Long	Lanzhou University
Leying Wu	Henan University	Chen Wang	Nanjing University
Weichen Zhong	Jilin University	Yingying Zhang	Beijing University of Aeronautics and Astronautics
Ning Zhang	Shenzhen University	Xiaofen Hu	Lanzhou City College
Yihe Miao	Shanghai Jiao Tong University	Yan Dong	Tianjin Chengjian University
Linlin Huang	Fujian Normal University	Dan Wang	University of Groningen
Like Wang	Tianjin University	Shihui Guan	China Coal Science and Industry Group
Yupeng He	Xi'an Jiaotong University	Jiaqi Wang	Guangxi University
Ning Liu	University of Edinburgh	Xukun Li	Southern University of Science and Technology
Ke Wang	China University of Geosciences	Nana Li	Nankai University
Ren Cong	The University of Hong Kong	Zhi Zheng	Heilongjiang University of Science and Technology
Yuru Guan	North China Electric Power University	Caiquan Bai	Shandong University
Chao Zhong	Beijing Normal University	Xiaoya Xu	Nankai University
Jiawen Miao	University of Shanghai for Science and Technology	Danyang Cheng	Tsinghua University
Yannan Zhou	Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences	Liyuan Wei	Wuhan University
Jincheng Wang	University of International Business and Economics	Xiaowei Zou	Shandong University
Yuying Wang	China University of Geosciences (Beijing)	Qi Huang	Shandong University
Weinan Liu	Zhejiang University	Zaihan Gao	Durham University
Minda Ma	Chongqing University	Taochun Sun	Capital Normal University
Piyu Ke	Sun Yat-sen University		

Summer School Instructors

NAME	SCHOOL	NAME	SCHOOL
Peng Gong	The University of Hong Kong	Shu Tao	Peking university
Coffman D'Maris	University College London	Bin Chen	Beijing Normal University
Jinyue Yan	Royal Institute of Technology of Sweden	Jiahua Pan	Cass
Zhu Liu	Tsinghua University	Wei Xiong	Chinese Academy of Agricultural Sciences
Jinjun Xue	Nagoya University	Shantong Li	Development Research Center of the State Council
Zhongxiu Zhao	Shandong University of Finance and Economics	Kuishuang Feng	University of Maryland
Kebin He	Tsinghua University	Can Wang	Tsinghua University
Zhaohua Wang	Beijing Institute of Technology	Ya Zhou	Guangdong University of Technology

2022Summer School Students

NAME	SCHOOL	NAME	SCHOOL
Yunsong Yu	University of Chicago	Ze Yang	Shanxi University
Jinghang Xu	University of Birmingham	Haotian Zhang	Shandong University of Technology
Yangming An	City University of Hong Kong	Maojun Zou	University of Shanghai for Science and Technology
Yuqi Liu	Shanxi University of Finance and Economics	Jiandong Bai	Nankai University
Yinjie Zhang	Beijing University of Chemical Technology	Mengxu Li	Shanghai University of Finance and Economics
Mingzhi Fan	Institute of Ecological Civilization, Chinese Academy of Social Sciences	Zehao Li	Graduate School of the Party School of the Central Committee of the Communist Party of China
Yanwu Song	Beijing Institute of Technology	Shiwei Xu	Peking university
Niu Niu	Beijing Institute of Technology	Lei Li	Anhui Normal University
Jingwen Tian	Minzu University of China	Kun Zhou	Sichuan Agricultural University
Jiayi Shi	China Agricultural University	Yuan Zhuang	Hohai University
Can Wang	Beijing Institute of Technology	Yukun Wang	Beijing Institute of Technology
Jiaoyan Li	Tianjin University	Hongyu Zhang	Tianjin University/Academy of Environmental Planning, Ministry of Ecology and Environment
Yifan Hu	Northeast Forestry University	Hao Xiao	Tsinghua University
Ziqi Yin	University College London	Haozhe Sun	Dalian University of Technology
Meng Li	Northwest A&F University	Rui Li	Chongqing University
Yu Qiu	Dongbei University of Finance and Economics	Xiaobin Ye	Dongbei University of Finance and Economics
Tianyua Fu n	South China Normal University	Yi Wang	Nanjing University
Yanan Hu	Xinjiang Institute of Ecology and Geography, Chinese Academy of Sciences	Yanrong Chen	Xi'an University of Science and Technology
Xuemei Zhang	Tsinghua University	Zixu Guo	Zhejiang Gongshang University
Yushuo Chen	Chinese Academy of Environmental Sciences	Yixu He	East China Normal University
Yanzi Guo	Jiangsu University	Xianglan Wen	Beijing University of Civil Engineering and Architecture
Yu Yu	Southwestern University of Finance and Economics	Meihui Tian	Guizhou University
Xueqing Ma	China University of Petroleum (Beijing)	Kangying Hu	Shandong University of Finance and Economics
Xiaohong Meng	North University of China	Chao Zhang	Beijing Normal University
Yanmei Zhang	Qingdao University of Science and Technology	Jiaxiu Wang	Shandong University
Yihong Yuan	Tongji University	Liting Hu	Zhejiang University
Yanshan Guo	Southwest Petroleum University	Xinyu Wang	Xiamen University
Xiaoyan Qi	Taiyuan University of Technology	Yinan Feng	Zhejiang University
Xinmeng Jiang	Southwest Jiaotong University	Fang Liu	Westlake University
Ruihan Si	Heilongjiang Institute of Engineering	Jun Tang	Northwestern University
Xiaoshi Li	North China University of Water Resources and Hydropower	Xidian Li	Hunan University
Yang Wang	University of Groningen, Netherlands	Yueying Xu	Xi'an Jiaotong University
Guangying Pu	School of Environment, Tsinghua University	Peixiu Chen	The Hong Kong University of Science and Technology
Nan Zhang	Chinese Academy of Environmental Sciences	Lin Tang	China University of Geosciences (Beijing)
Lanxin Zhang	Tsinghua University	Zejun Chen	Guangdong Technical Normal University
Xiaonan Shi	Northeast Institute of Geography and Agroecology, Chinese Academy of Sciences	Maoying Ye	Central University of Finance and Economics
Zewen Zhang	Nanjing Agricultural University	Jiaowei Gong	Chinese People's University
Xing Zhang	Institute of Atmospheric Physics, Chinese Academy of Sciences	Yishuang Liu	Wuhan University
Nianjiao Gong	Shanghai University of Finance and Economics	Shanxiu He	Shanghai Yicarbon Technology Co., Ltd

NAME	SCHOOL	NAME	SCHOOL
Liu Chen	Chongqing University	Xiaohan Wu	Northeastern University
Qingxi Cheng	Hanshan Normal University	Yichao Fang	Xiamen University
Shiqi Liu	Tianjin Chengjian University	Ji Qi	Hubei Normal University
Congyu Zhao	University of International Business and Economics	Yunlong Pan	China University of Geosciences (Beijing)
Xiuwen Su	University of Edinburgh	Jiahao Xing	Jilin University
Xiaohan Zhang	Nanjing Agricultural University	Fan Yang	Inner Mongolia Normal University
Yuqing	Shandong Normal University	Ziqiang Lin	University of Jinan
Han	Shenyang Jianzhu University	Chenxin Ding	Xinjiang University
Qingyue Zhao Xinyang Zhang	Capital University of Economics and Business	Yitian Bao	Beijing Jiaotong University
Xiaotian Ma	Peking university	Yanhong Zhan	Xiamen University
Jingpeng Guo	University of Inner Mongolia/Massey University	Mingrui Ji	Sichuan University
Shujie Sun	Research Institute for Global Frontiers, Sophia University, Japan	Yancheng Wang	Xiamen University
Liang Peng	Nanjing Normal University	Chenyang Wang	Institute of Urban Environment, Chinese Academy of Sciences
Xinhao Yu	Henan University	Mingli Xie	Zhongnan University of Economics and Law
Jin Ouyang	Capital University of Economics and Business	Hengcai Chen	University of Nottingham Ningbo China
Jizhao An	Northwestern Polytechnical University	Hanshi Chen	Institute of Urban Environment, Chinese Academy of Sciences
Pu Yang	Tsinghua University	Xiaoxiao Chen	Xiamen University
Jiaran Wei	Southeastern University	Chenchen Huang	Xiamen University
Yang Yang	Harbin Institute of Technology (Shenzhen)		

Summer School Instructors

NAME	SCHOOL	NAME	SCHOOL
Kebin He	Tsinghua University	Shu Tao	Peking university
Yongmiao Hong	University of Chinese Academy of Sciences	Minhan Dai	Xiamen University
Qiang Zhang	Tsinghua University	Xiang Yu	Chinese Academy of Social Sciences
Shouyang Wang	University of Chinese Academy of Sciences	Yang Xia	Nature Journal

2023Summer School Students

NAME	SCHOOL	NAME	SCHOOL
Qiaoying Liu	Anhui University of Finance and Economics	Tao Cao	University of Tokyo, Japan
Yilong Xiao	Peking university	Qian Zhang	Xiamen University
Shanquan Wan	Peking university	Pengcheng Sun	Xiamen University
Chengmeng Zhang	Peking university	Chuanzeng Zheng	Xiamen University
Shuo Jiang	Beijing University of Technology	Lingze Meng	Xiamen University
Xiaoyi Xu	Beijing University of Aeronautics and Astronautics	Yuedi Yang	Shandong University of Finance and Economics
Xiangtong Su	Beijing Jiaotong University	Weidong Jia	Shandong University
Zhenjun Zhang	Beijing Institute of Technology	Haotian Zhang	Shandong University of Technology
Yan Cheng	Beijing Forestry University	Wentao Li	Shanxi University of Finance and Economics

NAME	SCHOOL	NAME	SCHOOL
Xiaoyu Duan	Beijing Normal University	Rentao Zhang	Shanxi University
Jingyi Zhao	Chengdu University of Technology	Yingxin Wu	Shanxi Normal University
Changzan Duan	Dalian University of Technology	Yan Liu	Shanxi Normal University
Mingsheng Yuan	Northeastern University	Yueqing Zou	Shanghai University of Finance and Economics
Qingyun Kao	Northeast Forestry University	Xiaoyue Yao	Shanghai National Accounting Institute
Xinyao Wang	Northeast Agricultural University	Jihao Peng	Shanghai Jiao Tong University
Siyuan Zhang	Donghua University	Hongru Yi	University of Shanghai for Science and Technology
Wentao Wang	Southeastern University	Jiamin Xu	Shanghai Normal University
Yang Zhou	University of International Business and Economics	Wenrui Liu	Sichuan University
Ce Guo	Fudan University	Jiawen Xie	Tianjin University
Aiqun Guan	Guangdong University of Technology	Jiaoyan Li	Tianjin University
Chenkai Luo	Guangdong University of Technology	Qingrui Jiang	Tongji University
Zhitong Chen	Guangdong University of Technology	Le Ma	Wuhan University
Heyuan Huang	Guangzhou University	Zheming Dong	Xi'an University of Finance and Economics
Kuanyuan Zhang	Guizhou University of Finance and Economics	Zhengguang Liu	Xi'an Jiaotong University
Lishan Yang	Guizhou University	Qingling Wang	Northwest A&F University
Yuanheng Tang	Harbin Engineering University	Dexin Zhang	Westlake University
Bingqian Wang	Harbin Institute of Technology	Bin Shui	City University of Hong Kong
Wei Shi	Hunan University	Renfeng Wang	The University of Hong Kong
Jialin Li	North China Electric Power University	Yucong Xu	The Hong Kong University of Science and Technology (Guangzhou)
Yaduo Han	North China University of Water Resources and Hydropower	Zhiwei Wang	Xinjiang University
Jianheng Li	East China University of Science and Technology	Diling Liang	University of British Colombia
Qinzi Cheng	East China Normal University	Hongfei Zhao	Zhejiang University
Yifei Liu	Hust	Xin Xu	Zhejiang University
Liwen Yuan	Huazhong Agricultural University	Kun Fan	North University of China
Chaoshuo Liu	Jilin University	Feng Xu	China University of Geosciences (Beijing)
Yuanyu Cao	Jinan University (exempted from Tsinghua University Graduate School)	Yi Zheng	China University of Geosciences (Wuhan)
Xiaoyu Sun	Cardiff University	Rongxin Tong	China University of Geosciences (Wuhan)-
Xi Chen	Lanzhou University	Haiyang Zhang	Ocean University of China
Xiaochun Wang	University of Leeds	Jingjing Dong	Chinese Academy of Environmental Sciences
Xiyu Lu	University College London	Jiwei Zhang	Guangzhou Institute of Geochemistry, Chinese Academy of Sciences
Jiawei Li	London School of Economics and Political Science	Le Niu	Shenyang Institute of Applied Ecology, Chinese Academy of Sciences
Jinjin Huang	Ecole Polytechnique Fédérale de Lausanne	Xueli v	China University of Mining and Technology
Minfang Zeng	Nanchang Hangkong University	Tongfang Guo	Chinese Academy of Forestry
Renpei Zhang	Nanjing University	Mengqing Geng	China Agricultural University
Wenxin Zhao	Nanjing University	Yujin Huang	Renmin University of China
Yueting Hao	Nanjing University	Jiangyun Yu	University of Chinese Academy of Social Sciences
Sipei Pan	Nanjing Agricultural University	Xin Gao	China University of Petroleum (Beijing)
Tianyu Wang	Nanjing Audit University	Hongxuan Zhang	Zhongnan University of Economics and Law
Yuzhu Shang	Nanjing University of Information Science & Technology	Zhihui Zhang	Sun Yat-sen University
Shijing Zhu	Nankai University	Meijia Xu	Central University of Finance and Economics

NAME	SCHOOL	NAME	SCHOOL
Jingyu Li	University of Inner Mongolia	Lin Chen	Chongqing University & University of Cambridge
Xinyue Dong	University of Nottingham Ningbo China	Yuze Zhang	Cardiff University
Ningning Zhai	Qingdao University	Yuwen Zheng	Peking university
Chi Zhang	Tsinghua University	Ling Zhang	Peking university
Liao Guan	Tsinghua University	Zhiying Yang	Beijing Institute of Technology
Jianqun Feng	Tsinghua University (Shenzhen)	Xiaofan Li	Beijing Normal University
Jinhui Ren	Tsinghua University	Yitong Zhi	East China Normal University
Xiongfei Fan	Tsinghua University	Luxuan Sun	Shanghai Jiao Tong University
Liye Chen	Hong Kong University of Science and Technology & Tsinghua University	Ruichao Li	Beijing Forestry University
Shuai Zhang	Southwestern University	Zewei Fu	China University of Political Science and Law
Ke Jiang	Peking university	Wenqiang Wang	Shandong University
Ran Xing	Peking university	Shuxuan Wang	Beijing Institute of Technology
Yatai Men	Peking university	Danni Meng	Harbin Engineering University
Yifan Huang	Peking university	Yutong Sun	Beijing Normal University
Hongyi Zhang	Chengdu University of Technology	Yayan Wang	Yantai University
Tianchen Li	Northeast Forestry University	Qingyue Zhao	Shenyang Jianzhu University
Yaqi Liu	Nankai University	Yuqian Zheng	Chongqing University
Hao Hu	Tsinghua University	Shipian Shao	Shenyang Jianzhu University
Jinliang Xie	Tsinghua University	Xinyuan Zhang	Shenyang Jianzhu University
Cenyang Han	Tsinghua University (Shenzhen)	Xiaoqi Chen	Xiamen University
Yi Yan	Tsinghua University (Shenzhen)	Lina Liu	Assistant researcher at the Northwest Institute of Eco-Environment and Resources, Chinese Academy of Sciences

Summer School Instructors

NAME	SCHOOL	NAME	SCHOOL
Kebin He	Tsinghua University	Minhan Dai	Xiamen University
Jilan Su	Second Institute of Oceanography, Ministry of Natural Resources	Minjun Shi	Zhejiang University
Jun Bi	Nanjing University	Yang Xia	Nature Journal
Long Cao	Zhejiang University		

2024Summer School Students

NAME	SCHOOL	NAME	SCHOOL
Yuchen Gao	Tsinghua University	Junnan Mai	Guizhou University of Finance and Economics
Zheng Li	Tsinghua University	Yanyan Guo	Dalian University of Technology
Xiangping Bai	Shihezi University	Shengnan Cui	Northeast Petroleum University
Xinwen Zhang	University of Southern California	Mingwei Zhou	Beijing Forestry University
Yiwen Zhang	Ocean University of China	Yinfan Wang	The Chinese University of Hong Kong
Aixi Han	Department of Environmental Science and Engineering, Fudan University	Shuxin Xie	Beijing Normal University
Ye Zhang	Guangdong University of Technology	Junjie Chen	Shanghai University of Technology
Weiqin Shen	School of Ecology, Environment and Resources, Guangdong University of Technology	Jiachao Zou	Donghua University

NAME	SCHOOL	NAME	SCHOOL
Boyu Pu	School of Ecology, Environment and Resources, Guangdong University of Technology	Qinyuan Shen	Nanjing Audit University
Pingda Lu	School of Ecology, Environment and Resources, Guangdong University of Technology	Shuai Yan	Lanzhou University
Luming Wang	Sorbonne University	Jianyu Liu	University of Pennsylvania
Zhenbiao Hong	Brown University	Chensi Sun	North China Electric Power University
Olabisi Isaac Ewumi	Tsinghua University	Ting Zhang	Jilin University
Romain Gressot	EHESS	Wei Wei	Xinjiang Institute of Ecology and Geography, Chinese Academy of Sciences
Karolina Bieryt	Tsinghua University EHESS	Guoxiang Chai	WHU-Otto Beisheim School of Management, Germany
Marianne de Gaalon	Environmental Engineer	Tao Feng	Wuhan University of Technology
Ismail Ait	EHESS	Jiao Du	Southern University of Science and Technology
Yiyi Zhao	Yellow River Civilization and Sustainable Development Research Center, Henan University	Xiaoyue Kang	Chengdu University of Technology
Zhaoyuan Li	Beijing Institute of Technology	Wei Wang	China University of Mining and Technology
Xupeng Jiang	Northwest University (Carbon Neutral Institute)	Yue Zhao	Huazhong University of Science and Technology
Kaiyuan Xiao	Peking University	Wenjin Lai	Chongqing University
Yixiang Bai	Guangdong University of Finance and Economics	Zhuotao Lu	Hong Kong Polytechnic University
Pengkun Zhu	Kunming University of Technology	Feiyu Cheng	Beijing Jiaotong University
Shufang Feng	Xiamen University	Jie Liu	Guangdong University of Technology
Hairu Nie	Yili Normal University	Yang Shen	Huaqiao University
Shikang Gao	Hong Kong University of Science and Technology (Guangzhou)	Hanting Wang	Jinan University
Xinyu Miao	University of Malaya	Zihang Shi	University of Political Science, Paris
Lu Wang	Harbin Engineering University	Yingxue Liu	Zhejiang University
Wenbin Liu	Southeast University	Rufeng Sun	Jilin University
Fengzhi Wang	Shanxi University of Economics and Management	Yancheng Zhu	Zhejiang University
Lijia Zhang	East China Normal University	Ange Yang	Western Liverpool University
Nami Lai	Harbin Institute of Technology College of Environment	Jiayi Wu	Nanjing University of Aeronautics and Astronautics
Jiaxin Li	Nanjing Normal University	Dongzhe Liu	City University of Hong Kong
Zexin Qi	Shanghai Jiao Tong University	Guangcan Hong	Beijing Institute of Technology
Lixiang Wang	Anhui University of Science and Technology, School of Economics and Management	Rongyu Liu	Sun Yat-sen University
Peixue Xing	Northwest Agriculture and Forestry University	Pengyi Zhang	Northwest Agriculture and Forestry University
Yuqing Li	Hubei University of Technology	Yaxian Wang	China University of Mining and Technology (Beijing)
Zhenghao Meng	China University of Geosciences (Wuhan)	Wenhao Deng	Taiyuan University of Technology
Hang Zhou	Hunan University of Technology	Haiming Li	Yonsei University
Caifeng Bi	Institute of Frontier Cross-Science, Shandong University (Weihai)	Zejun Ding	Beijing Foreign Studies University
Liuzhen Zhao	Zhejiang University of Finance and Economics	Haitao Zhang	Chang'an University
Yijia Hao	Xinjiang Agricultural University	Yazhuo Lu	The University of Hong Kong
Yaduo Han	Zhengzhou University	Yujia Chen	Fuzhou University
Wei Zheng	Renmin University of China	Fei Peng	Nanchang University
Minqi Gao	Shenyang University of Architecture	Chuyi Zhang	University of Nottingham
Zhenzi Ge	Nanjing University of Information Engineering	Shuoguang Zhu	University of California Davis
Jiahong Guo	Central University for Nationalities	Xinwen Zhang	University of Southern California
Xiaoran Chen	University of London School of Oriental and African Studies	Qingyu Hao	University College London
Yang You	Hubei University	Xiaonan Xu	University of Manchester

NAME	SCHOOL	NAME	SCHOOL
Xinjie Jiang	Nanchang University of Aeronautics and Astronautics	Zishi Fu	Cardiff University
Yihan Jiang	Hong Kong University of Science and Technology (Guangzhou)	Renpei Zhang	University of Cambridge
Yumeng Zhang	University College London UCL	Yixin Wang	National University of Singapore
Yubin Chen	Guangzhou Polytechnic	Tao Wu	College of Architecture and Urban Planning, Tongji University
Jianing Liu	Tsinghua University	Mengyao Xu	East China University of Science and Technology
Yiying Gao	China University of Petroleum (Beijing)	Ziyan Zhang	Shanghai University of International Business and Economics
Guohao Fu	Huazhong Agricultural University	Zheyu Wang	Xi'an University of Science and Technology
Jianyu Xiao	University of Chinese Academy of Social Sciences School of Applied Economics	Qianhong Ouyang	School of Statistics, Beijing Normal University
Junjie Liu	Harbin Engineering University	Yanfang Cui	China University of Geosciences (Beijing)
Fan Zhang	Zhejiang University	Yanxin Li	Xi'an Jiaotong University
Ying Wang	University College London	Jingna Yang	Hefei University of Technology
Runyao Huang	Tongji University	Na Li	College of Environmental Science and Engineering, Tianjin University
Yida Wang	University of Southampton		

Summer School Instructors

NAME	SCHOOL	NAME	SCHOOL
Kebin He	Tsinghua University	Tim Broyd	Professor, Bartlett School of Architecture, University College London, UK; Director, Institute for Digital Innovation in the Built Environment; Fellow of the Royal Academy of Engineering, UK
Li Zhang	Executive Director of CLP Engineering, China Electric Power Engineering Consultants Group Limited, CLP Carbon Neutral Development Research Institute	Jinyue Yan	Member of the European Academy of Sciences and Arts, Member of the Hong Kong Academy of Engineering Sciences
Xiang Gao	Academician of Chinese Academy of Engineering, Director of Carbon Neutral Research Institute of Zhejiang University of Technology, Zhejiang University	Tieli Pan	Director of the Department of Science and Technology of Heilongjiang Province
Deliang Chen	Academician of the Royal Swedish Academy of Sciences, Foreign Academician of the Chinese Academy of Sciences	Hui Ding	Secretary, Foreign Cooperation and Exchange Center, Ministry of Ecology and Environment
Xiang Yu	Researcher, Institute of Ecological Civilization, Chinese Academy of Social Sciences	Monica Contestabile	Senior Editor, Nature Sustainability