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إطار تحليلي لقياس البصمة الكربونية في محافظة أسوان وتوجهات خفضها لتحقيق الإستدامة الاقتصادية

An analytical framework for measuring the carbon footprint of Aswan Governorate and trends to reduce it to achieve Economic Sustainability

كريمة محمد الصغير *(١)

(١) المؤلف المختص*: مدرس اقتصاد، قسم السياسة والاقتصاد، معهد البحوث والدراسات الإفريقية ودول حوض النيل، جامعة أسوان.

الملخص

مع تصاعد الاهتمام العالمي بتأثيرات التغير المناخي ودور الأنشطة البشرية في زيادة الضغوط البيئية، برزت ضرورة قياس البصمة الكربونية على المستويات المحلية باعتبارها أداة لتحليل مصادر الانبعاثات وتوجيه السياسات نحو تحقيق الاستدامة الاقتصادية. تسعى هذه الدراسة إلى تقدير البصمة الكربونية لمحافظة أسوان خلال عام ٢٠٢٣، من خلال تحليل تسعة قطاعات رئيسية تشمل: المنازل والطاقة، المياه والصرف الصحي، الزراعة، الصناعة، النقل، السياحة، الخدمات والمرافق العامة، التشييد والبناء، إلى جانب تكنولوجيا المعلومات والاتصالات.

استندت الدراسة إلى بيانات رسمية صادرة عن الجهاز المركزي للتعبئة العامة والإحصاء، والوزارات المعنية، فضلاً عن التقارير المحلية، حيث جرى تحويل كميات الطاقة والأنشطة الاقتصادية المختلفة إلى مكافئ انبعاثات ثاني أكسيد الكربون باستخدام معاملات انبعاث وطنية ودولية معتمدة (GHG Protocol, IPCC). كما تضمن التحليل حساب مؤشرات مساندة مثل نصيب الفرد من الانبعاثات ونسبة الانبعاثات إلى الناتج المحلي.

وقد أظهرت النتائج أن إجمالي البصمة الكربونية لمحافظة أسوان بلغت نحو ٣٧ مليون طن مكافئ ثانى أكسيد الكربون(CO_2e) خلال عام ٢٠٢٣. واحتل القطاع الزراعي المرتبة الأولى بمساهمة قاربت ثلاثة أرباع الإجمالي (≈٧٦%)، تلاه القطاع الصناعي بنسبة ١٠,٥%، ثم المنازل والطاقة بنسبة ٥,٨%. بينما جاءت القطاعات الأخرى مثل النقل، التشييد، الخدمات العامة، السياحة، والاتصالات بمساهمات أقل نسبيًا.

وتبرز النتائج الدور الكبير للأنشطة الزراعية، خاصة الميكنة الزراعية، استخدام الأسمدة، وحرق المخلفات، في تشكيل البصمة الكربونية للمحافظة، مما يتطلب توجيه الاهتمام والسياسات نحو هذا القطاع. كما أوصت الدراسة بتحسين كفاءة استخدام الطاقة في الصناعة والمنازل، وتشجيع التوسع في مصادر الطاقة المتجددة، وتعزيز نظم إدارة المخلفات الزراعية، إلى جانب تطوير منظومة نقل أكثر استدامة. وتؤكد هذه الدراسة أهمية إدماج مفهوم البصمة الكربونية في السياسات المحلية بمحافظة أسوان، وبناء قواعد بيانات قطاعية محدثة تتيح المتابعة المنتظمة للانبعاثات، بما يعزز قدرة المحافظة على مواجهة تحديات التغير المناخي وتحقيق الاستدامة الاقتصادية.

الكلمات الدالة :البصمة الكربونية – محافظة أسوان – استهلاك الطاقة – الانبعاثات – الاستدامة الاقتصادية.

An analytical framework for measuring the carbon footprint of Aswan Governorate and trends to reduce it to achieve Economic Sustainability

Abstract

With the increasing global attention to climate change and the growing awareness of the environmental impacts of human activities, economic sustainability has become a fundamental pillar of modern development policies. Nations today strive to balance economic growth with environmental protection and the efficient use of resources. In this context, assessing the carbon footprint at the local level serves as a vital tool for analyzing emission sources and guiding policies toward comprehensive sustainable development that integrates both economic efficiency and environmental sustainability. Accordingly, this study aims to estimate the carbon footprint of Aswan Governorate for the year 2023 by analyzing nine key sectors: households and energy, water and sanitation, agriculture, industry, transport, tourism, public services, construction, and information and communication technology.

The analysis was based on official data from the Central Agency for Public Mobilization and Statistics, relevant ministries, and local reports. Energy consumption and various economic activities were converted into carbon dioxide equivalents using nationally and internationally recognized emission factors (GHG Protocol, IPCC). Additional indicators, such as per capita emissions and the ratio of emissions to GDP, were also calculated.

The findings revealed that the total carbon footprint of Aswan reached approximately 37.0 million tons of CO_2e in 2023. Agriculture was the dominant contributor, accounting for nearly three-quarters of the total (≈76%), followed by industry (10.5%) and households and energy (5.8%). Other sectors—including transport, construction, public services, tourism, and ICT—contributed smaller shares. The study recommends enhancing energy efficiency in industry and households, promoting renewable energy adoption, improving agricultural waste management, and advancing more sustainable transport strategies.

Overall, the study underscores the importance of integrating the carbon footprint concept into local policy frameworks in Aswan and developing updated sectoral databases to enable continuous monitoring of emissions. Such measures would enhance the governorate’s capacity to address climate change challenges and promote progress toward **economic sustainability.**

Keywords: Carbon footprint – Aswan Governorate – energy consumption – emissions – Economic Sustainability.

First: Research Plan

1/1 Introduction

In recent decades, the concept of economic sustainability has attracted growing attention as the consequences of human activity on the natural environment have become more evident. The persistent reliance on fossil fuels and the prevailing patterns of overconsumption have contributed significantly to the increase in greenhouse gas emissions, thereby amplifying the effects of climate change on ecosystems and human societies (IPCC, 2023). Within this context, the notion of the carbon footprint has been developed as a practical tool to quantify the environmental impact of different actors—ranging from individuals and institutions to entire regions. Such measurements provide a necessary quantitative basis for formulating effective climate policies and for supporting global efforts to achieve the Sustainable Development Goals, particularly Goal 13, which focuses on climate action (United Nations, 2022).

At the local scale, the need for accurate carbon footprint assessments has become particularly pressing in regions characterized by diverse consumption patterns and specific socio-economic and demographic conditions. Aswan Governorate represents a clear example: despite its rich endowment of natural resources and its considerable potential for development, it faces persistent environmental challenges. These include changing patterns of transportation, the growth of industrial activities, and structural shifts in agriculture (EEAA, 2023). Assessing the governorate's carbon footprint, therefore, is not merely a descriptive exercise; rather, it is a strategic endeavor that can identify priority areas for intervention and provide decision-makers with a a solid scientific basis for designing balanced pathways that support both environmental integrity economic sustainability.

This study employs the carbon footprint framework to examine Aswan Governorate, with particular attention to its environmental and geographical features that position it as one of Egypt's strategic regions. The analysis is structured around major sectors, including households and energy, water and sanitation, agriculture, industry, transportation, tourism, public services and utilities, construction, and information and communications technology. Focusing on these sectors allows for a more comprehensive understanding of the sources of emissions and provides a basis for identifying measures to improve resource efficiency and reduce environmental stress at the local level.

In this context, the study contributes to the broader effort of developing a localized model for assessing environmental performance in Egyptian governorates. Establishing such a model would strengthen the capacity to monitor emissions systematically and support the formulation of economic sustainability plans that are both evidence-based and sensitive to local socio-economic conditions (EEAA, 2023; UNDP, 2022)

1/2 Previous Studies

The present study builds on a wide range of research that has examined methods for assessing the carbon footprint and formulating strategies to reduce emissions in the context of sustainability objectives. For clarity and organization, the reviewed works were divided into two main sections: studies written in Arabic and international research published in other languages.

1/2/1 Studies in Arabic

1/2/1/1 Nasreddine, H. (2019): The study aimed to provide a theoretical analysis of the ecological footprint of energy and its role as an indicator for assessing the sustainability of energy consumption patterns. It employed a conceptual and analytical approach, drawing on key literature related to the ecological footprint framework, its methodological foundations, and its applications in the energy sector. The study highlighted the relationship between energy consumption and ecological overshoot, underscoring the importance of integrating ecological footprint indicators into energy planning and environmental policy. The findings showed that conventional energy production and consumption patterns contribute substantially to environmental degradation and exert growing pressure on global biocapacity. The study also emphasized that energy represents a core component of national ecological footprints, especially in countries heavily dependent on fossil fuels. It recommended promoting the transition to clean and renewable energy sources, enhancing energy efficiency, and embedding ecological footprint accounting tools within national energy strategies to advance sustainable development goals.

1/2/1/2 Rahim, L. A. M. (2020). The study aimed to assess the direct carbon footprint of ovens and bakeries in Al-Kut City and to evaluate their associated environmental impacts. It employed an applied analytical approach based on statistical data obtained from the Central Statistics Directorate in Wasit Governorate and the Al-Kut Municipality, complemented by field surveys and desk-based analysis. The collected data were processed using the SPSS statistical software to estimate emission levels and determine their contribution to local air pollution. The findings indicated that ovens and bakeries constitute a major source of carbon dioxide emissions in the city, mainly due to the extensive use of fossil fuels. The study also underscored the clear connection between these emissions and the deterioration of ambient air quality, which poses serious environmental and public health concerns. It recommended enforcing stricter environmental regulations on energy use in bakeries, encouraging the adoption of cleaner fuel alternatives, and enhancing awareness among bakery owners and workers regarding sustainable energy practices.

1/2/1/3 Zine & Bradji (2022). This study aimed to clarify the concept of the ecological footprint as a composite indicator for measuring progress toward environmental sustainability, focusing on the evolution of Algeria’s carbon footprint between 2000 and 2019. It adopted a descriptive and analytical methodology, using official statistics and international indicators to examine the link between fossil fuel dependence, rising carbon emissions, and ecological deficits. The findings showed that Algeria has experienced a persistent ecological deficit since the 1970s, driven by heavy reliance on fossil energy and raw material exports, without corresponding progress in environmental or social development. The study recommended strengthening legal and policy frameworks, expanding renewable energy use, gradually removing fossil fuel subsidies, and promoting green and circular economy models to support sustainable development.

1/2/1/4 Fawzy & Ahmed (2022). This study aimed to examine the relationship between key economic and energy-related factors and the ecological footprint in four North African countries—Egypt, Algeria, Tunisia, and Morocco—over the period 1973–2017. It employed a longitudinal panel-data methodology using dynamic econometric techniques, including FMOLS, DOLS, and PMG-ARDL, to capture both short- and long-term effects. The results showed that higher per-capita GDP, increased final energy consumption, greater natural resource rents, and higher trade openness are all linked to an expansion in the ecological footprint, placing additional pressure on environmental quality. Conversely, population growth was found to have a negative association with per-capita ecological footprint, reflecting resource constraints and demographic structure in the region. Based on these findings, the study recommended reinforcing environmental governance, promoting cleaner energy use, and diversifying economic activity to reduce dependence on natural resource extraction. It also emphasized integrating sustainability considerations into trade and investment policies to prevent further ecological degradation and support long-term environmental stability.

1/2/1/5 Al-Hadidi (2023). This study investigated the relationship between carbon footprint levels and sustainable development indicators, using the industrial zone in Tenth of Ramadan City as a case study that mirrors many of the environmental challenges facing Egypt's industrial areas. The research combined a descriptive-analytical approach with field-based methods, incorporating data gathered through questionnaires, site visits, and a review of environmental reports and official documents. International indicators were also employed to quantify the carbon footprint and to evaluate its implications for economic sustainability. The evidence points to a negative correlation between elevated carbon footprint levels in the industrial zone and the deterioration of sustainability indicators, particularly those linked to air quality and patterns of energy consumption. The findings underscore the dominant contribution of energy-intensive industrial activities to overall emissions, further aggravated by the limited adoption of clean production practices and weak enforcement of energy efficiency measures. In light of these challenges, the study emphasizes the need for targeted policies, including the expansion of renewable energy use, the imposition of binding environmental standards on factories, and the promotion of environmental awareness among workers in the industrial sector.

1/2/2 Studies in English

1/2/2/1 Ruževičius, J. (2011): This study aimed to examine the ecological footprint as a quantitative indicator for measuring sustainable development at both the global and national levels, with a particular emphasis on the gap between human consumption and the planet's biocapacity. It employed an analytical and international benchmarking methodology, supported by a systematic review of scientific, legal, and statistical sources, and conducted a field survey involving 125 public and private institutions in Lithuania to assess the level of awareness of the ecological footprint concept. The findings showed that global resource consumption exceeds the Earth's regenerative capacity by roughly 1.5 times. Some countries, such as Finland and Sweden, maintain a positive ecological balance, whereas others—including the UAE, Qatar, and the United States—face considerable ecological deficits. The results also highlighted low awareness among decision-makers and managers regarding the ecological footprint and its significance. The study recommended incorporating the ecological footprint indicator into national sustainable development strategies, expanding public awareness initiatives, increasing reliance on renewable energy sources, and encouraging environmentally responsible institutional practices.

1/2/2/2 Larsen, H. N., & Hertwich, E. (2011): This study aimed to analyze the carbon footprint generated by public services delivered by county governments, with a focus on their contribution to overall greenhouse gas emissions. It employed a quantitative analytical approach using environmentally extended input–output analysis combined with emission coefficients to estimate both direct and indirect emissions across different service sectors. The findings showed that public services such as health care, education, and public administration represent a considerable share of total county-level emissions, with a large portion stemming from energy consumption and transportation activities. The study recommended improving energy efficiency in public facilities, integrating low-carbon technologies, and implementing comprehensive carbon accounting systems to guide emission reduction efforts in the public sector.

1/2/2/3 Moffatt, I. (2022): This study aimed to explore the relationship between the ecological footprint and sustainable development by applying a comprehensive international benchmarking approach. It employed a quantitative methodology to estimate ecological footprint values for multiple countries and compare them with biocapacity levels, drawing on global datasets and applying regression analyses to assess the influence of economic, social, and environmental factors. The findings showed that many countries are exceeding their ecological limits, with ecological footprints surpassing biocapacity and generating sustainability deficits. The results also indicated that higher income levels and industrial expansion are strongly associated with larger ecological footprints, which in turn undermine sustainable development goals. The study recommended integrating ecological footprint accounting into national sustainability strategies, promoting resource-efficient policies, and strengthening institutional capacity to monitor and address ecological overshoot.

1/2/2/4 Pinto da Silva, L., & Esteves da Silva, J. C. G. (2022): This study aimed to review and evaluate existing literature on the carbon footprint associated with the life cycle of wine production. It employed a systematic literature review methodology, examining published research on greenhouse gas emissions linked to different stages of the wine production process—including viticulture, vinification, bottling, and distribution—across major wine-producing regions. The findings revealed considerable variation in carbon footprint estimates between studies and identified bottling and viticulture as the most emission-intensive stages of the life cycle. The study recommended enhancing environmental performance in the wine sector by targeting high-impact stages, adopting lighter packaging, improving energy and fuel efficiency in viticulture, standardizing carbon accounting boundaries and methodologies, and integrating footprint assessments into broader sustainability strategies.

1/2/2/5 Chaurasia, M., Srivastava, S. K., & Yadav, S. P. (2024): This study aimed to compare different carbon footprint metrics and evaluate their criteria to identify which approaches best support sustainability assessments. It employed a comparative analytical methodology, examining existing carbon footprint methods applied to products and organizations by analyzing their objectives, system boundaries, data sources, calculation techniques, and consistency with international standards such as ISO 14064 and the GHG Protocol. The findings revealed substantial variation between methodologies in how system boundaries, emission categories, and data transparency are treated, which can compromise the comparability and reliability of results. The study recommended developing harmonized guidelines for carbon footprint metrics, standardizing system boundaries and data practices, and strengthening organizational capacity to implement these metrics in sustainability-oriented decision-making.

Research Gap

A review of the existing literature shows a noticeable scarcity of studies that examine the carbon footprint at the governorate level in Egypt, particularly those that adopt a sectoral framework supported by precise quantitative analysis. Furthermore, research exploring the relationship between carbon footprint reduction and economic sustainability remains limited, leaving an important area of inquiry underdeveloped. Likewise, the link between carbon footprint assessments and the formulation of local development policies has not been adequately addressed. In response to these gaps, the present study focuses on measuring the carbon footprint of Aswan Governorate using updated scientific methods and offers practical recommendations aimed at supporting economic sustainability.

1/3 Research Problem

Despite the efforts made by the Egyptian government to integrate environmental considerations into national policies, a significant gap remains in the measurement and analysis of carbon emissions at the local level, particularly in remote governorates. Aswan is one such governorate that faces both economic and environmental challenges, which makes the estimation of its carbon footprint across different sectors an urgent necessity.

Although the concept of the carbon footprint has received increasing attention in environmental literature over recent years, applied studies focusing on Egyptian governorates are still limited. In particular, very few studies adopt a sector-based approach that disaggregates emissions into nine key sectors—households and energy, water and sanitation, agriculture, industry, transport, tourism, public services, construction, and information and communications technology—and apply a comprehensive quantitative methodology. Furthermore, most current environmental policies suffer from a lack of accurate local-level datasets, which undermines their capacity to design and implement effective interventions.

The selection of Aswan Governorate in this study serves as an entry point for understanding the dynamics of the carbon footprint beyond the framework of major cities. Aswan represents a mixed pattern that combines agricultural, developmental, and demographic activities, while facing environmental challenges that can be addressed through sustainable planning. Moreover, the governorate's inclusion of clean energy projects positions it to become a potential model of a green Egyptian governorate in the near future (EEAA, 2023; Ministry of Local Development, 2022)

From this standpoint, the main research problem can be framed in the following question:

To what extent do the different sectors in Aswan Governorate contribute to the generation of the carbon footprint, and what possible measures can be taken to reduce this footprint in line with the requirements of economic sustainability? This main question gives rise to a number of sub-questions, including:

- What is the concept of the carbon footprint, and what are the different methods used to measure it?
- What is the relative contribution of the various sectors in Aswan Governorate to the generation of the carbon footprint?
- What measures can be proposed to reduce this footprint in ways that align with economic sustainability?
- What are the strengths, weaknesses, opportunities, and challenges associated with assessing the carbon footprint of Aswan Governorate?

1/4 Importance of the Study

While economic sustainability is often addressed at the global level, its practical implementation requires translating broad concepts into tangible and locally applicable actions. This necessity arises from the variations in human activities and the diversity of emission sources across regions. From this perspective, the importance of the present study lies in its attempt to measure the carbon footprint of the main sectors in Aswan Governorate, covering nine key sectors: Households and Energy, Water and Sanitation, Agriculture, Industry, Transport, Tourism, Public Services, Construction, and Information and Communications Technology. The study aims to provide a comprehensive scientific assessment of the emissions generated by these sectors and to propose practical pathways for reducing them, thereby achieving a balance between economic development and environmental protection. Accordingly, the findings of this study are expected to offer direct value to local decision-makers and contribute to national and regional efforts toward formulating more sustainable environmental policies.

1/5 Research Hypothesis

This study hypothesizes that the main contributors to carbon emissions in Aswan Governorate are the agriculture, industry, and household & energy sectors. It also assumes that accurately identifying these sources can support the design of targeted and effective interventions to reduce overall emissions and contribute to achieving economic sustainability.

1/6 Research Objectives

The main objective of this study is to test the validity of the above hypothesis and to quantitatively measure the carbon footprint of Aswan Governorate across its key sectors. The purpose is to identify the main emission sources and propose practical mechanisms to reduce them, thereby contributing to achieving economic sustainability.

In addition to the main objective, the study also seeks to achieve the following specific objectives:

- To estimate the volume of carbon emissions generated by different sectors within the governorate.
- To analyze the relative contribution of each sector to the overall carbon footprint.
- To provide practical and targeted recommendations for reducing emissions in line with national environmental goals.

1/7 Research Methodology

The study adopts an inductive approach by tracing the evolution of economic sustainability concepts, culminating in the adoption of the carbon footprint as a key environmental assessment tool. This concept is integrated with local indicators to support economic sustainability. The research relies on both a descriptive-analytical method and a quantitative approach. Official data on energy consumption across different sectors in Aswan Governorate for the year 2023 are collected and converted into carbon dioxide equivalents. The calculations follow the Greenhouse Gas (GHG) Protocol and the Intergovernmental Panel on Climate Change (IPCC) guidelines, with a significant reliance on locally derived emission factors. This enhances the accuracy of the results compared to previous studies that largely depended on default or generalized factors.

Additionally, the study employs SWOT analysis to identify the strengths, weaknesses, opportunities, and challenges facing Aswan Governorate in reducing its carbon footprint and progressing towards economic sustainability.

1/8 Limits of the Study

- Temporal limitation: The study is restricted to the year 2023 due to data availability and alignment with current scientific standards.
- Spatial limitation: The research focuses exclusively on Aswan Governorate.
- Thematic limitation: The study is confined to estimating the carbon footprint of four main sectors, without extending to other areas (Scope 3).

1/9 Proposed Framework of the Study

- First: Theoretical framework: economic sustainability and the carbon footprint concept.
- Second: Contextual analysis: Current situation of Aswan Governorate.
- Third: Empirical assessment: Measuring the carbon footprint of Aswan Governorate
- Fourth: SWOT Analysis of Aswan's Carbon Footprint
- Fifth :Conclusion (Findings and Recommendations).
- Sixth: Annexes.

First: Theoretical Framework of Economic Sustainability and the Carbon Footprint

1- Economic Sustainability

1/1/ Origins and Concept of Economic Sustainability

The concept of economic sustainability has evolved over several decades as global development debates shifted from short-term growth objectives to long-term strategies that integrate economic, environmental, and social dimensions. In its economic dimension, sustainability refers to the economy's ability to generate continuous growth and wealth while maintaining the overall stock of capital — including physical, human, and natural assets — for future generations. This conceptual shift became more explicit after the publication of the landmark Brundtland Report in 1987, which defined sustainable development as meeting the needs of the present without compromising the ability of future generations to meet their own needs (Brundtland, 1987).

Economic sustainability goes beyond traditional growth indicators such as GDP, emphasizing the preservation of productive capacity after accounting for resource depletion and environmental degradation. As a result, measurement approaches like Genuine Savings and Green Net National Product (Green NNP) have emerged as key tools to assess whether an economy is growing sustainably or merely consuming its capital base (Evans et al., 2015; Strezov et al., 2017). This perspective aligns with a broader understanding of development as a process of maintaining and enhancing the productive foundation of society over time rather than maximizing output in the short run. (Brundtland, 1987; Evans et al., 2015; Strezov et al., 2017).

1/2 Theoretical Approaches to Economic Sustainability

Economic sustainability has been conceptually approached through three main theoretical orientations that reflect different perspectives on the relationship between economic growth and environmental considerations:

1/2/1 Traditional Growth Approach: This perspective prioritizes economic growth as the primary objective while assigning secondary importance to environmental concerns. It assumes that improving economic performance will eventually create the financial and technological capacity needed to address environmental degradation in later stages of development (Strezov et al., 2017).

1/2/2 Transformative Approach: This approach emphasizes the necessity of restructuring the economy by integrating environmental dimensions at the core of growth strategies. It calls for investment in renewable energy, resource efficiency, and technological innovation to achieve a balanced relationship between economic expansion and carbon emissions (Barbier, 2009).

1/2/3 Integrated Sustainability Approach: This orientation considers genuine sustainability as achievable only through the harmonious integration of economic, environmental, and social dimensions within a unified framework. It argues that economic policies should be designed in line with planetary boundaries while ensuring both social and economic justice (Strezov et al., 2017; Barbier, 2009).

1/3 Key Characteristics of Economic Sustainability

The fundamental characteristics of economic sustainability provide a conceptual foundation for understanding how economic systems can remain resilient and viable without depleting natural resources or damaging the environment. The main characteristics include:

1/3/1 Continuity: The ability of the economy to achieve long-term growth while maintaining natural capital and ensuring intergenerational equity (Baumgärtner & Quaas, 2009).

1/3/2 Resilience: The capacity of economic systems to adapt to environmental, climatic, and technological changes while preserving structural stability (Baumgärtner & Quaas, 2009).

1/3/3 Efficiency: The optimal use of material, natural, and human resources to achieve maximum benefit with minimal environmental cost.

1/3/4 Economic Equity: Ensuring a fair distribution of wealth and resources across groups, regions, and generations, fostering economic and social balance (de Carvalho, J. F. (2011).

1/3/5 Innovation: Embracing clean technologies and green innovations to enhance production efficiency and strengthen sustainable growth pathways (de Carvalho, J. F. (2011).

1/3/6 Institutional Capacity: Emphasizing the role of institutions and governance structures in supporting the transition towards sustainable economic systems (Baumgärtner & Quaas, 2009).

1/4 Indicators and Measurement Methods of Economic Sustainability

Indicators of economic sustainability are essential tools used to assess an economy’s ability to maintain long-term growth without depleting natural resources or undermining environmental and social systems. These indicators integrate economic performance with environmental responsibility and social well-being.

Table (1)

Key Indicators and Measurement Methods of Economic Sustainability

Indicator	Measurement Method / Description
Genuine Savings (Adjusted Net Savings)	Measures real savings after accounting for depletion of natural resources and environmental degradation.
Environmentally Adjusted Net Domestic Product (EDP)	Adjusts conventional GDP by deducting environmental costs such as air and water pollution and resource depletion.
Index of Sustainable Economic Welfare (ISEW)	Adjusts national income for income distribution, environmental degradation, and household welfare factors.
Green Growth Index (GGI)	Assesses progress toward a low-carbon and resource-efficient economy through renewable energy and green technologies.
Global Economic Sustainability Indicator (GESI)	Composite index integrating Genuine Savings, renewable energy share, and green goods competitiveness.

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The indicators presented in Table (1) collectively provide a comprehensive framework for assessing economic sustainability, combining economic growth analysis with environmental and social dimensions. Genuine Savings and EDP highlight the importance of incorporating ecological costs into national accounts, ensuring that economic expansion does not come at the expense of natural capital. The ISEW broadens the evaluation of welfare by considering equity and environmental quality, while the Green Growth Index and GESI reflect the global shift toward cleaner production and resource efficiency. Together, these measures form a multidimensional basis for monitoring and comparing sustainable economic performance across countries.

1/5 Economic Sustainability Indicators for Egypt

Table (2)

Economic Sustainability Indicators for Egypt (2023)

Indicator	Value	Unit	Interpretation	Source
Genuine Savings (Adjusted Net Savings)	5.3	% of GNI	Positive value indicates that Egypt is accumulating net national wealth after accounting for resource depletion.	World Bank (2024)
Real GDP Growth	7.94	%	Reflects Egypt's real economic expansion during 2023, supported by investment and export growth.	World Bank (2024)
Renewable Energy Share in Electricity Mix	22	%	Indicates Egypt's progress toward a low-carbon energy transition.	UNDP (2024)
CO_2 Intensity of GDP	0.42	kg CO_2 / USD GDP	Lower value reflects higher energy efficiency and reduced emissions per output unit.	IEA (2024)
R&D Expenditure	0.9	% of GDP	Shows national investment in research and innovation supporting sustainable growth.	UNESCO (2024)

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Table (2) indicates that Egypt's economic sustainability performance in 2023 shows clear progress toward a more balanced and resource-efficient growth model. The country achieved a solid real GDP growth rate of 7.9%, reflecting ongoing investment and production expansion. Genuine savings reached 5.3% of GNI, suggesting that Egypt continues to accumulate net national wealth after accounting for resource depletion. Meanwhile, renewable energy represented about 22% of total electricity generation, underscoring steady progress toward a low-carbon energy structure. The carbon intensity of GDP (0.42 kg CO_2/USD) highlights moderate efficiency gains in energy use, while R&D expenditure, at 0.9% of GDP, reflects growing attention to innovation and technology-driven sustainability. Collectively, these indicators point to a positive but gradual movement toward economic sustainability, contingent on maintaining momentum in clean energy and innovation policies

2. Carbon Footprint

2/1 Origin

The concept of the carbon footprint emerged during the 1990s as an extension of the earlier notion of the “ecological footprint,” first introduced by Mathis Wackernagel and William Rees in 1996. With the intensification of climate change and the growing recognition of its impacts, attention shifted more directly toward the role of greenhouse gas (GHG) emissions—particularly carbon dioxide—in driving global warming. This shift led to the development of the carbon footprint as a quantitative tool for assessing these impacts. International organizations, including the IPCC and UNEP, have since adopted the concept as part of broader sustainability assessment frameworks (Wiedmann & Minx, 2008).

2/2 Definition

The carbon footprint refers to the total volume of greenhouse gas emissions generated by an individual, organization, or activity, expressed in terms of carbon dioxide equivalents (CO_2e). It encompasses both direct and indirect emissions linked to energy use, transportation, production, and service provision. As a widely recognized environmental indicator, the carbon footprint serves as a benchmark for measuring ecological impact and provides a basis for designing strategies to reduce emissions (Carbon Trust, 2020).

2/3 Categories

Carbon emissions are typically divided into three major categories that help identify the sources and responsibilities of greenhouse gas generation:

1. **Direct emissions (Scope 1):** These are emissions released directly from owned or controlled sources, such as fuel combustion in company facilities or vehicles.
2. **Indirect energy emissions (Scope 2):** These result from the consumption of purchased electricity, heat, or steam generated outside the organization.
3. **Other indirect emissions (Scope 3):** These include all other emissions that occur along the value chain, such as those from the production and transport of purchased goods, waste disposal, business travel, and product use (GHG Protocol, 2015).

2/4 Measurement Method

The carbon footprint is commonly measured in units of tons or kilograms of carbon dioxide equivalents (CO_2e). Its calculation is generally based on the following core equation:

Carbon Footprint = Activity Data × Emission Factor × Impact Factor

The impact factor is used to convert the emissions of greenhouse gases other than CO_2—such as methane (CH_4) and nitrous oxide (N_2O)—into CO_2e, reflecting their relative global warming potential. This standardization allows for the aggregation of different gases into a single metric that captures their combined effect on climate change (IPCC, 2021).

2/5 Determinants

Several interrelated factors shape the size of the carbon footprint:

- **Economic activities**: Industrial production and agricultural practices are among the most carbon-intensive sectors, contributing significantly to emissions.
- **Individual consumption patterns**: Daily choices in food, energy use, and transportation directly influence resource demand and consequently emissions levels.
- **Type of fuel utilized**: The carbon intensity of fuels varies considerably; coal, for instance, produces much higher emissions compared to natural gas, underscoring the role of fuel mix in overall carbon outcomes.
- **Infrastructure and policy frameworks**: The availability of efficient public transport systems and the enforcement of energy efficiency standards can substantially mitigate emissions and help reduce the aggregate carbon footprint (Hertwich & Peters, 2009).

2/6 Economic Sustainability and the Carbon Footprint

Recent empirical literature demonstrates a clear and consistent relationship between economic sustainability and carbon emissions. Economies that improve their efficiency in resource management and expand investment in renewable energy tend to experience lower carbon footprints over time. In this context, economic sustainability reflects not only the capacity for continuous growth but also the ability to decouple production from environmental degradation through technological innovation and cleaner energy transitions.

Dong et al. (2018) provided cross-regional evidence that renewable energy development significantly mitigates CO_2 emissions while sustaining economic growth, indicating that economic expansion and environmental protection can coexist under appropriate policy frameworks. Similarly, Nathaniel and Iheonu (2019) found that renewable energy consumption and trade openness contribute to emission reduction across African economies, emphasizing that sustainable development strategies must integrate both environmental and economic dimensions. Together, these findings underscore that achieving true economic sustainability requires balancing growth objectives with climate responsibility through innovation, green investment, and structural transformation toward low-carbon systems

2.7 International Initiatives to Reduce the Carbon Footprint

- **Transition to renewable energy:** Germany's "Energiewende" represents one of the most comprehensive national strategies for transforming the energy system toward sustainability. The policy framework focuses on a large-scale transition from fossil fuels to renewable energy sources—primarily wind and solar power—while simultaneously enhancing energy efficiency across sectors. The initiative aims not only to mitigate greenhouse gas emissions but also to secure long-term energy independence and stimulate green innovation within the German economy. According to the Wuppertal Institute (2020), the Energiewende has significantly reduced the carbon intensity of electricity generation, positioning Germany as a global leader in the shift toward a low-carbon future.

- **Electric and sustainable mobility:** Norway has launched a national initiative to promote electric vehicles through tax exemptions and the development of charging infrastructure, making it the world leader in terms of the share of electric cars in its total vehicle fleet (IEA, 2021).

- **Green buildings:** Singapore has implemented the "Green Building" program, which encourages the use of environmentally friendly materials and energy-efficient technologies in architectural design, thereby reducing electricity consumption and cutting emissions (Building and Construction Authority Singapore, 2019).

- **Circular economy promotion:** The Netherlands has positioned itself as a pioneer in the transition toward a circular economy through the adoption of the "A Circular Economy in the Netherlands by 2050" national program. This strategy outlines a comprehensive framework for decoupling economic growth from resource use by promoting reuse, recycling, and sustainable product design. The initiative seeks to achieve a fully circular economy by 2050, with intermediate goals targeting a 50% reduction in the use of primary raw materials by 2030. According to the European Circular Economy Platform (2016), the Dutch approach integrates government, business, and civil society efforts to reduce waste, minimize environmental pressure, and lower the national carbon footprint through systemic innovation and resource efficiency.

- **Urban sustainability initiatives**: Copenhagen has implemented one of the world's most ambitious climate strategies through its "Copenhagen Climate Plan: CPH 2025", which sets the clear objective of becoming the first carbon-neutral capital city by 2025. The plan focuses on reducing emissions across key sectors—energy, transportation, buildings, and waste—while simultaneously promoting economic growth and quality of life. Major actions include large-scale investments in renewable energy, district heating and cooling systems, expansion of cycling infrastructure, and green urban design. According to the City of Copenhagen (2019), these integrated policies are expected not only to achieve carbon neutrality but also to serve as a global model for sustainable urban transformation.

- **Low-carbon agriculture:** Brazil has established the Low-Carbon Agriculture Program (ABC Program) as a cornerstone of its national climate strategy in the agricultural sector. The program promotes sustainable farming practices such as no-till cultivation, integrated crop-livestock-forestry systems, biological nitrogen fixation, and the recovery of degraded pastures. These actions aim to increase productivity while significantly reducing greenhouse gas emissions from agriculture. According to the Ministry of Agriculture, Livestock and Food Supply (MAPA, 2021), the ABC Program contributes to Brazil's Nationally Determined Contributions

(NDCs) under the Paris Agreement by fostering climate-resilient, low-emission rural development and supporting the transition toward a sustainable bioeconomy.

- **Industrial emission reduction**: Japan has implemented a comprehensive national strategy to reduce industrial carbon emissions as part of its Long-Term Strategy under the Paris Agreement (LTS). This framework emphasizes technological innovation, energy efficiency, and the transition toward hydrogen-based and renewable energy systems in the industrial sector. The strategy promotes the deployment of advanced manufacturing technologies, carbon capture, utilization and storage (CCUS), and clean production methods. These initiatives aim to achieve carbon neutrality by 2050 while maintaining industrial competitiveness and sustainable economic growth (Government of Japan, 2021).

Second: Description of Aswan Governorate

Aswan Governorate constitutes a distinctive case on Egypt's administrative and environmental map, given its unique geographical, demographic, economic, and ecological characteristics. As a border governorate encompassing desert, valley, and river environments, Aswan exhibits distinct patterns of resource consumption and energy use. This diversity underscores the importance of examining Aswan within the framework of carbon footprint analysis, as it integrates major urban centers with sparsely populated rural areas. The residential, agricultural, and service sectors account for the largest share of economic activity, while industrial activities remain comparatively limited relative to other major urban governorates (CAPMAS, 2023; EEAA, 2023).

2/1 Geographical Location and Area

Aswan Governorate is situated in the far south of the Arab Republic of Egypt and is regarded as one of the country's strategically important border regions. It is bordered by Luxor Governorate to the north, the Red Sea Governorate to the east, the New Valley Governorate to the west, and the Republic of Sudan to the south. The total area of the governorate is about 62,726 km², representing approximately 6.2% of Egypt's total area. Its physical landscape is diverse, ranging from the Eastern Desert and the narrow Nile Valley to numerous river islands and limited agricultural land along the riverbanks (Statistical Yearbook, 2024).

2/2 Administrative Division

The governorate comprises five main centers—Aswan, Daraw, Kom Ombo, Nasr al-Nuba, and Edfu. These include five cities, 39 local units, 104 main villages, and 441 hamlets and dependencies.

2/3 Population and Demographic Structure

By the end of 2023, the population of Aswan was estimated at around 1.63 million, with males accounting for 51.1% and females for 48.9%. The urban population represented 43% of the total, compared to 57% residing in rural areas (Statistical Yearbook, 2024).

2/4 Labor Force and Unemployment

In 2023, the governorate's labor force reached approximately 579,000 individuals, of whom 521,000 were employed and 58,000 were unemployed, resulting in an unemployment rate of around 10%. The agricultural and public service sectors represent the main absorbers of the local labor force (Statistical Yearbook, 2024)

2/5 Sectoral Contribution to Employment

Table (3)
Contribution of Different Sectors to Employment in Aswan Governorate (2023)

Sector	Share of Employed Persons (%)
Agriculture, Forestry & Fishing	19.2
Manufacturing Industries	11.6
Construction	12.9
Transportation & Storage	4.4
Wholesale & Retail Trade	14.8
Education	7.5
Health	3.8
Public Administration & Defense	5.9
Other Services (Finance – Tourism)	16.4

Source: Central Agency for Public Mobilization and Statistics (CAPMAS), Statistical Yearbook, 2024.

As shown in Table (3), the agricultural sector continues to account for approximately 19.2% of the total workforce, serving as a primary source of employment in rural areas. However, this sector is also associated with relatively higher carbon emissions resulting from energy consumption in irrigation systems, agricultural machinery, fertilizers, and pesticides. Improving resource-use efficiency and promoting sustainable agricultural practices are therefore essential for reducing its environmental footprint. The manufacturing sector, employing about 11.6% of the workforce, plays a crucial role in economic activity; nevertheless, it remains among the most carbon-intensive sectors due to its dependence on conventional energy sources. Similarly, the construction sector, which employs 12.9% of workers, is linked to the use of emission-intensive materials such as cement and steel. Transitioning toward cleaner production methods and adopting green building technologies thus represent key strategies for mitigating emissions in these sectors. By contrast, service sectors such as wholesale and retail trade (14.8%), other services including finance and tourism (16.4%), education (7.5%), health (3.8%), and public administration and defense (5.9%) collectively account for a significant share of employment. Although these sectors generate relatively lower direct emissions compared to agriculture and industry, their ongoing expansion contributes to increased energy demand across transportation, service provision, and building operations.

Overall, Aswan's employment structure illustrates a combination of high- and low-emission sectors. This composition presents opportunities to reorient employment policies toward supporting low-carbon activities—such as climate-smart agriculture, sustainable tourism, renewable energy, and environmental services—while simultaneously promoting awareness and the adoption of clean technologies within traditional sectors

2/6 Key Economic Sectors with Environmental Impact in Aswan

2/6/1 Agricultural Sector: The agricultural sector remains the largest employer in Aswan, accounting for approximately 19.2% of the total workforce (CAPMAS, 2024). This sector exerts a considerable environmental impact, primarily because of the intensive use of chemical fertilizers and pesticides, reliance on traditional irrigation systems that consume large amounts of water and energy, and the open burning of agricultural residues. Reports from the Egyptian Environmental Affairs Agency (EEAA, 2023) identify agriculture as one of the primary contributors to greenhouse gas emissions in rural Egypt.

2/6/2 Industrial Sector: The manufacturing sector employs around 11.6% of the workforce (CAPMAS, 2024). Industrial activities are mainly concentrated in food processing, construction materials (such as bricks and cement), and small-scale workshops. Although Aswan's industrial base is modest compared with that of major urban centers, its reliance on fossil fuels makes it a notable source of carbon emissions. The Ministry of Local Development (2022) has cautioned that unregulated industrial expansion may increase the environmental burden in the future.

2/6/3 Residential Sector and Energy Use: Residential activities are another key source of emissions, mainly through household electricity consumption—primarily for lighting and cooling—as well as the use of liquefied petroleum gas for cooking. With the governorate's population reaching 1.6 million in 2023 (CAPMAS, 2023), urban expansion in Aswan city and surrounding towns has driven higher energy demand, thereby increasing the environmental footprint.

2/6/4 Transport Sector: Transport is a significant driver of emissions due to its dependence on fossil fuels. CAPMAS (2023) data show that this sector employs about 4.4% of the workforce. Seasonal peaks in tourism further intensify energy consumption, as buses and tourist vehicles operate at full capacity during high-demand periods, resulting in increased fuel use and associated emissions.

2/6/5 Tourism and Service Sector: Tourism is among the most vital economic activities in Aswan, with a substantial share of the workforce employed in hotels, hospitality, and related services. These are included in the "other services" category, which accounts for around 16.4% of total employment (CAPMAS, 2024). This sector generates indirect emissions through energy use in accommodation facilities and transport services. Nonetheless, it also presents opportunities for adopting green tourism initiatives that can mitigate the carbon footprint in the governorate (Ministry of Tourism, 2023).

2/6/6 Water Supply and Wastewater Sector: This sector includes groundwater extraction, water pumping, and the treatment of drinking water and wastewater—activities that are highly energy-intensive. Although its employment contribution is not separately reported in official statistics, the EEAA (2023) identifies it as an environmentally significant sector due to its heavy reliance on electricity.

2/6/7 Construction Sector: The construction and building sector is one of the most environmentally impactful sectors in Aswan. It plays a vital role in the local economy, contributing around 7.5% of the governorate's total output and employing nearly 12% of the workforce (CAPMAS, 2024). The recent expansion of public investments in infrastructure, housing, and road projects has led to a significant increase in energy consumption, particularly electricity, diesel, and natural gas. Consequently, the sector has become a major source of greenhouse gas emissions, underscoring the need for sustainable construction practices and improved energy efficiency.

Third: Measuring the Carbon Footprint of Aswan Governorate

The carbon footprint is considered a key analytical tool in sustainability studies, as it provides a standardized measure of greenhouse gas (GHG) emissions resulting from human activities. These emissions are expressed in terms of carbon dioxide equivalent (CO_2e), which allows for consistent comparison across different sources and facilitates comprehensive environmental analysis.

The methodological framework for calculating the carbon footprint follows primarily the Intergovernmental Panel on Climate Change (IPCC) Guidelines and the Greenhouse Gas (GHG) Protocol, both of which are internationally recognized references that ensure methodological consistency and the credibility of results.

In accordance with these international standards, GHG emissions are commonly categorized into three scopes, as follows:

1. **Scope 1 : Direct emissions** from sources physically located within the geographical boundaries of the study area, such as fuel combustion in households and transport, or emissions from industrial and agricultural processes.
2. **Scope 2: Indirect emissions** resulting from the consumption of purchased electricity or other forms of energy supplied by the national grid. Although these emissions occur at the point of generation, they are attributed to the end user to reflect actual consumption.
3. **Scope 3 : Other indirect emissions** occurring across the value chain, including those linked to imported goods, international transportation, waste management, and tourism. This category is generally the most expansive yet also the least precise, due to the frequent lack of reliable localized data.

For the purposes of this study, the analysis concentrated on **Scopes 1 and 2**, which constitute the mandatory core of carbon footprint assessments under international standards. This focus was informed by two considerations: the availability of robust official data from national institutions—such as the **Central Agency for Public Mobilization and Statistics (CAPMAS)** and the **Ministries of Electricity, Petroleum, and Agriculture**—and the need to ensure comparability with national and international studies. **Scope 3 was deliberately excluded, for three main reasons:**

- the lack of sufficiently detailed local data on many of its components (e.g., supply chains or international transport),
- the fact that most academic studies and Egypt's National Communications to the UNFCCC limit their accounting to Scopes 1 and 2,
- and the necessity of aligning with the methodological boundaries most commonly adopted in comparative research.

This study employed the following standard methodological equation to estimate emissions:

Emissions (t CO_2e) = Activity Data × Emission Factor (EF) × Global Warming Potential (GWP).

Priority was given to the most recent Egypt-specific emission factors published by the Egyptian Environmental Affairs Agency (EEAA) and the Ministry of Environment, which reflect the national energy mix. Where local coefficients were unavailable, default values from the Intergovernmental Panel on Climate Change (IPCC) Guidelines (2006; 2019 Refinement) and other internationally validated databases were used.

Emission equations and conversion factors used in this study were mainly derived from the *IPCC Guidelines for National Greenhouse Gas Inventories* (2006; 2019 Refinement). These guidelines provide standardized methodologies for estimating greenhouse gas emissions across a wide range of activity sectors. Building on this framework, the present study expanded the scope to include **nine key sectors relevant to Aswan Governorate**: households and energy, water and sanitation, agriculture, industry, transport, tourism, public services, construction, and information and communication technology (ICT). The formulas were verified and complemented by data from the *GHG Protocol: Corporate Accounting and Reporting Standard* (WRI & WBCSD, 2004), ensuring consistency with internationally recognized accounting practices and methodological coherence

To adapt global standards to local conditions, national coefficients and activity data were integrated from Egyptian sources, including the EEAA, the Ministry of Environment, and the Central Agency for Public Mobilization and Statistics (CAPMAS). This hybrid approach enhances the accuracy and contextual relevance of the estimates while maintaining comparability with IPCC Tier 1 methodologies.

Accordingly, all sectoral equations—covering **households and energy, water and sanitation, agriculture, industry, transport, tourism, public services, construction, and information and communication technology (ICT)**—were aligned with IPCC default emission factors and national datasets. This alignment ensures methodological robustness and transparency in estimating Aswan Governorate's total carbon footprint.

In all cases, activity data were converted into carbon dioxide equivalent (CO_2e) using official national emission factors whenever available, in order to better reflect Egypt's specific energy mix and production patterns rather than relying exclusively on international default values.

The calculations were based on actual activity data for the year 2023, obtained from authoritative national sources such as the Central Agency for Public Mobilization and Statistics (CAPMAS), the Ministry of Petroleum, the Ministry of Electricity and Energy, the Ministry of Agriculture, and other relevant governmental institutions. The reliance on national emission factors significantly improved the precision of the estimates and enhanced their comparability with Egypt's official national reports and international Climate Change (UNFCCC).

The calculations in this study covered nine major sectors representing the principal sources of carbon emissions in Aswan Governorate:

1. **Households and Energy:** This sector encompassed electricity consumption, natural gas, liquefied petroleum gas (LPG), and diesel use in household generators.
2. **Water and Wastewater:** Included emissions arising from the pumping, distribution, and treatment of potable water, as well as sewage collection and management.
3. **Agriculture:** Covered emissions associated with major crops (such as sugarcane, wheat, maize, and cotton), livestock and poultry production, the application of nitrogen-based fertilizers, the operation of agricultural machinery, and the open burning of crop residues.
4. **Industry:** Comprised emissions generated from sugar manufacturing, quarrying and processing of granite and marble, and mining activities, particularly gold and phosphate extraction.
5. **Transport:** Accounted for emissions from private cars, buses, trucks, railway services, and inland water transport operating within the governorate.
6. **Tourism:** Included energy and transport-related emissions associated with hotels, resorts, and tourism facilities and services.
7. **Public Services:** Covered government buildings, healthcare facilities, educational institutions, and street lighting systems.
8. **Construction:** Encompassed emissions from the production of building materials, on-site energy use, and construction activities across the governorate.
9. **Information and Communication Technology (ICT):** Captured emissions linked to telecommunications infrastructure, data centers, and related electricity consumption.

Activities classified under **Scope 3**, such as international air travel or emissions associated with external supply chains, were excluded to maintain methodological consistency with internationally recognized standards

National Emission Factors for Carbon Footprint Assessment in Aswan Governorate

Emission factors constitute a fundamental component of carbon footprint estimation, as they provide the conversion coefficients that translate various human and economic activities into quantifiable greenhouse gas emissions. While international frameworks—such as the IPCC Guidelines and the GHG Protocol—offer standardized default values, the use of national emission factors often yields more accurate results, as these factors better reflect Egypt's specific energy mix, technological efficiency, and waste management practices.

In this study, priority was given to the most recent Egypt-specific emission factors officially published by the Egyptian Environmental Affairs Agency (EEAA) and the Ministry of Environment, ensuring alignment with the country's actual energy production and consumption patterns. When national coefficients were unavailable, internationally recognized default factors from the IPCC (2006 Guidelines; 2019 Refinement) and other validated databases were applied. All such substitutions were clearly indicated in the analytical tables to maintain full transparency and methodological consistency

Table (4)

National Emission Factors for Carbon Footprint Assessment in Aswan Governorate

Sector	Activity / Fuel	Emission Factor (kg CO_2e/unit)	Source
Households & Energy	Electricity (kWh)	0.55	NBK Egypt 2024; IEA/BTR Egypt
Households & Energy	LPG (kg)	2.95	DCarbon Egypt; ECC 2023
Households& Energy	Diesel (L)	2.68	NBK Egypt 2024; DCarbon Egypt
Households & Energy	Natural Gas (m^3)	2.10	MoPMR 2023; ECC 2023
Households & Energy	Municipal Solid Waste (kg)	0.80	EEAA 2022; BTR Egypt
Water & Wastewater	Potable Water (m^3)	0.40	EEAA 2022; CAPMAS 2023
Water & Wastewater	Wastewater Treatment (m^3)	0.40	EEAA 2022; CAPMAS 2023
Agriculture & Livestock	Sugarcane (kg)	0.00065	FAO 2021; CAPMAS 2023

Agriculture & Livestock	Wheat (kg)	0.00052	FAO 2021; CAPMAS 2023
Agriculture & Livestock	Maize (kg)	0.00052	FAO 2021; CAPMAS 2023
Agriculture & Livestock	Cotton (kg)	0.00070	FAO 2021; CAPMAS 2023
Agriculture & Livestock	Fertilizers (kg N)	0.424	EEAA 2018; FAO 2021
Agriculture & Livestock	Cattle (head/yr)	1540	EEAA 2018
Agriculture & Livestock	Buffalo (head/yr)	1340	EEAA 2018
Agriculture & Livestock	Sheep/Goats (head/yr)	140	EEAA 2018
Agriculture & Livestock	Poultry (bird/yr)	3.6	EEAA 2018
Agriculture & Livestock	Crop Residues Burning (kg)	1.50	MoE Egypt 2022
Agriculture & Livestock	Diesel (L, machinery)	2.68	NBK Egypt 2024; MoE 2021
Agriculture & Livestock	Electricity (kWh, irrigation)	0.55	NBK Egypt 2024
Industry	Electricity (kWh)	0.55	NBK Egypt 2024; IEA
Industry	Ammonia (t)	1800	IFA 2014; IEA 2019
Industry	Urea (t)	350	IFA 2014
Industry	Clinker (t)	870	IPCC 2006; WBCSD 2011
Industry	Sugar Industry (t)	900	MoS 2023; DCarbon Egypt
Industry	Quarry Extraction (t)	120	World Bank 2024; Aswan Gov Bulletin 2024
Industry	Mining (t)	280	World Bank 2024
Industry	Industrial Waste (kg)	0.80	EEAA 2022; ECC 2023
Transport	Gasoline (L)	2.31	NBK Egypt 2024; DCarbon Egypt
Transport	Diesel (L)	2.68	NBK Egypt 2024; DCarbon Egypt
Transport	Railways (passenger-km)	0.045	EEAA 2021
Transport	Domestic Aviation (passenger-km)	0.285	IPCC 2006
Transport	International Aviation	0.195	IPCC 2006

	(passenger-km)		
Transport	Electricity (kWh, facilities)	0.45	CAPMAS 2022; EEAA 2021
Tourism	Electricity (kWh)	0.55	NBK Egypt 2024
Tourism	Diesel (L)	2.68	NBK Egypt 2024
Tourism	LPG (kg)	2.95	ECC 2023
Tourism	Waste (kg)	0.95	Gaafar 2015
Services & Facilities	Electricity (kWh)	0.55	NBK Egypt 2024
Services & Facilities	Diesel (L)	2.68	NBK Egypt 2024
Construction	Diesel (L)	2.68	NBK Egypt 2024
Construction	Electricity (kWh)	0.55	NBK Egypt 2024
Construction	Cement (t)	520	IPCC 2006
Construction	Steel (t)	1850	World Steel Association 2022
ICT	Electricity (kWh)	0.47	MCIT 2023; ECC 2023
ICT	Diesel (L, backup generators)	2.68	ECC 2023; IPCC 2006

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Some of the emission factors presented in Table (4), particularly those associated with quarry extraction, mining operations, and sugar industry production, were derived from estimated values rather than directly measured national coefficients. This estimation was necessitated by the unavailability of officially published Egypt-specific emission factors for these particular activities. The adopted values were therefore inferred from average fuel and energy consumption per unit of output, as reported in national industrial bulletins and validated international databases, including the World Bank and the International Energy Agency (IEA). Although these factors are approximations, they were selected to remain consistent with Egypt’s actual production conditions and to conform to the methodological framework of the IPCC Tier 1 approach, thereby ensuring the overall reliability and comparability of the carbon footprint estimates.

Calculating Aswan's carbon footprint

1. **Households and Energy Sector**

Calculation formulas:

• Electricity emissions = Electricity consumed (kWh) × 0.00055 tons CO_2e/kWh
• LPG emissions = LPG consumed (kg) × 0.00295 tons CO_2e/kg
• Diesel emissions = Diesel consumed (liters) × 0.00268 tons CO_2e/liter
• Natural gas emissions = Natural gas consumed (m^3) × 0.00210 tons CO_2e/m^3
• Municipal solid waste emissions = Waste generated (kg) × 0.00080 tons CO_2e/kg

Table (5)

Estimated Carbon Footprint of the Households and Energy Sector in Aswan Governorate (2023)

Activity / Fuel	Data (2023)	Emission Factor (EF)	Result (t CO_2e)	Source
Electricity consumed	2,578,700,000 kWh	0.55 kg CO_2/kWh	1,418,285	CAPMAS (2023); Egyptian Carbon Center
LPG (households)	124,000 t (≈ 5.2M cylinders)	2.95 kg CO_2/kg	365,800	CAPMAS (2023); Egyptian Carbon Center
Diesel (household generators)	5,000,000 L (estimated)	2.68 kg CO_2/L	13,400	EEAA (2022); DCarbon Egypt
Natural Gas (households)	12,187,520 m^3 (estimated)	2.10 kg CO_2/m^3	25,594	CAPMAS (2024); MoPMR (2023)
Municipal solid waste (household share)	414,000 t/year	0.80 kg CO_2e/kg	331,200	CAPMAS (2023); Egyptian Carbon Center / EEAA (2022)
Total (Households & Energy)			**2,154,279**	

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Notes:

- The estimated number of LPG cylinders was derived from the reported annual household consumption of 124,000 tons in 2023 (CAPMAS, 2023). A standard cylinder weight of 24 kg was applied, resulting in approximately 5.2 million cylinders. This conversion ensures consistency between mass-based reporting (tons) and household-level usage (cylinders).

- Natural Gas Estimation: The number of buildings connected to the natural gas grid in Aswan Governorate was 38,086 buildings in 2023 (CAPMAS, 2024). To estimate household natural gas consumption, the national average consumption of 320 m^3/building/year was applied (based on CAPMAS energy publications and Ministry of Petroleum data).
- **Calculation of Natural Gas Estimation:**
    - Consumption (m^3) = 38,086 × 320 = 12,187,520 m^3
    - Emissions (t CO_2e) = (12,187,520 × 2.10) ÷ 1000 = 25,594 t CO_2e

Table (5) provides a consolidated view of the major household energy-related emission sources in Aswan Governorate. The results indicate that electricity use accounts for the dominant share of emissions, largely due to the high level of consumption (2.58 TWh in 2023) combined with the carbon intensity of the national grid. LPG continues to represent a considerable portion of household emissions, reflecting the reliance on bottled gas for cooking across many households. Municipal solid waste also contributes significantly when national emission factors are applied, underscoring the need for enhanced waste management strategies such as composting or anaerobic digestion to mitigate this burden. By contrast, emissions from natural gas and small-scale diesel use are relatively modest, although they still warrant attention. It is important to note that natural gas emissions were derived using a proxy method based on household connections and average national consumption rates. While this approach is valid in the absence of detailed local metering data, the accuracy of estimates would improve if more granular consumption statistics become available. Overall, the reliance on nationally recognized emission factors strengthens the robustness of the calculations and ensures their alignment with Egypt's reporting standards.

2-Water and Wastewater Sector

Calculation formulas:

- Potable water emissions = Water produced (m^3) × 0.00040 t CO_2e/m^3
- Wastewater emissions = Treated wastewater (m^3) × 0.00040 t CO_2e/m^3

Table (6)

Estimated Carbon Footprint of the Water and Wastewater Sector in Aswan Governorate (2023)

Activity	Data (2023)	Emission Factor (EF)	Result (tons CO_2e)	Source
Potable water produced	348.3 million m^3	0.00040 tCO_2e/m^3	139,300	CAPMAS(2023); EEAA (2022)
Treated wastewater	120.6 million m^3	0.00040 tCO_2e/m^3	48,200	CAPMAS(2023); EEAA (2022)
TOTAL			**187,500**	

References

- Central Agency for Public Mobilization and Statistics (CAPMAS). (2023). Annual bulletin of public utilities statistics. Cairo: CAPMAS.
- Egyptian Environmental Affairs Agency (EEAA). (2022). Annual environmental report. Cairo: Ministry of Environment.

The estimated carbon footprint of the water and wastewater sector in Aswan Governorate for 2023 amounts to approximately 187,560 tons of CO_2e. These emissions primarily originate from Scope 2 sources, reflecting the indirect energy demand associated with water pumping, treatment, and distribution processes, as well as the operation of wastewater treatment plants. Potable water production accounts for nearly three-quarters of the total sectoral emissions, while the remainder arises from wastewater treatment activities. It is important to note that this assessment focuses solely on energy-related emissions, following the boundaries applied in national energy-based inventories. Consequently, the results do not include fugitive methane (CH_4) or nitrous oxide (N_2O) emissions that may arise from untreated or partially treated wastewater systems. While this methodological boundary ensures consistency with Egypt's official reporting framework, it may lead to an underestimation of the total carbon footprint of the sector.

This limitation highlights the need for more detailed data on the energy intensity of local water utilities and the inclusion of biological process emissions in future assessments. Nevertheless, the current results provide a robust basis for evaluating the sector's environmental performance and for identifying potential mitigation strategies—particularly through improvements in energy efficiency, leakage reduction, and the integration of renewable energy sources in water and wastewater operations

3- Agriculture Sector

“The agricultural sector in Aswan Governorate plays a vital role in the local economy, encompassing extensive crop cultivation, livestock production, and expanding mechanization practices. The governorate is especially known for its large-scale sugarcane production, complemented by wheat, maize, and cotton cultivation. Livestock activities, including cattle, buffalo, sheep, goats, and poultry, provide additional contributions to agricultural output. Furthermore, mechanization—covering tractors, irrigation pumps, threshing units, and other machinery—has expanded significantly, shaping both productivity and emissions. The following assessment estimates the sector's carbon footprint for 2023, using activity data from CAPMAS and international emission factors.

Formulation of Equations for the Agriculture and Livestock Sector

- **Crop Production:**

Sugarcane Emissions (t CO_2e) = Quantity of sugarcane produced (kg) × 0.00065

Wheat Emissions (t CO_2e) = Quantity of wheat produced (kg) × 0.00052

Maize Emissions (t CO_2e) = Quantity of maize produced (kg) × 0.00052

Cotton Emissions (t CO_2e) = Quantity of cotton produced (kg) × 0.00070

Fertilizer Emissions (t CO_2e) = Quantity of nitrogen applied (kg N) × 1.6 × 265 / 1000

This formula estimates N_2O emissions and converts them to CO_2-equivalent using the global warming potential.

- **Livestock Activities:**

Cattle Emissions (t CO_2e) = Number of cattle × 55 kg CH_4/head/year × 0.001 × 28

Buffalo Emissions (t CO_2e) = Number of buffalo × 48 kg CH_4/head/year × 0.001 × 28

Sheep/Goat Emissions (t CO_2e) = Number of heads × 5 kg CH_4/head/year × 0.001 × 28

Poultry Emissions (t CO_2e) = Number of birds × 0.13 kg CH_4/bird/year × 0.001 × 28

- **Mechanization:**

Tractor Emissions (t CO_2e) = Number of tractors × hp × operating hours × 0.291 (liters/hp-hr) × 2.67 / 1000

Irrigation Machinery Emissions (t CO_2e) = Number of machines × hp × operating hours × energy split × EF / 1000

Threshing Machines Emissions (t CO_2e) = Number of machines × avg hp × operating hours × 0.291 × 2.67 / 1000

Other Agricultural Machinery Emissions (t CO_2e) = Number of machines × avg hp × operating hours × 0.291 × 2.67 / 1000

- **Residue Burning:**

Emissions (t CO_2e) = Crop production (t) × RPR × 35% × 1.50 (kg CO_2e/kg residue) × 0.001

This equation captures the quantity of residues subject to open burning and applies the national emission factor of 1.50 kg CO_2e per kg residue (MoE, 2022). (see annex1)

Table (7)

Estimated Carbon Footprint of the Agriculture Sector in Aswan Governorate (2023)

Activity	Data (2023)	Emission Factor (EF)	Emissions (t CO_2e)	Source
Sugarcane	16.1 million t	0.00065 t CO_2e/kg	10,465,000	CAPMAS 2023; FAO 2021
Wheat	110,200 t	0.00052 t CO_2e/kg	57,300	CAPMAS 2023; FAO 2021
Maize	45,600 t	0.00052 t CO_2e/kg	23,700	CAPMAS 2023; FAO 2021
Cotton	5,600 t	0.00070 t CO_2e/kg	3,920	CAPMAS 2023; FAO 2021
Fertilizers	2.4 million kg N	1.6 × 265 /1000	1,015,000	CAPMAS 2023;

				EEAA 2018
Cattle	65,700 heads	55 × 0.001 × 28	101,000	CAPMAS 2023; EEAA 2018
Buffalo	37,500 heads	48 × 0.001 × 28	50,400	CAPMAS 2023; EEAA 2018
Sheep/Goats	161,200 heads	5 × 0.001 × 28	22,500	CAPMAS 2023; EEAA 2018
Poultry	3.7 million birds	0.13 × 0.001 × 28	13,500	CAPMAS 2023; EEAA 2018
Crop residues (burning)	Calculated	1.50 kg CO_2e/kg residue	2,647,460	MoE 2022; EEAA 2018
Tractors	133,500 units – 8.3 million hp	600 h/yr; 0.291 L/hp-hr; 2.67 kg CO_2/L	3,869,311	CAPMAS 2021; literature estimates
Irrigation machines	1,017,900 units – 11.9 million hp	1000 h/yr; 70% elec (0.55 EF), 30% diesel	6,191,600	CAPMAS 2021; literature estimates
Threshing machines	74,300 units (avg 30 hp)	300 h/yr; diesel	519,560	CAPMAS 2021; literature estimates
Other agri. machinery	314,700 units (avg 40 hp)	400 h/yr; diesel	3,912,199	CAPMAS 2021; literature estimates
Total		—	**28,892,400**	—

References

- Central Agency for Public Mobilization and Statistics (CAPMAS). (2023). *Agricultural statistics yearbook 2023*. Cairo: CAPMAS.
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- Egyptian Environmental Affairs Agency (EEAA). (2018). *Egypt's Fourth National Communication to the UNFCCC*. Cairo: Ministry of Environment.
- Ministry of Environment (MoE), Egypt. (2022). *National report on solid waste and agricultural residues management*. Cairo: EEAA.
- Food and Agriculture Organization of the United Nations (FAO). (2021). *FAOSTAT emissions database: Agriculture*. Rome: FAO. Retrieved from https://www.fao.org/faostat

Notes

- Nitrogen Fertilizers: Emissions were estimated by converting applied nitrogen into N_2O using an emission factor of 1.6% (IPCC, 2019), then applying a GWP of 265 to express results in CO_2e. This approach ensures alignment with international methodologies.

- Scopes and Mechanization: Diesel use in tractors and farm machinery is reported under Scope 1, while electricity for irrigation pumps is included in Scope 2. Calculations are based on standard operational assumptions (horsepower, annual hours, fuel consumption rates).

Table (7) reveal the significant contribution of mechanization to agricultural emissions in Aswan. Crop production and fertilizer use remain the dominant sources, with sugarcane cultivation and residue burning accounting for the largest share. However, tractors, irrigation machines, threshers, and other machinery collectively add nearly 13.9 million t CO_2e/year under baseline assumptions.

Nitrogen fertilizers are confirmed as the second largest contributor, underscoring the importance of precision nutrient management. Livestock emissions, though smaller in comparison, remain relevant through methane emissions from cattle and buffalo. Residue burning remains a critical hotspot, with opportunities for mitigation via composting, bioenergy, or use as animal feed.

Mechanization emerges as a major new category of emissions. While operating-hour assumptions introduce uncertainty, sensitivity analysis (low–baseline–high) demonstrates a robust magnitude of several million tonnes of CO_2e annually. Policies targeting energy efficiency, renewable-powered irrigation, and gradual electrification of farm equipment could complement existing measures on crops and residues. Overall, the integrated analysis shows that agricultural emissions in Aswan are driven not only by crops, fertilizers, and residues but also by the substantial contribution of mechanization.

4- industrial Sector

The industrial sector in Aswan Governorate represents a central pillar of economic development and employment. As reported in the Governorate Bulletin (January 2024), the Al-‘Alaqi industrial zone extends over 272.6 feddans, hosting 67 operational factories with an additional 21 under construction. Overall, the governorate accommodates 1,544 industrial establishments, encompassing a wide spectrum of activities that range from large-scale fertilizer and cement production to sugar processing, quarrying, mining, and a significant number of small- and medium-sized enterprises (SMEs).

Carbon Footprint Assessment — Industrial Sector

The carbon footprint of the industrial sector was estimated using activity data and standard emission factors (EFs). The following equations were applied:

1. Sugar industry (production) emissions = Sugar production (t) × 0.9 t CO_2e / t

2. Sugar industry waste emissions = Sugar residues (t) × 0.0008 t CO_2e / kg (0.80 kg/kg)

3. Quarry (extraction) emissions = Extracted stone (t) × 0.12 t CO_2e / t

4. Quarry waste emissions = Quarry residues (t) × 0.0008 t CO_2e / kg (0.80 kg/kg)

5. Mining emissions = Extracted ore (t) × 0.28 t CO_2e / t

6. KIMA-2 Fertilizer Plant emissions = NH_3 production (t) × 1.8 t CO_2e/t + Urea production (t) × 0.35 t CO_2e/t + Electricity consumption (kWh) × 0.55 kg CO_2/kWh

7. Medcom Aswan Cement Plant emissions = Clinker production (t) × (0.52 + 0.35) t CO_2e/t + Electricity consumption (kWh) × 0.55 kg CO_2/kWh

8. SMEs emissions = Number of establishments × average emission intensity per establishment.

Table (8)

Estimated Carbon Footprint of The industrial Sector in Aswan Governorate (2023)

Activity / Establishment	Data (2023)	EF / Method	Emissions (t CO_2e)	Source
KIMA-2 Fertilizer Plant	NH_3 435,000 t; Urea 570,000 t; Elec 27.2 MW	1.8 t/t NH_3; 0.35 t/t Urea; 0.55 kg/kWh	1,113,550	IEA; IFA; EEAA; Argus; KIMA
Medcom Aswan Cement Plant	Cement 750,000 t; Clinker 913,000 t	0.52 t/t clinker; 0.35 t/t clinker; 90 kWh/t × 0.55 kg/kWh	831,435	IPCC; WBCSD; EEAA; GEM
Sugar industry (production)	600,000 t sugar	0.9 t CO_2e/t	540,000	MoS (2023); DCarbon Egypt
Sugar industry waste	200,000 t residues	0.80 kg/kg = 0.0008 t/kg	160,000	MoS (2023); ECC
Granite quarries (extraction)	3,200,000 t extracted	0.12 t CO_2e/t	384,000	Gov Bulletin (2024); World Bank
Quarry waste	300,000 t residues	0.80 kg/kg = 0.0008 t/kg	240,000	World Bank (2024); ECC
Mining (gold/phosphate)	500,000 t extracted	0.28 t CO_2e/t	140,000	Gov Bulletin (2024); World Bank
SMEs (1,544 establishments)	Avg. 299 t CO_2e/establishment	1,544 × 299	461,656	Gov Bulletin (2024);
Total	—	—	3,869,641	

References

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- Global Energy Monitor (GEM). (2023). Aswan Cement Plant.
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- World Bank. (2024). Industrial and Quarry Data for Egypt.
- Aswan Governorate. (2024). Monthly Bulletin — January 2024.
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- Egyptian Carbon Center (ECC). (2023). National waste emission factors.
- Ministry of Supply (MoS). (2023). Sugar industry statistics in Egypt

Electricity-related emissions from the KIMA-2 Fertilizer Plant were estimated based on continuous operation at full installed capacity (27.2 MW × 8,760 hours), providing an upper-bound estimate, as actual emissions are expected to vary depending on plant load factors and operational efficiency. Overall, the industrial sector in Aswan was responsible for approximately 3.87 million tonnes of CO_2e in 2023. The KIMA-2 Fertilizer Plant alone accounted for about 29% of these emissions, while the Medcom Aswan Cement Plant contributed roughly 21%. Sugar production and associated industrial residues represented around 18%, granite quarrying and its waste about 16%, and SMEs contributed approximately 0.46 million tonnes CO_2e. Although the footprint of each small or medium enterprise is relatively modest, their cumulative impact is significant. This distribution highlights the dual challenge of mitigating emissions, with a large share concentrated in a few very large facilities while a broad base of smaller enterprises contributes lower individual emissions but notable cumulative effects.

Annex 2 provides a detailed explanation of the methodology used to calculate the carbon footprint of both the KIMA-2 Fertilizer Plant and the Medcom Aswan Cement Plant.

5-Transport Sector

The transport sector in Aswan Governorate constitutes a vital pillar of both passenger movement and goods transportation. According to the Central Agency for Public Mobilization and Statistics (CAPMAS, 2023), Aswan recorded around 36,100 registered passenger cars, 2,074 buses, and approximately 9,435 trucks. The railway network accounted for nearly 5.89 billion passenger-kilometers, while river transport consumed close to 25 million liters of diesel fuel during the year. Air travel also plays a crucial role, with about 1.2 million passengers passing through Aswan International Airport in 2023. This variety of transport modes mirrors the governorate's geographic and economic characteristics—particularly its position along the Nile corridor and its function as a key gateway for tourism and trade in Upper Egypt. Collectively, these modes shape the overall carbon footprint of the transport sector in distinct ways

Carbon Footprint Equations for the Transport Sector

• Passenger car emissions (gasoline) = Quantity of gasoline consumed (liters) × 0.00231 tCO_2e/liter

• Bus/truck emissions (diesel) = Quantity of diesel consumed (liters) × 0.00268 tCO_2e/liter

• Railway emissions = Passenger-kilometers × 0.000045 tCO_2e/passenger-km

• Domestic aviation emissions = Passenger-kilometers × 0.000285 tCO_2e/passenger-km

• International aviation emissions = Passenger-kilometers × 0.000195 tCO_2e/passenger-km

• River transport emissions = Quantity of diesel consumed (liters) × 0.00268 tCO_2e/liter

Table (9)

Estimated Carbon Footprint of the Transport Sector in Aswan (2023)

Activity	Data (2023)	Emission Factor (EF)	Emissions (tCO_2e)
Passenger cars	36,100 vehicles; 38,988,000 L gasoline	0.00231 t/L	90,062
Buses	2,074 units; 33,184,000 L diesel	0.00268 t/L	88,933
Trucks	9,435 units; 165,112,500 L diesel	0.00268 t/L	442,502
Railways (diesel)	5.89×10^9 passenger-km	0.000045 t/pkm	265,050
Air transport	1.2 million passengers ≈ 1.2×10^9 passenger-km	0.000285 t/pkm	342,000
River transport	25,000,000 L diesel	0.00268 t/L	67,000
Total		—	**1,295,547**

References

- Central Agency for Public Mobilization and Statistics (CAPMAS). (2023). Bulletin of Licensed Vehicles. Cairo: CAPMAS.
- Central Agency for Public Mobilization and Statistics (CAPMAS). (2023). Air Transport Bulletin. Cairo: CAPMAS.
- Central Agency for Public Mobilization and Statistics (CAPMAS). (2022/2023). Petroleum Bulletin. Cairo: CAPMAS.

- Egyptian Environmental Affairs Agency (EEAA). (2021). National Emission Factors Report. Cairo: Ministry of Environment.
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Methodological Notes and Assumptions

The emission estimates were developed within Scope 1 and Scope 2 boundaries, focusing primarily on direct fuel combustion and, where relevant, electricity consumption. The following assumptions were applied in the estimation process:

- Passenger cars: average annual distance of 12,000 km, with a fuel consumption rate of 9 L/100 km.
- Buses: 40,000 km per year, consuming 40 L/100 km of diesel.
- Trucks: 50,000 km per year, consuming 35 L/100 km of diesel.
- Railways: operated mainly by diesel-based traction in Aswan.
- Aviation: total passenger-kilometers estimated at 1.2×10^9, equivalent to an average of approximately 1,000 km per passenger.
- River transport: calculated based on the reported annual diesel consumption of 25 million liters.
- All emission values in Table (9) are expressed in metric tons of CO_2 equivalent (tCO_2e). The total corresponds to approximately 1.3 million tons (1.3 Mt CO_2e)

Table (9) indicates that the carbon footprint of the transport sector in Aswan Governorate was estimated at around **1.3 million tons of CO_2 equivalent (Mt CO_2e)** in 2023, based on national emission factors and official sectoral activity data. The assessment focused on **Scope 1 emissions**, encompassing direct fuel combustion across **road, rail, air, and river transport**. The findings reveal that **road freight (trucks)** and **air transport** are the dominant contributors, jointly responsible for more than half of the sector's total emissions. **Passenger cars** and **railways** also account for notable proportions, whereas **buses** and **river transport** contribute relatively smaller shares. While these estimates are grounded in standard assumptions regarding fuel consumption and travel activity, they provide a reliable and consistent foundation for evaluating the sector's emission profile and identifying key priorities for future mitigation efforts.

6-Tourism sector

The tourism sector in Aswan is one of the most significant contributors to the local economy and employment. The governorate attracts millions of visitors annually to enjoy its cultural and natural heritage, including the Philae Temples, the High Dam, and the Nubia Museum. In 2023, the number of tourist nights was approximately 2.1 million, according to the Annual Tourism Bulletin (CAPMAS, 2023).

Calculation Equations

• Emissions ($t\ CO_2e$) = Activity × Emission Factor ($kg\ CO_2e$/unit) ÷ 1000

• Electricity: kWh × EF ($kg\ CO_2e$/kWh) ÷ 1000

• Diesel: L × EF (kg CO_2e/L) ÷ 1000

• LPG: kg × EF (kg CO_2e/kg) ÷ 1000

• Waste: kg × EF (kg CO_2e/kg) ÷ 1000

Table (10)

Estimated Carbon Footprint of the tourism Sector in Aswan (2023)

Activity	Activity Data (2023)	Emission Factor (EF)	Emissions (t CO_2e)
Electricity (Scope 2)	2.1M nights × 6.95 kWh/night = 14,595,000 kWh	0.55 kg CO_2e/kWh	8,027
Local Transport (diesel – S1)	2.1M nights × 3.5 L/day = 7,350,000 L	2.68 kg CO_2e/L	19,698
Generators (diesel – S1)	2.1M nights × 1.25 L/night = 2,625,000 L	2.68 kg CO_2e/L	7,035
LPG (Scope 1)	2.1M nights × 0.2 kg/night = 420,000 kg	2.95 kg CO_2e/kg	1,239
Total (Scope 1 + 2)	—	—	35,999
Hotel waste (Scope 3, reference only)	—	0.95 kg CO_2e/kg (average)	≈ 2,700

References

- CAPMAS (2023). Annual Tourism Bulletin.
- Gaafar, H. A. A. (2015). *Tourism ecological footprint: Energy consumption of domestic and international tourists in Egypt*. International Academic Journal of Tourism Studies & Research, 1 (1), 45-60. Retrieved from https://www.researchgate.net/publication/342296762_Tourism_Ecological_Footprint_Energy_Consumption_of_Domestic_and_International_Tourists_in_Egypt.
- NBK Egypt (2024). Egypt Carbon Footprint Report.
- Egyptian Carbon Center; DCarbon Egypt.
- GHG Protocol (2015). Corporate Standard.

Methodology and Assumptions

- The calculations are based on 2.1 million tourist nights recorded in Aswan (CAPMAS, 2023).

- Electricity consumption per night was estimated at 6.95 kWh/night on average, applying a national grid emission factor of 0.50 kg CO_2e/kWh.
- Local transport diesel consumption was assumed to be 3.5 liters per tourist per day, based on field studies conducted in Luxor and Aswan.
- Generator diesel consumption was estimated at 1.25 liters per night on average.
- LPG consumption was set at 0.2 kg per night, representing typical hotel usage patterns.
- Waste generation (Scope 3) was estimated at approximately 2,700 tCO_2e, excluded from the official total but included for reference.
- Scope 2 emissions were calculated using the location-based approach in accordance with the GHG Protocol.
- Midpoint values were adopted as representative averages to avoid over- or underestimation across scenarios

Table (10) indicates that emissions from the tourism sector in Aswan (Scopes 1 and 2) amount to approximately 36,000 tCO_2e annually, equivalent to about 17 kg of CO_2e per tourist night. The largest share of emissions arises from local transport and diesel generators, followed by electricity consumption, while LPG contributes only a minor fraction.

Including hotel waste (Scope 3) would increase the sector's footprint by approximately 2,700 tCO_2e. These results are broadly consistent with previous academic studies and provide a transparent foundation for developing mitigation measures, such as enhancing energy efficiency, expanding renewable energy use, and promoting low-carbon transport services for tourists.

7-Services and Facilities Sector

The public services and facilities sector is a vital part of Aswan Governorate, covering hospitals, government and administrative buildings, educational and health institutions, public lighting, and local transport infrastructure. According to official statistics, Aswan has 29 hospitals with a total of 4,806 beds, around 2,711 government and administrative buildings, 2,345 educational, health, and administrative facilities, and 684 establishments in the transport and storage sector. The governorate also operates about 74,700 public lighting poles along networks covering approximately 3,890 km. Aswan University is one of the largest educational institutions in Upper Egypt, with a total carbon footprint of about 16,746.7 tCO_2e as reported in its official 2023 sustainability report. (CAPMAS Statistical Yearbook 2024; Aswan Buildings and Facilities Files; Aswan University Carbon Footprint Report, 2023).

Calculation Formulas

- Emissions (tCO_2e) = Activity × Emission Factor (kgCO_2e/unit) ÷ 1000
- Electricity: kWh × EF (kgCO_2e/kWh) ÷ 1000

- Diesel: L × EF ($kgCO_2e$/L) ÷ 1000

Table (11)

Estimated Carbon Footprint of the Services and Facilities Sector in Aswan (2023)

Item	Activity (kWh/L)	Emission Factor ($kgCO_2e$/unit)	Emissions (tCO_2e)
Hospitals - Electricity	13,216,500 kWh	0.55	7,269.08
Hospitals - Diesel	360,450 L	2.68	966.01
Government Buildings	67,775,000 kWh	0.55	37,276.25
Educational/Health/Admin Facilities	35,175,000 kWh	0.55	19,346.25
Local Transport - Diesel	13,680,000 L	2.68	36,662.40
Public Lighting - Low	68,163,750 kWh	0.55	37,490.06
Public Lighting - High	130,874,400 kWh	0.55	71,980.92
Aswan University (Reported)	—	—	16,746.70
total			**173,000 tCO_2e.**

reference

- CAPMAS (2024). Statistical Yearbook.
- Aswan Governorate Building and Facilities Files.
- Population and Housing Bulletin, Aswan Governorate.
- Aswan University (2023). Energy and Carbon Footprint Report.
- NBK Egypt (2024); Egyptian Carbon Center; DCarbon Egypt (emission factors).

Methodology and Notes

1. Assumptions: Hospitals were assumed to consume an average of 2,750 kWh of electricity and 75 liters of diesel per bed per year. Government buildings consume approximately 25,000 kWh per building annually, while educational, health, and administrative facilities consume around 15,000 kWh per facility per year.
2. Public lighting was estimated under two operational scenarios:
   - Low scenario: 0.25 kW × 10 hours/day
   - High scenario: 0.40 kW × 12 hours/day
3. Waste management, water-related emissions, and refrigerant leakages were excluded from the current assessment due to data unavailability.
4. The Aswan University emission value (16,746.7 tCO_2e) was adopted directly from its official 2023 sustainability report.

5. The results indicate that the carbon footprint of the public services and facilities sector in Aswan ranges between 156,000 and 190,000 tCO_2e per year. The reported figure (≈173,000 tCO_2e) represents the average of the two scenarios, providing a single representative indicator for the sector.

Table (11) indicate that Public lighting is the largest contributor, followed by government buildings and local transport. Including Aswan University's officially reported value highlights the significant role of educational institutions. For greater accuracy, it is recommended to collect actual utility bills (electricity and fuel) for hospitals and government buildings, and to monitor lighting hours precisely. Energy efficiency programs, expanded use of renewable energy, and efficient public lighting systems are key opportunities for mitigation.

8-Construction Sector

The construction and building sector represent a central pillar of Aswan's economy, both through its contribution to output and its role as a major source of employment. According to the CAPMAS Statistical Yearbook (2024), construction activities accounted for about 7.5% of the governorate's total economic product. Employment in this sector is also notable, with nearly 12% of the workforce engaged in construction-related jobs, making it one of the largest non-agricultural employers. Recent government bulletins indicate a rise in public investment in infrastructure projects, including roads, housing, and utilities under national development programs (Aswan Governorate Economic Bulletin, 2024). These trends not only stimulate local economic growth but also drive higher energy consumption, particularly of electricity, diesel, and natural gas. Consequently, assessing the carbon footprint of the construction sector is crucial, given the direct link between energy use and greenhouse gas emissions.

Calculation Equations

1. Diesel emissions (tCO_2e) = Diesel consumed (L) × 0.00268 tCO_2e/L

2. Electricity emissions (tCO_2e) = Electricity consumed (kWh) × 0.00055 tCO_2e/kWh

3. Cement emissions (tCO_2e) = Cement consumed (t) × 0.52 tCO_2e/t

4. Steel emissions (tCO_2e) = Steel consumed (t) × 1.85 tCO_2e/t

Carbon Footprint Results – Construction Sector (2023)

Table (12)
Estimated Carbon Footprint of the Construction and Building Sector in Aswan Governorate (2023)

Activity / Material	Data (2023)	Emission Factor (EF)	Emissions (tCO_2e)
Diesel (construction machinery)	48,000,000 L	0.00268 tCO_2e/L	128,640
Electricity (construction sites)	62,000,000 kWh	0.00055 tCO_2e/kWh	34,100
Cement	2,150,000 t	0.52 tCO_2e/t	1,118,000
Steel	185,000 t	1.85 tCO_2e/t	342,250
Total	—	—	1,622,990

References

- CAPMAS (2024). Statistical Yearbook. Cairo: Central Agency for Public Mobilization and Statistics.
- Aswan Governorate (2024). Economic Bulletin. Aswan: Governorate Publications.
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Methodological Notes

- The **cement and steel emissions** presented in this table correspond to their **final use** in construction activities rather than their industrial production, in order to avoid double counting.
- Consequently, the construction sector calculations capture only the **downstream carbon footprint** associated with material consumption in building activities, together with **direct fuel and electricity use** (Scope 1 and Scope 2)

Table (12) indicate that The construction sector in Aswan represents a significant contributor to the governorate's overall carbon footprint, mainly driven by the intensive use of cement and steel. Together, these two materials accounts for nearly 90% of the sector's emissions. Energy consumption from diesel-powered machinery and site electricity also adds considerable emissions, though to a smaller extent.

9-Information and Communication Technology (ICT) sector

The Information and Communication Technology (ICT) sector in Aswan witnessed notable growth in 2023. Mobile subscribers reached about 1.85 million. Fixed internet subscribers totaled approximately 220,000, while mobile internet users were about 1.6 million, bringing the total number of internet users to nearly 1.82 million. The ICT infrastructure includes around 1,150 mobile base stations, 120 post offices, and 15 digital service centers, in addition to one small regional data center. The sector contributed about 3.1% to the governorate's GDP, with a growth rate of 16% in 2023.

Equations Used for Calculation

- Electricity emissions (t CO_2e) = Electricity consumption (kWh) × Emission factor (kg CO_2e/kWh) × 0.001
- Generator emissions (t CO_2e) = Diesel consumption (liters) × 2.68 (kg CO_2e/liter) × 0.001
- Total carbon footprint (t CO_2e) = Electricity emissions + Generator emissions
- Carbon footprint per subscriber (t/subscriber/year) = Total footprint ÷ Number of mobile subscribers.

Table (13)

Estimated Carbon Footprint of Information and Communication Technology (ICT) sector in Aswan (2023)

Activity / Material	Data (2023)	Emission Factor (EF)	Emissions (tCO_2e)
Mobile base stations	35.259.000 kWh electricity	0.55 kg CO_2e/kWh	19,392.45
Post offices	5.256.000 kWh electricity	0.55 kg CO_2e/kWh	2,890.80
Digital service centers	1.314.000 kWh electricity	0.55 kg CO_2e/kWh	722.70
Data center (regional)	876.000 kWh electricity	0.55 kg CO_2e/kWh	481.80
Subtotal electricity	**42.705,000 kWh**	—	**23,487.75**
Backup diesel generators	92.000 L diesel	2.68 kg CO_2e/L	246.6
Total footprint	—	—	**23,734.31**

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Methodological Notes

- It was assumed that the ICT infrastructure operates continuously throughout the year, corresponding to **8,760 hours annually**.
- In the absence of official data, the presence of a **small regional data center** with an estimated capacity of **100 kW** was considered.
- The use of **diesel generators** was incorporated into the estimation, assuming that **20% of communication towers** operate on backup power for approximately **200 hours per year**.
- **Household internet electricity consumption** was excluded from the calculations to prevent **double counting**, as it is already included under the **residential energy sector**

The ICT sector in Aswan generated an estimated **23,734 tCO_2e** in 2023, Electricity consumption remained the dominant source, accounting for nearly **99%** of total sectoral emissions, while diesel use from backup generators contributed less than **1%**. The per-subscriber footprint is estimated at approximately **13 kg CO_2e per mobile subscriber per year**, which still indicates relatively high energy efficiency compared with other economic sectors. However, with the sector's rapid expansion and growing data demand, absolute emissions are expected to rise in the coming years. Key mitigation measures include expanding the use of **renewable-powered base stations**, enhancing **data center energy efficiency**, and integrating **smart-grid and energy management systems** across ICT infrastructure

Total Carbon Footprint of Aswan Governorate

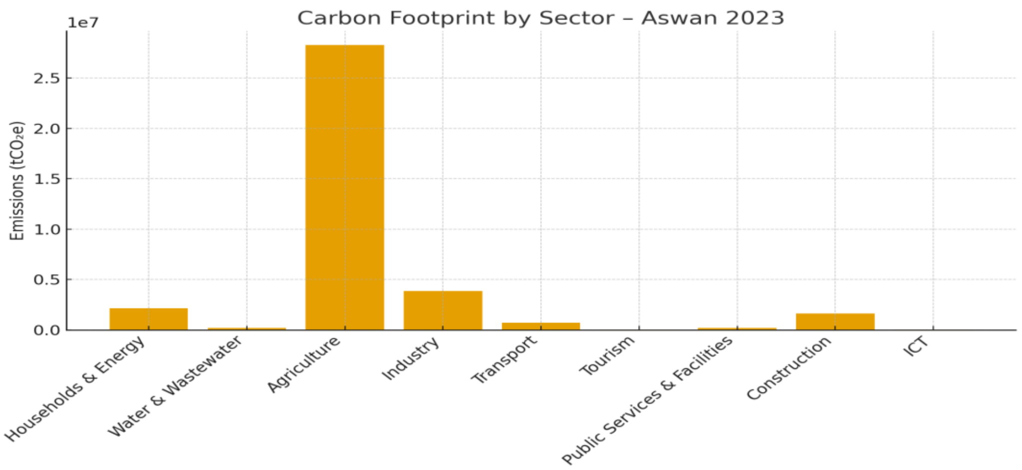
Table (14)

Carbon Footprint of Aswan Governorate – Summary (2023)

Sector	Emissions (t CO_2e)	Share of Total (%)
Households & Energy	2,154,279	5.8
Water & Wastewater	187,500	0.5
Agriculture	28,269,889	76.4
Industry	3,869,641	10.5
Transport	693,031	1.9
Tourism	35,999	0.1
Public Services & Facilities	173,000	0.5
Construction	1,622,990	4.4
ICT	**23,734.31**	0.1
Total	37,030,063.31	100%

Note: Public services and facilities emissions represent the average of two scenarios (low = 156,000; high = 190,000).

Figure (1)



Analytical Indicators

- Population (2023): 1,670,122 persons (CAPMAS).

- GDP (2023): ≈ 118.2 billion EGP (Ministry of Planning).

- Per capita emissions: 22.2 t CO_2e/person/year.

- Per GDP emissions: 313,236 t CO_2e/billion EGP.

- Agriculture dominates (76.4%), followed by Industry (10.5%).

The results clearly indicate that agriculture is the dominant contributor to Aswan's carbon footprint in 2023, responsible for more than three-quarters of total emissions. Industry follows at around 10%, while households and construction contribute smaller but still relevant shares. Sectors such as ICT, tourism, and public services appear negligible in relative terms, though their absolute values remain environmentally significant. This distribution highlights the dual challenge for Aswan: addressing the overwhelming impact of agriculture (notably mechanization, fertilizer use, and residue burning) while also implementing targeted strategies in industry and construction.

Policy Recommendations

1. Energy Efficiency: Improve household electricity efficiency, introduce efficient public lighting, and modernize industrial operations.

2. Renewable Energy Integration: Expand solar PV for ICT infrastructure, water facilities, and public services.

3. Waste-to-Energy & Composting: Reduce agricultural residue burning and household solid waste emissions.

4. Cleaner Transport: Promote modal shift to rail, adopt electric buses, and improve freight truck efficiency.

5. Low-Carbon Construction: Encourage the use of green cement, recycled steel, and electrification of construction machinery.

6. ICT Sector Innovation: Leverage smart-grid solutions and renewable-powered base stations to keep ICT emissions low while expanding digital services.

Potential for Carbon Footprint Reduction and Advancing Economic Sustainability in Aswan Governorate

- **Benban Solar Park as a Model for Clean Energy** Transition The Benban Solar Park, covering 37 km² north of Aswan, is one of the largest renewable energy projects in the Middle East. With a total installed capacity exceeding 1.5 GW, it prevents nearly 2 million tonnes of CO_2 emissions annually compared with an equivalent thermal power source, positioning Aswan as a hub for clean energy in Upper Egypt.

- **Low Industrial Emission Levels:** Industrial activities in Aswan are relatively less polluting compared to other urban governorates, making emission control more achievable without extensive corrective costs.
- **Community Environmental Awareness:** Growing awareness in tourism-dependent areas is strengthening local support for conservation efforts, contributing to the governorate's economic sustainability.
- **Lessons from International Experiences:** Global initiatives highlight diverse approaches to carbon reduction, including renewable energy expansion, electric mobility, carbon-neutral urban planning, circular economy practices, and sustainable agriculture. For Aswan, these lessons translate into:
    - Expanding renewable energy capacity, particularly solar power.
    - Promoting sustainable transport, including electric buses and improved public transit, to reduce emissions from tourism and commuting.
    - Applying green building standards in new developments and encouraging recycling to align with circular economy principles.
    - Introducing low-carbon agricultural practices to enhance soil fertility, water efficiency, and emission reductions.

These opportunities provide Aswan with a clear pathway to reduce its carbon footprint while advancing economic sustainability in line with Egypt's national commitments to climate resilience.

Fourth: SWOT Analysis of Aswan's Carbon Footprint

Table (15)

SWOT Analysis of Aswan's Carbon Footprint

Strengths	**Weaknesses**
• Availability of official sectoral data from CAPMAS and relevant ministries provides a reliable foundation for emission estimation based on real activity data rather than assumptions. • Use of nationally recognized emission factors (ECC, 2023; IGES, 2022) ensures methodological consistency with Egypt's greenhouse gas inventory and enhances comparability across sectors. • Abundant solar resources and flagship renewable projects such as the Benban Solar Park give Aswan a competitive advantage for expanding low-carbon energy generation. • Lower industrial pollution compared to more urbanized governorates means that Aswan starts from a relatively cleaner baseline in its transition toward sustainability. Alignment with national sustainability strategies (Egypt Vision 2030, NDCs) supports policy integration and encourages the development of local carbon management initiatives.	• High dependence on conventional transport systems, mainly diesel-powered vehicles and riverboats, continues to generate significant carbon emissions across mobility activities. • Low energy efficiency in households and industries, particularly small and medium facilities lacking modern equipment or proper insulation, contributes to unnecessary energy loss. • Lack of detailed data for informal activities, including small workshops and unregistered transport, limits the accuracy and completeness of the footprint assessment. • Exclusion of Scope 3 emissions, such as indirect emissions from imported goods and external waste management, leads to underestimation of total emissions. • Limited institutional capacity and the absence of a fixed local monitoring framework hinder continuous carbon tracking and regular data updates.
Opportunities	**Threats**
• Expansion of renewable energy systems, especially decentralized solar PV installations for households and public facilities, can significantly reduce dependence on fossil fuels.	• Rising ambient temperatures driven by climate change will likely increase cooling demand and electricity consumption, offsetting gains from mitigation efforts. • Unregulated urban expansion risks

• Investment in sustainable transport, including electric buses, solar-powered boats, and improved public transit, offers a practical path to reducing fuel-related emissions. • Promotion of energy efficiency programs and smart grids allows better energy management and helps minimize losses across distribution networks. • Agricultural modernization, through efficient irrigation systems, reduced residue burning, and improved fertilizer practices, can substantially lower emissions in the agricultural sector. • Growing environmental awareness among local authorities and communities provides momentum for institutionalizing carbon accounting and sustainable development planning.	increasing per capita emissions and encroaching on agricultural lands, adding pressure to local ecosystems. Financial instability and limited green financing remain major barriers to implementing large-scale renewable or mitigation projects. • Climate variability threatens crop yields and may raise dependence on energy-intensive irrigation, increasing indirect emissions. • Dependence on centralized national decisions may delay local implementation of climate actions, reducing the effectiveness of local mitigation initiatives

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Fifth: Conclusion (Findings and Recommendations)

5/1 Conclusion

The assessment of the carbon footprint of Aswan Governorate for the year 2023 provides a comprehensive overview of sectoral emissions and their underlying drivers. The results reveal that the governorate's total emissions amounted to approximately 37.0 million tonnes of CO_2e, with agriculture emerging as the dominant source. Agricultural practices, particularly the use of fertilizers, mechanization, and residue burning, are responsible for more than three-quarters of the total footprint. Industry, households, and construction also contribute noticeable shares, while sectors such as ICT, tourism, and public services, although relatively minor in percentage terms, remain environmentally relevant.

This distribution underscores a dual challenge: the urgent need to address the structural emissions embedded in agriculture, while simultaneously adopting sector-specific strategies to improve energy efficiency, promote renewable energy, and advance sustainable development across other domains of the local economy.

5/2 Findings

The main empirical findings of the study can be summarized as follows:

5/2/1 Agricultural dominance: Agriculture accounts for 76.4% of total emissions, making it the most critical sector for mitigation efforts.

5/2/2 Moderate industrial share: Industrial emissions represent 10.5% of the total. Compared with other urban governorates, this lower share suggests that emission reduction is achievable without imposing excessive costs.

5/2/3 Significant household and construction emissions: Households contribute 5.8% and construction 4.4%, highlighting the importance of efficiency measures in these sectors.

5/2/4 Secondary but non-negligible sectors: Tourism, ICT, and public services record relatively small percentages, yet their cumulative environmental impact remains meaningful in the context of sustainability planning.

5/2/5 Key analytical indicators:

- Per capita emissions reached 22.2 t CO_2e/person/year, which is relatively high.
- Emissions intensity of GDP was approximately 313,000 t CO_2e per billion EGP, pointing to the need for improved energy productivity and decoupling of emissions from economic growth.

5/2/6 Emerging opportunities: The Benban Solar Park, with its 1.5 GW capacity, prevents nearly 2 million tonnes of CO_2 annually and positions Aswan as a renewable energy hub in Upper Egypt.

5/3 Recommendations

Based on these findings, the study proposes the following policy directions:

5/3/1 Sustainable agriculture

- Promote modern irrigation systems to reduce water and energy consumption.
- Replace open-field burning of residues with composting and waste-to-energy solutions.
- Encourage low-carbon farming practices and improved fertilizer management.

5/3/2 Energy efficiency

- Introduce energy-efficient appliances and expand the use of LED lighting in households and public facilities.
- Develop smart-grid systems to integrate higher shares of solar power.

5/3/3 Green industry and construction

- Upgrade industrial facilities with cleaner production technologies.
- Encourage the use of green cement, recycled steel, and electrified machinery in the construction sector.

5/3/4 Sustainable transport

- Deploy electric buses in urban centers and expand public transit options.
- Enhance the role of river and rail transport to reduce dependence on trucks.

5/3/5 Tourism and ICT

- Apply eco-tourism standards and energy efficiency measures in hotels and tourist facilities.
- Rely on renewable-powered ICT infrastructure to sustain low emissions while expanding digital connectivity.

5/3/6 Governance and community engagement

- Mainstream carbon footprint considerations into local development planning.
- Strengthen community awareness campaigns, especially in rural and tourism-dependent areas.
- Draw on international best practices in renewable energy, clean transport, sustainable urban planning, and circular economy initiatives.

Sixth: Annexs

Annex(1): Agriculture and Livestock Sector Emissions (Aswan 2023)

Estimation of Agricultural Residues and Open Burning Emissions

Agricultural residues constitute a significant source of greenhouse gas emissions in Egypt, particularly due to the practice of open burning in rural areas. According to the Egyptian Environmental Affairs Agency (EEAA, 2018) and the Ministry of Environment (2022), only part of the residues generated from major crops are subjected to open-field burning, while the rest are either used as animal feed, recycled into organic compost, or processed in agro-industries such as sugarcane mills. In this study, the total amount of crop residues was first estimated using the Residue-to-Product Ratios (RPRs) provided by the Food and Agriculture Organization (FAO, 2021) and national agricultural research. However, not all residues are assumed to be burnt. Following the national inventory approach (EEAA, 2018) and consistent with the findings of the National Report on Agricultural Residues Management (MoE, 2022), it is estimated that approximately 30–40% of residues are burned in the open. To avoid overestimation and to align with the most commonly cited national figures, this analysis adopts 35% as the baseline burning fraction.

1. Equations and Assumptions

The following equation was applied in this study to estimate open-burning emissions:

Emissions (t CO_2e) = Crop production (t) × RPR × 35% × EF (kg CO_2e/kg residue) × 0.001

2. Crop Residues and Open-Burning Emissions

Table (16)

Crop Residues and Open-Burning Emissions (2023)

Crop	Production (t)	RPR	Total residues (t)	Burning fraction (%)	Burned residues (t)	EF (kg CO_2e/kg)	Emissions (t CO_2e)
Sugarcane	16,100,000	0.30	4,830,000	35%	1,690,500	1.50	2,535,750
Wheat	110,200	1.30	143,260	35%	50,141	1.50	75,212
Maize	45,600	1.50	68,400	35%	23,940	1.50	35,910
Cotton	5,600	0.20	1,120	35%	392	1.50	588
Total	—	—	5,042,780	35%	1,764,973	—	2,647,460

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Annex(2): Carbon Footprint Calculation — Industrial Sector (Aswan, 2023)

This annex provides a detailed, reproducible calculation of the carbon footprint for two major industrial facilities in Aswan (reference year 2023): KIMA-2 Fertilizer Plant and Medcom Aswan Cement Plant.

All equations use the following symbols:

Q_prod = annual production (t/year)
EF_process = process emission factor (t CO2e / t product)
E_kWh = annual electricity consumption (kWh/year)
EF_elec = electricity emission factor (t CO2e / kWh)
V_NG = annual natural gas volume (m^3/year)
EF_NG = natural gas emission factor (t CO2e / m^3)

Equations:

1) Process emissions (product-based): E_process = Q_prod × EF_process

2) Electricity emissions: E_elec = E_kWh × EF_elec

3) Natural gas combustion (fuel):E_NG = V_NG × EF_NG

4) Total facility emissions (preferred method):
E_total = Σ E_process(products) + E_elec(fuel-related) + E_fuel_others

Table (17)

Emission Factors (EFs) and Key Assumptions

Activity / Parameter	EF (unit)	Source (APA)
Ammonia (process, SMR)	1.8 t CO2 / t NH3	IEA (2019); IFA (2014)
Urea (process)	0.35 t CO2 / t Urea	IPCC (2006)
Electricity (Egypt grid average)	0.00055 t CO2 / kWh	EEAA (2022); Egyptian Carbon Center
Natural gas (combustion)	0.00210 t CO2 / m^3	IPCC (2006) / national estimates

KIMA-2 Fertilizer Plant (Aswan): Detailed Calculations

Input data

• Ammonia (design capacity): Q_NH3 = 435,000 t/year
• Urea (design capacity): Q_Urea = 570,000 t/year
• On-site power: P = 27.2 MW (assumed max continuous for sensitivity)
• Natural gas design throughput (project reference): V_NG_design ≈ 438,000,000 m^3/year
• Reference workdays in Mubasher doc: 330 days/year

Table (18)

Estimated Carbon Footprint of KIMA-2

Activity	Formula / Steps	Intermediate units	Emissions (t CO2e/yr)
Ammonia (process)	E = Q_NH3 × EF_NH3 = 435,000 × 1.8	t × (tCO2/t)	783,000
Urea (process)	E = Q_Urea × EF_Urea = 570,000 × 0.35	t × (tCO2/t)	199,500
Electricity (upper bound)	E_kWh = P × hours = 27.2 MW × 8,760 h = 238,272 MWh = 238,272,000 kWh E_elec = E_kWh × EF_elec	kWh × (tCO2/kWh)	131,049.6
Total (preferred)	-	-	1,113,549.6

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Medcom Aswan Cement Plant: Detailed Calculations

Input data / assumptions:

• Cement production (finished): Q_cement = 750,000 t/year
• Clinker production (approx.): Q_clinker ≈ 913,000 t/year
• Electricity intensity: 90 kWh / t cement (WBCSD estimate)
• EF_elec = 0.00055 tCO2/kWh
• Process EF (calcination) = 0.52 tCO2 / t clinker (IPCC)
• Fuel combustion EF (approx.) = 0.35 tCO2 / t clinker (WBCSD range)

Table (19)

Estimated Carbon Footprint of Medcom Aswan Cement(2023)

Emission Source	Formula / Steps	Intermediate units	Emissions (t CO2e/yr)
Calcination (process)	E = Q_clinker × 0.52 = 913,000 × 0.52	t × (tCO2/t)	474,760
Fuel combustion	E = Q_clinker × 0.35 = 913,000 × 0.35	t × (tCO2/t)	319,550
Electricity	E_kWh = Q_cement × 90 kWh/t = 750,000 × 90 = 67,500,000 kWh E_elec = 67,500,000 × 0.00055	kWh × (tCO2/kWh)	37,125
Total	-	-	831,435

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Table (20)

Aggregated Industrial Emissions (Selected Facilities)

Facility	Emissions (t CO2e/yr)
KIMA-2 (preferred)	1,113,550
Medcom Aswan Cement	831,435
Selected facilities total	1944985

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