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Climate Change and CO_2 in the Municipality of Campinas/SP

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Mudanças climáticas e plano de ação de mitigação das emissões de CO_2 no município de Campinas/SP

RESUMO

Objetivo - Este artigo tem como objetivo analisar como as metas de redução das emissões de CO_2 do Plano Local de Ação Climática de Campinas/SP (PLAC), podem se alinhar com a Política Municipal de Enfrentamento dos Impactos das Mudanças Climáticas de Campinas.

Metodologia - O método de pesquisa é qualitativo, descritivo e documental.

Originalidade/relevância - A relevância do artigo reside em examinar as emissões de GEE no município de Campinas, focando nas transições necessárias identificadas em suas políticas e planos de combate à crise climática para tornar o município mais sustentável, inclusivo e resiliente.

Resultados - As evidências científicas mostram que o aquecimento global já está avançado, impulsionado pelas atividades humanas que emitem Gases de Efeito Estufa (GEE). Mesmo que as emissões futuras sejam drasticamente reduzidas, os efeitos das emissões passadas continuarão a impactar o clima global por décadas. Isso torna urgente não apenas reduzir as emissões, mas também adotar medidas de adaptação e mitigação para minimizar os impactos das mudanças climáticas em curso.

Contribuições teóricas - O estudo concluiu que cidades que controlam suas emissões, com visão e ações de curto, médio e longo prazo, para o enfrentamento das crises climáticas, com objetivos quantificáveis, reportáveis e verificáveis, e soluções inovadoras, estão mais bem preparadas para enfrentar eventos climáticos extremos, como enchentes, secas e ondas de calor, as quais tendem a ser intensificados em virtude do aquecimento global.

Contribuições sociais e ambientais - As emissões de Gases de Efeito Estufa (GEE) são apontadas como as principais responsáveis pelas mudanças climáticas no planeta. As cidades e as indústrias são os grandes geradores de GEE gerando consequências nocivas à população. Mitigar as mudanças climáticas e adaptar-se aos seus efeitos são questões centrais na formulação de políticas públicas em todos os níveis — nacional, estadual e local.

PALAVRAS-CHAVE: Emissões de Gases de Efeito Estufa (GEE). Mudanças Climáticas. Sustentabilidade.

Climate Change and the CO_2 Emissions Mitigation Action Plan in the Municipality of Campinas/SP

ABSTRACT

Objective – This article analyzes how the CO_2 emission reduction targets of the Campinas/SP Local Climate Action Plan (PLAC) can align with the Municipal Policy to Address the Impacts of Climate Change in Campinas

Methodology – The research method adopted is qualitative, descriptive, and documentary.

Originality/Relevance – The relevance of the article lies in examining GHG emissions in the municipality of Campinas, focusing on the necessary transitions identified in its policies and plans to combat the climate crisis to make the municipality more sustainable, inclusive and resilient.

Results – Scientific evidence shows that global warming is already advanced, driven by human activities that emit Greenhouse Gases (GHG). Even if future emissions are drastically reduced, the effects of past emissions will continue to impact the global climate for decades. This makes it urgent not only to reduce emissions, but also to adopt adaptation and mitigation measures to minimize the impacts of ongoing climate change.

Theoretical Contributions – The study concludes that cities that control their emissions, with short, medium, and long-term visions and actions to address climate crises, with measurable, reportable, and verifiable goals, and innovative solutions, are better prepared to face extreme weather events, such as floods, droughts, and heatwaves, which tend to intensify due to global warming.

Social and Environmental Contributions – Greenhouse Gas (GHG) emissions are identified as the main drivers of climate change. Cities and industries are the major GHG emitters, and the population bears the consequences. Mitigating climate change and adapting to its effects are central issues in public policy formulation at all levels — national, state, and local.

KEYWORDS: Greenhouse Gas Emissions (GHG). Climate Change. Sustainability.

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Cambio Climático y el Plan de Acción para la Mitigación de Emisiones de CO_2 en el Municipio de Campinas/SP

RESUMEN

Objetivo – Este artículo tiene como objetivo analizar cómo los objetivos de reducción de emisiones de CO_2 del Plan Local de Acción Climática de Campinas/SP (PLAC) pueden alinearse con la Política Municipal para Enfrentar los Impactos del Cambio Climático de Campinas.

Metodología – El método de investigación adoptado es cualitativo, descriptivo y documental.

Originalidad/Relevancia – La relevancia del artículo radica en examinar las emisiones de GEI en el municipio de Campinas, centrándose en las transiciones necesarias identificadas en sus políticas y planes de combate a la crisis climática para hacer el municipio más sostenible, inclusivo y resiliente.

Resultados – La evidencia científica muestra que el calentamiento global ya está avanzado, impulsado por actividades humanas que emiten Gases de Efecto Invernadero (GEI). Incluso si las emisiones futuras se reducen drásticamente, los efectos de las emisiones pasadas seguirán impactando el clima global durante décadas. Esto hace que sea urgente no sólo reducir las emisiones, sino también adoptar medidas de adaptación y mitigación para minimizar los impactos del cambio climático en curso.

Contribuciones Teóricas – El estudio concluye que las ciudades que controlan sus emisiones, con visión y acciones a corto, medio y largo plazo para enfrentar las crisis climáticas, con objetivos cuantificables, reportables y verificables, y soluciones innovadoras, están mejor preparadas para enfrentar eventos climáticos extremos, como inundaciones, sequías y olas de calor, los cuales tienden a intensificarse debido al calentamiento global.

Contribuciones Sociales y Ambientales – Las emisiones de Gases de Efecto Invernadero (GEI) son señaladas como las principales responsables del cambio climático en el planeta. Las ciudades y las industrias son los grandes generadores de GEI y la población sufre las consecuencias. Mitigar el cambio climático y adaptarse a sus efectos son cuestiones centrales en la formulación de políticas públicas en todos los niveles —nacional, estatal y local.

PALABRAS CLAVE: Emisiones de Gases de Efecto Invernadero (GEI). Cambio Climático. Sostenibilidad.

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1 INTRODUCTION

Climate change has been recognized as one of the greatest challenges to global sustainability, resulting from human activities that produce Greenhouse Gas (GHG) emissions, such as carbon dioxide (CO_2). These emissions are driven by fossil fuel combustion, deforestation, land use for agriculture, and other industrial activities, contributing to global warming and changes in climate patterns. Climate stabilization requires rapid and sustained reductions in greenhouse gas emissions, with a particular focus on reducing CO_2 emissions to avoid catastrophic climate impacts in the future (IPCC, 2023; Fawzy et al., 2020). On a global scale, the ramifications of these changes are evident across various sectors, from agriculture to public health, with even more pronounced effects in urban environments.

Approximately 40% of the world's population lives in areas vulnerable to climate change, and Brazil is located in a region with a high mortality rate from climate events (Birmann et al., 2022). The most vulnerable regions of the world must be prioritized in climate-resilient development initiatives, as they have already faced disproportionate impacts due to climate-related disasters. The validation of the World Resources Index (WRI) and INFORM Index, conducted by Birmann et al. (2022), demonstrated that a country's vulnerability amplifies the effects of natural phenomena such as floods, droughts, and storms, resulting in higher mortality rates compared to less vulnerable countries. This discrepancy of up to 15 times in mortality per climate event between highly and less vulnerable countries highlights the urgency of directing adaptive efforts toward the most affected areas to mitigate future risks and protect both human and non-human lives.

Climate change is considered so significant and challenging that in 1988, the World Meteorological Organization (WMO) and the United Nations Environment Program (UNEP) formed the Intergovernmental Panel on Climate Change (IPCC). The IPCC analyzes scientific work worldwide to create and compile reports that serve as a basis for public policies around the world and international negotiations. In the 1990s, the IPCC began providing reliable scientific and technical assessments to policymakers for climate change mitigation.

The most recent IPCC report, the Synthesis Report (SYR) identified as the AR6 Assessment Report of 2023. In its presentation the IPCC (2023) confirms that due to fossil fuel combustion, Earth's temperature increased by 1.1ºC between 2011-2020 compared to 1850-1900. This systematic increase in global temperature causes adverse impacts and loss and damage to human lives and nature. The report states that limiting global warming requires immediate action to achieve net-zero CO_2 emissions. Only a structured and profound mitigation process, implemented with a sense of urgency, will reduce projected losses and damages to ecosystems and human beings.

IPCC projections (2023) for 2030, based on nationally determined contributions (NDCs), show a temperature increase of 1.5ºC in the first half of the 2030s and indicate a major challenge in controlling a rise close to 2ºC by the end of the 21st century. The NDCs are thus key elements for achieving any climate change mitigation and should be pursued by each country and municipality. Climate change demands various initiatives, ranging from global agreements to national and local actions, in the municipality where one lives. Another crucial aspect is the importance of Greenhouse Gases (GHG) that contribute to global temperature increases. The most impactful anthropogenic emissions are related to CO_2 - carbon dioxide - emissions, resulting from fossil fuel combustion and industrial processes. Although varying across countries due to development stages,

> [...] Approximately 48% of the world's population in 2019 lived in countries emitting an average of more than 6 metric tons of CO_2 equivalent (tCO_2e) per capita; about 35%

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> lived in countries emitting more than 9 tCO_2e, while 41% lived in countries emitting less than 39 tCO_2e (IPCC, 2023, p. 62).

The municipality of Campinas, located in the state of São Paulo, is a significant economic and technological hub where industrial operations and urban expansion contribute to CO_2 emissions. Given the local and global importance of this phenomenon, the city of Campinas has implemented several initiatives, including the Local Climate Action Plan (Campinas, 2024a), aimed at harmonizing urban development with mitigation and adaptation strategies in response to climate change.

With the publication of the PLAC in 2024, Campinas became the "14th Brazilian city, the 3rd in the state of São Paulo, and the first in the Piracicaba-Jundiaí (PCJ) Basin and Metropolitan Region of Campinas to have a plan recognizing future trends and climate risks" (Campinas, 2024a, p. 7), establishing strategic actions for climate change mitigation. It is also worth noting that since 2013 Campinas has voluntarily assumed the commitment to take measures aligned with global and local actions to tackle climate change. In 2021, Campinas joined the Climate Action Alliance (ACA), a coalition to coordinate and promote measures to combat the climate crisis, meeting the commitments of the Paris Agreement (Campinas, 2024a). In 2022, Campinas adhered to the United Nations Framework on Climate Change (UNFCCC), integrating the Cities Race to Zero and Race to Resilience, global climate mitigation and adaptation campaigns, and at the state level, joined the São Paulo State Government's Environmental Agreement for voluntary GHG emission reduction commitments (Campinas, 2024a).

Furthermore, in 2020, Campinas established Law No. 16.022, of November 5, 2020, the Policy for Addressing the Impacts of Climate Change and Air Pollution in Campinas (Campinas, 2020). This law sets clear targets for reducing anthropic emissions in the municipality based on the Metropolitan Inventory of Greenhouse Gas Emissions and Air Pollutants, using 2016 as the baseline year.

It is observed that the goals for reducing GHG emissions are in compliance with international treaties and agreements, as well as the voluntary targets established by Brazil within the International Climate Community and the Federal, State, and Municipal regulations (Campinas, 2020).

In 2020, Campinas was committed to reducing emissions by 5% by 2025, 8% by 2030, 16% by 2040 and 32% by 2060. Among the challenges of these goals, it is noteworthy that in 2016, Campinas emitted 2.7 million tons of carbon dioxide equivalent (tCO_2e) and, by 2021, this number had already risen to 3.5 million tons, representing an increase of approximately 33% (Campinas, 2024a). To achieve the first reduction target by 2025, Campinas must emit approximately 2.56 million tons of carbon dioxide equivalent, that is, a reduction of around 1 million tons of CO_2 compared to 2021 levels.

In this context, the following research problem arises: What have been the CO_2 emissions trends in Campinas in recent years? How does the Local Climate Action Plan address the development of long-term emission reduction actions?

2 OBJECTIVE

This article aims to analyze how the CO_2 emission targets of Campinas' Local Climate Action Plan (PLAC) align with the Municipal Policy for Addressing Climate Change Impacts.

3 METODOLOGY

Periódico Eletrônico Fórum Ambiental da Alta Paulista
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Edição em Português e Inglês / *Edition in Portuguese and English* - v. 21, n. 1, 2025

The research method employed is qualitative, descriptive, and documentary. Qualitative research allows for an understanding of the nature of a social phenomenon and the functioning of social structures (Richardson, 2007). While the descriptive research is applied to characterize a population or define relationships between variables (Gil, 2008).

The study adopts a case study approach to analyze how the CO_2 emission targets of Campinas/SP align with the Municipal Climate Change Policy. Case study methodology is a strategy used to answer questions about a contemporary social phenomenon by exploring "how" and "why" (Yin, 2015).

The choice of a case study is justified by the ongoing and potential actions in Campinas/SP aimed at reducing CO_2 emissions, with targets extending to 2050. Campinas was the 14th Brazilian city, the 3rd in the State of São Paulo, and the 1st in the Metropolitan Region of Campinas to develop a Climate Action Plan (2024) with strategic axes for climate goals until 2050.

As for documentary research, publicly accessible official reports and documents were used. According to Severino (2013, p. 106), documentary research includes data sources "not only from printed documents but also from other types such as newspapers, photos, films, recordings, and legal documents" that have not undergone analytical processing.

Data collection was conducted based on documents addressing climate change and greenhouse gas emissions. For this purpose, data from the following documents were used: (1) Campinas/SP Local Climate Action Plan (PLAC), developed in 2024 by the city's Department of Climate, Environment, and Sustainability with support from the World Resources Institute (WRI) Brazil; (2) PLAC – Greenhouse Gas Emissions Inventory (2024); (3) Municipal Policy for Addressing Climate Change Impacts and Air Pollution in Campinas (2020); (4) Climate Change 2023: Synthesis Report (IPCC, 2023).

4 CLIMATE CHANGE

The Intergovernmental Panel on Climate Change (IPCC), in its Fifth Assessment Report on Climate Change (AR5) from 2018 (IOPCC, 2018), defines GMST as the Global Mean Surface Temperature. The term GMST refers to:

> the globally estimated average of near-surface air temperatures over land and sea ice, and at sea surface temperatures over ice-free ocean regions, with variations typically expressed as deviations from a specified reference period" (IPCC, 2018, p. 27).

In the same document, global warming is defined as "an estimated increase in the mean surface temperature over a 30-year period, or the 30-year period centered on a given year or decade, expressed relative to pre-industrial levels unless otherwise specified" (IPCC, 2018, p. 27).

Mitigating climate change and adapting to its effects are central elements in formulating global and local public policies. Although efforts to mitigate Greenhouse Gas (GHG) emissions are essential, ongoing climate change makes adaptation essential to minimize impacts. However, progress in implementing adaptation measures has not kept pace with increasing climate risks, especially in developing countries. The Adaptation Gap Report 2023 reveals that although 85% of countries have at least one adaptation planning instrument in place, implementing these plans still faces significant challenges, such as funding gaps and difficulties in Monitoring and Evaluation (M&E) (United Nations Environment Programme, 2023).

The same report emphasizes the need to strengthen the monitoring and evaluation of adaptation actions, as less than 6% of reported measures provide information on their actual

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outcomes. It also underscores the importance of increasing international funding, as the adaptation financing gap for developing countries is estimated between $194 billion and $366 billion annually.

Another crucial aspect addressed is the issue of loss and damage, which has emerged as a third pillar of climate policies alongside mitigation and adaptation. Given the slow progress in reducing GHG emissions and adapting to climate risks, many losses and damages are already occurring, with the expectation that more are inevitable (United Nations Environment Programme, 2023). This highlights the urgency of effective governance and the need for innovative financing sources to address the financial and operational challenges associated with these losses and damages.

In this context, Mendes and Viola (2023) discuss interest groups in Brazilian climate policy, focusing on the agricultural and energy sectors. The authors highlight that agreements and sectoral interests, as well as the public sphere for low-carbon transition, exert pressure on climate institutions and industries in the agricultural and energy sectors, particularly regarding deforestation and forest degradation.

It is believed that local mitigation and adaptation plans of the climate and climate change policies must be supported by a robust governance structure. that includes adequate financing mechanisms, clear merger and acquisition strategies, and an inclusive approach that considers the particularities of different population groups and their vulnerabilities.

5 GREENHOUSE GAS EMISSION-GENERATING ACTIVITIES

In both national and international scientific literature, it is widely accepted that human activities are the primary drivers of global warming and climate change effects.

> Humans have significantly disrupted the energy balance of the climate system, mainly not only by extracting and burning fossil fuels but also through land-use changes and the use of halocarbons. Agriculture and waste management also release nitrous oxide and methane into the atmosphere, both of which are potent greenhouse gases (GHGs). In response to anthropogenic GHG emissions, the global atmosphere has warmed over the past half-century (Bruhwiler *et al*., 2021, p. 2).

According to the AR6 Synthesis Report (IPCC, 2023), as previously mentioned, when comparing the period from 2011 to 2020 with the baseline from 1850 to 1900, the global surface temperature was 1.1°C higher. Specifically, land surfaces recorded an average increase of 1.59°C, with regional variations ranging from 1.34°C to 1.83°C, depending on geographical location. Meanwhile, oceans experienced an average warming of 0.88°C, with variations between 0.68°C and 1.1°C. Changes resulting from this global warming are observed, such as the impacts of human activity, mainly through emissions of Greenhouse Gases (GHG), dominated by carbon dioxide (CO_2) and methane (CH4).

With the current level of CO_2 emissions and existing greenhouse gas reduction policies, global warming is expected to exceed 1.50°C in the 2020s and likely surpass 2°C before 2050 (Hansen et al., 2023). While GHGs contribute to the greenhouse effect, which warms the atmosphere, anthropogenic particles suspended in the atmosphere, such as dust, soot, and other compounds, reflect some solar radiation back into space, therefore, even if GHG emissions were drastically reduced, the planet would still suffer the significant consequences of climate change caused by past GHG emissions (Hansen et al., 2023).

Among the main anthropic GHG-emitting activities, the most notable are electricity generation, fossil fuel use in transportation, waste disposal, activities categorized under the acronym AFOLU, which includes Agriculture, Forestry, and Other Land Use. This term is used in the context of climate change and refers to human activities that affect land use, such as

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Edição em Português e Inglês / *Edition in Portuguese and English* - v. 21, n. 1, 2025

agriculture, forest management and other land-use practices that influence greenhouse gas emissions or sequestration.

For example, the study by Aguilar and Paulino (2024) discusses productive practices based on agroecology and regenerative agriculture aimed at mitigating GHG emissions and enhancing local climate resilience, however, the effectiveness of these practices requires political support, which could pose a challenge to their implementation.

Globally, in 2021, these activities contributed the following CO_2e emissions in billions of tons: Energy - 34.41; Transportation - 7.84; Waste - 1.68; Agriculture, Forestry, and Other Land Use - 7.2 (Climate Watch, 2024). Table 1 highlights the percentage of CO_2e emissions in 2021 for Brazil, the world, and Campinas/SP.

Tabela 1 - Percentage of CO_2e emissions in 2021.

Titles	Energy	Transportation	Waste	AFOLU
World	69%	14%	3%	13%
Brazil	29%	12%	4%	55%
Campinas	22%	60%	17%	1%

Source: Authors, 2024 - Adapted from Climate Watch and Campinas, 2024a.

Table 1 shows how the proportion of each major GHG-emitting activity differs significantly when comparing global data with Brazil and the city of Campinas. In Campinas, transportation accounts for 60% of emissions (Campinas, 2024a), nearly three times the impact of the same activity worldwide or in Brazil. The GHG emissions from energy generation in both Brazil and Campinas are significantly lower than global figures.

This comparison suggests that climate change mitigation policies must be tailored to the characteristics of each world region. The municipality of Campinas can define in its policies and action plans how to guide its efforts to mitigate GHG emissions in accordance with the priorities presented in the Greenhouse Gas Emissions Inventory (Campinas, 2024b), focusing efforts on reducing emissions from the most impactful activities.

6 DISCUSSION ON GREENHOUSE GAS EMISSIONS IN CAMPINAS/SP

The final agreement of COP 28, the 28th UN Climate Conference held in Dubai, was considered a significant step forward as it included the gradual reduction of fossil fuel use (oil, coal, and natural gas) as a measure to lower greenhouse gas emissions, main responsible for the climate changes that affect the planet. At COP 28, cities gained importance in the discussion on global warming, as they are both major contributors to emissions and among the most vulnerable to its consequences. For countries to increase their climate goals' ambition, active municipal involvement will be essential.

According to PLAC Campinas (Campinas, 2024a), since 2013, Campinas voluntarily assumed, before Brazilian institutions and international bodies, the commitment to take measures aligned with global actions to tackle climate change. Climate issues are central to the city's governance, involving inclusion, equality, and prosperity. The municipality aims to implement public policies that foster a fair and equitable society while emphasizing social responsibility in addressing climate impacts. To institutionalize this commitment, Campinas established the Municipal Policy for Addressing Climate Change Impacts and Atmospheric Pollution through Municipal Law No. 16.022, enacted on November 5, 2020 (Campinas, 2020).

Municipal Law No. 16,022 is aligned with the guidelines of the 1992 United Nations Framework Convention on Climate Change; the Kyoto Protocol approved by the 1997 United Nations Framework Convention on Climate Change; the National Policy on Climate Change -

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Federal Law No. 12,187 of December 29, 2009; the State Policy on Climate Change - State Law No. 13,79 of November 9, 2009; the Paris Agreement, enacted by Federal Decree No. 9,705 of July 5, 2017; and the Global Covenant of Mayors for Climate and Energy, of which the city of Campinas/SP is a signatory. Therefore, Municipal Law No. 16,022 has as its principle the relevance of local government action in supporting the implementation of international and national policies to mitigate and adapt to climate change and to combat air pollution.

Another crucial aspect is the issue of losses and damages, which is emerging as the third pillar of climate policies alongside mitigation and adaptation. Given the slow progress in reducing GHG emissions and adapting to climate risks, many losses and damages are already occurring, with expectations of more becoming inevitable (United Nations Environment Programme, 2023). This underscores the urgency of effective governance and the need for innovative financing mechanisms to address the financial and operational challenges arising from these losses and damages.

In February 2024, the Campinas City Hall announced its local climate action plan, which includes measures to tackle climate change impacts, including the creation of the Climate Change Response Committee and reorganizing various municipal activities under a newly created Secretariat named the Municipal Secretariat for Climate, Environment, and Sustainability (SECLIMAS). Additionally, the 2024 Climate Action Plan was launched (Campinas, 2024a). The Plan is a

> strategic document aims to provide the city with an integrated and inclusive vision, aligned with social, environmental, and economic priorities, and includes the necessary enablers and implementation milestones for reducing greenhouse gas emissions (Campinas, 2024a, p. 6).

The Campinas PLAC reflects the municipality's adherence to the State Plan for Climate Adaptation and Resilience (PERAC) – SP, according to the Secretary of Environment of the State of São Paulo, Jonas de Souza Trindade (Campinas, 2024a). Campinas' Climate Action Plan received technical support from the Ross Center for Sustainable Cities (WRI Brazil), an organization dedicated to promoting sustainable development in urban areas. The center collaborates to make cities more resilient, inclusive, and sustainable, addressing challenges such as climate change, urban growth, and social inequalities.

In February 2024, the Campinas City Hall made available a report on the Greenhouse Gas (GHG) Inventories of Campinas for the base years 2016, 2019, 2020, and 2021. The report was titled "Campinas Climate Action Plan - Greenhouse Gas (GHG) Emissions Inventory - Comparative Analysis 2016-2021 - Version II" (Campinas, 2024b). This report provides a comparative analysis of GHG emission inventories for the years 2016, 2019, 2020, and 2021. The inventories cover Scopes 1, 2, and 3 and analyze the Stationary Energy, Transportation, Waste and Effluents, and AFOLU (Agriculture, Forestry, and Land Use) sectors. Below, Table 2 presents a summary of these GHG emissions.

Table 2 - GHG Emissions in Campinas by Year and Sector (in thousand tons of CO2 equivalent).

Sector	2016		2019		2020		2021	
Stationary Energy	559.42	21%	622.17	19%	541.48	19%	783.52	22%
Transportation	1,864.73	70%	1,997.49	61%	1,652.94	58%	2,137.01	60%
Waste	186.47	7%	622.17	19%	626.98	22%	605.49	17%
AFOLU	53.28	2%	32.75	1%	28.50	1%	35.62	1%
Total	2,663.90	100%	3,274.58	100%	2,849.90	100%	3.561.69	100%

Source: Authors, 2024. Adapted from Campinas Reports (2024a) and Campinas (2024b).

Periódico Eletrônico Fórum Ambiental da Alta Paulista
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ISSN 2966-2931 Suporte Online / Online Support - ISSN 1980-0827 Suporte CD-ROM / CD-ROM Support
Edição em Português e Inglês / *Edition in Portuguese and English* - v. 21, n. 1, 2025

The consolidated results show that in 2016, Campinas emitted a total of 2,663,901 tCO_2e, with Scope 1 accounting for the majority of emissions (2,350,698 tCO_2e, or 88% of the total). In 2019, total emissions increased to 3,274,580 tCO_2e, with Scope 1 representing 2,851,168 tCO_2e, or 87% of the total. In 2020, emissions decreased to 2,849,899 tCO_2e, with Scope 1 accounting for 2,491,345 tCO_2e, or 87.4% of the total. By 2021, emissions rose again, totaling 3,561,690 tCO_2e, with Scope 1 responsible for 3,005,958 tCO_2e, or 84% of the total. The reduction in emissions in 2020 is directly related to the COVID-19 pandemic (Campinas, 2024b).

Comparing only total GHG emissions, there was an increase of approximately 23% between 2016 and 2019, followed by a 13% reduction between 2019 and 2020, but an overall increase of 34% between 2016 and 2021 (Campinas, 2024b).

6.1 Greenhouse Gas Emissions in Campinas/SP from the Transportation and Stationary Energy Sectors

The Transportation sector has been the largest emitter of Greenhouse Gases (GHG) in Campinas in recent years, accounting for 70% of emissions in 2016, 61% in 2019, 58% in 2020, and 60% in 2021. Compared to 2016, CO_2 emissions in the transportation sector increased by 12% in 2021 (Campinas, 2024b).

As in other major cities, the primary source of GHG emissions in Campinas is linked to energy use for transportation, particularly the burning of fossil fuels such as gasoline, natural gas, and diesel in cars, motorcycles, buses, and trucks, as well as airplanes refueled at Viracopos International Airport, which contributes approximately 55% of the city's total transportation emissions (Campinas, 2024a).

The Stationary Energy sector is the second largest GHG emitter in the city. According to the 2021 GHG Emissions Inventory, approximately 21% of CO_2e emissions are related to energy consumption in residences and other buildings. Of this total, 11% of emissions come from electricity use, while the remaining 10% come from the use of natural gas and cooking gas. Almost all electricity consumed in Campinas is produced outside the municipality and supplied through the National Interconnected System (SIN). Cooking gas, mainly composed of methane, is produced by Replan and distributed by different companies, either as piped gas or in cylinders. Some families resort to firewood when gas prices increase.

According to the data described above, it is clear that in the municipality of Campinas the priority is to adopt practices that can mitigate GHG emissions caused mainly by the Transportation and Stationary Energy sectors.

6.2 GHG Reduction Targets in the Context of International Agreements

In 2022, Campinas joined the Cities Race to Zero and Cities Race to Resilience initiatives, committing to the goals of the Paris Agreement, according to Municipal Law No. 16,022 of November 5, 2020 (Campinas, 2020). In the 2024 Climate Action Plan, the city aims to reduce its GHG emissions by 35% by 2030, 55% by 2040, and 80% by 2050, using 2016 levels as a baseline. These targets align with Chapter III of Municipal Law No. 16,022, which establishes guidelines, objectives, and targets for addressing climate change.

The law requires that the municipal plan include "quantifiable, reportable, and verifiable objectives for the reduction of Greenhouse Gases and pollutants from anthropic activities" (Law No. 16.022, 2020, p. 6).

However, there is a difference between the GHG reduction targets established by the 2020 Municipal Law (Campinas, 2020) and the 2024 PLAC (Campinas, 2024a). The PLAC sets more ambitious targets due to the severity of climate transformations. While the 2020 law

proposed a reduction of 5% by 2025, 8% by 2030, 16% by 2040, and 32% by 2060, the 2024 PLAC, aligned with international and national agreements, defines targets of 5% by 2025, 35% by 2030, 55% by 2040, and 80% by 2050.

The justification given (Campinas, 2024a) was that, due to Campinas' international commitments and its adherence to the Paris Agreement, it became necessary to increase the targets established in 2020 under the Municipal Policy (Campinas, 2024a).

The Transportation sector, the primary source of greenhouse gas (GHG) emissions in the municipality, has specific targets in the Local Climate Action Plan (Campinas, 2024a): a 5% reduction by 2025, 21% by 2030, 55% by 2040, and 80% by 2050. The Stationary Energy sector, the second-largest emitter, has the following reduction targets: 5% by 2025, 15% by 2030, 24% by 2040, and 44% by 2050 (Campinas, 2024a).

The 2024 Climate Action Plan aims to transform Campinas into a sustainable and resilient city by 2050, focusing on low-carbon development and socio-environmental justice. To comply with the 2020 Municipal Law, the plan must align with the commitments made by Brazil and the State of São Paulo, as well as the municipality's international, national, and state-level agreements.

Regarding the economic challenges in implementing the PLAC targets, a global joint effort involving public authorities and Civil Society Organizations is essential for achieving a low-carbon city with climate justice. Resolving this issue requires participation and influence from multisectoral civil society agents capable of coordinating the entities involved in agreements on climate risks.

From this perspective, the greatest economic challenge is failing to consider the diagnosis and analysis of Campinas' current situation regarding the prioritization and direction of public investment, involving the business sector, which can help establish a solid foundation for advancing decisions on climate change mitigation and adaptation strategies, particularly those aligned with sectoral policies for social, urban, and environmental planning and development.

This broader issue cannot be attributed to a single cause, therefore, it is believed that attempting to understand Campinas' situation without considering the common dynamics that hinder investments in the implementation and supervision of the PLAC would be ineffective. Well, it seems that creating conditions for the full and equal participation of society, in view of the benefits arising from these actions, is a way to demonstrate the impact and commitment so that future generations can enjoy a quality of life similar to that of current generation.

It is clear that implementing the PLAC targets requires a perspective that does not separate economic, political, and social factors. This involves considering the limiting factors of each goal, using Veiga (2015) approach, and recognizing the ecological costs that are difficult to assess and associated with increasing the scale of the economic system.

The economic challenges in implementing municipal climate changes adaptation and mitigation plans, along with insufficient investment in infrastructure and deficiencies in monitoring plan actions, were discussed in the study by Masiero, Menegaldo, and Tavares (2023). It is noteworthy that, in cities across different countries, implementation challenges are linked to the region's natural conditions and resource availability. In Brazilian cities, however, there is a gap between planned and executed actions in terms of targets and resource allocation for climate change mitigation and adaptation (Masiero, Menegaldo, and Tavares, 2023).

6.3 Climate Commitments and Campinas/SP Action Plan

By joining climate initiatives, Campinas has revised its targets for a more sustainable future, committing to reducing emissions and developing low-carbon infrastructure. To achieve

Periódico Eletrônico Fórum Ambiental da Alta Paulista
Electronic Journal Environmental Forum of Alta Paulista
ISSN 2966-2931 Suporte Online / Online Support - ISSN 1980-0827 Suporte CD-ROM / CD-ROM Support
Edição em Português e Inglês / *Edition in Portuguese and English* - v. 21, n. 1, 2025

these goals, the municipality has aligned itself with Brazil's Nationally Determined Contributions (NDCs), the targets of the Government of the State of São Paulo, and other cities with similar economic and emissions profiles (Campinas, 2024, p. 39).

To ensure these targets are met, PLAC 2024 has established a multi-year action plan covering actions from 2024 to 2050. Campinas' Climate Action Plan is structured around five Strategic Axes, all aligned with the United Nations' Sustainable Development Goals (SDGs). Each axis has a specific focus.

Strategic Axis 1 focuses on promoting renewable energy and resilient buildings. Strategic Axis 2 is dedicated to building resilient basic sanitation systems. Strategic Axis 3, related to urban mobility and sustainable transportation, is particularly important as it encompasses the transportation sector, which is the largest CO_2 emitter in Campinas. Strategic Axis 4 addresses urban and rural development in relation to climate. Strategic Axis 5 focuses on education, resilience, and climate integration.

In Strategic Axis 1, the goal is to implement a social housing program that is resilient to climate change, improve energy efficiency, and increase the use of renewable energy in buildings. These goals are aligned with the UNO Sustainable Development Goals (SDGs) 7, 11, 13, and 17. The objective is to proactively establish a renewable, efficient, and reliable energy system with resilient buildings. To achieve this, the focus is on electricity and gas consumption across different types of constructions (buildings, residences, commercial and industrial establishments), in addition to considering design and resilience aspects of these structures

In Strategic Axis 3, the goal is to develop infrastructure that prioritizes active, inclusive and high-quality mobility while encouraging the transition to low-carbon transportation. These goals align directly with SDGs 9, 11, 12, 13, and 17. Key planned actions include improving and integrating the public transportation system to attract more users, the expansion of pedestrian-friendly and accessible networks, the expansion of the cycling network with integration into public transportation and green infrastructure, and promoting the adoption of low-carbon transportation modes.

The transportation sector in Campinas was responsible for approximately 60% of the city's Greenhouse Gas (GHG) emissions in 2021 (Campinas, 2024a). The city has approximately 962,000 motorized land vehicles, with car usage being predominant, accounting for 68% of trips in 2022. As the center of the Campinas Metropolitan Region, the city faces high demand for intermunicipal travel. Another major challenge is balancing the economic growth driven by Viracopos International Airport with the need to reduce GHG emissions. The municipal public transportation system consists of a fleet of 1,100 buses, transporting around 560,000 people daily. However, in many areas, inadequate lighting at sidewalks and bus stops affects passenger circulation, comfort, and safety (Campinas, 2024a).

6.4 Necessary Transitions for GHG Reduction in Campinas/SP

The Campinas Climate Action Plan (Campinas, 2024a) highlights several essential transitions for reducing Greenhouse Gas (GHG) emissions in both the Transportation and Stationary Energy sectors.

Among the 10 necessary transitions identified for the Transportation sector, some stand out. The first is the promotion of sustainable transportation, encouraging walking and cycling by improving pedestrian pathways and cycling infrastructure. Another key transition is increasing fuel efficiency in businesses, industries, and the public sector, with particular attention to logistics activities. In addition to enhancing efficiency, it is essential to replace fossil fuels with cleaner alternatives such as biofuels, electricity, and green hydrogen.

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Electronic Journal Environmental Forum of Alta Paulista
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The third critical transition for GHG reduction involves the aviation sector, requiring both compensation for current emissions and the adoption of cleaner fuels in air operations. Lastly, the plan emphasizes the integration of municipal and metropolitan public transportation, highlighting the proposal for a railway line connecting Campinas to São Paulo, which would significantly contribute to reducing transportation-related emissions.

In the Stationary Energy sector, several necessary transitions were also identified. Among them is the need for existing buildings to become more energy-efficient and resilient to climate events such as heat waves, heavy rains, strong winds, and flooding. Another key aspect is ensuring that new constructions follow high energy efficiency standards, including site selection in areas with lower exposure to climate risks.

Additionally, the PLAC (Campinas, 2024a) stresses that it is crucial for the city to transition to a cleaner and more reliable electrical grid, reducing dependence on hydropower and increasing the use of renewable sources such as solar and wind energy.

This transition can also contribute to local job creation, such as: the implementation of solar panels, wind turbines, and renewable energy distribution networks requires a locally skilled workforce for installation, maintenance, and operation. This can generate both temporary and permanent jobs, or even, as the demand for green technologies grows, there will be a need for qualified professionals. This can result in training and capacity building programs for the local population, generating jobs in educational and technical training centers.

The discussion on Greenhouse Gas (GHG) emissions in Campinas, especially regarding the reduction of carbon dioxide (CO_2), refers to the 2020 Municipal Policy for Addressing the Impacts of Climate Change and Air Pollution and the 2024 Local Climate Action Plan. Both initiatives aim to integrate climate issues into municipal policies and plans. The Campinas Municipal Policy for Addressing the Impacts of Climate Change and Air Pollution (Campinas, 2020) and the Local Climate Action Plan (Campinas, 2024a) reflect a scenario similar to that of the State of São Paulo, which also has a State Climate Change Policy (Law No. 13,798 of 2009) and the State Climate Change Forum, highlighting the state's efforts to establish a solid framework to tackle the environmental crisis.

At the national level, this movement is reinforced by the 2009 National Policy on Climate Change (PNMC) (Brazil, 2009) and the 2016 National Climate Change Adaptation Plan (PNA) (Brazil, 2016). However, despite these efforts at the national, state, and municipal levels, practical results in reducing GHG emissions remain below established targets. In Campinas, the effectiveness of policies, plans, and climate action projects in reducing CO_2 and other greenhouse gas emissions necessitates broad integration among diverse sectors and stakeholders, both national and international. Innovative and transformative solutions can decouple energy consumption from oil dependence and help municipalities achieve climate targets.

7 RESULTS

Given the recurring increase in extreme climate events, there is a global mobilization for municipal governments to implement local mitigation and resilience policies. In Brazil, some cities stand out for having already published their Local Climate Action Plans, such as Campinas. However, there is still a long way to go, as many municipalities, including some state capitals, have yet to finalize or publish their plans.

According to a survey conducted by the Jones dos Santos Neves Institute in May 2024, of the 27 brazilian state capitals, including the Federal District, 15 still do not have a Municipal Climate Change Plan, while 11 do, and 4 are in the drafting phase (IJSN, 2024). In this context, Campinas stands out for adopting public policies to mitigate climate change impacts, such as

Law No. 16,022 of November 5, 2020, and for publishing its Local Climate Action Plan (PLAC) in 2024.

Scientific evidence shows that global warming is already advanced, driven by human activities emitting greenhouse gases. Even if future emissions are drastically reduced, past emissions will continue to impact the global climate for decades. This makes it urgent not only to reduce emissions but also to adopt adaptation and mitigation measures to minimize ongoing climate change impacts. Global cooperation and ambitious policies are essential to prevent an even more catastrophic rise in temperatures and to protect ecosystems, economies, and societies.

Municipalities play a central role in this issue as major GHG emitters while their populations suffer intensely from the consequences. How, then, can we prepare them for this challenging scenario? This research addresses the case of Campinas, which has sought integrated actions to tackle climate impacts since 2013. The objective of this study was to assess the alignment between the Campinas Municipal Policy for Addressing the Impacts of Climate Change and Air Pollution (Law No. 16,022 of November 5, 2020) and the Campinas Local Climate Action Plan (PLAC) (Campinas, 2024a).

The results indicate an efficient alignment between the two documents. The Campinas Local Climate Action Plan (PLAC) strictly follows the guidelines of the Municipal Policy for Addressing the Impacts of Climate Change and Air Pollution (Campinas, 2020), including adjustments in GHG emission targets, as stipulated in Chapter I of the policy, which emphasizes the importance of adhering to national and international agreements, conventions, and protocols.

8 CONCLUSIONS

The discussion on greenhouse gas (GHG) emissions in Campinas/SP, especially regarding the reduction of carbon dioxide (CO_2), must be based on the 2020 Municipal Policy for Addressing the Impacts of Climate Change and Air Pollution and the 2024 Local Climate Action Plan.

Given the methodological nature of this work, a more simplified political commitment agenda was chosen, considering publicly available documents on the research topic.

The existence of divergent targets for GHG reduction among these documents reflects the severity of the climate crisis recognizes the municipality's efforts to integrate climate issues into its policies and plans, reflecting the urgency in combating climate change and its impacts.

Both the Municipal Policy (Campinas, 2020) and the Local Climate Action Plan (Campinas, 2024a) explicitly consider the potential to improve quality of life and population resilience, in addition to bringing economic and environmental benefits. Reducing GHG emissions and pollutants improves public health and lowers healthcare costs. A more resilient city faces fewer economic and social losses in natural disasters, aligning with the United Nations' Sustainable Development Goals (SDGs), such as SDG 11.

Returning to the initiatives included in the PLAC of Campinas/SP, it is necessary to emphasize that investment projections are essential for a prospective reflection on the effectiveness of transforming the conditions that contribute to the current scenario of the municipality regarding the generation of GHG, especially CO2.Various paths, possibilities, and the potential of public efforts to invest in energy efficiency, clean transportation, and renewable energies are presented, aiming to build a reality less dependent on fossil fuels, towards mitigation and adaptation to climate change, therefore aligned with SDG 13 of the 2030 Agenda.

To achieve these results, a long-term vision is essential, as adopted in the formulation of the Municipal Policy for Addressing the Impacts of Climate Change and the Local Climate Action Plan (Campinas, 2024a).

The main aspect of the discussion is understanding how cities control their GHG emissions with short, medium, and long-term vision and actions and how control mechanisms and self-regulation could gradually redefine the neutralization of structural conflicts in the face of climate change threats. Moreover, local governance becomes significant as a political authority by implementing measures that enable the confrontation of climate crises with quantifiable, reportable, and verifiable objectives, offering innovative solutions in an integrative perspective that allows for the handling of extreme climate events on different territorial scales.

However, a point of uncertainty identified in this research is whether the municipality intends to update its policy to ensure it remains aligned with the 2024 PLAC regarding GHG emission targets. A gap in this study that could be explored in future research concerns the financial resources required for implementing the 2024 PLAC. Many of the transitions described in the document (Campinas, 2024a) require significant investments, and this research did not analyze the Multi-Year Plan in relation to these investments or any other economic aspect.

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Edição em Português e Inglês / *Edition in Portuguese and English* - v. 21, n. 1, 2025

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DECLARAÇÃO DE CONFLITOS DE INTERESSE

Nós, Irineu José Bottoni, Bruno de Aguiar Normanha, Cibele Roberta Sugahara, Denise Helena Lombardo Ferreira, Marcelo Pereira da Silva, declaramos que o manuscrito intitulado "Mudanças climáticas e plano de ação de mitigação das emissões de CO_2 no município de Campinas/SP":

1. **Vínculos Financeiros**: Não possui vínculos financeiros que possam influenciar os resultados ou interpretação do trabalho. Este trabalho foi financiado pelo Centro Nacional de Desenvolvimento Científico e Tecnológico (CNPq) e Pontifícia Universidade Católica de Campinas (PUC-Campinas) por meio de bolsas de estudos.
2. **Relações Profissionais**: Não possui relações profissionais que possam impactar na análise, interpretação ou apresentação dos resultados. Nenhuma relação profissional relevante ao conteúdo deste manuscrito foi estabelecida.
3. **Conflitos Pessoais**: Não possui conflitos de interesse pessoais relacionados ao conteúdo do manuscrito. Nenhum conflito pessoal relacionado ao conteúdo foi identificado.