PLAN

CLIMATE CHANGE MITIGATION AND ADAPTATION PLAN

CLIMA

DECEMBER 2020

C40 CITIES

CCI

IPPUC

CURITIBA

MUNICIPAL GOVERNMENT OF CURITIBA

MUNICIPAL SECRETARY OF THE ENVIRONMENT

URBAN PLANNING AND RESEARCH INSTITUTE OF CURITIBA

MUNICIPAL PLAN FOR CLIMATE CHANGE MITIGATION AND ADAPTATION | PlanClima

December - 2020

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MESSAGE FROM THE MAYOR

Faced with the challenges that these times of climate change have posed, we dare to say that we are not afraid of the future, and this *First Municipal Plan of Adaptation and Mitigation to Climate Change*, the result of Curitiba's adhesion to the Goal 2020 of the C40 Group of Major Cities for Climate Leadership, is an example.

By integrating a government agenda committed to the city's resilience, this plan is part of a process that has already been developed, since it reaffirms our responsibility to the Curitiba community to promote the necessary strategic measures at a local level, while contributing on a global scale.

At the same time that they concentrate the largest amount of greenhouse gas emissions, energy consumption and waste production, feeling the effects of climate change, cities are also the protagonists of the change process. It is here that we generate knowledge, implement actions, and determine the agenda of new behaviors capable of reducing vulnerabilities and making us more supportive.

Our pact of reconciliation between ancestral knowledge, which recognizes nature as a source of knowledge, and the opportunities that contemporary technology can offer us is translated into the 20 priority actions defined in this Plan, such as the regulation for buildings adapted to climate threats and the encouragement of energy efficiency and the use of renewable energy sources.

These sustainable energies will also feed the transportation sector, the main contributor to the emission of Greenhouse Gases. There is an urgent need for transition in the energy model currently adopted. To this end, the Plan's actions emphasize the decarbonization emergency in the city's mobility. And here we ratify our political will as inductor and facilitator of this process of adopting new dynamics capable of reducing these environmental impacts.

It is necessary to recognize the possibilities in every corner of the city, even in consolidated areas such as parks, expanding green areas to increase carbon sequestration and ecosystem-based adaptation.

But it is necessary to go beyond the city limits. The proposals of this Plan will allow us, in the short, medium and long term, to improve and expand the policies adopted so far, such as Food and Water Security, with a broader vision of Curitiba and the Metropolitan Region. Certainly our initiatives will be more assertive the more climate information, as foreseen in the Plan, is aggregated to monitor and evaluate the results.

In this context of actions aimed at sustainability, PlanClima translates our commitment to consolidate a climate policy, by systematizing the necessary actions aligned with the national and international objectives and targets, implementing transformative and inclusive actions to deliver an emission-neutral and climate resilient city by 2050, consistent with the objectives of the Paris Agreement and the 2030 Agenda for Sustainable Development.

But this transformation requires collective action. And we will be successful when the measures listed in this Plan become part of the agenda of all citizens who believe in the human potential to reinvent itself in the face of adversity. Because if there is an energy that surpasses all the alternatives we can adopt, it is the energy of the Curitiba people.

Rafael Greca de Macedo

MESSAGE FROM THE MUNICIPAL SECRETARY OF ENVIRONMENT AND THE PRESIDENT OF THE INSTITUTE OF RESEARCH AND URBAN PLANNING OF CURITIBA

The urbanization process produces changes in the environment resulting in greater exposure of society to environmental and socioeconomic risks and vulnerabilities due to climate change. Its effects have been demonstrated in the quality of water and air, in the occurrence of floods, flooding, and heat waves, impacting the quality of life of the population.

Curitiba has been improving its urban planning and strengthening its environmental policy since the 1960s, when it began to adopt an approach that integrates the concepts of environmental conservation and urban development, which has allowed it to respond more effectively to the effects of climate change.

However, it is necessary to increase its prominence in the context of the global effort to address climate change by integrating into municipal planning transformative actions that ensure decarbonization, adaptation, and increased resilience of the city's urban, environmental, economic, and social systems.

The attainment of PlanClima's objectives and targets depends on municipal planning focused on climate action, but we will only achieve the expected results with the participation and engagement of all sectors of society, ensuring that the next generations have adequate living conditions in the long term.

Marilza do Carmo Oliveira Dias

Luiz Fernando de Souza Jamur

PRESENTATION

This document presents the Municipal Plan of Mitigation and Adaptation to Climate Change of Curitiba (PlanClima), which aims to guide the municipal action, productive sectors and society to face the effects that may arise from climate change. The PlanClima is aligned with the 2030 Agenda of the United Nations (UN), through the Sustainable Development Goals (SDGs); the Climate Action Planning Framework of the C40 Network of Cities; and the goal set in the Paris Agreement to contain the increase in global average temperature within 2°C, compared to pre-industrial levels, but making efforts to stabilize the warming around 1.5°C. This will require achieving greenhouse gas (GHG) emissions neutrality by 2050 and making the city more resilient.

SUMMARY

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LIST OF ABBREVIATIONS

AbE - Ecosystem-based Adaptation

ABRAPCH - Brazilian Association of Small Hydroelectric Plants AFD - French Development Agency

AR - *Assessment Report*

ASAP - *Action Selection and Prioritization*

ANEEL - National Electric Energy Agency APA - Environmental Protection Area

APP - Permanent Preservation Area BAU - *Business as Usual*

BCBU - Urban Biodiversity Conservation Forest CGH - Hydroelectric Generating Station

CONCITIBA - Curitiba City Council

CONRESOL - Intermunicipal Consortium for Integrated Management of Solid Urban Waste

GHG - Greenhouse Gases

GPC - *Global Protocol for Community-Scale*

GWP - *Global Warming Potential*

IBGE - Brazilian Institute of Geography and Statistics IPCC - *Intergovernmental Panel on Climate Change* ICLEI - *Local Governments for Sustainability*

NUC - Central Urban Core

ODS - Sustainable Development Goals UN - United Nations

GDP - Gross Domestic Product

PMCADS - Municipal Plan for Environmental Control and Sustainable Development

POD - Origin-Destination Survey

RIT - Integrated Transportation Network

RNPPNM - Private Reserve of Municipal Natural Heritage

SPVS - Society for Wildlife Research and Environmental Education UNEP - *United Nations Environment Programme*

UNFCCC - *United Nations Framework Convention on Climate Change*

WRI - *World Resources Institute*

1 | CLIMATE CHANGE AND THE MUNICIPAL PLAN FOR MITIGATION AND ADAPTATION TO CLIMATE CHANGE OF CURITIBA

In October 2018, the Intergovernmental Panel *on* Climate Change (IPCC), a United Nations (UN) initiative that brings together scientists from around the world to evaluate climate-related research on the planet, published a special report finding that the goal of the Paris Agreement ratified [20161], limiting global warming to 2°C this century, is insufficient to ensure sustainable and equitable societies. According to the scientists, the increase in the planet's average temperature should not exceed 1.5°C, in relation to the pre-industrial era. The document also warned that the current voluntary initiatives are unable to contain warming within this limit. In other words, for the temperature increase to remain at this level, scientists say that an unprecedented commitment from all nations is necessary, as well as a rapid change in production and consumption systems.[2]

The decade ending in 2019 recorded exceptional global warmth. Average temperatures for the five-year (2015-2019) and ten-year (2010-2019) periods are the highest ever computed. Carbon dioxide (CO_2) concentrations in the atmosphere reached a record high of 407.8 parts per million in 2018 and continued to rise in 2019. CO_2 lasts in the atmosphere for centuries and in the oceans for longer, thus increasing global warming and causing climate [change3].

Urbanization patterns and urban lifestyle appear as central elements of climate change because of their direct relationship with greenhouse gas (GHG) emissions: they are like "engines" of economic development due to high demands for industrialized products, food, and [infrastructure4].

[1]https://nacoesunidas.org/wp-content/uploads/2016/04/Acordo-de-Paris.pdf[2] https://www.ipcc.ch/sr15/
[3]https://public.wmo.int/en/media/press-release/2019-concludes-decade-of-exceptional-global-heat-and-high-impact-weather
[4]https://www.scielo.br/pdf/rap/v45n3/04.pdf

These same urban areas that accelerate emissions can be severely affected by the impacts of climate change, especially the effects of increased frequency and intensity of extreme weather events. The process of urbanization itself produces changes in the environment that tend to accentuate these impacts. Cold and heat waves, changes in rainfall intensity and regime, strong winds and hail often bring consequences such as flooding, inundations, landslides, dry spells, thermal discomfort, falling trees, among many other events.

Individually or together, these effects can affect well-being, increase the demand for health care, cause human, material, and economic losses, and put water and food security at risk. The impacts are even more severe for the least favored populations, with greater exposure to risks and greater environmental and socioeconomic vulnerabilities. In addition, there are also risks to the biodiversity of ecosystems.

In Curitiba it is no different. The city's temperature is already, on average, 1.2 ºC higher than six decades ago. An alteration in the rainfall regime has been observed, with the occurrence of strong and intense storms being more common, as well as periods of drought. In both cases the population is impacted, sometimes by disruption due to flooding, sometimes by water shortage or thermal discomfort.

The challenges posed by climate change require investments and demand new forms of planning and action. However, they also offer opportunities that, if planned and implemented in a reasoned, consistent, articulated and participatory manner, will result in benefits for all. The intensification of climate events presents itself as a new challenge to urban management, which must identify, develop and implement effective responses to improve the mitigation and adaptation capacity of cities and reduce environmental and socioeconomic risks and vulnerabilities related to the issue.

The cities are, therefore, protagonists in the local responses to the climate crisis. It is evident the need to align and coordinate the efforts of cities with the other spheres of government, private sector and society in facing this challenge.

As the theme gains relevance in the world, Curitiba also seeks to evolve in its actions to face the challenges, which is why it launches this Municipal Plan for Mitigation and Adaptation to Climate Change (PlanClima). Aligned with the Paris Agreement, the purpose of the initiative is to join efforts to contain the increase in average temperatures and improve the city's adaptive capacity.

Curitiba incorporated in 2017 the strategies of UN Agenda 2030 and its Sustainable Development Goals (SDGs) and also adhered to the Global Compact, a United Nations initiative to foster the engagement of companies in social responsibility and sustainability policies. Thus, the actions of PlanClima, besides directly meeting SDG 13 - Action Against Global Climate Change, also present strong interaction with the other objectives, contributing to the achievement of 169 proposed goals. The city's commitment to these international agreements is fundamental to the establishment of a long-term municipal sustainability policy, and PlanClima reaffirms it. Figure 1 summarizes the objectives of the Paris Agreement and the SDGs.

Figure 1: Paris Agreement Goals and the 17 Sustainable Development Goals (SDGs)

The Climate Plan seeks to promote strategies, articulation and integration of multi-sectoral and transversal actions, aiming at reducing GHG emissions (mitigation) and increasing the city's adaptive capacity to climate risks, making it more resilient. It also brings a focus of attention to the most vulnerable groups to climate risks, aiming at their inclusion in this planning, and proposes a governance structure that promotes the involvement and participation of public authorities, productive sectors, and society.

2 | PLAN DEVELOPMENT PROCESS

In May 2018, the Letter of Commitment of the City of Curitiba was signed with the *Deadline 2020 - Target* [20205] report of the **C40 Group of Large Cities for Climate Leadership**, regarding the Climate Action Planning (CAP), to support the preparation of PlanClima.

By making this commitment, the city was given access to the Climate Action Planning Framework, which contains the essential components for developing a climate action plan consistent with the goals of the Paris Agreement, as well as a set of resources including technical guidance, capacity building, tools, and knowledge sharing through an extensive Technical Assistance Program.

From the commitment made by the city with the 2020 Target, the process of elaboration of the PlanClima was started, which included the following steps: development of the technical basis and reference documents; definition of strategies; prioritization of actions with the participation of various actors; and preparation of preliminary draft. The draft Plan and the reference documents were submitted to the C40 Network review, to verify compliance with the essential criteria of the Climate Action Planning Framework. The complementation of the recommendations pointed out in the approval letter will be incorporated in 2021. Figure 2 presents the main stages of elaboration of PlanClima.

[5]The "*Deadline* 2020" report, published by C40 and Arup the same year, shows that the world is rapidly approaching the permissible limit of carbon emissions (known as the "carbon budget") for global temperature increase to be kept within 1.5 degrees Celsius. Seventy percent of C40 cities are already experiencing the effects of climate change. Events such as drought, floods, storms, food insecurity, climate migration, and the spread of communicable diseases are projected to increase in frequency and severity over the years.

Figure 2: Key steps in the Climate Action Planning process

The Climate Action Planning Framework also determines that the elaboration process of the Plan involves the community, evaluating the expected social, economic and environmental benefits and promoting the equitable distribution of these benefits - with special attention to the population most vulnerable to climate risk. In other words, it is an essential criterion the consultation of the main actors and stakeholders (government agents, businessmen, and civil society), especially the communities directly affected by climate change.

The PlanClima was prepared by Curitiba's City Hall staff, with the participation of representatives from Copel, Sanepar and the collaboration of civil society, through representatives of Curitiba's Forum on Climate Change and *Global Shapers*. In addition, it had the technical support of the city advisor of the C40 Group, responsible for managing the hiring of consultants for the production of some of the reference documents and for supporting the engagement of stakeholders.

During the elaboration process of the Plan, the principles of building a democratic and participative management were observed - the PlanClima was presented and discussed in the Council of the City of Curitiba - CONCITIBA, in the Municipal Council of Environment - CMMA and in the Curitiba Forum on Climate Change, and its draft was sent to the Councilors and Members for contributions.

After this process, PlanClima became ready for approval, and its implementation began.

2.1 | ORGANIZATIONAL STRUCTURE FOR THE ELABORATION OF THE CLIMATE PLAN

In September 2018, after the city adhered to Target 2020, the Working Group - GT Clima was created for the preparation of PlanClima. The institution of the Climate WG occurred through a municipal decree that characterized it as a collegiate instance, coordinated jointly by the Municipal Secretariat of Environment and the Institute for Research and Urban Planning of Curitiba.

The composition structure of the Climate WG portrays the interdisciplinarity in climate issues: it brings together representatives of the municipal secretaries of Environment; Planning, Finance and Budget; Public Works; Social Defense and Traffic; and Food and Nutritional Security; in addition to the Institute of Research and Urban Planning of Curitiba; the Urbanization of Curitiba S.A.; the Curitiba Development Agency S.A.; the Attorney General's Office; the International Relations Office; COPEL; and SANEPAR.

The performance of collegiate instances, such as CONCITIBA, the Municipal Environment Council, the Managing Committee of Resilient Cities and the Curitiba Forum on Climate Change, appreciating and endorsing PlanClima, is essential for the involvement of the various actors. For example, in the appropriation of the subject by servers and employees of related institutions and in the alignment of transversal actions with the society.

Figure 3 presents an organization chart of the governance structure on which PlanClima was built.

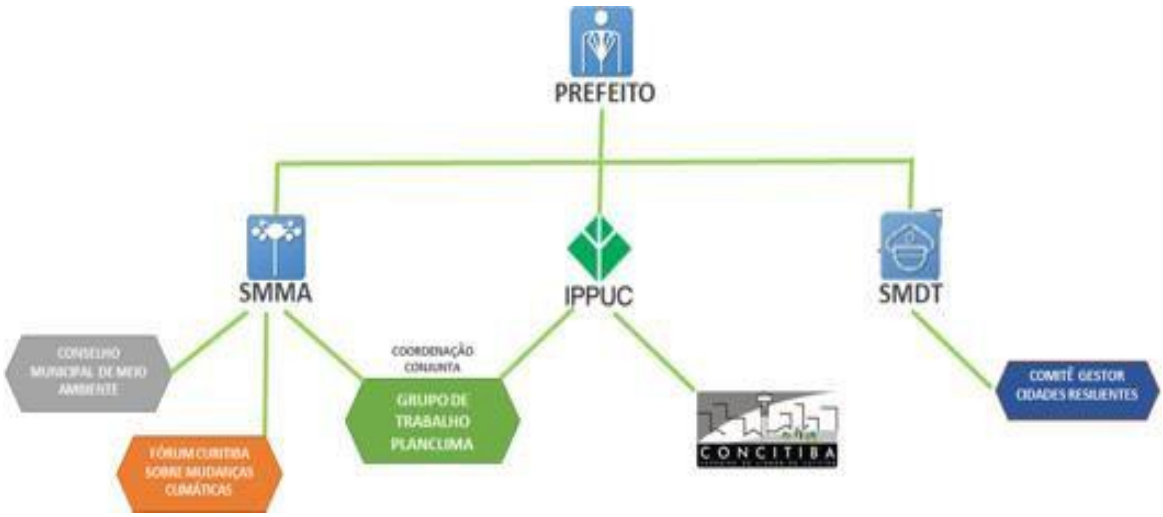


Figure 3: Organizational chart of the governance structure on which PlanClima was built.

The initial stages of Technical Diagnosis and Identification of Strategies were prepared by the Climate WG and consultants under the C40 Group Technical Assistance Program. The Climate WG held monthly meetings during 2019 and biweekly meetings until May 2020.

Specific trainings were also held, one of them, in 2018, in Quito (Ecuador), where the 1st Regional Climate Action Planning Academy of C40 cities in Latin America took place. A technician from the city of Curitiba and a city advisor from the C40 Group participated in the training.

In 2019, training was provided to the City Hall technicians that enabled the preparation of Curitiba's GHG Emissions Inventory Base Year 2016, with the technical support of the city's advisory in the C40 Group.

Another important event, this time focused on adaptation training, was held in 2019 by the Adaptation Academy in Rotterdam, the Netherlands. Seven servers from the City Hall participated in it, as well as the technical advisor of the C40 Group. Also in 2019, two representatives of the City Hall attended the C40 *World Mayors Summit*, a global meeting held in Copenhagen, Denmark, where mayors, business representatives, and society leaders presented climate actions and solutions strongly committed to the

low carbon development for building more resilient and inclusive cities.

In February 2020, before the Covid-19 pandemic spread in Brazil, the city of Salvador hosted the 2nd Regional Climate Action Planning Academy of Latin American C40 Cities. The objectives of the event were to support the construction of the Climate Action Plan and generate capacity, present methodologies, and promote the exchange of experiences on climate action planning. The meeting was attended by representatives from Curitiba, Buenos Aires, Guadalajara, Lima, Medellin, Mexico City, Quito, Rio de Janeiro, São Paulo, and Santiago.

In addition to the members of the Climate WG, a larger group of City Hall collaborators participated in the action prioritization stage, such as the members of the Curitiba Forum on Climate Change and the *Global Shapers*. It was a collective construction, with presentation and discussion of results that allowed a transparent and objective analysis of the actions that the city wanted to prioritize in its climate action plan. The process was developed under the guidance of technical consultants from the C40 Group's Technical Assistance Program. This stage lasted approximately four months, with weekly meetings. Due to the pandemic, all meetings were held virtually, respecting the measures to prevent the spread of the coronavirus.

The methodology used for prioritizing actions took into consideration, besides the primary mitigation and adaptation benefits, the cobenefits in other sectoral areas, funding criteria, and governance.

The finalization of the action prioritization process enabled the elaboration of the PlanClima draft, which was submitted to the evaluation of the C40 Group and to the appreciation of CONCITIBA[6], thus completing the last stage necessary to make the Plan ready for its formalization by PMC.

[6] CONCITIBA, in the context of the city's democratic management, is the municipal collegiate body for urban policy, which has the task of acting in the formulation, elaboration, and monitoring of the Municipal Urban Policy, according to the guidelines of the City Statute and the Master Plan.

3 | CHARACTERIZATION OF CURITIBA AND REGION

Curitiba, capital of the State of Paraná, is located on the first plateau of Paraná, at an altitude of approximately 935 meters above sea level, occupying an urbanized area of 435.06 km² (IBGE, 2017), with 635,631 occupied households (IBGE, 2017) and a demographic density of 4,027.04 hab/km² (IBGE, 2017). Its estimated population is 1,917,185 inhabitants (IBGE; IPPUC, 2018), distributed in 75 neighborhoods. It is the hub city of the set of 29 municipalities that form the Metropolitan Region of Curitiba (RMC) in an area of 15,622.34 km2and population of
3,615,027 inhabitants (IBGE; IPPUC, 2018).

With a temperate climate, the city is located in the Atlantic Forest biome and has 58 m² of forest masses per inhabitant (CURITIBA, 2019), a number almost four times higher than the15 m²/inhabitant recommended by the Brazilian Society of Urban Afforestation (SBAU,1996). This rate of afforestation per inhabitant of Curitiba reflects the 1,217 Municipal Conservation Units (SMMA, 2020), distributed in 27 parks, 16 woods, 1 botanical garden, 8 Urban Biodiversity Conservation Woods (BCBU), 33 Private Reserves of Municipal Natural Heritage (RPPNM), 1,127 squares, garden centers / axes, squares and environmental gardens, 2 Environmental Protection Areas (APA), 1 Wildlife Refuge and 2 Ecological Stations.

Curitiba's urbanization process was a reflection of the socioeconomic situation, with the rural-urban migrations from Paraná being absorbed by the northern and western regions of Curitiba. The city had its growth directed according to specific urbanistic parameters, established from the Master Plan of 1966, which contemplated social promotion, housing, work, transportation, circulation and environment. The Plan established the decongestion of the center, with the valorization of the historical sector, the prioritization of pedestrians and public transportation, besides defining the distribution of the education, health, recreation and leisure equipment for the entire city and providing economic support for the development of the municipality, from the implementation of the Cidade Industrial de Curitiba - CIC. Figure 4 shows the location of Curitiba.

Figure 4: Location of Curitiba and the Curitiba Metropolitan Region

The State of Paraná and specifically the city of Curitiba have for decades been among the most developed regions in Brazil, according to quality of life and economic development indicators. It occupies the 4th place among the Brazilian capitals with the best human development indexes (HDI-M - 2010 - 0.823) and the 5th place with the highest *per capita* income of the Paraná plateau.

The GDP is rising with policies for plants with low environmental impact, with a third part represented by the secondary sector and the rest by a sophisticated offer of commerce and services, where the most important services are in the institutional, cultural, education, and health branches.

The city of Curitiba expands this dynamic to the neighboring municipalities, especially in the neighboring districts. The profile of economic activities in the City of Curitiba indicates that 12.10% of the activities are in industry, 30.43% in commerce, 57.15% in services, and 0.32% in the primary sector. The number of

establishments in the county is 155,296 thousand according to 2018 data. (FMTE/DES/CGET/RAIS). Table 1 presents a summary of the main socioeconomic indicators of the Municipality.

Table 1: Socioeconomic Indicators

INDICATOR	VALUES / CURITIBA	SOURCE
GDP	R$84.702 billion	IBGE/2019
GINI	0,56	IBGE/Censo Demográfico 2010
Occupied population [2018]	53,7 %	IBGE, Central Business Register (CEMPRE) 2018 (reference date: 12/31/2018), IBGE, Population Estimate 2018 (reference date: 1/7/2018)
Average income per capita Curitiba	R$1.246	IBGE/Censo Demográfico 2010
Percentage of population with nominal monthly income per capita of up to 1/2 minimum wage [2010].	26,9 %	IBGE/ Demographic Census 2010
Proportion of the extremely poor population	0,48%	IBGE/Censo Demográfico 2010
Infant Mortality [2017]	8.31 deaths per thousand live births	Infant Mortality: Ministry of Health, Department of Informatics of the Single Health System - DATASUS 2017
Schooling rate of 6 to 14 year olds [2010]	97,6 %	IBGE/ Demographic Census 2010
The literacy rate of the population 15 years old and older in Curitiba was 97.9%,	97,90%	IBGE/Censo Demográfico 2010
Percentage of permanent private residences served by water mains	99,08%	IBGE/Censo Demográfico 2010
Percentage of permanent private residences served by sewage system	92,30%	IBGE/Censo Demográfico 2010

4 | CURITIBA AND URBAN PLANNING

4.1 | URBAN PLANNING PROCESS

Curitiba has historically privileged urban planning actions that incorporate the environmental dimension, mainly through the observance of criteria for the conservation of strategic resources such as water, soil, vegetation cover and air quality. These are measures that promote health and environmental comfort for the population.

Regarding urban occupation, the current conformation of the city is guided by guidelines established by the Master Plan of 1966 and its continuous process of improvement. The Plan had as its main premise to change the city's growth typology, from radial to a linear model of urban expansion, adopting as strategy the integration of land use, road system, public transport and economic, social and environmental development aspects in the definition of local policies.

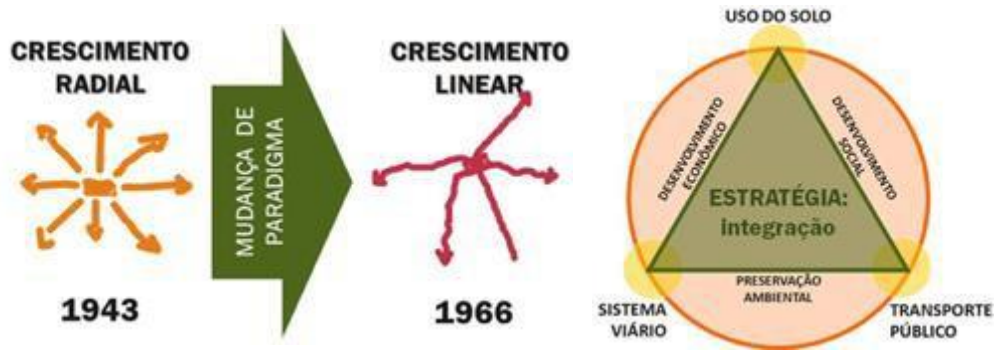


Figure 5: Schematic of the improvement process according to the Master Plan

This model, characterized by the implementation of the Eixos Estruturais and the use of public transportation as the main driver of urban growth, is a hallmark of the city to this day. The approach adopts land use and occupation parameters that encourage higher densities and mixed uses. The result is a more compact city, which offers the population easy access to a diversity of activities, shops, services, and public spaces, favoring social interaction, economic development, and urban mobility.

With these guidelines, the city took a more sustainable path. It became a pioneer in Brazil, for example, in the use of the strategy currently called Sustainable Transport Oriented Urban Development (DOTS)[7]. In the area of environmental conservation, it has been implementing a policy of vegetation and fauna protection, especially in areas bordering the rivers. Thus, it protects the springs and at the same time guarantees the maintenance of the natural rainwater drainage system to avoid flooding.

The policy of establishing parks from the 1970s on also helped to protect the rivers and preserve the valley bottoms. In 20 years (between 1972 and 1992), the city's green areas were multiplied a hundredfold, going from 0.5 ^{m2} to 50 $^{m2\ of\ green}$ area per inhabitant (PMC, 1992), until reaching the current ^{58m2} of green area per inhabitant.

These aspects, initially understood as guidelines for environmental protection in the municipality, currently constitute a set of actions that strengthen urban resilience, so important to address climate change. An urban development model guided by the incentive to the use of public transportation and by urban densification parameters favors the reduction of GHG emissions.The 1966 Master Plan underwent two revisions, one in 2004 and another in 2015. The 2004 revision was mainly due to the need to adapt it to the City Statute, Federal Law 10.257/2001. In this adaptation priority issues such as: sustainable development, recognition of the social function of the city and of urban property, and democratic management in the administration of the city were contemplated. Within its scope, the 2004 Master Plan also promoted the integration of sectoral policies with urban development issues that structure the various areas of municipal management, such as mobility and transportation, housing, education, health, and social, economic and environmental development.

[7] According to WRI Brasil, "the DOTS strategy seeks to bring housing areas and employment opportunities closer together by encouraging mixed land use near public transportation corridors" (Available at: <https://wribrasil.org.br/pt/o-que-fazemos/projetos/desenvolvimento-orientado-ao-transporte-sustainable-dots> Accessed: 09/27/2020).

The 2015 revision of the Master Plan reinforced and expanded the continuity of the planning process. For example, it extended Curitiba's sustainable development guidelines to the Metropolitan Region, aligning with international, national and state commitments. Figure 6 demonstrates the transversality of environmental aspects in the process of conforming the urban policy of the municipality - which is, in fact, one of the guiding principles of the 2015 Master Plan.

Figure 6: Environment of the commitments and interactions with the Municipal Planning System

Among the main concepts of the Master Plan revision are:

- **Vision of the Future**: urban structuring oriented by the qualification of already occupied areas and redefinition of urban compartments, seeking the balance between the natural and the built environment; integration between public transportation, use and occupation of the soil, and the road system; improvement of the integrated transportation system with the creation of axes that, together with the existing ones, provide new connections and alternative displacements, besides defining urban compartments; plurality of functions and activities in the urban compartments; and metropolitan integration with the definition of transportation axes;
- **Organization of Urban Space**: it is oriented by macro-zoning, observing population densification with a view to urban and environmental qualification. The following are used

instruments such as Compulsory Land Development, Compulsory Land Development, Regional Development Plan, Urban Redevelopment, and Neighborhood Impact Assessment;

- **More Compact City**: stimulating housing closer to work, commerce, services and leisure, reducing undesirable displacements, and propitiating the emergence of new centralities;
- **Improved Quality of Life**: to provide a more socially, economically, and environmentally accessible city;
- **Preparing the City for Climate Change**: improving soil drainage, mitigating problems caused by heavy rainfall, environmental comfort, and a climate change mitigation and adaptation plan;
- **Preparing the City for New Technologies**: electronic sensing of the city, autonomous car, drones (VANTS), mobility by applications and augmented reality, among others;
- **Economic Development**: stimulate the low carbon economy, knowledge economy, creative economy, green economy, and encourage the generation of products and services with high added value. Promote the design of the city in a way that favors economic development;
- **More Human and Participative City**: humanization; citizens' right to the city's landscape and identity; stimulus and favoring of the concept of neighborhood; democratic management, among others;
- **Multimodality**: incentive to transportation multimodality, besides the implementation of five new public transportation axes in the east-west direction, forming a network and expanding the connections; the urban mobility policy foresees the integration of the various modes of transportation, the incentive to bicycle mobility and walking;
- **Citizen Security**: stimulus, through inter-institutional, governmental and social construction, of a culture of violence prevention as a prerequisite for public security at the municipal level; integration with state and federal agencies for the confrontation of criminality; and
- **Metropolization**: articulation of development strategies for the city in the regional context, promoting, within the scope of municipal competence, interfederative governance among the municipalities of Curitiba's Metropolitan Region and authorizing consortiated urban operations.

Considering the concepts of the Master Plan, as described above, there is a full alignment with the actions required to address climate change. Figure 7 presents the urban structuring that reflects the adoption of

of these concepts, demonstrating its vision of the future, compatible with the 2050 horizon foreseen in PlanClima.

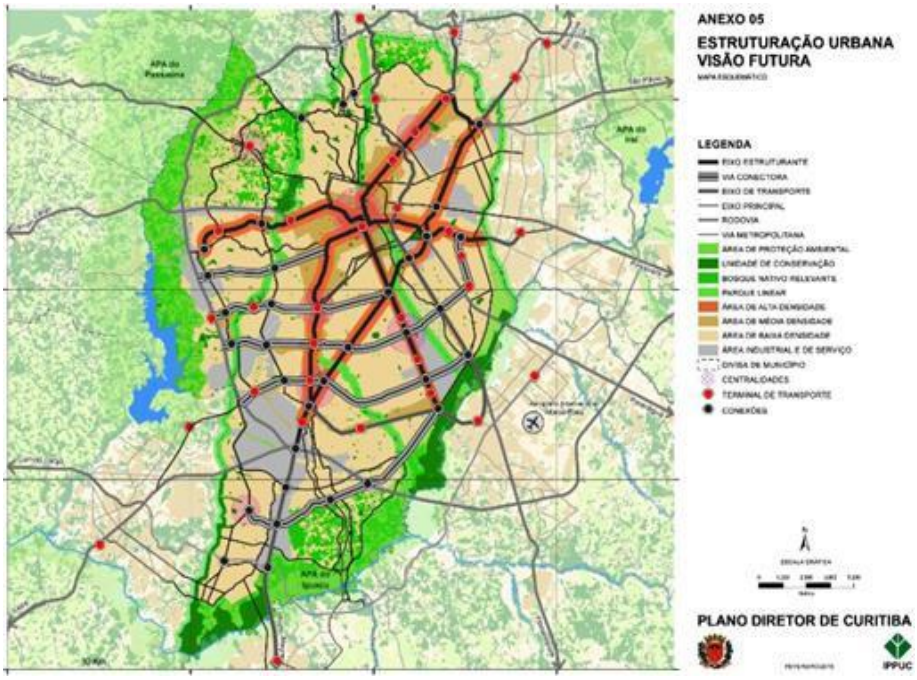


Figure 7: Urban Structuring - Future Vision of the 2015 Master Plan

4.2 | MUNICIPAL PLANNING SYSTEM

Curitiba's Master Plan establishes the **Municipal Planning System**, characterized by the development of a dynamic and continuous process, which articulates public policies with the various interests of society and promotes instruments for the management and monitoring of urban development.

The Municipal Planning System is effective by means of the instruments foreseen in its Master Plan, organized according to three distinct categories: (i) sectorial public policy instruments; (ii) territorial application instruments; and (iii) urbanistic instruments.

Figure 8: Schematic of the 2015 Master Plan Municipal Planning System

PlanClima is characterized as a **Strategic Plan** within the hierarchy of the Municipal Planning System. The Master Plan defines strategic plans as those that contemplate specific actions and projects, within a certain area of action, but whose scope involves the entire territory.

The structure of the Municipal Planning System, coupled with the integration of economic, social and environmental development, is characterized as a differential of the city in relation to the planning of its urban occupation. The strategy strengthens the municipal performance in relation to aspects of mitigation, adaptation, and resilience to current climate challenges.

Another important aspect of the Municipal Planning System is its monitoring process, which is carried out through the Master Plan Monitoring and Control System. The system uses indicators that relate and analyze municipal information to then cross-reference the results achieved to the Master Plan's objectives. Besides strengthening the transparency of information and social control over municipal actions, this monitoring model is extremely relevant in the process of implementing PlanClima.

5 | TRAJECTORY OF CURITIBA'S ACTIONS IN FACING CLIMATE CHANGE

Curitiba is progressively strengthening its environmental policy and advancing in the establishment of initiatives for tackling climate change at the local level.

Initially, the municipal environmental approach was based on the ecological issue and sustainability, including the protection and conservation of green areas, the implementation of parks, and the encouragement of waste recycling, among several other actions. The context of climate change in the municipality emerged with the preparation of actions for its participation in Rio 92, the United Nations Conference on Environment and Development, held in Rio de Janeiro in June 1992, which initiated the debate on sustainable development, a relatively new concept at the time.

Curitiba received delegates at the *World Forum of Cities*, an event that preceded the Rio 92 Summit, in order to formulate alternatives to some of the questions posed at that time. For example, the need to rediscover cities as transforming agents, especially through the multiplying effect of their local actions in the region where they are located, and in the country to which they belong. It was about the premise of local action as a guarantee of global survival.

Later, in 2006, Curitiba hosted the 8th Conference of the Parties of the Convention on Biological Diversity (COP8) and the 3rd Meeting of the Parties to the Cartagena Protocol on Biosafety (MOP3), promoted by the UN and the Brazilian government. In these meetings, themes such as protection of traditional knowledge associated to biodiversity and access to the benefits arising from the use of genetic resources8 were debated. (Source: Vulnerability Study project Novo Caximba neighborhood, 2019).

8Source: Vulnerability Study project Novo Caximba neighborhood, 2019

In 2008, Curitiba prepared its first Sectorial Plan of Environment, called Municipal Plan of Environmental Control and Sustainable Development (PMCADS), in compliance with the guidelines and instruments of urban policy brought by the City Statute. This Plan innovated by placing historically and spatially the concept of "sustainable society" - one that determines its mode of organization, production and consumption from its history, culture and natural resources, stimulating and strengthening a critical consciousness on environmental issues, for the balance of the city's development with environmental conservation.

But it was in 2009 that Curitiba started to develop a series of strategies and actions to act more incisively on the climate issue in the municipality. That year it was created the **Curitiba Forum on Climate Change**, established by municipal decree, with the aim of discussing and proposing mitigation measures and adaptation to climate change for the city. The Forum, in effect until today, is chaired by the Municipal Environment Secretary (SMMA) and has the participation of other municipal agencies, universities and civil society organizations.

The creation of the forum accompanied the establishment of **Curitiba's Climate Change Strategy**, foreseeing medium and long-term actions for the technical and scientific basis of the proposition of the Municipal Plan of Mitigation and Adaptation to Climate Change. The steps defined by the Forum were as follows:

1. Inventory of Absorption Sources (sinks) of the city (carbon stock in green areas);
2. Preparation of an Inventory of Greenhouse Gas Emission Sources in the municipality;
3. Elaboration of an Environmental and Socioeconomic Vulnerability Study; and
4. Elaboration of the Municipal Plan of Mitigation and Adaptation to Climate Change.

Following up on the steps defined by the Forum, in 2018, by means of Official Letter no. 115/2018-EM, dated May 14, 2018, the Letter of Commitment of the City of

Curitiba with the C40 Climate Action Planning Group (CAP) 2020 Target, as a goal to support and assist the city in developing a climate action plan by the end of 2020.

In the last two years, during the elaboration process of PlanClima, aware of the need to fight climate change and seek innovation, the city emphasized actions aligned with the confrontation of climate change. Among the initiatives already implemented in the city, we highlight the urban vegetable garden development program, such as the Urban Farm; the incentive to innovation and creative economy, such as the Pine Nut Valley - an innovation ecosystem; and the environmental education grid within the Lines of Knowledge program.

Actions that contemplate the use of renewable energy have also received special attention. An example of the city's commitment to this theme is the investment in technologies aimed at energy efficiency, through the **Curitiba More Energy Program**, which provides for greater use of solar energy in the [city9].

Curitiba also participates in the C40 *Cities Finance Facility* Program (CFF), operated by the German Agency for International Cooperation - GIZ (*Deutsche Gesellschaft Für Internationale Zusammenarbeit*) and Group C40, with international resources from the German and British governments and a US fund. The partnership, signed in February 2019, focuses on the following actions: feasibility study for the implementation of five photovoltaic plants; evaluation of applicable legislation and standards; selection of technologies; technical specifications for acquisition, implementation, maintenance, and operation; development of business models; analysis of potential funding sources; and extensive training of City Hall technicians. The project includes photovoltaic generation units at the city's Rodoviária railway station, at the Boqueirão, Santa Cândida and Pinheirinho terminals, and at the area of Curitiba's old landfill. The program is in progress and should be completed by the end of 2020.

[9Curitiba], Prefeitura Municipal, 2020. Curitiba More Energy Program (Available at:<https://www.curitiba.pr.gov.br/noticias/piramide-solar-da-caximba-vai-produzir-43-do-consumo-de-energia-de-predios-municipais/55081>

This was not the only action aimed at harnessing solar energy. In June 2019, the energy efficiency project at Palácio 29 de Março, the administrative headquarters of the City Hall, implemented with resources from Copel's Energy Efficiency Program and ANEEL, provided for the installation of 439 photovoltaic modules on the roof and replaced about 5,000 light bulbs with more efficient models. Another initiative was the construction, in October 2019, of the Nicolau Klüppel Hydroelectric Generating Plant (CGH), in Barigui Park, a donation from the Brazilian Association of Small Hydroelectric Plants (ABRAPCH), with the potential to generate half the energy consumed in Barigui Park.

Besides these actions, other projects and participations of the municipality involving climate change are worth mentioning:

- **2010**: The Biocity Program - Sustainable Municipal Management System worked with the purpose of restoring and conserving local biodiversity, fighting climate change and promoting environmental, social and economic sustainability in the city.

- **2011**: First participation of Curitiba in the C40 Network, in a meeting held in São Paulo, from May 31st to June 2nd. The goal of the meeting was to support the promotion of inclusive, low-carbon urban development in developing economies.

- **2013**: Curitiba was selected to participate in the project Promoting Low Carbon Urban Development Strategies in Emerging Economies (*UrbanLEDS*), the result of a partnership of ICLEI Local Governments for Sustainability, UN - HABITAT and the European Commission (PMC; ICLEI; 2016), which enabled the preparation of the 2nd and 3rd GHG Inventories of the city. In the same year, Curitiba received from the UN the Resilient City certificate.

- **2015**: Curitiba hosted the *Seminar on Resilient Cities Community and Climate* (SECIRE), of October 14-16, when the *Curitiba Charter on Confronting Climate Change was* signed. The document presented the participants' vision on the theme, the proposals to the Brazilian government for Brazil's participation at COP-21 (Paris) and suggested actions to local governments. Also in 2015, Curitiba participated in COP 21.

- **2016**: In June, a new *Compact of Mayors for Climate and Energy* was formed. The adhesion of Curitiba and 32 other cities configured the Act of Mayors for Climate and Energy, held

during the programming of the 72nd General Meeting of the National Front of Mayors, at SEBRAE Recife.

- **2017**: The Management Committee of the "Building Resilient Cities" program was established, through Municipal Decree No. 798/2017. In the same year, Curitiba participated in COP 22, in Bonn, Germany.
- **2018 - 2020**: Period in which the Curitiba More Energy Project participated in the CFF - *C40 Cities Finace Facility* Program, which aims to provide technical assistance for the structuring of photovoltaic power plant projects at the landfill, the bus station, and three bus terminals in the city.
- **2018**: The National Green Roofing Association of Portugal (ANCV) held a *workshop* on green roofs, in April, aimed at training PMC's employees.
- **2019**: C40 Network promoted, in May, the training of seven PMC technicians in the Rotterdam Adaptation Academy as part of the actions for the elaboration of PlanClima, and, in June, the training of city hall servers in the elaboration of GHG inventories.
- **2020**: The Cajuru Urban Farm, a pioneer in the country in sustainable agricultural practices in cities, will occupy an area of 4.4 thousand square meters, for activities related to social, citizen, and food education.

The actions related to climate change adopted by the municipality are summarized in Figure 9.

Figure 9: Trajectory of actions to address climate change

It is important to highlight that climate change, besides being configured as a transversal theme to the several sectorial policies of the city, has become a key dimension for the approval of programs and projects with international and national funding agents. This is the case of the **Climate Risk Management Project Bairro Novo do Caximba,** of climate change adaptation, for an area of irregular occupation in the southern region of the city. The project, developed in 2019, is emblematic for being the first intervention funding with a seal of approval to tackle climate change with resources provided by the French Development Agency (AFD). The development of this project was based on co-creation with the community, which provided engagement and ownership, and the spaces designed consider intergenerational promotion and gender coexistence, universal accessibility, and improved education and career guidance.

6 | ELEMENTS OF THE PLANCLIMATE ELABORATION PROCESS

The structure of PlanClima was established based on the Climate Action Planning Framework, developed by the C40 Group, and contemplates four key components to be worked on by the cities:

(i) carbon neutrality;

(ii) resilience to climate risks;

(iii) climate governance and collaboration; and

(iv) inclusive climate action.

Carbon neutrality refers to ***mitigation*** actions, that is, actions aimed at reducing GHG emissions. Resilience to climate risks refers to local ***adaptation actions to*** the effects of climate change. Governance and collaboration refers to the institutional and non-institutional structures and partners that enable the effective construction and implementation of the climate action plan. Inclusive climate action refers to the expected social, environmental, and economic benefits and the equitable distribution of these benefits to the population. Figure 10 illustrates the key components of the Climate Action Planning Framework.

Figure 10: Key components of the Climate Action Planning Framework

The planning of climate action is based on technical and procedural evidence obtained through studies, evaluations, and actions. From this material it was possible to establish a baseline that, in turn, allowed the elaboration of a diagnosis to define the necessary actions to reach the objectives and expected goals.

Thus, the following studies and documents preceded the preparation of PlanClima: GHG Emissions Inventories, Inventories of Sinks, Scenarios of GHG Emissions Reductions, Assessment of Demands for Inclusive Climate Action, Climate Risk Assessment, and Engagement, Participation and Collaboration Actions.

Figure 11: Studies and documents that make up PlanClima

The following is a brief summary of each of the studies, documents, and actions that provided inputs for the preparation of PlanClima.

6.1 | GREENHOUSE GAS EMISSIONS INVENTORY

Considered a strategic tool for monitoring GHG emissions, the Emissions Inventories allow the identification and quantification of the emissions profile of a particular location. In addition to providing knowledge of the reality of emissions in a city, they also contribute to the following aspects:

Figure 12: Aspects related to greenhouse gas emissions

6.1.1 | GHG emissions profile in Curitiba

Curitiba began accounting for its GHG emissions in 2011, and since then has produced four Greenhouse Gas Emissions Inventories:

- 1st Inventory: Base Year 2008 / Completion 2011;
- 2nd Inventory: Base Year 2012 / Realization 2015;
- 3rd Inventory: Base Year 2013 / Completion 2015;
- 4th Inventory: Base Year 2016 / Realization 2019.

The inventories applied different methodologies, according to the instruments available at each time. The 1st Inventory used the IPCC methodology (1996 and 2006 versions) and the IPCC Good Practices Guide 2000. The 2nd and 3rd, followed the methodology of the Global Protocol for *Community Scale Greenhouse Gas Emission Inventories (*GPC) (PMC; ICLEI; 2016). The 4th Inventory, which served as a baseline

for the construction of the emission reduction scenarios for PlanClima, maintained the GPC methodology.

The differences in methodological approaches imply a limitation in the comparative exercise of the inventories. However, observing all of them, one can see that the greatest contributions of the city are linked to the Transport Sector. Figure 13 shows the GHG emissions profile of the first three inventories.

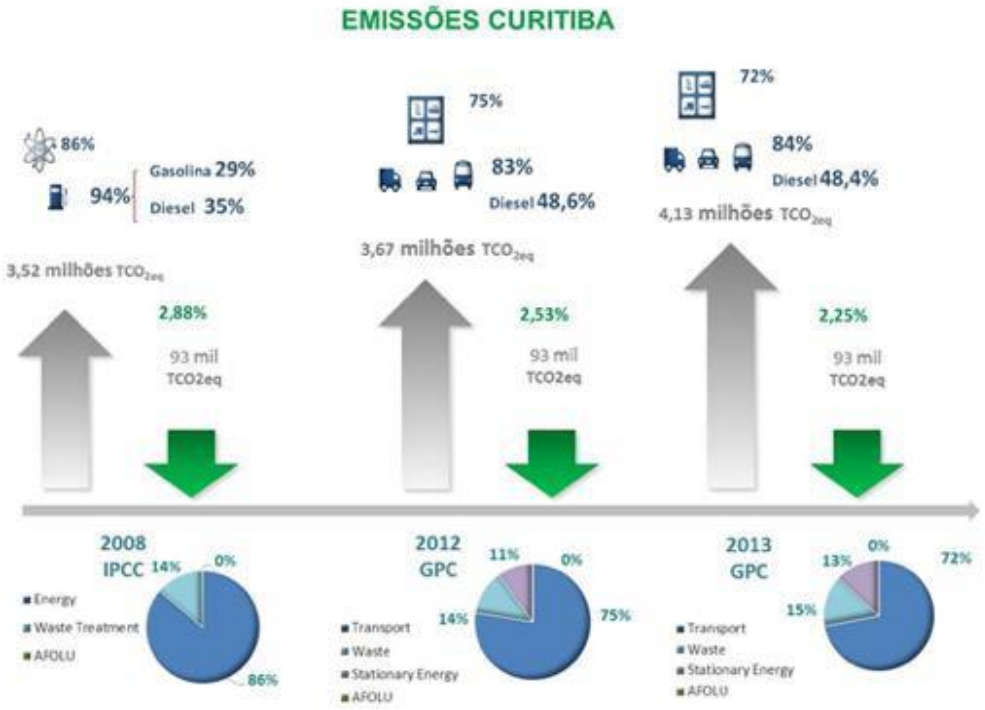


Figure 13: GHG Emissions Profile of Curitiba's 1st, 2nd and 3rd GHG Inventories[10]

The 4th GHG Inventory followed the BASIC approach level, with the calculation of emissions from the following sectors: (i) Stationary Energy - emissions arising from electricity consumption by buildings; and the consumption of fossil fuels for heating and cooking, electricity generation (generators) in residential, commercial and institutional buildings, industries, public lighting and rural properties, (ii) Transportation and (iii) Solid Waste.

[10] Note that the data presented regarding the 3rd GHG Emissions Inventory is not updated according to the latest update of the Global Compact of Mayors requirements in 2016.

The total emissions reported in the 4th Inventory amounted to 3,505,046 tons of carbon dioxide equivalent (CO_2e) distributed percentually as shown in Figure 14:

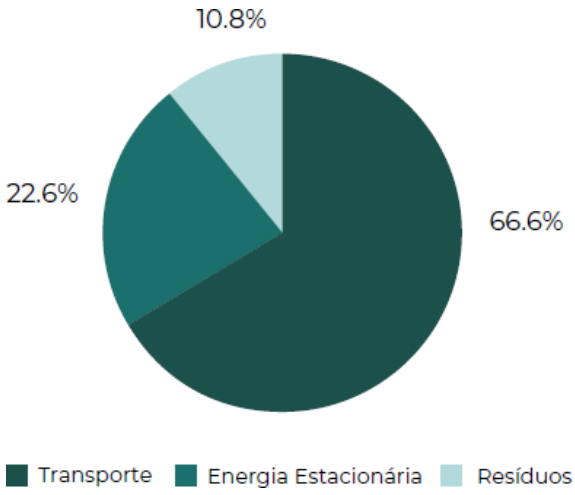


Figure 14: Percentage of GHG emissions by Sector for the year 2016

The profile of emissions shows that the Transport Sector represents the largest contribution to the total, corresponding to 66.6%, followed by the Stationary Energy Sector with 22.6% and, lastly, the Waste Sector with 10.8% of the emissions.

According to the GPC methodology, it is also necessary to report the emissions with respect to the Scopes. Scope 1, which corresponds to the emissions generated within the city limits, accounted for the total of 3,045,254 tons of CO_2e. Scope 2, represented by indirect emissions from the generation of electricity and thermal energy consumed within the city limits, totaled 368,882 tons of CO_2e. Scope 3, referring to emissions from waste generated in the city and treated outside the city, totaled 90,910 tons of CO_2e. Figure 15 depicts the distribution of emissions among the scopes:

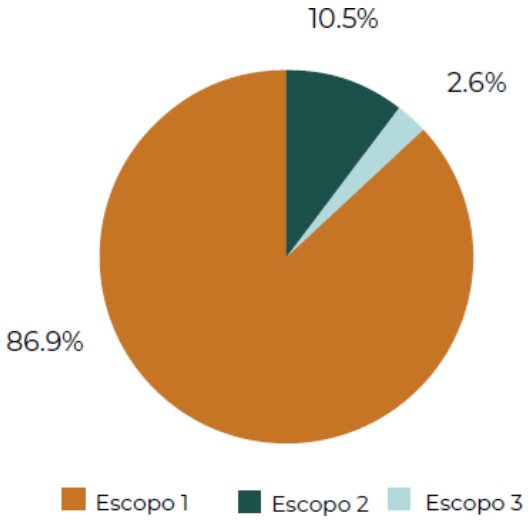


Figure 15: Distribution of GHG emissions in Curitiba separated by Scopes

Considering the limits reported in this GHG emissions inventory, it is possible to establish intensity indicators. These indicators can be computed in relation to the estimated population, economic activity - as a function of Gross Domestic Product (GDP) - and the area of the municipality (^{km2}). Table 1 presents the results of this analysis:

Table 2: Intensity Indicators

DESCRIÇÃO	INDICADOR
Emissões de GEE per capita	1,85 tCO_2e/hab
Emissões de GEE pelo PIB	41,8 tCO_2e/R$1.000.000,00
Emissões de GEE por unidade de área	8.057 tCO_2e/km^2

Figure 16 complements the results of emissions in the Subsectors, in tons of CO_2e.

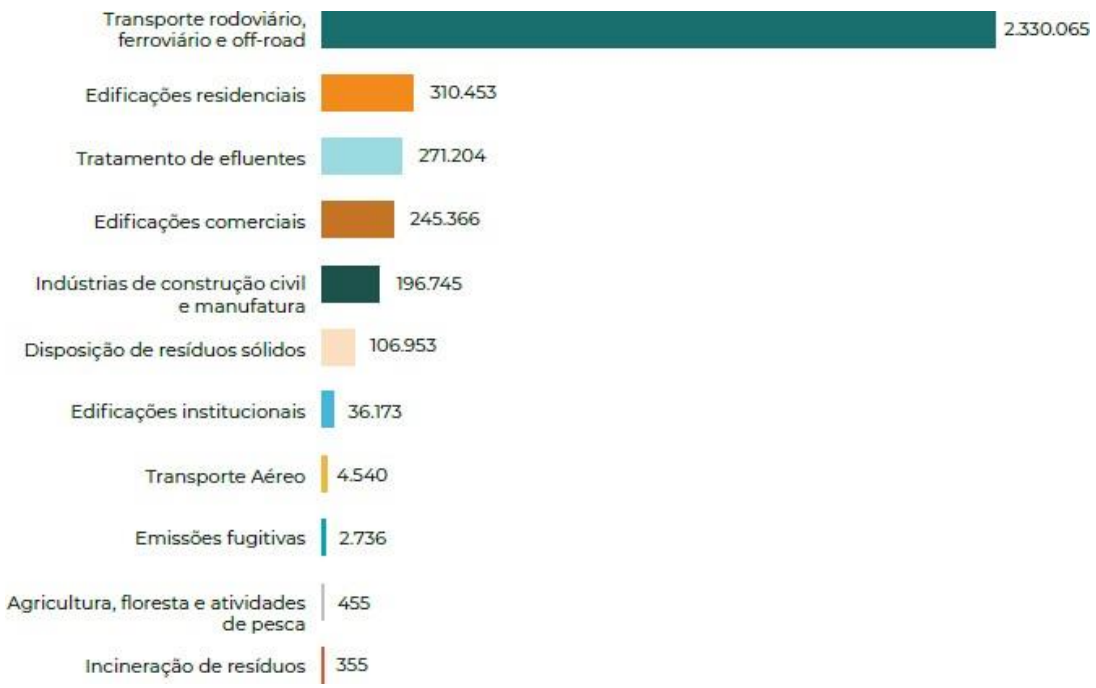


Figure 16: Distribution of GHG emissions in Curitiba by subsectors (in tCO2e)

The fact that emissions from the Transport Sector are not disaggregated due to the methodological approach adopted makes it impossible to visualize the contribution of the subsectors. Even so, it is possible to say that a good part of the emissions in this sector comes from [road] transport11. Residential buildings appear as the second subsector that most contributes to the city's total emissions, followed by emissions from wastewater treatment and commercial and industrial buildings. Biogenic emissions - which correspond to the burning of biofuels and methane avoided by burning or energy use, released into the atmosphere in the form of CO_2 - calculated for the city of Curitiba totaled 750,288 tons of CO_2e in 2016. These emissions come from the Energy Sector and the Transport Sector.

11According to the Origin-Destination Survey (POD), 45.8% of passenger trips are made by private cars, 25.2% by public transportation, 2.7% by motorcycle, and 2% by cab. This suggests that about 75% of all trips made in the city use fossil fuels for their displacement. A survey carried out by IPPUC, concluded in 2017, takes an X-ray of urban flows between the city's neighborhoods and between these and the 16 metropolitan municipalities with which daily relations are more intense. The POD visited 60 thousand households to reach the total of 15.8 thousand families (45 thousand people) interviewed who answered the complete questionnaire.

6.2 INVENTORY OF CARBON STOCKS OF NATURAL AREAS AND GREEN AREAS (INVENTORY OF SINKS)

The United Nations Framework Convention *on Climate* Change (UNFCCC) defines carbon dioxide removals as the process of removing atmospheric CO_2 and incorporating it into biomass (UNFCCC, 2020).

Taking into account strategies not only to reduce emissions, but to capture and fix atmospheric carbon, the information contained in the Sinks Inventories contributes significantly in planning climate action permitting:

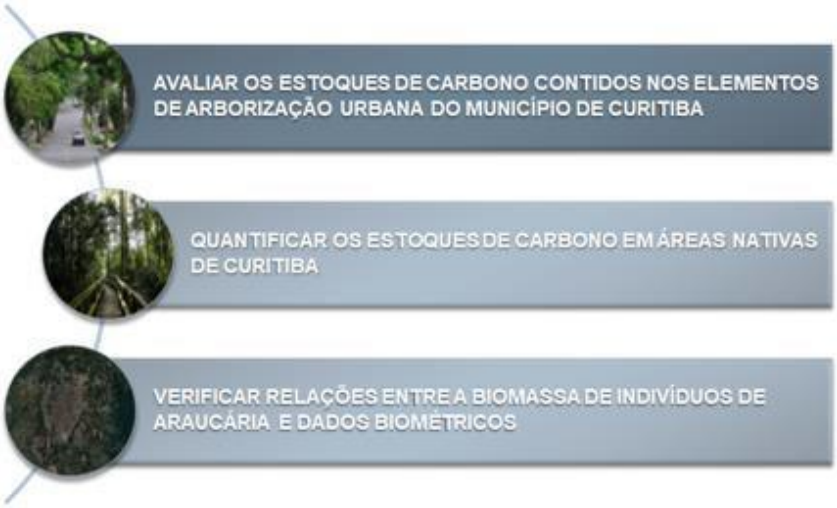


Figure 17: Actions linked to climate action planning

6.2.1 | Evaluation and Quantification of the Potential for Carbon Absorption by Native Forests in Curitiba

Curitiba has massifs with remnants of Araucaria forests (Araucaria Ombrophylla Mista Forest) in different stages of conservation. In addition to its enormous contribution to maintaining biodiversity and improving the quality of life of residents, this vegetation also helps to mitigate climate change. To estimate the amount of carbon absorbed and stored in native vegetation, Curitiba pioneered the "Program for Evaluation and Quantification of the

Potential for Carbon Absorption by Native Forests", in partnership with the Society for Wildlife Research and Environmental Education (SPVS).

Three measurements were made, in 2009, 2011 and 2019 (PMC; ICLEI; 2016), evaluating 39 plots in 15 Municipal Conservation Units. In 2009 there was an average total of 168.25 tons of carbon per hectare (tC/ha) fixed in the vegetation. In 2011, there was an increase to 174.10 tC/ha (SPVS; PMC, 2009 and Ribeiro et. al., 2013). Studies conducted in 2019 indicated a decrease to 141.25 tC/ha, a fact that demonstrates the need for constant actions by the Conservation Units of the municipality, such as management of exotic species, monitoring, and enforcement.

In 2020, the study expanded its scope, also including the Municipal Private Natural Heritage Reserves - RPPNM (private conservation unit category) and the large number of forest remnants with conservation potential in the municipality. It was found that these areas have an average stock potential of 147.59 tC/ha, i.e., 6.34 tons more than public natural areas. The private reserves are under a management that enhances the accumulation and maintenance of fixed carbon, which makes them great allies in the mitigation and adaptation to climate change.

It was demonstrated that the natural areas of Curitiba retain significant amounts of carbon, in addition to the other ecosystem services they offer to society. This result reinforces the efforts to maintain public Conservation Units and justifies the creation of incentives for the preservation of green areas on private lots. When located in strategic points, such as Permanent Preservation Areas (APPs), the benefit is doubled - in addition to storing carbon, the forests also absorb the waters from extreme rainfall.

Because of the service they provide, these reserves are relevant in the Ecosystem-based Adaptation (EBA) strategy, which seeks to reduce human vulnerability to climate change by managing and using biodiversity and ecosystem services in the adaptation of cities. AbE is one of the innovative premises

in the radar of managers for investment decision-making. Its use is one of the guidelines of the National Adaptation Plan (Brazil, 2015), and also of Curitiba's Master Plan (article 66), according to which, besides being an important strategy for adaptation to climate change, it brings cobenefits of biodiversity preservation.

6.3 | GHG EMISSION REDUCTION SCENARIOS

Part of a GHG Emissions Inventory is the planning process of the mitigation climate action, which takes place through the construction of scenarios: a first scenario shows the profile of emissions if nothing is done to reduce them; another, includes the implementation of actions that are planned; and a third, works with mitigation actions that are more ambitious than expected. This stage of emissions scenario building contributes to the following aspects within climate action planning:

Figure 18: Aspects considered in the construction of emissions scenarios

6.3.1 Trajectories of future GHG emissions and Residual Emissions in Curitiba

The GHG Emissions Inventory allows the projection of future emissions considering the characteristics of the baseline emissions, i.e., a reference scenario in which no additional mitigation efforts are made by the city or other actors. From this baseline, the impact of emission reduction actions can be measured.

The city has built scenarios that consider implementing GHG emission reduction measures for 2050, with an intermediate target for 2030.

Emission reduction scenarios for climate action planning are often developed based on technology change models that require implementation assumptions - parameters for changing reduction strategies, for example by changing the energy source used for transportation. With this, it is possible to calculate the potential for emission reductions and the extent of a given strategy's impact on the community.

The emissions scenarios are, therefore, elaborated based on evidence, that is, they consider the characteristics of the proposed strategies, measures, and actions and their potential to reduce GHG emissions.

The construction of scenarios for PlanClima, facilitated by the use of the ***Pathways*** tool, allowed the projection of emissions in the Transport, Energy and Waste sectors to be visualized, applying different assumptions of actions in each emission reduction scenario. The scenario assumptions were defined with the technical support of specialized consultants who conducted workshops with actors from different sectoral areas and, subsequently, were validated by the Plan's development team.

Four scenarios were created:

(i) **Trend Scenario** (no mitigation) - This is the one that maintains the *status quo,* also called *business as usual* (BAU) emissions. This scenario considers

the projections of population, economic and sectoral energy intensity changes according to the emission trends identified in the baseline;

(ii) **Planned Scenario** - Includes existing or planned regional and national actions (e.g. policies, projects, etc.) aimed at reducing community GHG emissions in the coming years. The scenario may also include market trends not driven by public policy if there is strong evidence that they will prevail;

(iii) **Ambitious Scenario** - Includes ambitious but consensually achievable strategies and actions. This scenario can expand upon existing and planned actions, and also identify new strategies and actions that reduce additional sources of GHG emissions; and

(iv) **Extended Scenario** - Identifies key emission reduction strategies beyond those in the Ambitious Scenario, but with barriers to overcome. For example, changes in paradigms, processes, behaviors or technologies that innovate traditional ways of doing things.

Figure 19 presents the trajectories of Curitiba's emissions modeled for the scenarios described above. Each of these scenarios is associated with a GHG emission quantity projection, thus demonstrating the reduction potential of each scenario compared to the 2016 base year emissions.

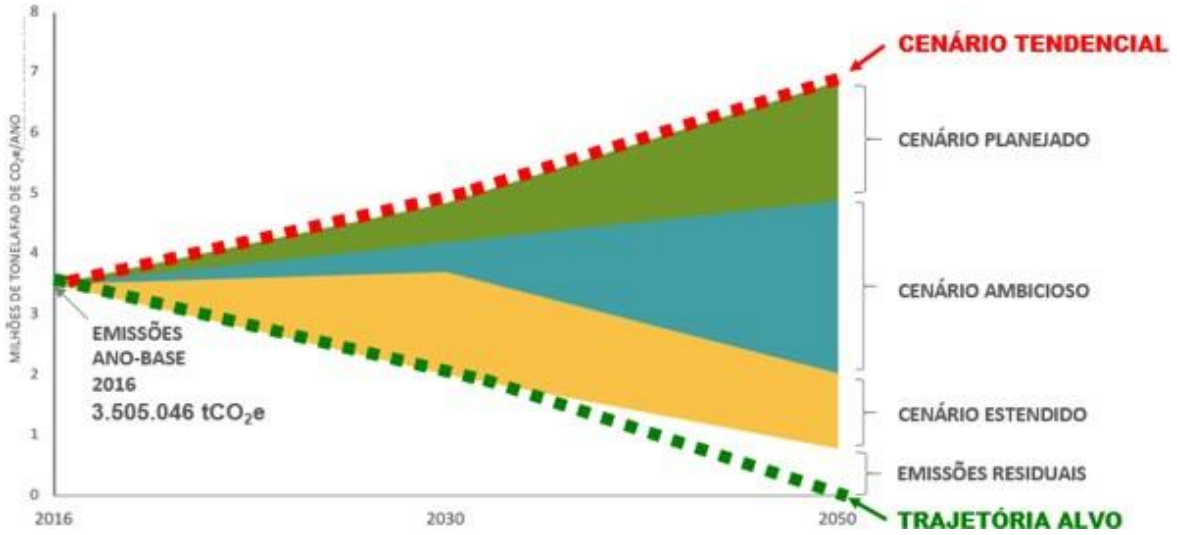


Figure 19: Curitiba GHG emissions trajectory for the Trend, Planned, Ambitious and Extended Scenarios

The upper red line of the graph represents the Trend **Scenario** (no mitigation) and shows the upward trajectory of emissions due to population and economic growth, without considering any climate action to reduce them. In this modeling, total emissions are estimated to be 4,834,507 $_{tCO2e}$ in 2030 and 6,855,886 $_{tCO2e}$ in 2050. The projections show that emissions will almost double by 2050 compared to 2016.

The green portion of the graph shows the potential emission reduction of the **Planned Scenario**, where the projected emissions appear based on the actions that the city already develops. In this scenario, total emissions are estimated to be 4,179,073 tCO2e in 2030 and 4,872,442 $_{tCO2e}$ in 2050. Even with the trends of fuel switching and increased efficiency, along with the other actions promoted by the city, there is an increase in emissions both in 2030 (19.2%) and in 2050 (39.0%). However, this increase is relative to the base year (2016). When these emissions are compared to the future projections of the Trend Scenario, a reduction occurs. Still, the planned action scenario is not sufficient to address the city's GHG mitigation goals and targets, which only become more feasible in the Ambitious and Extended Scenarios.

The emission reduction potential of the **Ambitious Scenario**, represented in the graph by the blue portion, considers measures over which the municipality has governability and that were consensually agreed upon among the actors participating in the elaboration process of the development of this module. In this scenario, it is estimated that in 2030 total emissions will reach 3,707,762 tCO2e and, in 2050, 2,030,665 tCO2e.

The Ambitious Scenario presents a 5.8% increase in emissions in 2030 and a 42.1% reduction in 2050, in relation to 2016 emissions. It is noteworthy the contribution of the Transport Sector from the change of fuel, from individual modal to public transport or active mobility (walking and cycling). However, as can be seen in the figure above, the Ambitious Scenario does not reach the emission reduction levels consistent with the **Target Pathway,** of carbon neutrality in 2050, according to the goals set in the commitment to the 2020 Target.

Given this perspective, the **Extended** Emissions Reduction **Scenario** was developed - represented in the chart by the yellow portion - for which key strategies capable of reducing emissions were identified, provided that the barriers to their implementation were overcome. In this scenario, total emissions are estimated to be 2,002,891 tCO2e in 2030 and 768,982 tCO2e in 2050.

The development of the Extended Scenario required a review of the emissions profiles that remained after the Ambitious Scenario was completed. For each key strategy (those with high emissions reduction potential), barriers were identified that currently make it unfeasible[12]. An analysis identified the main reasons why the city perceives barriers to implementing certain strategies, measures and or actions.

Table 2 presents the main types of barriers to emission reduction strategies in the Extended Scenario context.

12Barrier is understood to be a difficulty, problem, rule, or situation that prevents someone from doing something or makes an action impossible.

Table 3: Identification and definition of barriers to emission reductions

Barrier Type	Definition
Legal and Institutional	They include lack of legal powers to implement a particular strategy or action, situations in which legal responsibilities are divided among agencies or levels of government, limiting the municipal authority's ability to implement the strategy or action. For example, when laws or regulations from other levels of government (or their absence) prevent or limit implementation.
Financial and Economic	They may include insufficient financial resources or rules that restrict spending on specific strategies, limitations on the flexibility with which revenues can be used to fund actions, as well as incentives that affect the economics of a strategy (e.g. fossil fuel subsidies).
Political and Social	These can include lack of political or public acceptance, or restrictions imposed by group pressure, or cultural issues, such as resistance to compliance with rules or regulations, which influence the implementation of actions.
Practical and Technological Implications	They include practical limitations on the implementation of actions, such as obstacles associated with the physical geography of the city or technological development and technological availability.

The Extended Scenario, despite presenting barriers to its effective implementation, is the scenario closest to achieving neutrality, reaching a potential reduction of 42.9% of emissions in 2030 and 78.1% in 2050, compared to 2016 emissions. Compared to the Trend Scenario emissions for the year 2050, the Extended Scenario reaches a potential reduction of 88.8%.

Adopting the measures modeled for the Extended Scenario results in 11.9% residual emissions in 2050, relative to 2016 emissions. Residual emissions are emissions remaining after all technically and economically feasible GHG reduction opportunities across Scopes and Sectors have been adopted. Figure 20 presents the profile of residual emissions in the Extended Scenario.

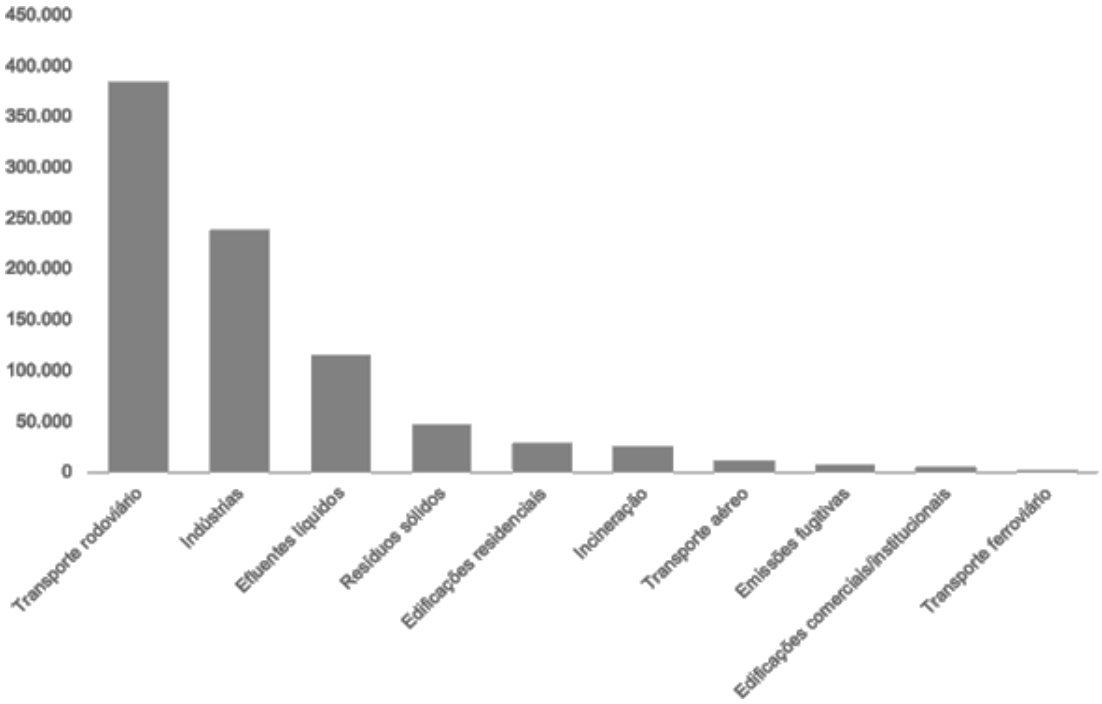


Figure 20: Curitiba's residual emission profile for the year 2050

The residual emissions result mainly from road transport - represented by passenger (individual and collective) and freight vehicle travel - followed by energy consumption by industries. With the exception of public transport, these are areas over which the municipality has limited governance.

Deliberating on such issues often involves the federal level of government. This is the case, for example, with the energy transition of individual vehicles from fossil fuels to renewable energies. The transition to low-carbon production processes also involves decisions by the private sector.

One possible strategy for dealing with residual emissions is to invest in increasing the city's natural carbon stocks. In addition to green areas being essential to maintaining the quality of urban life, regulation of microclimate, air and water quality, they also have the function of contributing to the absorption and storage of carbon dioxide.

The studies carried out in Curitiba to evaluate the quantity stored in the city's green areas were pioneering initiatives and there is the intention to continue them

to this work. The monitoring of the stock contained in the 15 municipal Conservation Units sampled showed, in 2019, that the natural areas of these sites have the capacity to store 141.25 tons of carbon per hectare.

6.3.2 Implementation assumptions for mitigation strategies, measures and actions

In the development of emission reduction modeling in the *Pathways* tool, assumptions were adopted that, according to each scenario (Planned, Ambitious and Extended), present different levels of increased ambition in relation to the strategies, measures and/or actions outlined, resulting in different GHG emission reduction potentials. Table 3 highlights the main assumptions considered for the Energy, Transport and Waste Sectors.

Table 4: Main assumptions adopted for modeling the Scenarios

Setor	Principais premissas
Energia	Aumento da participação das fontes de energia renovável na matriz energética brasileira
	Ampliação da geração distribruída de energia solar
	Aumento da eficiência das edificações e equipamentos
Transporte	Aumento da eficiência dos veículos (melhoria dos motores ou combustíveis; mudança da tecnologia dos veículos)
	Aumento significativo dos deslocamentos feitos pelo transporte de massa e da mobilidade ativa (a pé e de bicicleta)
	Diminuição expressiva dos deslocamentos feitos por automóveis
Resíduos	Redução da parcela orgânica disposta em aterros sanitários
	Ampliação de medidas para redução da GEE em Estações de Tratamento de Efluentes

Considering that PlanClima's main goal regarding mitigation is to reach carbon neutrality in 2050, the main strategies, measures and/or actions used for the modeling of the Extended Scenario, which presents the maximum emissions reduction potential, are presented below.

Energy Sector

The emissions have a strong relationship with the emission factor[13] of the Brazilian energy matrix, which is considered hydrothermal, but with about 80% of the energy production coming from renewable sources.

For the **Energy Sector**, the measures used in the modeling are aimed at increasing the share of renewable energy sources in the Brazilian energy matrix, distributed solar generation, and increasing the efficiency of buildings and equipment. Figure 21 presents the distribution of the Brazilian energy matrix modeled for the year 2050 in the Extended Emissions Reduction Scenario.

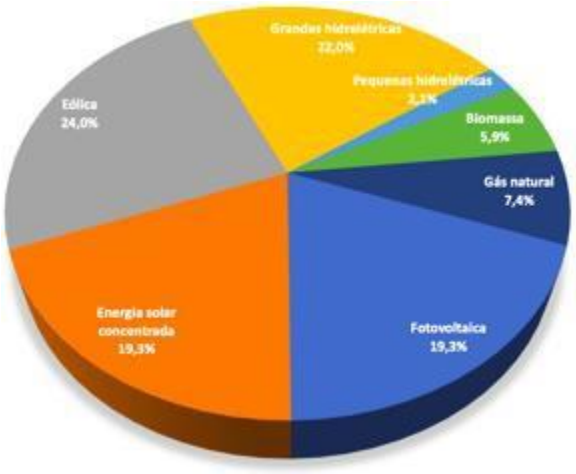


Figure 21: Distribution of the modeled energy matrix for the Extended Emission Reduction Scenario

[13] Emission factor is a measure of the mass of GHG emissions relative to the unit of an activity. For example, estimating CO_2 emissions from electricity consumption involves multiplying kilowatt-hour (kWh) data for electricity consumed by the emission factor ($_{kgCO2/kWh}$) for electricity, which depends on the type of technology used to generate electricity (Source: GPC, 2014). Available at: <https://ghgprotocol.org/sites/default/files/standards/GHGP_GPC_0.pdf>. Accessed on: 10/16/2020.

In modeling this scenario, the predominant energy sources are: large hydro, wind and solar (photovoltaic and concentrated[14]) power, accounting for approximately 85%; followed by natural gas, biomass and small hydro, accounting for about 15%.

In the case of distributed generation, the availability of solar radiation in the municipality, calculated based on the projection of the solar potential of rooftops from *Google Environmental Insights Explorer* (*Google* EIE), was used as a methodological reference for the establishment of the emission reduction potential.

Google IEE calculates that 84% of the roofs in the city of Curitiba are suitable for the installation of distributed solar power generation systems. However, this figure results in electricity generation by photovoltaic modules that is higher than the electricity consumption in the city's distribution network.

This fact is considered a constraint by the *Pathways* tool in calculating GHG emission reductions, because it does not take into account the self-generation of electricity disconnected from the distribution network. Thus, in order to equate generation with consumption, the percentage of 39% of buildings with roofs taking advantage of the potential of solar radiation for distributed electricity generation was used.

With regard to energy efficiency in residential, commercial, and institutional buildings, the modeling mainly applies measures such as switching from fossil fuels to cleaner, or more efficient, energy sources and improving technology for the following processes and equipment:

- Heating or cooling of environments;
- Cooking;
- Water heating;

[14] Also known as heliothermal energy or thermosolar energy, "concentrated solar energy is produced with the help of several mirrors that direct the sun's energy at one point to heat water, which will be turned into steam. This vapor will turn a turbine, generating electricity. (Source: EPE, Energy Research Company, 2020). Available at: <https://www.epe.gov.br/pt/abcdenergia/fontes-de-energia>. Accessed on: 10/16/2020.

- Lighting; and
- Building envelope.

For the decarbonization of industries, in the Extended Scenario modeling, assumptions were established for switching the energy matrix and increasing efficiency.

Transport Sector

In the **Transportation Sector**, the measures adopted for the Extended Scenario modeling propose a disruptive restructuring of the current mobility system and services in Curitiba, applying a number of concepts and principles of a low-carbon mobility system.

In addition to increasing vehicle efficiency, either by improving engines or fuels, or by changing vehicle technology, changes in the city's commuting profile were considered, as shown in Figure 22.

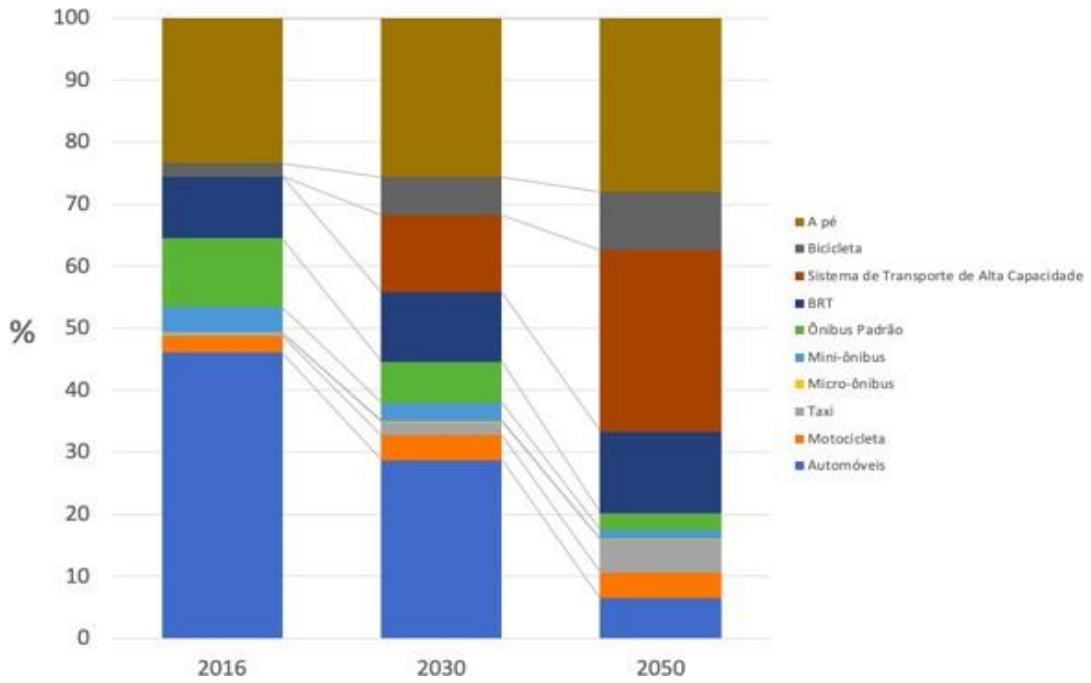


Figure 22: Displacement profile considered for the base year 2016 and the years 2030 and 20 50 simulated for the Extended Scenario

The change in the commuting profile modeled for 2050, presents an increase of approximately 85% in commuting by public transport and by

active mobility (walking and cycling). In addition, it foresees the implementation of a high-capacity transportation system as early as 2030, representing about 12% of displacements in this same year and approximately 30% of displacements in 2050.

There is also an increase in the cab mode, including in this category the contribution of the growth of trips made by app transport, as well as a slight increase in the share of trips made by motorcycles, due to the increase in delivery services.

It is also outlined a decrease in the displacements made by standard buses, minibuses and minibuses, based on the assumption that the optimization of the transportation system is sought. Thus, it is possible to connect the displacements of the first and last mile to the city's trunk system (BRT and High Capacity Transport System15), aiming to eliminate possible overlaps of conventional and feeder lines.

In the modeling, it was also estimated a reduction of displacements made by automobiles of about 38% in 2030 and 85% in 2050, in relation to the displacement profile of this modal in the base year. For this, we consider the creation of a highly attractive public transportation system and the implementation of policies and initiatives to discourage the use of individual vehicles.

To decarbonize the Transportation Sector, one of the most important strategies is to reduce the use of fossil fuels. For example, Figure 23 demonstrates the change in the fuel and technology of individual cars, with an increase in the share of electric and hydrogen-powered vehicles, a reduction in the share of gasoline-powered vehicles, and the elimination of diesel-powered vehicles.

[15] High Capacity Transportation System is understood as systems with a capacity higher than that of the BRT.

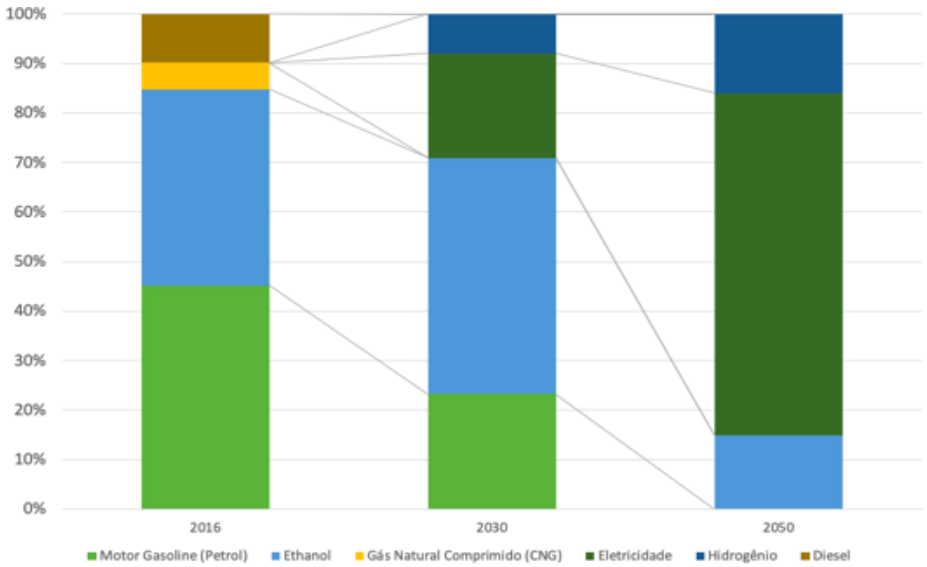


Figure 23: Change in passenger vehicle fuel and technology for the 2016 base year and the simulated years 2030 and 2050 for the Extended Scenario

Waste Sector

In the **Waste Sector,** the measures modeled in the Extended Scenario refer to reducing the organic portion of landfills, increasing the efficiency of landfill biogas collection and use, and increasing waste recycling rates. The modeling also addressed the implementation of measures to reduce emissions from wastewater treatment, considering more energy efficiency in the process.

To take charge of solid waste management, the Intermunicipal Consortium for the Management of Urban Solid Waste (CONRESOL)[16] was created in 2001. In this context, the Extended Scenario outlined strategies, measures, and actions based on the goals established in the Bidding Notice and based on the Technical and Financial Economic Feasibility Study.

[16] The coverage area of CONRESOL corresponds to the territorial area of the municipalities that integrate it, currently 23 (twenty-three) municipalities, totaling 10,389.52 km², covering a population of 3,075,954 inhabitants (IBGE 2010). It is worth noting that a public bidding process is underway for the Concession of the Integrated and Decentralized System of Waste Treatment and Final Disposal of Rejects.

Thus, the modeling of the Extended Scenario estimated that in 2030 the final disposal of tailings and waste in landfills is 25% and, in 2050, 5%. It also considered the use of the organic portion present in the urban solid waste of about 32% by composting and 63% by anaerobic digestion in 2050.

Regarding the reduction of emissions related to wastewater treatment, the modeling used measures addressed in the master's thesis of Filippini (2018) to analyze the mitigation potential of GHG emissions from wastewater treatment until the year 2030, in the State of Paraná. Projections were developed based on the goals of the Municipal Basic Sanitation Plans for service expansion and population growth. The modeling was designed during meetings with the technical team of the Paraná Sanitation Company (SANEPAR).

Currently, the municipality of Curitiba has five effluent treatment plants (ETEs), operated by SANEPAR, which also serve other municipalities in the metropolitan region. Only one of these stations performs treatment by activated sludge.

Thus, the Extended Scenario modeling considered that in 2050 all the wastewater generated in the municipality will be treated in activated sludge systems, resulting in a 73% reduction percentage over the total GHG emissions in 2016.

6.4 | ASSESSMENT OF DEMANDS FOR INCLUSIVE CLIMATE ACTION

Actions to address climate change are primarily designed to reduce GHG emissions and adapt the urban environment to climate risks. However, they often promote other benefits that may relate to health, air quality, jobs, equity, and more. This reinforces the fact that actions must be designed in an inclusive manner, seeking to achieve a fair and equitable distribution of the benefits of climate action planning. This is, in fact, the objective of the study "The Assessment of Demands for Inclusive Climate Action", conducted in 2020, by *WayCarbon* consultancy, through technical assistance provided by the C40 Group to the City of Curitiba under the Climate Action Planning Program.

The demand assessment for this goal covers the following aspects:

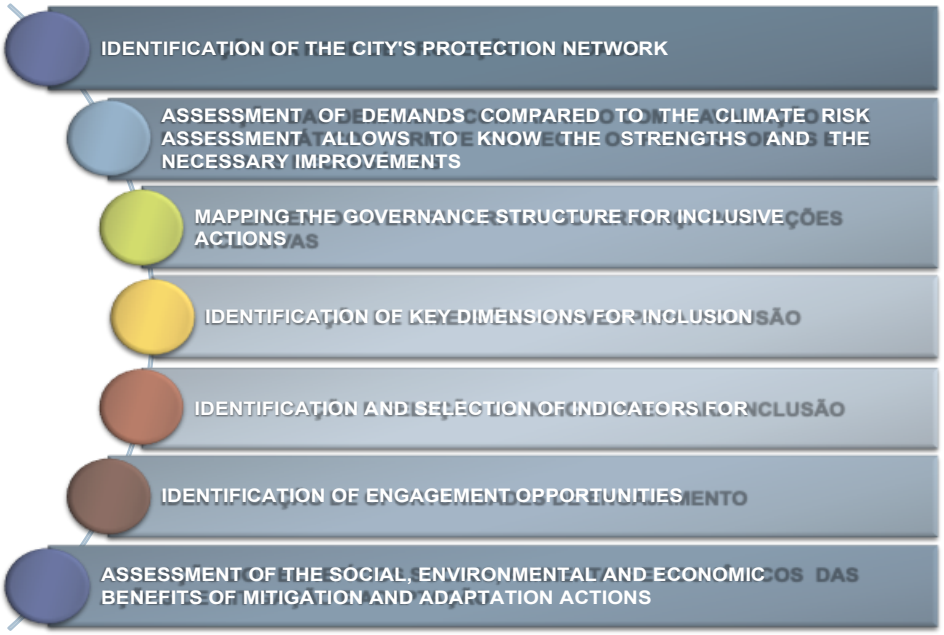


Figure 24: Aspects considered for demand assessment

In the scope of the study, Inclusive Climate Action is understood as the adoption of actions that aim to mitigate and increase the resilience of communities, especially those most vulnerable to climate change, and that eventually result in social and economic benefits for these communities.

In the assessment, the main inclusion issues and demands faced in the city, the most vulnerable regions, existing and planned actions, and the actors who have the political and economic resources necessary to influence inclusive climate policies were identified.

The identification of vulnerable groups was conducted according to the following definitions:

- Social Inclusion: rights, participation and access for typically marginalized populations;
- Economic Inclusion: equity of opportunity in the distribution of benefits, including jobs, wealth, etc.; and
- Spatial Inclusion: access to land, infrastructure, transportation, housing, etc.

In other words, the evaluation considered that vulnerable groups are those who lack actions for their inclusion, according to the above definitions.

In the regions of the city with the most vulnerable groups in the social, economic and spatial spheres, the evaluation points out that there is a correlation between the expansion of urban areas and their state of vulnerability. Thus, the peripheral regions are, in general, the most vulnerable. According to the assessment, the Administrative Regions of Tatuquara, Bairro Novo, CIC and Santa Felicidade (irregular occupations) deserve attention.

The analysis of the incorporation of the social, economic and spatial dimensions identified in the almost 50 official documents analyzed a tendency to address themes more related to social inclusion, although a good part of them also encompass the spatial and economic aspects.

It was identified that the city's main indicators, evaluated in the different plans in effect, reflect the results of the proposed measures and signal to managers the most important areas for intervention, as well as the most vulnerable groups.

A SWOT Matrix - synthesizing the strengths and weaknesses, according to the seven domains presented in the document *Needs Assessment Module of* Group C40 (C40, 2019), and the indicators related to them - was prepared, which enabled the design of more assertive strategies. According to this matrix, it was found that some domains are more consolidated, both in monitoring by indicators and in their results, and also in the volume of related plans/studies. These are the domains of Economic Prosperity and Essential Public Services. Other domains, such as Civil Society and Institutions and Governance, demand more indicators for a systematized monitoring of the areas.

Thus, it became possible to propose indicators that allow monitoring inclusion aspects beyond the domains of interest of public action. The evaluation suggested 28 priority indicators for inclusive action in the scope of climate action planning in Curitiba.

The evaluation also carried out a political-economic analysis in which the relevant actors in the construction of inclusive municipal policies that should be surveyed to integrate PlanClima were identified. This aspect is of great importance for governance, participation and engagement actions. In the elaboration of this work, it was also found that the different institutional mechanisms of social participation (public consultation, debates, discussions in councils/forums and collegiate bodies) were present, reinforcing the perception that the decision-making process values collective construction *with* and *for the* society, especially the most vulnerable groups.

The political-economic analysis facilitated the understanding of the inclusive municipal policy-making process. It was observed that Curitiba has a governance structure - composed of municipal, civil society and third sector instances - that enables the implementation, monitoring, commitment and engagement of those involved over time.

The assessment concluded that the challenge of inclusive climate action is therefore to ensure that vulnerable groups and communities develop the capacities to respond to extreme events. Climate resilience should be a widely shared capability and a collective investment in human development, so as to avoid that only better-off individuals (income, infrastructure, education, etc.) benefit. In this context, PlanClima should not exacerbate the vulnerabilities observed in the city, but minimize them by designing inclusive mitigation and adaptation actions.

6.5 | CLIMATE RISK ASSESSMENT

Scientific studies and research have been proving that climate change can cause significant environmental and socioeconomic damage, caused by greater frequency and intensity of extreme events in the form of heavy rains, storms, heat waves, droughts, etc., resulting in environmental and socioeconomic damage. Knowing the climate risks and their possible impacts contributes to the development of policies and prioritization of actions to minimize their effects in the future. In addition, climate risk assessment enables the:

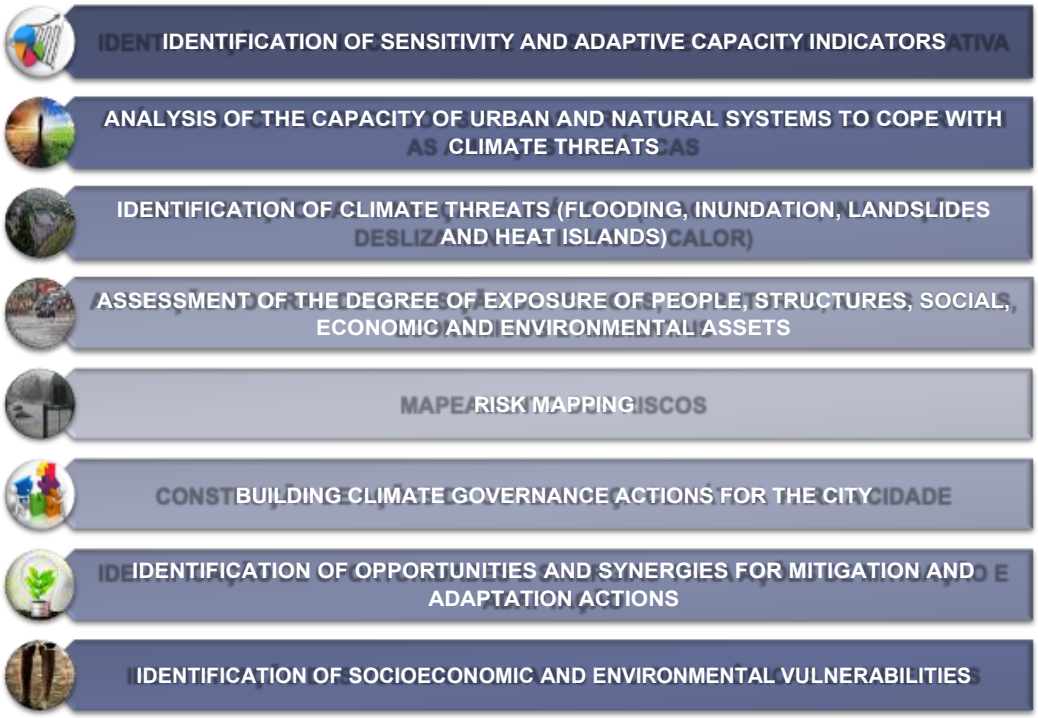


Figure 25: Expected results from the climate risk assessment

In order to be able to evaluate climate risks, it is necessary to carry out a characterization of the current and future climate by evaluating historical meteorological data reproduced by climate models. Future scenarios are described according to predictions derived from quantitative models that simulate climate dynamics. These GHG emission scenarios are published in *Assessment Reports* (AR) by the IPCC. To date, the IPCC has published five Reports

Assessment[17]. In this way, it is possible to estimate the future climate, considering different GHG emissions scenarios.

Curitiba presents two studies in this sense, the Environmental and Socioeconomic Vulnerability Assessment for the City of Curitiba and the Climate Risk Assessment for the City of Curitiba.

In 2014, the **Environmental and Socioeconomic Vulnerability Assessment for the Municipality of Curitiba** was completed by SNC-Lavalin Projetos LTDA[18], in partnership with IPPUC. The study developed a Risk Analysis Matrix in relation to vulnerabilities to climate change and guided preventive actions in public policies directed to minimize these risks and their potential impacts on three systems evaluated: built, social and environmental environments. For the elaboration of the Risk Matrix, the probability of occurrence of events resulting from climate change in these environments was considered - if rare, unlikely, possible, probable or almost certain - and the severity / severity of these impacts - if insignificant, low, medium, high or extreme.

Several phenomena were evaluated and mapped, such as erosion potential, increased sealing in the modeled basins and sub-basins, evolution of stormwater runoff resulting from this sealing, and identification of areas subject to flooding. The study allowed for the objective identification of the most vulnerable sectors of the municipality and the location of the infrastructure and populations exposed to environmental risks.

The study also pointed out that the greater environmental vulnerability in the climate change scenario is related to the probability of greater frequency and intensity of extreme climate phenomena, such as regime alterations

[17] IPCC Assessment Reports: 1990 - *First Assessment Report* (FAR): 1995 - *Second Assessment Report* (SAR); 2001 - *Third Assessment Report (*TAR); 2007 - *Fourth Assessment Report (*AR4); 2014 - *Fifth Assessment Report (*AR5).

[18] The Environmental and Socioeconomic Vulnerability Assessment for the Municipality of Curitiba was one of the projects promoted by the National Association of Public Transport (ANTP) within the *Sustainable Transportand* Air *Quality* (STAQ) Program, funded with resources from the *Global Environment Facility* (GEF), through a grant from the World Bank. In this case, the project was developed for the Municipality of Curitiba, in partnership with the Institute for Research and Urban Planning of Curitiba - IPPUC.

of rainfall, making the municipality more vulnerable to flooding. Regarding the socio-economic dimension, the study pointed out that vulnerability focuses on: residential infrastructure, water supply systems, wastewater collection systems, electricity supply, supply systems and municipal services related to emergencies, quality of life, soil, fauna and flora.

The Environmental and Socioeconomic Vulnerability Assessment was based on the methodology provided in the IPCC's fourth assessment report, AR4, from 2007. In addition to the climate scenarios, this study simulated the precipitation scenarios in hydrological models. These models are used to simulate the processes of transformation of precipitation into runoff, allowing the impacts on the flow regime in the study region to be estimated.

In 2020, as part of the C40 Technical Assistance Program, *iCare & Consult* prepared the **Climate Risk Assessment of the City of Curitiba**. The objective of this study was to expand the knowledge about the present and future risks of climate change in the city of Curitiba, reporting sufficient elements to support the development of actions to increase the city's resilience through PlanClima.

The first phase of the study included the historical assessment of the city's climate trends, covering the time horizon of the available baseline (1960-2019) and the projection of climate variables up to 2100. Future climate analyses considered a critical GHG emission increase scenario estimated by the *Representative Concentration Pathway* (RCP) in the IPCC's fifth assessment report, AR5, released in 2014 (RCP 8.5)[19].

In the second phase, the study sought to identify the main climate threats registered in the city, based on data of extreme events occurring between

[19]Known by the acronym RCP 8.5 (*Representative Concentration Pathway*), this scenario predicts an average carbon dioxide concentration corresponding to a radiative forcing of 8.5 watts per square meter across the planet, which would lead to an increase in global average temperature of about 5oC by 2100, a parameter developed in the fifth phase of the *Coupled Model Intercomparison Project* (CMIP5) and published in AR5 - IPCC Fifth Assessment Report (2014).

2012 e 2020. From a probabilistic analysis of these data - including historical and future assessments of climate variables, in addition to the availability of data that could be spatially explicit - a prioritization of the main climate threats was made: flooding, inundation, landslides, and susceptibility to heat waves.

The third phase of the assessment consisted of a risk analysis, composed of exposure, vulnerability, and climate threats analysis. In the exposure analysis, land use modeling was performed (pinpointing the city's critical infrastructures) as a way to simulate urban expansion for the 2100 time horizon. The city's population, road loading, and active establishments by economic activity sector were also taken into account. The assessment of vulnerability was made through sensitivity indicators, which make explicit the socioeconomic inequities existing in the city, and indicators related to its adaptive capacity. The fourth and last phase evaluated the level of resilience of the city in general, as a way to identify the gaps that impact the city's adaptation to climate change.

Figure 26 illustrates the Risk Representation based on the Vulnerability, Threat and Exposure variables of the approach taken in the Climate Risk Assessment.

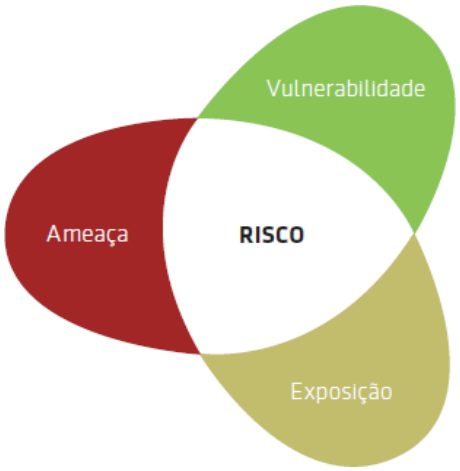


Figure 26: Risk representation from the Vulnerability, Threat and Exposure variables

The study spatializes climate risks on maps, facilitating their understanding. However, the concept of risk must be emphasized in order for the results to be correctly interpreted. Risk is defined as the materiality of the occurrence of dangerous events or trends (threats). In other words, a region with a high probability of occurrence of a threat (landslide, flood, inundation, or heat waves), to which it is vulnerable and exposed (it has many material assets and people), should have a high degree of associated risk. On the other hand, a region with a high degree of threat, but no assets or a population that is not as sensitive, has a comparatively lower degree of risk. Risk, therefore, results from the interaction between vulnerability, exposure, and threat. Figures 27 and 28 present the Risks of Flooding, Waterlogging, Heatwaves, and Landslides in 2050.

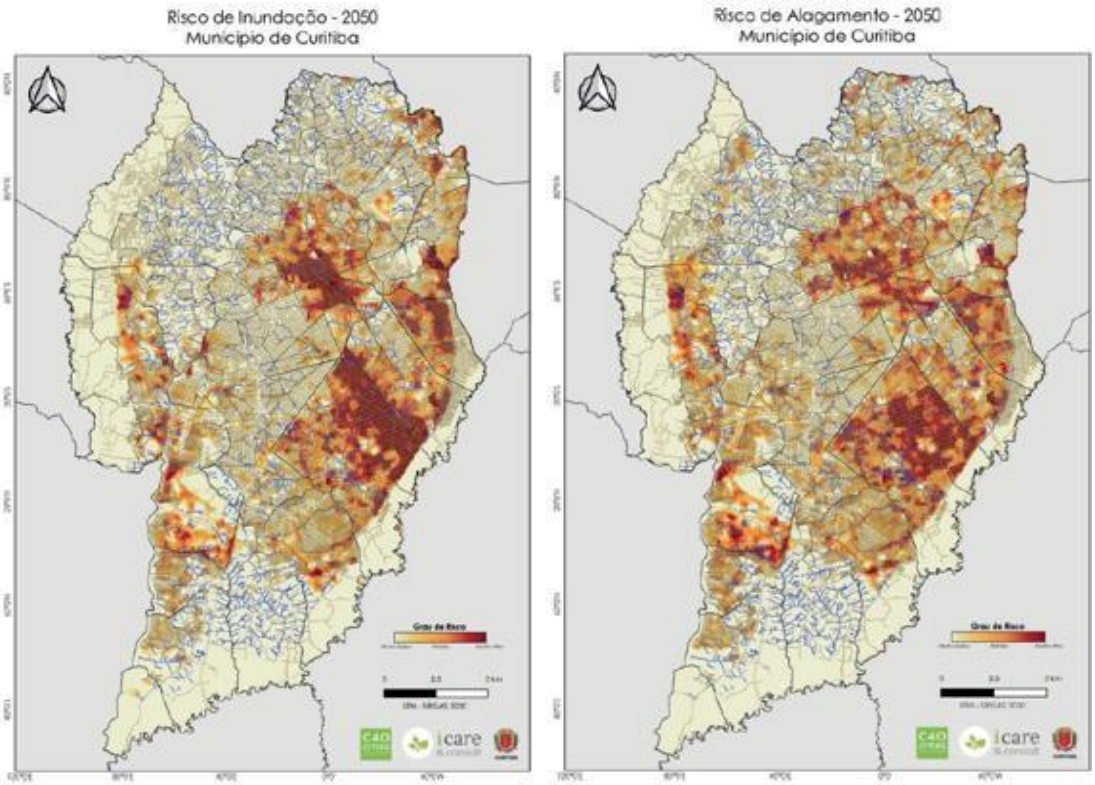


Figure 27: Flood and flood risk maps for Curitiba in 2050

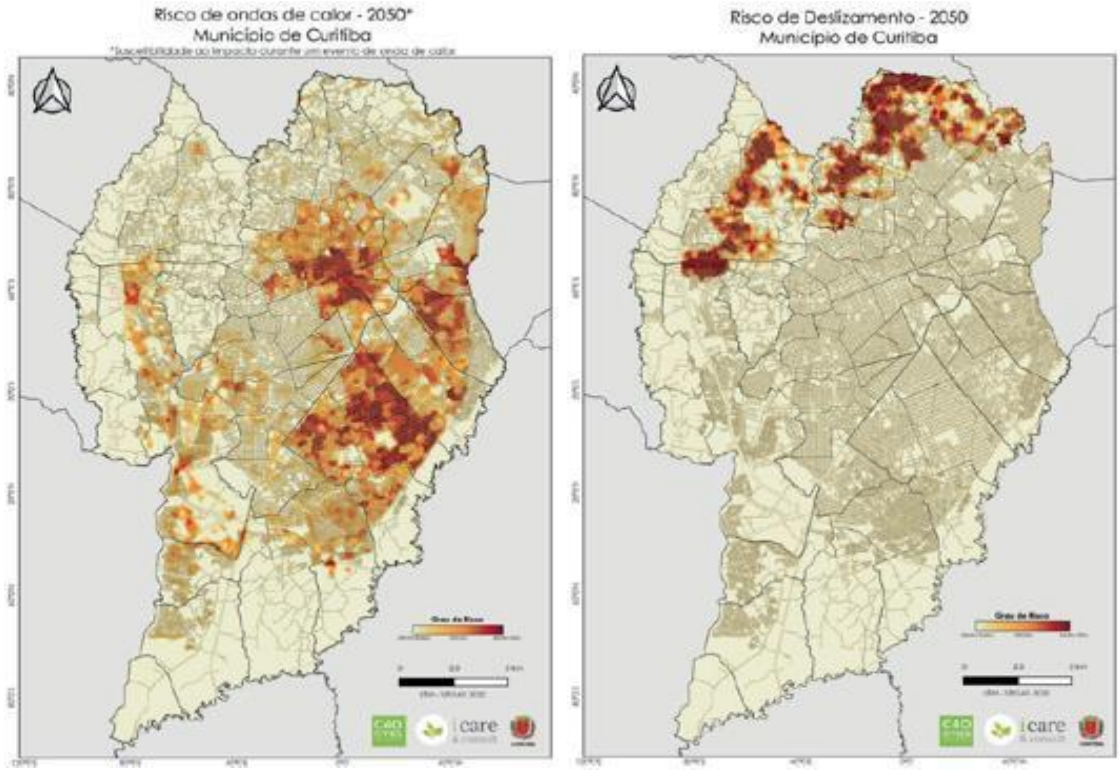


Figure 28: Heat wave and landslide risk maps for Curitiba in 2050

As results of this Evaluation, we highlight the following:

- future trend of increase in the average temperature of Curitiba;
- There is no specific trend for increase or decrease in the annual rainfall volume over the next decades, but the data indicate that the city may have some years with much above average rainfall, with several consecutive days of precipitation;
- There is a strong tendency for drought;
- maximum rainfall in one day, since in almost every year the city is expected to have at least one episode of very heavy rain; and
- On the other hand, consecutive days without rain will also be frequent and the city may experience long periods of drought, with repercussions on the water supply.

6.6 ENGAGEMENT, PARTICIPATION AND COLLABORATION

The PlanClima, a strategic instrument of municipal urban policy that should guide public and private agents and the population in relation to tackling climate change, consists of a socio-political pact towards a more sustainable, carbon-neutral city, adapted to the impacts of global warming, resilient, participative, inclusive, innovative, and that offers quality of life to its inhabitants, with special attention to the most vulnerable communities and groups directly impacted by climate change.

In the elaboration phase of PlanClima, these efforts were aimed at internal and external stakeholders, such as municipal departments and agencies, state agencies, institutions, companies, and civil society.

This involvement is necessary to ensure that there is broad understanding, participation, and support, while also allowing for:

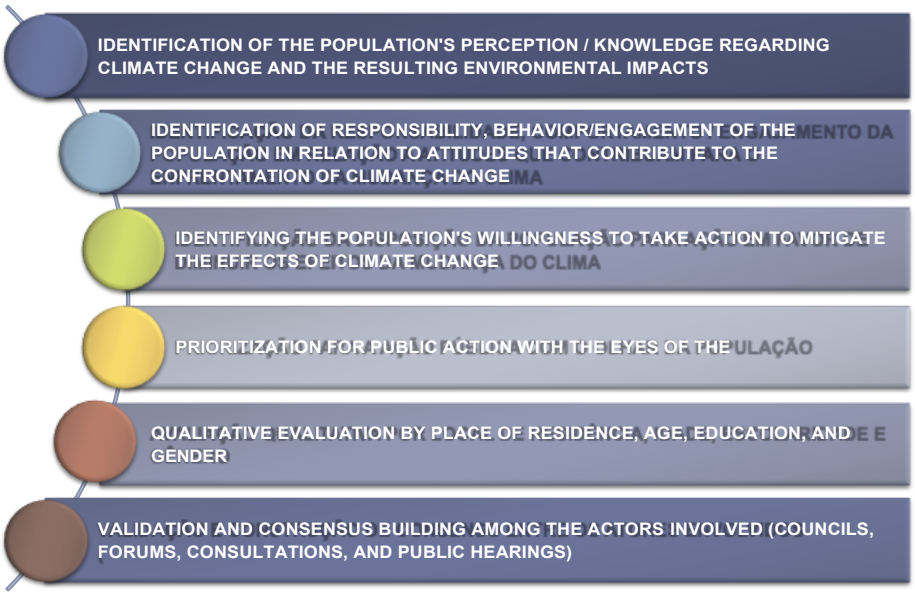


Figure 29: Results from society engagement, participation, collaboration

To achieve these goals, the participation of those who live and work in the city was sought, aggregating different perspectives, opinions, concerns, and experiences.

Consulting the stakeholders guarantees the inclusion of representatives from the various sectors in the elaboration of the Plan, and their broad support and adherence in building the commitments necessary for the implementation of the actions.

PlanClima is the result of a two-year process, built with many hands, by a Working Group formed by representatives from 12 institutions, and that counted on the support of the C40 Group, within the Climate Planning Technical Assistance Program of expert consultants.

Besides the technical team, the process of prioritizing actions received the collaboration of members of the Curitiba Forum on Climate Change and *Global Shapers*.

An *Online* Public *Consultation*[20] *was* held, launched on June 5th, 2020, World Environment Day, lasting one month, through the Conecta Platform, the same used by *Fala Curitiba* to prioritize actions involving the municipal budget. From the 664 responses of the population to a questionnaire with 12 questions, knowledge was obtained regarding the following aspects:

- perception of the population regarding climate change and the resulting environmental impacts;
- responsibility, behavior and engagement of the population in relation to attitudes that contribute to the confrontation of climate change;
- the population's willingness to take action to mitigate the effects of climate change; and
- identification of opportunities for prioritizing public actions.

The consultation allowed the qualitative evaluation of the population's profile in relation to the climate change theme, according to gender, age, level of education and neighborhood of residence. The results were the basis for the elaboration process of PlanClima, guiding the delineation of actions.

[20] The systematization of the *Online* Public Consultation presenting the main results is available in the

document *Online* Consultation Report.

Continuing the process of engagement, participation, and democratic management, the draft of PlanClima was forwarded to CONCITIBA, the Municipal Environment Council, and the Municipal Forum on Climate Change for its subsequent formalization by PMC.

The effectiveness and reach of programs, plans, projects, and actions can and should be enhanced through a broad set of actions that involve engagement, participation, collaboration, and consultation with society.

7 | STRATEGIC SECTORS

PlanClima is the urban planning instrument that indicates the path to be followed by the public power and society to build a resilient and carbon-neutral city.

Achieving these goals requires the implementation of transformative actions to reduce transport emissions, improve the energy efficiency of buildings, increase the supply of clean and renewable energy, and change consumption patterns. At the same time, the capacity to cope with the impacts of climate change through adaptation must be strengthened.

Besides considering the key components of the C40 Group Climate Action Planning Framework - carbon neutrality; resilience to climate risks; climate governance and collaboration; and inclusive climate action - PlanClima structures its actions in **Strategic Sectors** that emphasize areas of action interest.

Thus, considering the diagnosis prepared from the studies and documents that built the baseline[21] for the elaboration of PlanClima, five Strategic Sectors were defined for its structuring:

(i) Environmental and Urban Quality;
(ii) Energy Efficiency;
(iii) Solid Waste and Effluents;
(iv) Sustainable Urban Mobility;
(v) Urban Hypervisor and Innovation.

Another important aspect in relation to PlanClima are the governance and monitoring processes. They reinforce the intense dynamic of interaction that must exist between these Strategic Sectors, as illustrated in Figure 30.

21GHG Inventory (Base Year 2016); Sinks Inventory (2019); Planned and Disruptive Action Scenarios for 2030 and 2050 (2019); Demand Assessment for Inclusive Climate Action (2019); Climate Risk Assessment (2020); and Engagement, Participation, and Public Consultations (2019 and 2020).

Figure 30: PlanClima's Strategic Sectors

Each Strategic Sector includes themes, which facilitates the organization of PlanClima's priority actions and their future detailing during the implementation process, as can be seen in Figure 31.

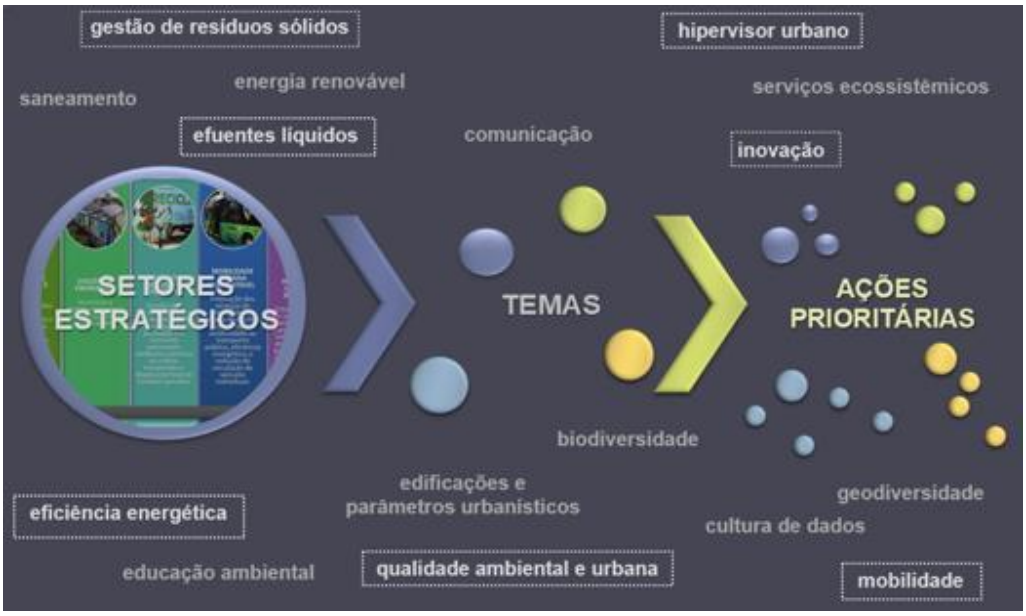


Figure 31: Outline of Strategic Sectors, Themes, and Priority Actions

The following is a description of each of the Strategic Sectors.

7.1 | STRATEGIC SECTOR ENVIRONMENTAL AND URBAN QUALITY

Maintenance of ecosystem services and promotion of environmental services in the urban environment, equitably distributing the city's inclusive wealth

Urban planning, focused on the environmental, urban and social quality of a city, is fundamental to the reduction of social risks resulting from climate change. The impacts caused by the activities developed in the city reflect directly on the environmental quality and must be adequate so that the interference is minimized.

The decrease in the environmental quality of cities directly affects the provision of ecosystem services, which promote well-being and a better quality of life for the population. The concept of ecosystem services is based on the idea that the environment provides benefits to society in different ways (direct or indirect). These benefits can be grouped into four categories of services:
(i) **provisioning** - include food, water, and raw materials such as timber and fiber; (ii) **regulatory** - regulate climate, control flooding, erosion, and disease, and are related to waste and water quality; (iii) **cultural** - provide recreational, aesthetic, spiritual, and educational benefits; and (iv) **supporting** - form soil, primary production, photosynthesis, and nutrient cycling (MEA, 2005; PANASOLO *et al.,* 2019).

Thus, the projects and actions that value the use of natural infrastructure and Nature-Based Solutions generate an important contribution to biodiversity, maintaining ecosystem services and promoting environmental services.

Curitiba throughout its planning process has been implementing measures to improve the urban and environmental quality of the city. The importance that the municipal administration gives to environmental policies is demonstrated by the consistency of municipal laws and decrees that deal with the theme. They involve

conservation of forest massifs and valley bottoms; maintain urbanistic parameters, promoting greater urban comfort, such as the distance between buildings, soil permeability, among others. Among the actions that contribute to a better balance of the relations of the city with its environment are the projects Gardens of Honey, Pollen Paths, Planting of 100 Thousand Trees, and the Urban Gardens and Urban Farm of Curitiba22 programs.

The above examples illustrate the city's concern for environmental and urban quality reflected in the adoption of policies that seek maximum utilization of the ecological, economic, and social benefits of the municipality's environmental assets.

Actions with this connotation involve the Strategic Sector Environmental and Urban Quality. For example, environmental protection and conservation, improvement of biodiversity, increasing adaptive capacity related to drainage and surface water runoff, resilience of buildings and urban settlements, and food and nutritional security.

22Programs and projects focused on food and nutritional security play an important role in generating and valuing ecosystem services. Innovative, they foster the provision of healthy and safe food, as well as contribute to the reduction of food deserts by encouraging the cultivation of vegetables and the planting of trees, forming the Pollen Paths. Moreover, these projects value the educational, recreational, and cultural character, for they rescue and stimulate the recognition of other values besides the economic and productive ones, as well as social interaction.

7.2 | STRATEGIC SECTOR ENERGY EFFICIENCY

Encouraging renewable energy and building efficiency

The way society relates to natural resources is extremely important for the quality of life of current and future generations. With regard to the use of energy, humanity is in a stage of natural resource use at the highest levels ever recorded. The use of these resources is directly related to consumption patterns and socioeconomic development models. The ways in which energy is generated, transmitted and used need to be discussed and reviewed in order to ensure sustainability worldwide.

Considering also that the production of part of this growing energy demand generates GHG emissions far beyond acceptable limits, it is extremely important to rethink ways of acting, both in the public and private sectors and in society in general.

Thus, the Energy Efficiency Strategic Sector covers three main themes: (i) Conscious Energy Consumption, (ii) Energy Efficiency, and (iii) Renewable Energy Generation.

The **conscious consumption of energy** requires the sensitization of society to a change in behavior aimed at the responsible use of energy. This awareness can be achieved through advertising campaigns, educational programs in schools and training courses. An alignment must also be sought with the commercial and industrial sectors, essential in the reduction of energy consumption in the city. It is understood that several actors working with this same purpose are more likely to make the conscious use of energy a reality for the inhabitants of Curitiba.

Energy efficiency in buildings and equipment contributes significantly to reducing GHG emissions. In this sense, it is appropriate to

establish actions for both the public and private sectors and for society in general.

In the municipal public power, the actions should involve a process of modernization of the facilities managed by the City Hall, carrying out gradual exchanges of technologies currently employed. It is worth mentioning the replacement of sodium vapor lamps by LED in public lighting, as well as the replacement of lamps and equipment with lower energy consumption in municipal buildings - schools, health units, leisure areas, among others.

Other strategies that can be adopted by the private sector and society in general are the use of more efficient light bulbs and equipment, and the substitution of energy from non-renewable sources for renewable ones. Thus, the search for energy efficiency of buildings, both in new buildings and in existing ones, through *retrofits* (*retrofit*) of facilities, equipment and building standards is one of the emphases of PlanClima.

Renewable Energy Generation, in the context of PlanClima, refers to public and private investments aimed at renewable energy generation. Renewable sources are characterized by the use of natural resources in energy generation that are replenishable: sunlight, wind (wind), water (hydro), tides (tidal), heat from the earth (geothermal) and biomass as fuel.

Curitiba has been investing in renewable energy generation by three modalities: (i) hydroelectric (at Barigui Park), (ii) solar (Caximba Solar Plant and photovoltaic modules installations on public equipment) and (iii) energy generation by biomass sources. The use of these sources contributes to the transition to low carbon energy consumption.

Such practices by the public authorities can stimulate society to opt for alternative sources of clean energy generation in their homes. Another form of promotion is the encouragement of universities and technical training courses, as well as the construction sector, to become partners in the development of

sustainable enterprises that contribute to the reduction of GHG emissions in the city.

7.3 | STRATEGIC SECTOR SOLID WASTE AND EFFLUENTS

Management of the city's solid and liquid residues, encouraging conscious production and consumption, continuous improvement in the collection, treatment and

final disposal of generated waste

The Strategic Sector is aligned with the objectives of the National Policy on Waste, which advocates the non-generation, reduction, reuse, recycling and treatment of solid waste, as well as the environmentally adequate final disposal of waste. Thus, PlanClima proposes, in general terms, actions for environmental education, to strengthen recycling and to encourage the use of the organic portion.

The Strategic Sector thus involves policies, programs, projects, actions, initiatives, training, and legislation related to solid waste management, wastewater collection and treatment, promotion of the circular economy, and conscious production and consumption.

For the topic Effluent Treatment, the Strategic Sector is also in line with the concepts of cleaner production, with environmental and energy efficiency, suggesting the use of biogas in industries and the replacement by low-carbon technologies.

Currently, the production system works in a linear way: exploitation of raw materials, production of goods, and disposal. The depletion of natural resources and the accumulation of waste that results from their processing generates great concern. Society needs to review its production, consumption and disposal patterns, because it is necessary to control finite stocks of natural resources and balance them with renewable resources.

Thus emerges the circular economy, a production model that eliminates the concept of *waste* by proposing that the resources extracted from nature and transformed into consumer goods

consumption are kept in circulation through integrated production chains, reducing dependence on new inputs while eliminating waste.

The public sector has a key role in promoting the concept of circular economy. Among the attributions within its reach are: the creation of laws; the construction of municipal plans (such as the Integrated Solid Waste Management Plan and the 2nd Municipal Food and Nutrition Security Plan); the establishment of partnerships (such as the term of understanding signed between Brazilian and Swedish educational institutions in 2017); and the execution of practical solution actions (such as the promotion of urban agriculture in the city, encouraging the population to produce their own food, and encouraging the purchase of local production, encouraging the short food chain). All these actions - avoiding waste, properly disposing of solid waste, knowing how to use organic waste, and consuming locally - reflect the principles of sustainability and are the basis of the circular economy.

7.4 | STRATEGIC SECTOR SUSTAINABLE URBAN MOBILITY

Promotion of Curitiba's urban mobility services with greater attractiveness to public transportation, energy efficiency, and reduction of circulation of individual vehicles

In the country's current scenario of social and economic development - which induces a significant increase in individual motorization (cars and motorcycles) and in the fleet of vehicles dedicated to cargo transportation - urban mobility is characterized as a challenge for both environmental and urban policies.

Mobility is directly related to several relevant aspects in the planning process of cities. It involves the issue of urban land use and occupation, the socioeconomic profile of the population, cultural aspects and public safety, among others. The economic conjuncture is also fundamental in this theme, not only because of the investments in services and infrastructure, but also because of the opportunities

regarding the technological alternatives and profiles of the professions that are emerging in the job market.

Thus, Sustainable Urban Mobility requires an intelligent combination of several factors in order to promote the necessary transformations for a low-carbon development.

In Curitiba, the Strategic Sector Sustainable Urban Mobility has a central role in PlanClima due to the fact that the Transportation Sector concentrates the largest percentage of GHG emissions in the city. According to the GHG Emissions Inventory 2016 base year, the sector is responsible for 66.6% of CO_2 emissions in the city. This emission profile is directly related to the standard of air quality and quality of life of the population, being, therefore, a strategic area that requires effective actions to reduce emissions.

The approach of Curitiba's urban planning model, integrating transportation, land use and road system, and its interaction with environmental, social and economic development, has generated important assets in the city for the promotion of a balanced development. However, it is currently necessary to glimpse ways to face the new challenges that are imposed. It is necessary to have a disruptive thinking, taking advantage of the accumulated skills and experiences in innovation, planning and sustainability, and start structuring alternatives to the current logic of displacements in the city.

At the same time that it demands an effort from society in order to mitigate its emissions in transportation, this Strategic Sector also has several opportunities to act. The most important of these is to base the supply of urban mobility services in the city on collective transportation powered by cleaner, low-emission technologies. Other actions are the encouragement of active mobility and the implementation of policies and strategies to reduce the circulation of individual vehicles.

By redesigning Curitiba's Urban Mobility Services logic, in order to give the transportation system greater attractiveness and energy efficiency, it is expected

an impact on reducing individual vehicle traffic and greenhouse gas emissions.

Based on these pillars, the actions prioritized in this Strategic Sector for PlanClima aim to encourage the electrification of the fleet of passenger vehicles; promote the renewal of the collective public transport bus fleet, focusing on electrification, better thermal comfort, full accessibility and less environmental pollution; develop integration studies of the actions in public transport with mitigation and adaptation objectives; implement low carbon or carbon neutral areas for mobility; encourage the expansion of the participation of collective public transport and the non-motorized mode of travel in the modal division; review and promote the regulation of the various modes or types of transport in order to strengthen their integration into the urban mobility system; strengthen the Transport Oriented Development through the adoption of urbanistic parameters; encourage the creation and expansion of mixed-use zones; strengthen bicycle and pedestrian travel, with the improvement of cycling and pedestrian infrastructure; promote the implementation of tax mechanisms and others that encourage low carbon mobility; expand the exclusive lanes for public transport; and strengthen the technical and operational structure for planning and operation of the Integrated Transport Network (RIT).

7.5 | URBAN HYPERVISOR AND INNOVATION STRATEGIC SECTOR

Establishing a data management culture to manage real-time services, planning long-term policies, and encouraging innovation

This Strategic Sector is structured to put the use of data and innovation at the base of the development of solutions for the city. Curitiba's innovation policy was established through Law 15.324/2018, which provides guidelines for the development of innovation in the city, in favor of socioeconomic dynamism and sustainable development of the city in an integrated manner with the metropolitan region.

A culture of data management to administer services in real time and subsidize policy planning, added to the monitoring of actions by the Urban Hypervisor, helps the development of actions prioritized in PlanClima.

The collection and analysis of reliable and diverse data form the basis for public agents to develop studies, programs and policies. Data are fundamental in the construction of viable models that have an impact on the development of actions to combat climate change[23]. The database and the analysis of the information collected are also important in monitoring the impacts of the actions established.

With the data made available in a structured way in an Urban Hypervisor model, it is possible to plan and measure actions, identify patterns within the city or a community, and perform digital interaction of actors and information.

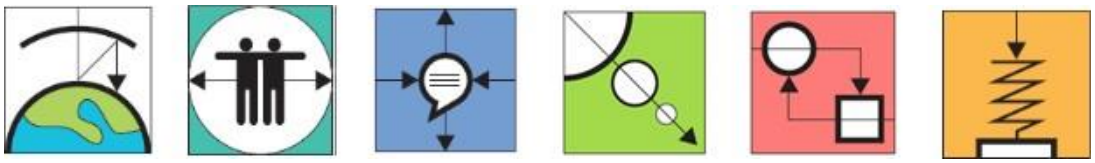
With this innovation process, data collection, use and analysis can be done in a practical and accessible way, and at different scales within the city. Innovation is a driver for the development of actions and initiatives to achieve the goals outlined in PlanClima, and is also a factor of engagement of different sectors of society - companies, universities, *startups* and communities.

[23] "Reliable, disaggregated, quality, accessible, and up-to-date data will be needed to help measure progress and ensure that no one is left behind. Such data are essential to the decision-making process. AGENDA 2030 FOR SUSTAINABLE DEVELOPMENT (Follow-up and review item 48.)".

8 | VISION AND GOALS 2050

The vision of PlanClima of Curitiba in the 2050 horizon is:

"To become by 2050 an emission-neutral city, resilient in the face of climate risks, inclusive and vibrant, with engagement and shared responsibility among all society."



Achieving **Vision 2050** will require the development and implementation of **robust** and **disruptive actions**, which today still face legal and institutional, financial and economic, political and social barriers, and practical and technological limitations.

In other words, efforts will be needed to explore **technological solutions**, foster **innovation**, encourage **changes in behavior,** and seek the **engagement of** society.

Thus, PlanClima and the Strategic Sectors of each area defined measures to be implemented in the medium and long term (2030 and 2050), as described in item 6.3 GHG EMISSIONS REDUCTION SCENARIOS, as well as a set of priority actions. This set of measures allows to outline the mitigation and adaptation goals and indicate the path to be followed by the society so that by 2050 the intended objectives regarding the confrontation of climate change in Curitiba are achieved.

However, these goals, especially the mitigation ones, are directly related to the measures used in the Extended Scenario simulation, i.e., with barriers to their implementation. In a 30-year horizon up to 2050, the overcoming of these barriers, for example with the emergence of new technological solutions, will make it possible to adjust the modeling of the scenarios. It will be possible to improve the definition

of the targets in PlanClima's systematic reviews, reducing the uncertainties and limitations that involve the scenario modeling process.

Regarding the climate adaptation goals, it will be essential that the city has, by 2030, implemented a series of actions such as the revision of the macro drainage plan, incorporating criteria for nature-based solutions, advance in the mapping of priority areas for the permeabilization of the urban soil, and expand the city's alert monitoring and response system, consolidating the path towards the city's resilience.

It is also worth noting that the achievement of these goals is aligned with the principles of sustainable economic, social and environmental development of the UN Agenda 2030 (SDGs - Sustainable Development Goals). Thus, it is expected the achievement of goals related to the benefits generated by the prioritized actions, mainly by generating jobs, improving the provision of essential services to the population, reducing the risk of disease from the effects of climate change, strengthening local governance and civil society participation in the implementation and monitoring of the plan, and improvements related to the natural environment, such as enriching the biodiversity and improving the environmental quality of the city.

The following is a summary of the **Mitigation** and **Adaptation** targets of a quantitative and qualitative nature, respectively, and of a long-term nature, to achieve the city's **Vision 2050.**

MITIGATION

ENERGIA

40% das edificações com com módulos fotovoltaicos

100% de edificações renovadas com padrões de alta eficiência energética

100% de novas edificações construídas com altos padrões de eficiência energética

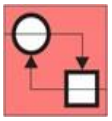
RESÍDUOS

10% de resíduos e rejeitos dispostos em aterro sanitário

TRANSPORTE

85% dos deslocamentos feitos por transporte coletivo e mobilidade ativa

100% dos veículos de passageiros movidos a energia limpa ou renovável



ADAPTATION

INUNDAÇÃO

Macrodrenagem

- Ampliar o volume de retenção distribuído de água de chuva ao longo dos rios principais das bacias hidrográficas priorizando soluções baseadas na natureza

ALAGAMENTO

Microdrenagem

- Ampliar o volume de reservação por meio dos reservatórios de retenção distribuídos no município
- Aprimorar o Sistema de manutenção, limpeza e desobstrução da rede de coleta de águas pluviais
- Ampliar a permeabilidade urbana

ONDAS DE CALOR

- Aumentar a capacidade de reservação da captação de água para consumo
- Ampliar e requalificar as áreas verdes urbanas dos maciços florestais e da arborização viária
- Reduzir as perdas de água no sistema de abastecimento hídrico na cidade

9 | ACTIONS PRIORITIZED IN THE CLIMATE PLAN

The selection and prioritization process arrived at a final list of both mitigation and adaptation actions that reflects the city's priorities to achieve neutrality of its emissions by 2050 - to adapt to the effects of climate change in the coming years and generate other benefits.

The prioritization of actions was a rich group work, involving members of the GT Clima Working Group and the extended participation of other PMC staff, CONRESOL, members of the Climate Change Forum, and *Global Shapers.*

The process lasted approximately four months. Figure 32 shows the steps of the action prioritization process.

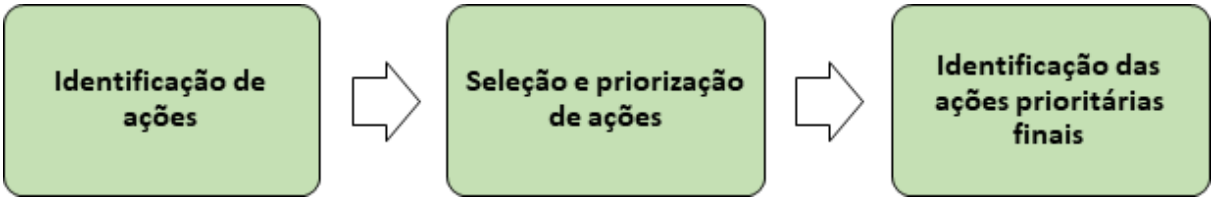


Figure 32: Overview of the action prioritization process

During the process, it was up to the city to identify actions with the potential to reduce GHG emissions and act on climate risk reduction.

We started from a set of approximately 120 actions that originated, in part, from the workshops and discussions for the elaboration of the documents that formed the baseline of PlanClima, and in part from actions already foreseen in the city's sectorial planning. There was also an active search in action banks, such as the one of the C40 Group.

The work was developed under the methodological guidance of a consultancy hired by Group C40 and involved the use of the ASAP (*Action Selection and Prioritisation*) tool developed by Group C40. The use of this tool helped the city in the prioritization process by proposing an evaluation framework

of multicriteria, including primary benefits (mitigation and adaptation), cobenefits and feasibility. For the analysis of mitigation actions emission reduction potentials, the ambitious scenario was considered, as described in item 6.3 GHG EMISSIONS REDUCTION SCENARIOS. This step resulted in a list with approximately 60 actions.

From this list, similar actions were grouped and the discussion was extended to a more detailed level, in order to agree on the main priorities of the city (greater GHG reductions and climate risk). From this process, the final list containing 18 mitigation and adaptation actions, 1 monitoring action, and 1 governance action was reached, totaling 20 priority actions. The methodological details of the action selection and prioritization process are described in the complementary document **ASAP - *Action Selection and Prior*itization Process**.

The prioritized actions are described below. It is worth noting that these actions are of broad spectrum, therefore, in the process of implementation of PlanClima they will be detailed, bringing together a set of sub-actions. Next, Table 4 presents the prioritized actions relating them to mitigation and adaptation aspects, to the strategic sectors, to the Sustainable Development Goals, which represent the expected cobenefits, as well as the implementation deadlines, which were estimated according to the priority and capacity of the city.

Actions List

Action 1

Implement actions to recover, maintain, conserve, preserve, and expand the city's green areas, aiming at increasing the carbon stock and ecosystem-based adaptation.

Action of: Adaptation and Mitigation

Strategic Sectors: Environmental and Urban Quality

Action

Carry out interventions in areas of interest in order to promote permeability, improved drainage conditions, shading, and natural refreshment.

Action of: Adaptation

Strategic Sectors: Environmental and Urban Quality

Action 3

Implement infrastructure projects related to stormwater management based on the concepts of Sustainable Urban Drainage and Nature-Based Solutions.

Action of: Adaptation

Strategic Sectors: Environmental and Urban Quality

Action 4

Carry out actions that promote water security in the city.

Action of: Adaptation

Strategic Sectors: Environmental and Urban Quality

Action 5

Establish and regulate requirements for buildings adapted to climate threats.

Action of: Adaptation

Strategic Sectors: Environmental and Urban Quality, Energy Efficiency, and Solid Waste and Wastewater

Action 6

Improve and expand the Food Security policies with a broad vision of Curitiba and MRC, promote urban and family agriculture on an ecological basis, strengthen short chain and conscious consumption networks for the conservation and promotion of biodiversity.

Action of: Adaptation and Mitigation

Strategic Sectors: Environmental and Urban Quality and Solid Waste and Effluents

Action

Encourage energy efficiency and the use of energy from renewable sources.

Action of: Mitigation

Strategic Sectors: Energy Efficiency

Action 8

Implement measures for the reduction of Greenhouse Gases in Effluent Treatment Plants.

Action of: Mitigation

Strategic Sectors: Solid Waste and Effluents and Energy Efficiency

Action 9

To increase the use of the portions of the urban solid residues, destining only the reject to sanitary landfills.

Action of: Mitigation

Strategic Sectors: Solid Waste and Wastewater, and Urban and Environmental Quality

Action 10

Expand low-carbon measures in mobility planning and operation.

Action of: Mitigation

Strategic Sectors: Sustainable Urban Mobility

Action 11

Promote active mobility by strengthening cycling and walking, through the improvement, expansion and integration of cycling and walking services and infrastructure within the city's mobility system.

Action of: Mitigation

Strategic Sectors: Sustainable Urban Mobility

Action 12

Promote the renewal of the public transportation fleet, aiming at decarbonization, better thermal comfort, full accessibility, and less environmental pollution.

Action of: Mitigation and Adaptation

Strategic Sectors: Sustainable Urban Mobility

Action

Improvement of air quality monitoring and adoption of actions to reduce air pollutants.

Action of: Mitigation and Adaptation

Strategic Sectors: Environmental and Urban Quality

Action 14

Intensify monitoring of diseases and vectors with direct relation to climate change.

Action of: Adaptation

Strategic Sectors: Environmental and Urban Quality and Urban Hypervisor and Innovation

Action 15

Promote control and monitoring actions of land use and occupation aimed at climate change.

Action of: Adaptation

Strategic Sectors: Environmental and Urban Quality and Urban Hypervisor and Innovation

Action 16

Improve the warning, monitoring and response system to extreme events in the city.

Action of: Adaptation

Strategic Sectors: Environmental and Urban Quality and Urban Hypervisor and Innovation

Action 17

Develop circular economy strategies in the municipality.

Action of: Mitigation and Adaptation

Strategic Sectors: Environmental Quality, Solid Waste and W a s t e w a t e r , Sustainable Urban Mobility and Urban Hypervisors and Innovation

Action 18

Promote environmental education and behavior change campaigns aimed at mitigating and adapting to climate change.

Action of: Mitigation and Adaptation

Strategic Sectors: Urban Hypervisor and Innovation

Action

Develop and implement an 'Urban Hypervisor' system or *Data Science* hub to gather data from databases to monitor, evaluate and update climate information.

Action of: Monitoring

Strategic Sectors: Urban Hypervisor and Innovation

Action 20

Set up a governance structure to implement and manage PlanClima.

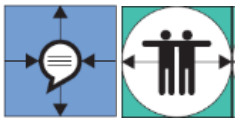
Action of: Governance

Table 5: PlanClima's Prioritized Actions

#	Ações priorizadas	Tipo de ação		Setores Estratégicos					Cobenefícios	Prazo estimado de implementação
		Mitigação	Adaptação	Qualidade Ambiental Urbana	Eficiência Energética	Resíduos Sólidos e Efluentes	Mobilidade Urbana Sustentável	Hipervisor Urbano e Inovação		Curto - 2025 Médio - 2030 Longo - 2050
1	Implementar ações de recuperação, manutenção, conservação, preservação e ampliação das áreas verdes da cidade, visando o aumento do estoque de carbono e a adaptação baseada em ecossistemas.	■	■	■					ODS: 3, 6 , 11, 13, 14, 15, 17	Longo
2	Realizar intervenções em áreas de interesse, a fim de promover permeabilidade, melhora das condições de drenagem, sombreamento e refrescamento natural.		■	■					ODS: 3, 11, 13, 14	Longo
3	Implementar projetos de infraestrutura relacionados ao manejo das águas pluviais baseados nos conceitos de Drenagem Urbana Sustentável e Soluções Baseadas na Natureza.		■	■					ODS: 3, 6, 11, 13, 14, 15, 17	Longo
4	Realizar ações que promovam a segurança hídrica na cidade		■	■					ODS: 3, 6, 9, 10, 11, 12, 13, 16, 17	Longo
5	Estabelecer e regulamentar requisitos para edificações adaptadas às ameaças climáticas		■	■	■	■			ODS: 3, 4, 6, 7, 8, 9, 11	Curto
6	Aprimorar e expandir as políticas de Segurança Alimentar com visão ampliada de Curitiba e RMC, promover agricultura urbana e familiar de base ecológica, fortalecer redes de cadeia curta e consumo consciente para conservação e promoção da biodiversidade	■	■	■	■	■			ODS: Todas	Médio
7	Incentivar a eficiência energética e o uso de energia de fontes renováveis	■			■	■			ODS: 3, 4, 7, 8, 9, 11, 12, 13, 16, 17	Médio
8	Implantar medidas para a redução de Gases de Efeito Estufa em Estações de Tratamento de Efluentes	■			■	■			ODS: 3, 4, 6, 7, 11, 12, 13, 17	Longo
9	Aumentar o aproveitamento das parcelas dos resíduos sólidos urbanos, destinando somente o rejeito aos aterros sanitários	■			■	■			ODS: 1, 2, 3, 4, 5, 6, 8, 9, 10, 11, 12, 13, 16, 17	Longo
10	Ampliar medidas de baixo carbono no planejamento e operação da mobilidade	■					■		ODS: 3, 5, 9, 10,11, 13, 17	Longo

#	Ações priorizadas	Tipo de ação		Setores Estratégicos					Cobenefícios	Prazo estimado de implementação
		Mitigação	Adaptação	Qualidade Ambiental Urbana	Eficiência Energética	Resíduos Sólidos e Efluentes	Mobilidade Urbana Sustentável	Hipervisor Urbano e Inovação		Curto - 2025 Médio - 2030 Longo - 2050
11	Promover a mobilidade ativa, fortalecendo os deslocamentos por bicicleta e a pé, por meio da melhoria, ampliação e integração dos serviços e da infraestrutura cicloviária e de pedestres dentro do sistema de mobilidade da cidade	■					■		ODS: 3, 5, 9, 10,11, 13, 17	Longo
12	Promover a renovação da frota do transporte público coletivo, visando a descarbonização, melhor conforto térmico, acessibilidade plena e menor poluição ambiental	■	■				■		ODS: 3, 11, 13, 17	Longo
13	Aprimoramento do monitoramento da qualidade do ar e adoção de ações para diminuição de poluentes atmosféricos	■	■	■				■	ODS: 3, 9, 11, 13, 17	Curto
14	Intensificar o monitoramento de doenças e vetores com relação direta com a mudança do clima		■	■				■	ODS: 3, 4, 6, 11, 17	Curto
15	Promover ações de controle e monitoramento de uso e ocupação do solo voltadas às mudanças do clima		■	■				■	ODS: 1, 3, 4, 5, 6, 7, 10, 11, 13, 14, 15, 16, 17	Médio
16	Aprimorar o sistema de alerta, monitoramento e resposta a eventos extremos na cidade		■	■				■	ODS: 3, 6, 10 , 11, 13 , 14 , 15, 16, 17	Médio
17	Desenvolver estratégias de economia circular no município	■		■		■	■	■	ODS: 1, 4, 8, 9 , 10, 12, 13, 14, 15, 16, 17	Médio
18	Promover campanhas de educação ambiental e mudança de comportamento voltadas à mitigação e adaptação à mudança do clima	■	■					■	ODS: 4, 5	Longo
19	Desenvolver e implementar um sistema 'Hipervisor Urbano' ou núcleo de Data Science para reunir dados de bancos de dados para monitorar, avaliar e atualizar informações climáticas							■	ODS: 12, 13, 14, 15, 16, 17	Médio
20	Instituir estrutura de governança para implementação e gestão do PlanClima	■	■	■	■	■	■	■	ODS: 16, 17	Curto

10 | PLANCLIMATE GOVERNANCE



Managing climate change involves several aspects in the context of cities (water, energy, biodiversity, waste, etc.) and at the same time has physical repercussions on the territory, as well as social and economic ones.

Each city, according to its own characteristics, needs to elaborate its plans geared to local realities. However, cities are also part of a global context, in which pacts for the common good are signed. The PlanClima, as well as the other city plans, must contemplate the various commitments and adherences signed nationally and internationally, besides being intrinsically aligned with the guidelines of other plans, for example the Sustainable Development Goals (SDGs) and the Master Plan.

Because it is a broad theme, involving several areas of knowledge and action, the Climate Plan should not be under the responsibility of a single municipal authority. It requires planning, development and practical implementation of a wide variety of sector-specific actions, such as the articulation between several departments, secretariats and agencies of the City Hall, so that the results are comprehensive and the whole surpasses the sum of the individual actions.

As the production and distribution of water and energy are responsibilities of companies linked to the state power - Paraná State, the collaborative interface with other levels of public power is also very relevant.

In addition, the city of Curitiba is inserted in the urban space of a metropolitan region, so that it is necessary to integrate with the other 28 municipalities that make up the MRC, more especially and more closely with the 13 that

configure the Central Urban Core (NUC)[24], whose daily dependencies are more intense.

On the other hand, a significant number of actions aimed at facing climate change depend not only on the public power, but also on the attitude and action of the private sector and the population. This is why the availability of information, quality education, communication, and engagement and participation processes are so important - including the decision-making process for the application of available public resources or the discussion of the municipality's budget and engagement in public consultations.

Thus, the effort can and must come from society as a whole - public authorities, academia, businesses, non-governmental organizations, and citizens. A governance process needs to involve all stakeholders and have a clear structure to cover the desired objectives. However, it should not be a rigid and watertight process, but a flexible one, with possibilities for adaptation and improvement.

Important parts of this structure are: (i) a specific information bank containing information relevant to climate change, with emphasis on information collection in precarious areas and in places where the most vulnerable population lives; (ii) articulation of the various actors involved, requiring communication and participation strategies; (iii) development of specific actions; (iv) evaluation and monitoring of results.

[24]Municipalities that make up the Central Urban Core (NUC) of the MRC: Almirante Tamandaré, Araucária, Campina Grande do Sul, Campo Largo, Campo Magro, Colombo, Curitiba, Fazenda Rio Grande, Itaperuçu, Pinhais, Piraquara, Quatro Barras, Rio Branco do Sul and São José dos Pinhais. Source: COMEC, 2020 (Available in: <http://www.comec.pr.gov.br/FAQ/Municipios-da-Regiao-Metropolitana-de-Curitiba> Accessed: 09/23/2020).

10.1 | GOVERNANCE STRUCTURE AT THE MUNICIPAL GOVERNMENT LEVEL

It consists of an internal governance institutional structure in PMC to manage the implementation of PlanClima, with an intersectoral characteristic and the following objectives:

- detailing the actions prioritized in PlanClima;
- management of the actions;
- monitoring the implementation of the actions;
- evaluation and monitoring of actions and results;
- organization of a specific database on the topic;
- articulation with the other municipalities of the MRC and other instances and government agencies; and
- strengthening the transparency and social control of PlanClima.

The governance structure to be established can be in the form of a Plan Implementation Unit, Implementation and Monitoring Committee, Plan Management Group or Working Group. Institutional instances can also be implemented in the scope of the secretariats and agencies with responsibilities related to sustainable development and climate change issues.

As PlanClima is characterized by intersectoriality, the governance structure of the municipal public power is responsible for the institutional articulation for the implementation of actions in the various sectoral areas, as well as for dealing with budgetary constraints and avoiding duplicity.

10.2 | GOVERNANCE WITH SOCIETY

As the effectiveness of PlanClima depends on the involvement of several actors outside the public power, it is necessary to map and get to know the several agents of society with interest and potential of acting on the climate change theme. Based on the mapping, the interaction forms are organized for the complementarity of actions, strengthening the implementation of PlanClima.

In the survey conducted to prepare the **Assessment of Demands for Inclusive Climate Action** it was possible to identify several actors capable of contributing to this process. Figure 33 illustrates in a schematic way a governance structure representing the interaction between these various actors, which can be gradually improved with more in-depth knowledge.

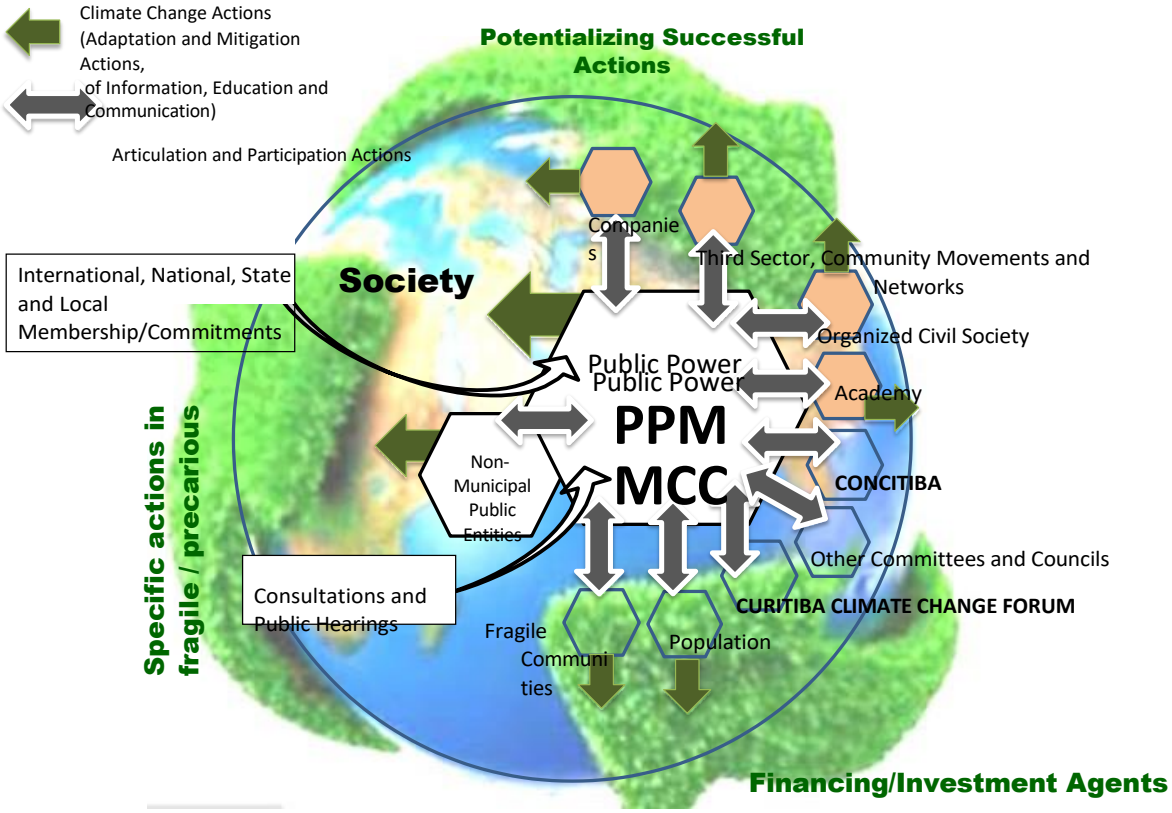


Figure 33: Governance Model PlanClima

10.3 | INFORMATION, EDUCATION, COMMUNICATION AND PARTICIPATION

Other important aspects concerning governance refer to the processes involving information, education, communication, and participation procedures.

Regarding **Information**, it is understood that it is essential to make available general information on climate change, as well as on the development and implementation of PlanClima's actions, enabling its monitoring and social control.

Regarding **Education**, it is understood that the greater the knowledge of the society on issues related to climate change, the greater its engagement to achieve the objectives and targets of PlanClima can be. In this sense, the Education focused on climate change must be directed to the various sectors of society, involving schools, industries, governmental and non-governmental organizations, among others.

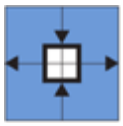
With regard to **Communication**, the essential factors are clarity, objectivity, and language that is appropriate for the target audience.

It is also necessary to define the means of communication to be used - newspaper, radio, television, *websites*, among others, according to the type of communication needed at the time and the characteristics of the target audience.

Regarding **Participation**, the involvement and cooperation of society (companies, universities, non-governmental organizations, citizens) is crucial, not only in the preparation of the Plan, but also in the implementation of actions to achieve its objectives and goals.

In summary, the governance of PlanClima is constituted by a set of actions for internal articulation, within the organizational structure of the City Hall, and external articulation, with other public bodies and society agents, in addition to information, education, communication, and participation actions.

11 | MONITORING, EVALUATION, REPORTING, AND REVIEW



The effective fulfillment of objectives and goals established in policies, programs, projects, and actions depends on a number of factors. We highlight the commitment of the stakeholders in the implementation, the technical and institutional capacity, the engagement of strategic sectors, and the allocation of financial resources.

However, to ensure that the prioritized actions are being properly carried out, it is necessary to establish a process for monitoring, evaluation, reporting, and review.

Curitiba's long term commitment to the implementation of PlanClima must be demonstrated through a process that includes key performance indicators, continuous monitoring, impact assessment and progress monitoring reports. This will give transparency to the process, inspiring confidence in the municipal government and its commitment to make the city emissions neutral and climate resilient by 2050.

The dissemination of knowledge about municipal climate action is another important action. This appropriation of knowledge results in better social control, or a collective monitoring process that, consequently, will culminate in the improvement of municipal public policies aimed at tackling climate change.

In this context, a minimum set of actions should be defined to enable the managerial monitoring of the implementation process of PlanClima. In Curitiba, the Municipal Planning System, established in its Master Plan, already has a Monitoring and Control System, which enables the monitoring and evaluation of the results of the implementation of the municipal urban policy, as well as the Sectoral Plans. PlanClima, as a Strategic Plan, is part of the Municipal Planning System and under this perspective should also be monitored and evaluated in its results.

These measures are in addition to the reporting that is already done by the municipality under the CDP *Disclosure Insight* Action[25] platform.

Thus, aligned to the existing reporting protocols and procedures defined in the Master Plan regarding monitoring and control, the managerial monitoring of the implementation of PlanClima has as guidelines: (i) monitor the performance achieved from the implementation of the actions prioritized in the Plan; (ii) provide information necessary for Plan reviews and possible adaptations; (iii) promote the publicity of the monitored information, allowing greater social control and effective participation of society in the democratic management of the city; and (iv) establish partnerships with organized civil society, universities and other public and private entities, aiming at access to the information necessary for monitoring the Plan.

PlanClima has the following monitoring commitments:

- perform the updating of the GHG Emissions Inventories every two years, according to the provisions of the complementary document **Inventory Management Plan**; and
- Perform a complete revision of the Plan every 5 years.

25The CDP operates a global disclosure system that allows companies, cities, states and regions to measure and manage their environmental impacts, and has the most comprehensive collection of self-reported environmental data in the world.

12 | DEADLINES, COSTS AND CLIMATE FINANCE

PlanClima has an implementation horizon with milestones for the years 2030 and 2050.

In order for the actions to be carried out within the established deadlines, considering their estimated costs, it is necessary to indicate potential funding sources in the process of detailing the actions. In addition to the allocation of resources from the municipal budget, some actions of a more robust nature require partnerships for funding purposes.

The financing of actions with resources from the municipal budget requires an articulation between the various sectoral areas to optimize municipal initiatives in the context of facing climate change.

13 | FINAL CONSIDERATIONS

Curitiba's Municipal Plan of Mitigation and Adaptation to Climate Change was developed to firm the city's commitment to the vision of becoming a carbon neutral, climate change adapted, and resilient city by 2050, in line with international goals for tackling global warming.

The signing of the City of Curitiba's Letter of Commitment to Target 2020 of the C40 Group of Major Cities for Climate Leadership has accelerated the development of climate action, which has been provided for in Curitiba's Master Plan since 2015.

After this signature, the process of elaborating PlanClima began. The first step was to carry out a diagnosis that would allow a greater knowledge about the aspects that the city must face to achieve the objectives of PlanClima.

Based on the diagnosis, the necessary actions to face climate change in the municipality were prioritized. A set of 18 actions address mitigation and adaptation aspects, plus one action related to monitoring and another focused on climate governance, totaling **20 priority actions**. These actions were organized based on the establishment of **Strategic Sectors** that emphasize areas of interest for municipal action: **Urban and Environmental Quality; Energy Efficiency; Solid Waste and Wastewater; Sustainable Urban Mobility; and Urban Hypervisor and Innovation.**

Among the elements of the diagnosis, the **GHG Emissions Inventory Base Year 2016** deserves **to be** highlighted. In addition to providing an updated profile of the city's emissions, it also establishes the baseline on which the ambitious and extended emissions scenarios can be compared with the business-as-usual and planned scenarios.

The GHG Emissions Inventory Base Year 2016 indicates that emissions from the Transport Sector represent the city's greatest challenge in the mitigation component, followed by the Energy Sector and the Waste Sector. Based on this profile, it was possible to prioritize mitigation actions aimed at the three sectors according to their reduction potential, as well as co-benefits and funding criteria.

In the Transport Sector, **three actions** with high potential for emissions reduction were prioritized: to expand the low carbon measures in the planning and operation of mobility, especially the energy transition of transport modes; to promote active mobility (walking and cycling); and to renew the public transport fleet with emphasis on its decarbonization (**Actions 10, 11 and 12**). Such actions require a municipal effort in terms of planning and financing, as well as a society's engagement in campaigns for the use of less emitting modes of transportation.

Regarding the Energy Sector, **an action** focused on encouraging energy efficiency and the use of energy from renewable sources was prioritized. The action has a very comprehensive character that encompasses developments related to the conscious consumption of energy, energy efficiency of equipment and buildings, as well as the generation of renewable energy (**Action 7**).

In the Waste Sector, **2 actions** were prioritized, one aimed at implementing measures for GHG reduction in Effluent Treatment Plants; the other at increasing the use of municipal solid waste (**Actions 8 and 9**).

Another important element in the diagnostic evaluation phase was the **Climate Risk Assessment**. The characterization of the current climate and the projection of future scenarios considering climate change identified, in a spatialized way, the main risks of the city - flooding, inundation, landslides, and susceptibility to heat waves.

The assessment confirmed the future trend of increasing average temperature in the city. It pointed out a higher probability of extreme storm events in the future, with the potential to cause flooding and inundation. It also showed that long dry spells will be more frequent, with repercussions on the city's supply - which has already occurred throughout 2020. This assessment reported enough elements to support the prioritization of **six actions** aimed at increasing the city's resilience: environmental policies for conservation and expansion of green areas aimed at increasing carbon stocks (mitigation), and integration of concepts such as Ecosystem-based Adaptation (EBA) and

Ecosystem Services (adaptation); permeability and improved drainage, shading and natural cooling conditions distributed throughout the city; stormwater management projects based on sustainable urban drainage concepts and Nature-based Solutions (NBS); water security; criteria for buildings adapted to climate threats; food and nutrition security **(Actions 1, 2, 3, 4, 5 and 6)**.

The processes of **Demand Assessment for Inclusive Climate Action** and **Engagement, Participation and Collaboration** provided important inputs for the establishment of **six actions:** improvement of air quality monitoring and reduction of atmospheric pollutants; intensification of monitoring of diseases and vectors related to climate change; promotion of control and monitoring of land use and occupation; improvement of the warning system; monitoring and response to extreme events in the city; development of circular economy strategies; and environmental education focused on mitigation and adaptation to climate change. (**Actions 13, 14, 15, 16, 17 and 18**).

Understanding that monitoring and governance are essential elements for the effective implementation of PlanClima, **an action** was prioritized for the implementation of an *Urban Hypervisor* system, which gathers data to monitor, evaluate and update climate information; and **another action** aimed at the institution of the governance structure for the implementation and management of PlanClima (**Actions 19 and 20**).

The elaboration of **GHG Emissions Scenarios,** which was also part of the elaboration of the diagnosis for the prioritization of PlanClima's actions, showed that the measures foreseen in the Trend and Planned Scenarios are not able to reduce the city's emissions in the 2030 and 2050 horizons. Even the measures of the Ambitious Scenario, which have the potential to reduce emissions by 23.3% in 2030 and 42.1% in 2050, in relation to the emissions of the BAU scenario, are still far from reaching the Target Path, whose goal is the neutrality of emissions.

Measures for the Extended Scenario, which face procedural or technical barriers, have the potential to reduce emissions by 42.9% in 2030 and 78.1% in 2050, relative to 2016 emissions. Although closer to achieving

of carbon neutrality, this scenario does not present a trajectory that would allow the goal of carbon neutrality to be met - the result still presents residual emissions that are due to the Transport Sector, followed by energy consumption in industry.

Residual emissions are those that remain after all the technically and economically feasible opportunities have been implemented. To eliminate them, strategies of engagement and articulation with actors who have governability over the aspects to be implemented are required, as well as investments in the increase of the city's natural carbon stocks.

It is evident, therefore, that the effort of the city and of the Curitiba society to achieve carbon neutrality by 2050 is an important challenge to be addressed through robust actions. For example, breaking away from traditional models of planning, management, production processes, and individual behavior.

The institution of a monitoring, evaluation, reporting and review process of PlanClima is essential to glimpse paths to meet the challenges imposed. In this process, the use of accumulated skills and experiences will enable the identification of necessary adjustments during its implementation.

In addition to this, the monitoring, evaluation, reporting, and revision process must be anchored in a climate governance structure capable of executing the plan in an articulated manner, strengthening the aspects of Information, Education, Communication, and Participation.

Despite all the efforts, the achievement of the Plan's objectives and goals will require disruptive actions, which currently still demand the confrontation of barriers to its implementation.

In this path, it will be necessary to develop new technologies and a lot of innovation to implement projects that contribute to the reduction of emissions and promote adaptation to climate change, making the city more resilient. In addition, the integration of actions between the various actors (public and private,

universities, communities, citizens) in support of the development of PlanClima's actions.

During the climate action planning process, the world entered a health crisis with the pandemic of the new coronavirus. The measures to prevent contagion - isolation and social distancing - impacted society, but left an important lesson, that it is possible to change behavior and consumption patterns, as well as implement disruptive actions towards a greater goal.

Therefore, PlanClima, while demanding a robust effort from society to mitigate its emissions and adapt to climate change, also brings several opportunities for action. It enables new, more sustainable ways of relating to the urban environment, which can result in a better quality of life for all.

It is also worth mentioning that the elaboration process of PlanClima demanded from the city and its collaborators the investment in knowledge building and capacity development for the climate change theme. This was only possible due to the intense process of engagement and participation, which generated a strong synergy aimed at outlining the prioritized actions.

Many challenges and barriers had to be overcome in the process, resulting in the certainty that it is possible to effectively implement PlanClima and achieve the vision: ***"To become an emission-neutral, climate-risk resilient, inclusive, and vibrant city by 2050, with engagement and shared responsibility among the whole society".***

Cities are an organism under permanent construction and, every day, new issues are present in the agenda of public managers and the community itself.

Recently were launched the projects Climate Risk Management Bairro Novo do Caximba, Curitiba Mais Energia and Fazenda Urbana, which address and encourage, respectively, adaptation to climate change for vulnerable populations, the generation of renewable energy, and the adoption of healthy eating habits and food production management. These projects represent examples of actions

that must be multiplied in order to face climate change. They are alternatives for an intelligent urban occupation, which brings the perspective of preservation of natural resources.

To conclude, the Climate Plan is a strategic document within the municipal urban policy that demonstrates how the city of Curitiba will be able to achieve the objectives and goals for the year 2050, aligned with the SDGs and the Paris Agreement. PlanClima configures itself as a window of opportunity for the city to assume a position of innovation, leadership and protagonism in relation to tackling climate change.

14 | GLOSSARY

Inclusive climate action: This is a fundamental pillar for the climate action of cities, especially in developing countries, because it presupposes the social, economic, and spatial inclusion of the most vulnerable groups. The socioeconomic context is closely linked to the response capacity of certain social groups. Therefore, reducing inequalities and fighting poverty are also a climate challenge (C40, 2020).

Paris Agreement: A global commitment to keep the global average temperature increase to well below 2°C above pre-industrial levels and to undertake efforts to limit this increase to 1.5°C, recognizing that this would considerably reduce climate risks and impacts. Beyond this commitment, the Paris Agreement aims to increase adaptive capacity to the impacts of climate change and to make financial flows compatible with climate-resilient development and low GHG emissions (BARBIERI, 2020).

Ecosystem-based Adaptation (EBA): These are adaptation measures that are based on ecosystems and the use of biodiversity through ecosystem services. It is focused on helping people adapt to the effects of climate change, aiming at reducing the vulnerability of populations (MMA, 2018).

Adaptation: The process of adapting to climate and its actual or expected effects. In human systems, adaptation seeks to lessen or avoid harm, and even to exploit beneficial opportunities. In some natural systems, human intervention facilitates adaptation to the expected climate and its effects.

Climate threats: Potential occurrence of a natural or physically human-induced event; physical impact, or tendency thereof, that may cause loss of life, injury, or other health problems. May also cause loss or damage to property, infrastructure, livelihoods, service delivery,

ecosystems and environmental resources. For example, temperature increase, precipitation decrease/increase, floods, landslides, heat waves, droughts, sea level rise, etc. In this report, the term "threat" generally refers to climate-related events, physical impacts, or a trend toward these.

Low carbon: This is a concept related to the economy because it deals with the search for new technologies and development of production processes that result in less impact on the planet's climate. It also seeks more efficient energy alternatives combined with the reduction of greenhouse gas emissions (FGV, 2012).

Adaptive capacity: the set of skills, attributes and resources available to a given group or individual to cope with the negative impacts of climate change in order to reduce these impacts, mitigate damages or explore opportunities (AdaptaCLIMA, MMA, 2020).

Co-benefits: These are benefits that go beyond the reduction of GHG emissions and contribute to the promotion of sustainable development. Examples of co-benefits are: increase in the local economy, creation of jobs and income, reduction of poverty and improvement of air quality (Paiva *et al*, 2015).

Composting: This is a technique that allows the transformation of organic material into fertilizer. It works as a recycling of organic waste by accelerating the decomposition of this material resulting in an organic compost to be reused in gardens, vegetable gardens, and orchards. The biological process resulting from composting allows the return of organic nutrients to the natural cycle (MMA, 2020).

Landslides: It is the generic term to designate the lowering of soil, rock and organic material when subjected to the action of gravity. They are also called mass movement and slope rupture (*Highland et. Al*. 2008).

Guideline: In the strict sense, a guideline is the basic line that determines a path. In the scope of Climate Action it is used in the figurative sense. They are the lines that guide the design of actions and strategies to achieve the objectives of climate action delivery.

Renewable energy: Non-fossil energy sources, such as those derived from petroleum. Examples of renewable energy are solar, wind and biomass (IPEA, 2011).

Water scarcity: Water scarcity is the lack of access to adequate sources of drinking water to meet diverse needs such as desiccation, irrigation, industrial processes, among others (Jacobi et al. 2016).

Exposure: Presence of people, livelihoods, species or ecosystems, ecosystem functions, services and resources, infrastructure, or economic, social, or cultural resources in locations and settings that may be adversely affected.

Greenhouse gases: These are the gases released by burning fossil fuels used in automobiles, industry, and thermoelectric power plants. They include carbon dioxide, methane, and nitrous oxide. Greenhouse gases also come from burning, deforestation, garbage decomposition, etc. The increase in the emission of these gases is associated with the increase in the planet's temperature and climate change (INPE, 2017).

Impacts: Effects on natural and human systems. In this report, the term impact is used primarily to refer to the effects on natural and human systems of extreme weather and climate events and climate change. Impacts are generally the effects on life, livelihoods, health, ecosystems, economies, societies, cultures, services, and infrastructure resulting from the interaction between hazardous weather events and the vulnerability of a society or system exposed to a hazard. Impacts also refer to consequences and outcomes.

Indicator: A parameter used to quantify information about a system/process and monitor its evolution over time relative to a *baseline*. Indicators are also used to compare the performance of different study areas (states, communities, etc.). Indicators can be simple - when they describe only one variable, such as temperature - or composite (also called indices) - when they summarize multiple pieces of information, such as the GDP, the technological development index, or the vulnerability index.

Reduction target: It is the degree of achievement of the levels of greenhouse gas emission reductions that countries that are signatories to international agreements and protocols must achieve in relation to emission baselines (Tilio Neto, 2010).

MITIGATION: human intervention to reduce the sources and enhance the reservoirs of greenhouse gases.

Active mobility: It is the non-motorized mobility, which depends only on human strength to transport oneself or goods, even if aided by some equipment (skates, rollerblades, *skateboards...*). Examples of active mobility are: walking and cycling. (National Secretary of Transportation and Urban Mobility, 2007).

Climate change: Climate change refers to a change in the state of the climate identified - in statistical tests - by changes in the mean and/or range of its properties and persisting over a long period. Climate change can occur either through natural internal processes or external forces, such as modulations of solar cycles, volcanic eruptions, and persistent anthropogenic changes in the composition of the atmosphere or in land use. The Framework Convention on Climate Change (UNFCCC), in its Article 1, defines climate change as "a change of climate that is attributed directly or indirectly to human activity, that alters the composition of the Earth's atmosphere, and that goes beyond the natural climate variability observed over comparable periods." The UNFCCC thus makes a distinction between climate change

attributed to human activities that alter the atmospheric composition and the variability of the climate attributed to natural causes.

Emission neutrality: This is the complete elimination of fossil fuels and other CO_2 emissions in sectors such as transport, power generation and industry. Residual emissions should be offset through carbon capture mechanisms, e.g., tree planting. (IPCC, 2014).

Heat waves: These are prolonged periods with extreme temperatures that are harmful to human health and impact economic activities, such as the agricultural and livestock sector, and also cause an increase in the demand for electricity (Bitencourt et al., 2016).

Global Covenant of Mayors for Climate and Energy (GCom): It is an alliance of voluntarily committed cities and local governments from around the world that are committed to addressing climate challenges such as mitigation, adaptation and access to secure, sustainable and affordable energy for all (GCoM, 2020).

Climate Action Plan: It is a document that defines actions aligned with the objectives of the Paris Agreement. The Plan should be integrated, inclusive, and address the needs of greenhouse gas reduction and adaptation to the impacts of climate change. It must deliver broad social, environmental, and economic benefits to the population (C40, 2020).

Atmospheric pollution: Any matter that makes the air unfit or harmful to the health of the population, fauna and flora. It impacts the quality of life, increasing the occurrence of respiratory diseases (MMA, s/d).

Air quality: It is the product resulting from a set of factors related to the amount of gases released into the atmosphere combined with the topography and the meteorological conditions of the cities. These physical and meteorological conditions

influence the dispersion or not of pollutants in the atmosphere implying a better or worse air quality. The management and monitoring of air quality are important for the development of public policies of sustainability and public health.

Resilience: The ability of social, economic, and environmental systems to cope with a dangerous event, trend, or disturbance, to respond or reorganize in ways that maintain their essential function, identity, and structure.

Risk: Potential consequence in a situation where something of value is at stake and the outcome is uncertain, recognizing the diversity of values. Risk is often represented as the probability of dangerous events occurring. It results from the interaction between vulnerability, exposure, and threats. In this report, the term risk is used primarily to refer to risks arising from climate change impacts.

Nature-based solutions (NBS): Actions designed to protect and restore natural environments or modified ecosystems to solve urban and environmental challenges. These actions use or simulate natural processes in ways that simultaneously safeguard biodiversity and human well-being. SbN are determined by local natural and cultural characteristics and are designed at the landscape scale, and can be applied in isolation or integrated with technological and engineering solutions (IUCN, 2020; ICLEI Glossary, n/d).

Carbon sink: It is an action, process or mechanism that sequesters greenhouse gases from the atmosphere (carbon dioxide, more specifically) in larger quantities than it emits, storing them for a period, thus contributing to the mitigation of global warming. Examples of carbon sinks are: soil, forests and oceans (FAO, 2020) (MMA, 2016).

Vulnerability: A propensity or pre-disposition to be adversely affected. It encompasses a variety of concepts and elements, including sensitivity or susceptibility to harm and lack of ability to cope and adapt.

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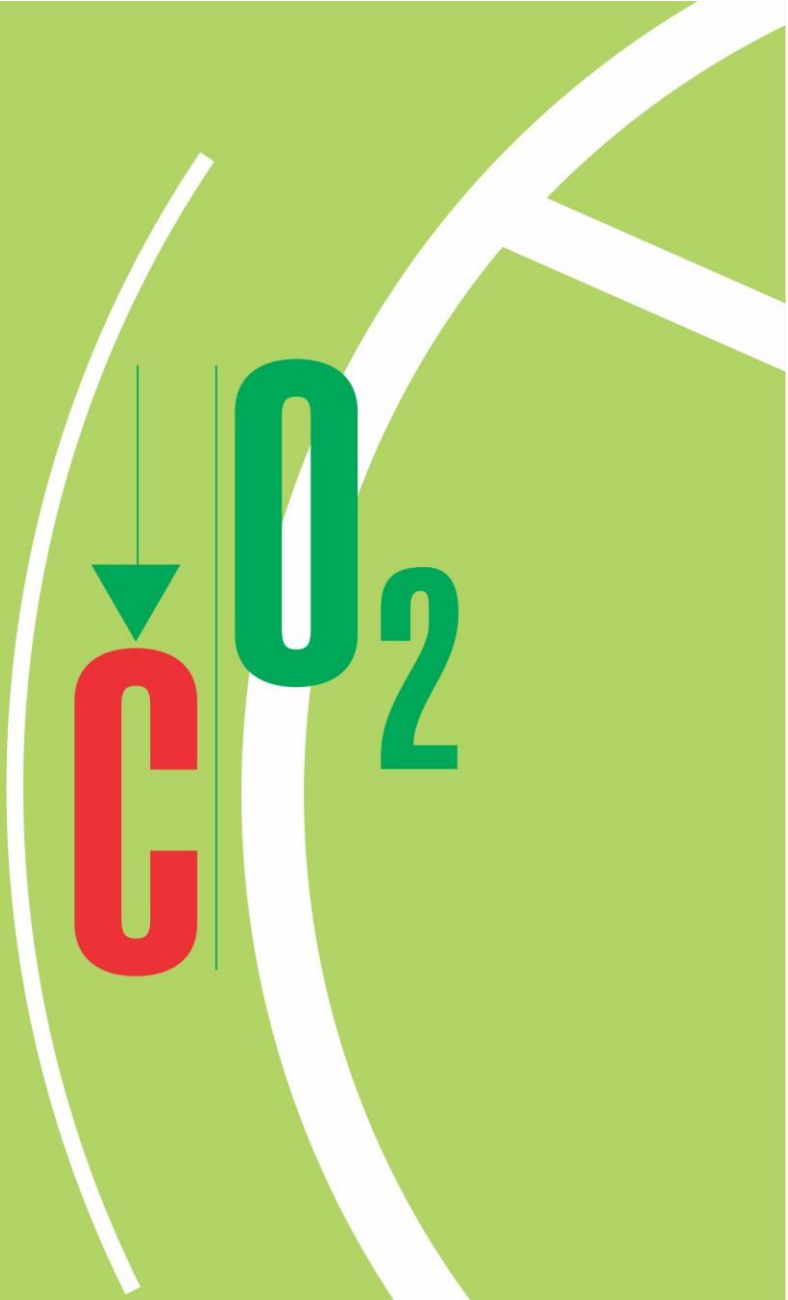
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