Climate crisis: paths to face its effects on houses in Curitiba

Crise climática: caminhos para enfrentar seus efeitos nas habitações em Curitiba

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Abstract

The objective of this article is to present paths that can contribute to mitigating the effects of climate change on houses built in the metropolis of Curitiba. The analysis of the occurrence of natural disasters in the state of Paraná demonstrates that the most frequent extreme climatic event is the windstorm, and the Curitiba region is the one that most presented occurrences of windstorms in the analyzed period. Federal laws and municipal plans related to the theme are presented, as well as points that can be adopted as tools to mitigate the impacts of the climate crisis on the city. Finally, it is concluded that, through the concept of demand-side innovation policies with the use of software programs, which simulate the future scenario of climate transformations, it is possible to contribute to the development of resilient housing.

Keywords: urban planning; climate crisis; resilient housing.

Resumo

O objetivo deste artigo é apresentar possíveis caminhos que contribuam para mitigar os efeitos das mudanças climáticas em moradias construídas na metrópole de Curitiba. A análise sobre desastres naturais no Paraná demonstra a ocorrência de vendavais como o principal evento climático crítico, sendo a região de Curitiba a que mais apresentou tais episódios no período analisado. Apresentam-se leis federais e planos municipais existentes e elencam-se pontos que podem ser adotados como ferramentas mitigadoras dos impactos da crise climática. Por fim, conclui-se que, através do uso do conceito de políticas de inovação pelo lado da demanda, com a aplicação de softwares, os quais simulariam o cenário futuro das transformações climáticas, é possível contribuir para o desenvolvimento de habitações resilientes.

Palavras-chave: *planejamento urbano; crise climática; moradias resilientes.*

Introduction

The objective of this article is to shed light on practices that mitigate the impacts resulting from climate change in housing, in order to incorporate them in the approval processes of architectural projects in the municipal government of Curitiba.

According to the Adaptation and Mitigation Plan of Curitiba (PlanClima), the city already has an average temperature of 1.2°C higher than in the 1960s. Therefore, the occurrence of periods of intense rain and prolonged drought is observed. "In both cases, the population is impacted, sometimes by disturbances resulting from flooding, sometimes by water shortages or thermal discomfort." (PlanClima, 2020, p. 16).

Regarding the scope of these impacts, the less favored part of the population is the most affected in terms of environmental and socioeconomic issues, because it already presents conditions of vulnerability, mainly because a large part of this population lives in precarious settlements and in risk areas.

Solutions such as software development, which help designers in decision-making, can be a way to be adopted to mitigate the effects of the climate crisis on living spaces in the city. There are examples of computer programs developed by universities, such as Analysis Sol-Ar, from the Federal University of Santa Catarina (UFSC), which help the designer to analyze the incidence of predominant winds and the annual temperatures of the city. Another example is the Fluxovento program, developed by students at the Pontifical Catholic University of Rio de Janeiro (PUC-RJ), which simulates the air flow inside the building and also results in information that can be used to make decisions regarding the project.

In order to meet with architectural quality the social housing (SH), developed in Curitiba by the Popular Housing Company of Curitiba (Cohab-CT), and also the new Bidding Law (law n. 14.133/2021), another possible solution would be the application of the tender modality in the development of projects. By using specialized technical knowledge for this purpose, such a practice would help to mitigate the effects of climate change on housing built by the municipal administration.

After this first moment, the article brings, in the second part, the presentation of the concepts that identify the climate crisis, in addition to a literature review about cities and climate change in a third moment. The cities analyzed are: Belo Horizonte, São Paulo, São Francisco (United States) and Toronto (Canada), in addition to Curitiba, which is analyzed in more depth. In the fourth part, it discusses the existing software developed by universities, which guarantee its free use by any professional responsible for the development of housing projects, and how this solution would be linked to the concept of Demand-Side Innovation Policies (Dsips), which stimulate innovation through investments in Research and Development (R&D) by the State. Finally, paths are presented for possible practices to mitigate the effects of climate change in new housing, whether developed by housing policies or not, and for them to be required in the approval of architectural projects in Curitiba, thus resulting in an urban built environment resilient to the ongoing climate crisis.

Regarding the methodology, according to Gerhardt and Silveira (2009, p. 32), the research has a qualitative approach, as it seeks to understand the reason for the situations analyzed and offer what can be done. It presents itself as an applied nature, as it aims to develop guidelines for practical application in the approval of housing projects.

Concepts about the climate crisis and its effects on the built environment

Extreme weather or weather events, also known as natural disasters, are classified as occurrences that prevent the normal functioning of a society's daily life (Fiocruz, 2022). In addition, such occurrences result in material damage to the urban environment and risk to the lives of residents.

According to the Climate and Health Observatory (ibid.), these events are classified according to their origin, which can be:

I – *Hydrological*, such as floods, overflows, floods and landslides;

II – *Geological* or *geophysical*, such as erosion processes and landslides arising from geological processes;

III – *Meteorological*, such as lightning, tropical and extratropical cyclones, tornadoes and windstorms;

IV – *Climatological*, such as dry spells and droughts, wildfires and forest fires, hail, frost and cold and heat waves.

Cities, more than ever, are subject to suffering from the consequences of these events (Espínola and Ribeiro, 2020), such as the existing buildings in the urban environment. According to the United Nations - UN (2022), in the publication of the World Cities Report 2022, 56% of the world's population lives in cities, and the trend, for 2050, is that this index rises to 68%.

Therefore, just as the climate crisis does not respect geographic boundaries, it also affects all social classes, regardless of where they are located. However, it affects more intensely the socially and economically vulnerable classes.

According to Silva (2012), in the metropolis of Curitiba, precarious settlements rose from 571 settlements and 54,662 households at the end of the 1990s to 984 settlements and 98,444 households at the end of the 2000s. Houses built on land located in risk areas are the most vulnerable to all classifications of weather events. Houses built on land located in areas designated for this purpose are less subject to hydrological events (floods, overflows, floods, land plants) and geological events (erosion processes and landslides originating from geological processes), as they are generally located in central areas of cities or in areas where may have already exists studies to the definition of residential zoning.

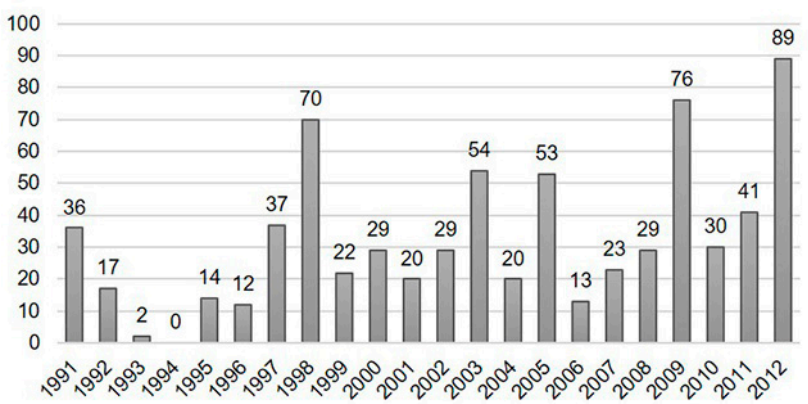
Regarding the damage caused by weather events in buildings, it can be adopted, for analysis, the events that affect the roofs of buildings, such as heavy rain and hail, usually accompanied by windstorms.

According to the Brazilian Atlas of Natural Disasters (Ceped-UFSC, 2013), windstorms are the category of natural disasters that most affect the state of Paraná. The period analyzed by the Atlas was from 1991 to 2012.

> Gales, directly related to the intensification of the wind regime or the strong reduction in atmospheric circulation, are the most recurrent type of disaster in the state of Paraná. This phenomenon corresponds to 722 records, equivalent to 29% of natural disasters in the state, [...]. 1,494,783 people residing in 259 municipalities were affected by these windstorms. Associated with them are the adverse effects such as tree fall and damage to plantations; knocking down electrical and telephone wiring; causing structural damage to buildings, as well as roofing. (Ibid., p. 149)

Fonseca and Ferentz (2020) analyzed the occurrence of these events, from 2013 to 2017, and found that 802 episodes of windstorms occurred in 240 of the 399 municipalities in the state. Among these years, the data show a trend of increasing frequency. In 2017, 234 occurrences were registered, while in 2013, this number was 127. According to the Brazilian Atlas of Natural Disasters (Ceped-UFSC, 2013), from 1991 to 2012, despite negative variations between some years, the occurrence of windstorms in Paraná also tended to increase. As seen in Figure 1, the highest number of windstorms occurred in the last year analyzed.

Figure 1 - Annual frequency of winds in the state of Paraná (1991 to 2012



Source: the author (2022), adapted from the Brazilian Atlas of Natural Disasters (Ceped-UFSC, 2013).

The Beaufort Scale is an empirical measure that classifies the intensity of winds according to their speed and their effects on the natural and built environment. It presents the speed in meters per second (m/s) and kilometers per hour (km/h). According to Chart 1, it classifies the intensity of the winds on a scale of 1 to 12, whose last classification brings winds of up to 120km/h. When the speed exceeds this limit, the winds are classified as hurricanes, and the methodology adopted for classification becomes the Saffir-Simpson Scale (Fonseca and Ferentz, 2020).

Chart 1 – The Beaufort scale

Beaufort scale					
Intensity	**Designation**	**m/s**	**km/h**	**Effects at sea**	**Ground effects**
0	Lull	0 to 0,5	0 to 1	Mirror sea	Smoke rises in the vertical direction
1	Puffiness	0,6 to 1,7	2 to 6	Scaled sea	The direction of the puff is indicated by the smoke
2	Breeze	1,8 to 3,3	7 to 12	Small ripples of 30cm without breaking	You can feel the wind on your face; movement of leaves on trees
3	Light	3,4 to 5,2	13 to 18	Large 60 cm undulations starting to break	Shaking tree leaves; flags unfurl
4	Moderate	5,3 to 7,4	19 to 26	Longer spaces, 1.5 m, with “rams”	Dust and small papers rise. Tree branches sway
5	Fresh	7,5 to 9,8	27 to 35	Spaces of 2.4 m with the possibility of spraying	Small trees move
6	Very fresh	9,9 to 12,4	36 to 44	3.6 m spaces with probability of splashes	The biggest branches of the trees move. Umbrella used with difficulty
7	Strong	12,5 to 15,2	45 to 54	Thick sea, with 4.8 m high waves; white surf foam	Large trees move. Difficulty walking against the wind
8	Very strong	15,3 to 18,2	55 to 65	Waves up to 7.5 m high, with white foam stripes	Tree branches break. Difficulty walking against the wind
9	Hard	18,3 to 21,5	66 to 77	7.5 m beams with dense foam bands. Sea spray starts to affect visibility	Damage to the protruding parts of trees. Inability to walk against the wind
10	Very hard	21,6 to 25,1	78 to 90	Big billows from 9 to 12m. The wind leaves the surface of the sea all white. Visibility is affected	Uprooted trees; damage to building structures
11	Stormy	25,2 to 29	91 to 104	Waves of up to 13.5m. Visibility greatly affected. Medium-sized ships disappear in the hollow of the waves	Rarely seen on land
12	Hurricane	30 to ...	105 to ...	Foam and splashes saturate the air. Visibility is seriously affected	Big damage

Fonte: Unesp (2013).

According to Tominaga, Santoro and Amaral (2009), from 75km/h, that is, winds classified from degree 9 of the Beaufort Scale, the material damage caused can be:

I – deroofing and/or destruction of buildings;

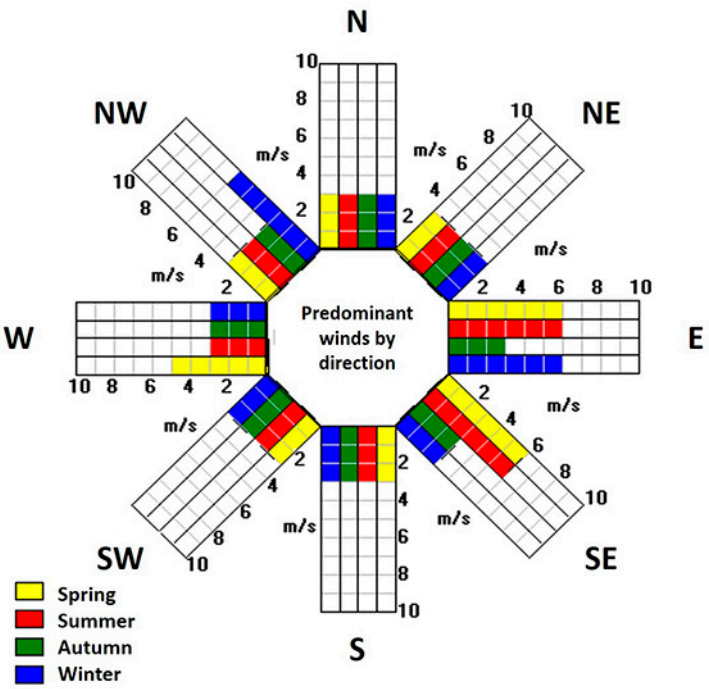
II – launching projectiles that can damage building windows;

III – falling trees, poles and high voltage towers;

IV – damage to crops.

Using the Analisys Sol-Ar software, a figure was generated that brings information about the prevailing winds for Curitiba, classifying their intensity according to the season of the year and the direction of the winds. When analyzing Figure 2, it appears that the prevailing winds come from the east (E), mainly because it is a municipality close to the sea. The average speed of the east wind is 6 m/s in all seasons of the year, except in

Figure 2 – Predominant wind speeds in Curitiba by direction and seasons



Source: the author, using Analysis Sol-Ar software.

autumn, when the average speed drops to 3 m/s. According to the Beaufort Scale, winds of 6m/s are considered moderate.

It is observed that winds from the northwest (NW) directions also have an average speed of 6m/s in winter, and winds from the southeast (SE) direction have the same average speed of 6m/s in spring and summer. According to the Brazilian Atlas of Natural Disasters (Ceped-UFSC, 2013), the month of October, which season is spring, is the one that presented the most occurrences of windstorms in Paraná in the period from 1991 to 2012. By crossing these data with the data in Figure 2, it can be seen that the most intense winds occur in spring. According to Fonseca and Ferentz (2020), the Metropolitan Mesoregion of Curitiba had the highest number of occurrences of windstorms in Paraná between 2013 and 2017, a total of 154. Southwest region with 109 episodes in that period.

Climate crisis and its effects on cities

Climate change occurs without considering the geographical limits of countries or municipalities (Espínola and Ribeiro, 2020). At the global level, countries have been promoting events, such as the United Nations Conferences on Climate Change (COPs), in which actions to be adopted by all to mitigate the effects of the climate crisis are discussed. During the COP 21 edition, 195 countries signed an international commitment to, by 2030, keep the increase in global temperature below 2°C, when compared to pre-Industrial Revolution measurements.

The future is still uncertain regarding the effects of climate change on the planet, but the involvement of different areas and dimensions is the best way to arrive at a perspective on this scenario. Therefore, in order to obtain practical results in the effort to mitigate and adapt housing, it is expected that government actions will be applied at the federal, state and municipal levels (ibid.).

According to Espínola and Ribeiro (ibid.), some of the impacts of climate change on cities involve:

I – growing use of electrical energy to run heaters and air conditioners;

II – lack of drinking water;

III – drainage and transport systems affected by increased frequency of storms;

IV – rapid increase in average temperatures;

V – increase in vector-borne diseases.

Bai et al. (2018) state that 75% of greenhouse gases (GHG) are generated by activities carried out in urban centers, and among them is civil construction.

Cities play an important role in the process of global governance of climate change, as local action is the starting point for possible solutions. Espínola and Ribeiro (2020) argue that municipal master plans are instruments that can lead to a successful path in the necessary adaptations due to climate change.

Also according to these authors:

> A possible solution to these gaps would be an adaptation of the legislation of municipal master plans. Despite not specifically addressing climate change in its urban-territorial management guidelines and instruments, it is expected that the master plan incorporate strategies aimed at urban adaptation and reduction of existing and future vulnerabilities of the population and territory. (Ibid., p. 374)

In order to insert urban planning strategies that help in the process of mitigating the climate crisis in the built environment and to support the use of master plans as standardization devices, the following federal laws related to climate change and urban planning can be cited:

I – Federal Law n. 12.187/2009, which establishes the National Policy on Climate Change; and

II – Federal Law n. 12.608/2012, which institutes the National Civil Defense and Protection Policy (PNPDEC).

Chart 2 deals with these two laws and the items related to urban planning actions, which can help in mitigating and adapting cities to climate change.

Regarding the socioeconomically less favored portion of the population, the location of housing in risk regions is an item often mentioned in the National Policy for Protection and Civil Defense. According to Chart 2, to alleviate the situation and in order to encourage the use of urbanized land, the Union can even transfer resources to municipalities that acquire land in areas equipped with infrastructure, with the purpose of housing use for social housing.

Examples of municipalities that introduce laws to combat the effects of climate change

This part of the article mentions some cities that have a type of planning aimed at mitigating the effects of climate change.

Belo Horizonte established, in 2006, the Municipal Committee on Climate Change and Eco-Efficiency (CMMCE), whose objective is:

> [...] support the implementation of the municipal policy of the City of Belo Horizonte for climate change, acting in the articulation of public policies and the private initiative aimed at reducing emissions of greenhouse gases and atmospheric pollutants, the reduction in solid waste production and greater efficiency in waste reuse and recycling processes; encouraging the use of renewable energy sources, improving energy efficiency and rational use of energy and increasing citizens' environmental awareness. (City Hall of Belo Horizonte, 2022, n/p)

The agency is composed by representatives of the municipal and state public authorities, in addition to members of civil society, in order to ensure democratic decision-making. In addition, the Committee has partnerships with national and international entities that aim to face climate change. Among these partnerships, the UN agency Habitat and the non-governmental organization (NGO) WWF-Brasil can be mentioned.

In 2020, the Climate Action Plan of the Municipality of São Paulo (PlanClima SP) was instituted in the city. According to Marimon (2018), in 2009, the city was a pioneer in this regard, when it launched the Climate Change

Chart 2 – Laws related to climate change and urban planning

Lei	Itens relacionados ao planejamento urbano
Federal Law n. 12.187/2009 – National Policy on Climate Change (PMNC)	Regarding the measures to be adopted to mitigate the effects of climate change, art. 3rd, item V: – "actions at the national level to face climate change, current, present and future, must consider and integrate actions promoted at the state and municipal levels by public and private entities". In art. 5°, the guidelines of the PNMC are mentioned; among them, in item V: – "encouraging and supporting the participation of federal, state, district and municipal governments, as well as the productive sector, from academia and organized civil society, in the development and implementation of policies, plans, programs and actions related to climate change". Another important item present in the PNMC: – "Single paragraph. Decree of the Executive Power will establish, in line with the National Policy about the Climate Change, the sectoral Plans for mitigation and adaptation to climate change aimed at consolidating a low-carbon economy, in the generation and distribution of electricity, in urban public transport and in the modal systems of interstate transport of cargo and passengers, in the transformation industry and in the durable consumer goods industry, in the fine and basic chemical industries, in the pulp and paper industry, in mining, in the civil construction industry, in health services and in farming, with a view to meeting gradual targets for the reduction of quantifiable and verifiable anthropogenic emissions, considering the specificities of each sector, including through the Clean Development Mechanism – CDM and Nationally Appropriate Mitigation Actions – Namas."
Federal Law n. 12.608/2012 – National Civil Defense and Protection Policy (PNPDEC)	At the beginning of the chapter that deals with the guidelines and objectives of the PNPDEC, it is mentioned that: "Single paragraph. The PNPDEC must integrate with the policies of territorial organization, urban development, health, environment, climate change, management of water resources, geology, infrastructure, education, science and technology and other sectoral policies, with a view to promoting development sustainable." Article 5° lists the objectives of the PNPDEC; among them are related to the topic the following items: "IV – encourage the development of resilient cities and sustainable urbanization processes; XII – encourage initiatives that result in the allocation of housing in a safe place". In art. 8, item I mentions that it is the responsibility of the municipalities to implement the PNPDEC. In the chapter dealing with final provisions, art. 14 cites that housing programs should prioritize the relocation of affected communities and residents of risk areas. For this, still in the chapter on final provisions, it is mentioned that the Union is authorized to transfer resources to municipalities that acquire urbanized land to meet these reallocations.

Source: Brazil (2009 e 2012).

Policy in the City of São Paulo (law n. 14,933), which aimed to prepare inventories with measurements of Greenhouse Gases (GEEs) released by activities that take place in the city every 5 years (PlanClima SP, 2020).

PlanClima SP aims to include climate change in decision-making by the municipal government, in addition to making the population aware of the impacts of the transformations to come. It is an extensive

document that covers the municipal actions that existed before the Plan and that deals with all the themes that happen in the daily life of an urban center. Regarding housing, the main focus is to increase the supply of social housing, in order to relocate populations located in areas at risk of landslides and flooding.

Although several extremely important topics are covered, in both plans analyzed, no discussions were found about the quality of housing – or even buildings in general –, in relation to resilience characteristics regarding the effects of climate change. However, it is understood that Brazil has a housing deficit of 5.876 million households (João Pinheiro Foundation, 2021) and that it is necessary to pay attention to this reality first.

On the international scene, an example is the city of *San Francisco*, in the United States, which launched, in 2020, the Hazards and Climate Resilience Plan (HCR). The municipality is the fourth most populous in the state of California and is located on the west coast of the country. Among the risk of earthquakes, extreme heat and drought, resulting from climate change, are the most discussed points in the plan. Comments from residents are presented, who are concerned about the quality of their homes, as they have doubts whether they would be a refuge for days of extreme heat or for poor air quality.

The plan does not present measures to adapt housing to withstand such problems, but it takes the first step towards the search for solutions, which is to identify weaknesses and give voice to residents (City and County of San Francisco, 2020).

The city of *Toronto*, Canada, launched, in 2019, the Climate Resilience Framework (The Climate Resilience Framework). Even in the case of a municipality whose average temperature hardly exceeds 30°C, the concern present in the document is also in relation to the heating of the city.

> One study estimated that higher temperatures and poorer air quality attributed to climate change would result in an additional five to ten deaths per 100,000 people in 2050 and seven to seventeen in 2080 in Toronto. In the next 20-30 years, Toronto is expected to triple the number of days with high temperatures, from an average of 12 days in the years 1976-2005 to an average of 55 in 2050. (City of Toronto, 2019, p. 13)

Regarding the impacts of heat waves on homes, there is greater concern with the elderly population and with residents whose homes do not have sufficient physical characteristics to withstand extreme heat.

Actions for mitigation and adaptation in Curitiba

In 2015, the Master Plan of Curitiba underwent a review process, which must occur every 10 years, according to law n. 10.257 of the City Statute. In this review, one of the concepts added was Preparing the City for Climate Change, which involves issues such as improving urban soil drainage and mitigating the problems caused by heavy rainfall (PlanClima, 2020).

In 2009, decree no. 1.186 instituted the Curitiba Forum on Climate Change, and decree n. 572 updated the composition of the Forum. In 2020, the Municipality of Curitiba – in partnership with universities, the Paraná Sanitation Company (Sanepar) and the Paranaense Energy Company (Copel), as well as other members of civil society – launched the Mitigation and Adaptation Plan to Climate Change (PlanClima). According to its presentation, PlanClima aims to:

> [...] guide municipal action, the productive sectors and society to face the effects that may result from climate change. PlanClima is aligned with the 2030 Agenda of the United Nations (UN), through the Sustainable Development Goals (SDGs); the C40 Cities Network Climate Action Planning Framework; and the goal established in the Paris Agreement to contain the increase in global average temperature within the limit of 2°C, compared to pre-industrial levels, but making efforts to stabilize warming around 1.5°C. To do so, it will be necessary to achieve neutrality of greenhouse gas (GHG) emissions by 2050 and make the city more resilient. (PlanClima, 2020, p. 9)

PlanClima aims to guide public and private sector actions so that the city of Curitiba is aligned with the 17 Sustainable Development Goals (SDGs), launched by the United Nations (UN) (Figure 3).

Figure 3 – 17 Sustainable Development Goals (SDGs)

Source: UN – United Nations Brazil (2015).

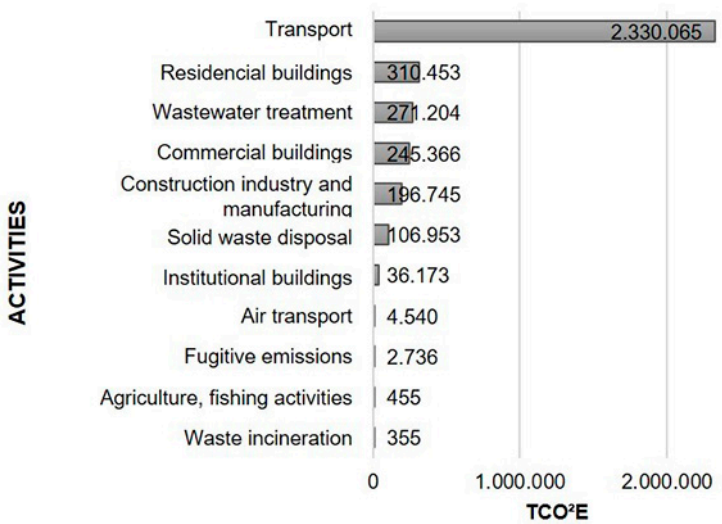
The goal to be achieved is to reach zero GHG emissions by 2050. However, as shown in the conclusion of the document, even considering optimistic scenarios, the forecast is that this goal will not be achieved in its entirety, which demonstrates the dimension of the challenge and the need for urgent multidisciplinary actions.

According to PlanClima (2020, p. 45), regarding GHG generators in the city of Curitiba, residential buildings appear in 2nd place, and commercial buildings in 4th place in the list. In addition, the civil construction industry ranks 5th in activities that generate the most GHGs, along with the manufacturing industry (Figure 4).

In order to organize PlanClima's areas of action, five Strategic Sectors were established, which classify the performance of public and private actors:

I – Environmental and Urban Quality;
II – Energy Efficiency;
III – Solid Waste and Effluents;
IV – Urban and Sustainable Mobility;
V – Urban Hypervisor and Innovation.

Figure 4 – Distribution of GHG emissions in Curitiba
(in tonnes of CO^2 emitted)



Source: the author, adapted from PlanClima (2020).

Chart 3 – Prioritized actions in the plan climate linked to urban planning

Action	Strategic sectors	Description
Action 5	Environmental and Urban Quality; Energy Efficiency; Solid Waste and Effluents	Establish and regulate requirements for buildings adapted to climate threats
Action7	Energy Efficiency	Encourage energy efficiency and the use of energy from renewable sources
Action 15	Environmental and Urban Quality; Urban Hypervisor and Innovation	Promoting actions to control and monitor land use and occupation aimed at climate change
Action 19	Urban Hypervisor and innovation	Develop and implement an "Urban Hypervisor" system or Data Science core to gather information from databases to monitor, evaluate and update climate information

Source: adapted from PlanClima (2020).

The sector linked to urban planning and housing is the Energy Efficiency sector, which mentions the objective of encouraging the use of renewable energy and building efficiency.

PlanClima also brings as a possible solution the partnership of the municipal government with educational entities, which would strengthen the relationship with the R&D (Research and Development) sector:

> Another form of support is to encourage universities and technical training courses, as well as the civil construction sector, to become partners in the development of sustainable projects that contribute to the reduction of GHG emissions in the city. (Ibid., pp. 79-80)

To try to get close to zero GHG emissions, PlanClima listed mitigation and adaptation actions in several areas. In Chart 3, the actions directly or indirectly linked to the areas of urban planning and housing are described.

Thus, practical actions are necessary so that the objectives of the actions listed by PlanClima become applicable in the urban environment. Thus, technological innovation associated with actions by the municipal government can represent this achievement.

Software and the concept of demand-side innovation policies (Dsip) as possible solutions

The objective of this stage is to present the analytical framework of demmand-side innovation policies, in addition to demonstrating which instruments can help in mitigating the impacts of the climate crisis on housing in Curitiba, whether or not they are developed by the public authorities.

According to Macedo (2017, p. 2), demand-side innovation policies (Dsip) refer to:

> [...] a set of instruments aimed at inducing, articulating or increasing demand and/or improving conditions for the dissemination of innovations in the market, such as government purchases associated with Research, Development and Innovation (RD&I) requirements; technological orders; *definition of new specifications for products, services and processes through standardization and regulations*; and promotion of user--innovation producer interaction, among others. (Emphasis added)

According to Edler et al. (2012, p. 3):

> The basic rationale for demand-based policies rests on the following pillars:
> • Create incentives for innovators by overcoming system failures;
> • Directing innovations towards social goals and political needs (e.g. the Grand Challenges); and
> • Promote business development in a given region/nation by exploring the potential lead market.

In order to foster the process of socioeconomic development, the Dsips help as instruments that seek to offer improvements through demands created by the State, whether through public policies or government purchases. According to Rauen (2017, p. 9), "to the vast set of values already considered in the most routine state actions (environmental sustainability, social responsibility, etc.), it is necessary to insert innovation".

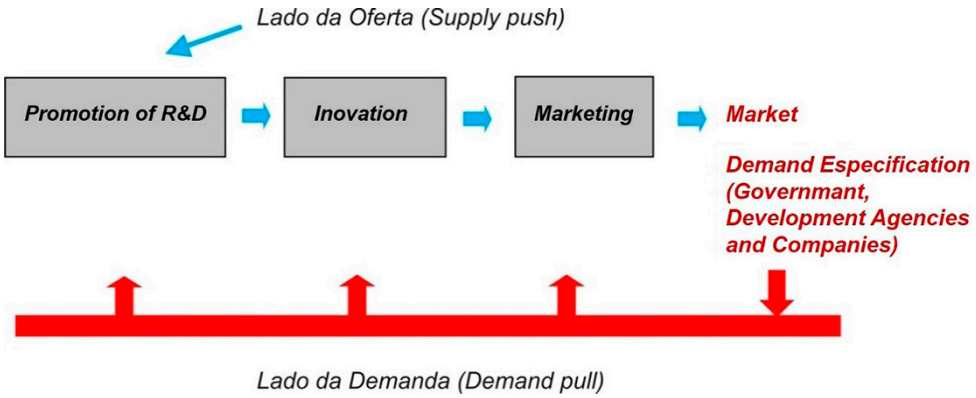
Still according to Rauen, in developed countries, the Dsips are in territories full of opportunities in relation to technological innovations, since the existing technologies have gone through a process of maturation throughout their history. In peripheral countries, such as Brazil, the "terrain" may not present technologies that are so present, mainly related to R&D, but this reality can change "with the use of quality management techniques, changes in layouts and the introduction of new machinery" (ibid., p. 25).

Macedo (2017) observes that most innovation policies originate from the supply side (supply-side innovation policies – SSIP). In Brazil, SSIPs, linked not only to improvements in science and technology infrastructure, but also to tax incentives for this area, lines of financing and economic subsidy, are not being enough to "promote the innovation process" in an intense way. In addition, demand-side innovation policies would be complementary to supply-side innovation policies, as shown in Figure 5.

Thus, the possibility of using software can help design choices for any type of housing. Chart 4 brings as an example four computer programs developed by educational institutions, which are free to use and can be adopted as part of demand-side innovation policies.

The information generated by the programs allows designers to predict mitigation actions, such as building protections, or even design strategies that avoid the intensification of the effects of wind on these building facades. Other software, such as Sketchup® and Revit®, make it possible to study the project regarding the solar incidence on the facades, which helps designers to decide the ideal location of windows, in order to heat or not a certain ambience. Such actions could be applied in master plans and municipal housing policies.

Figure 5 - Innovation policies on the supply and demand side



Source: Organization for Economic Co-operation and Development (OECD, 2011, p. 19). Adaptation from Macedo (2017).

Chart 4 – Software developed by educational institutions

Software	Institution	Program description
Fluxovento	Computer Graphics Technology Group at the Pontifical Catholic University of Rio de Janeiro (PUC-Rio)	Allows the analysis of ventilation in ambiences and simulates the air flow inside the building.
Analysis Sol-Ar	Laboratory of Energy Efficiency in Buildings (LabEEE) of the Federal University of Santa Catarina (UFSC)	Allows obtaining the Solar Chart of the municipality or specified latitude, in addition to obtaining the wind rose, which informs the direction and average speed of the prevailing winds, according to their direction and the season of the year.
Psicrom	Federal University of São Carlos (UFSCar); Eng. Mauricio Roriz	Program aimed at studying the properties of humid air, presenting results such as humidity rate, vapor pressure and absolute humidity.
Ciclone 5.0.1	Department of Structural Engineering at the University of São Paulo (USP)	Allows the simulation of the action of winds in the building, considering some cases present in ABNT NBR 6123/1988 – Forces due to winds in buildings (currently under revision).

Source: PUC-Rio (2005); UFSC (2014); Roriz Bioclimatic Engineering (2022); USP (2022).

With regard to social housing (SH), the Popular Housing Company of Curitiba (Cohab-CT) is the agency responsible for developing projects and executing works. In order to promote SH projects that present characteristics of mitigating the effects of the climate crisis, a path already adopted by several cities in Brazil and also by other countries is the bidding modality by project competition.

In 2018, CAU-PR (Council of Architecture and Urbanism of Paraná) and some architecture offices in Curitiba held the 1st Seminar Architecture in Debate, with the opening activity of the public hearing "Hosting Architecture and Urbanism Contests for Contracting Public Works Projects". At the event, several entities and professionals in the area highlighted the importance for society of the development of this type of bidding for public works in Curitiba and the Metropolitan Region, especially for social housing. The need to include this type of bidding in public policies was put on the agenda, which would allow specialized professionals working in the region to contribute to the portion of the population that most needs it.

In Brazil, the bidding law n. 8.666/1993 placed tenders as the main form of contracting services related to specialized technical projects, although normally this guideline was not followed, mainly due to the fear of public managers that their decisive role in the choice of projects could be jeopardized.

In 2021, the new Bidding Law n. 14,133/2021, which replaces the previous law and whose content has been simplified to facilitate bidding processes. However, in this amendment, most references to the contest modality were deleted. In Chart 5, a comparison is made between the contents related to project competitions between the two versions of the law.

Chart 5 – Comparison between Law n. 8,666/1993 and Law n. 14,133/2021

Law	Items related to the contest modality
Federal Law n. 8.666/1993 – Bidding Law	Chapter I, Section IV, art. 13: "§ 1o With the exception of cases where bidding is not required, contracts for the provision of specialized professional technical services should, preferably, be concluded through a tender, with a prior stipulation of a prize or remuneration." Chapter II, Section IV, art. 51: "§ 5o In the case of a tender, the judgment will be made by a special commission made up of people of unblemished reputation and recognized knowledge of the subject under examination, public servants or not."
Federal Law n. 14.133/2021 – new Bidding Law	• The citation of the tender modality is restricted to its definitions and classifications; • there is no longer a citation of the article that brought the modality preference for technical services that need specialized professionals; • there is also no longer the article that brought the condition of the trial, which would be carried out by a specialized commission.

Source: Brasil (1993 and 2021).

Sobreira, Ganem and Araújo (2014), after studying the policies of design competitions around the world, such as the guidelines of the UIA – International Union of Architects, the European Union and the Scandinavian Countries, present a Proposal for Regulation of Design Competitions in Brazil , which includes items such as:

I – use of what was foreseen in the Bidding Law n. 8666/1993 for design competitions;

II – mandatory for specified cases, but flexible to the point of local adaptations by public managers and due to cultural, political and economic differences;

III – holding public debates on the strengths and weaknesses of this modality, based on national examples and international experiences; and

IV – use of guidelines from international regulations for the development of the basis of this proposal.

As previously mentioned, the challenge for the municipality of Curitiba is to meet the 17 UN Sustainable Development Goals (SDGs), including zeroing GHG emissions by the year 2050. However, it was found in PlanClima (2020) that this objective will not be achieved, which demonstrates the challenges to be faced by public authorities and civil society. Still according to PlanClima (ibid.), multidisciplinary actions will be necessary to get as close as possible to the objectives mentioned in the document.

Possible paths for resilient housing in Curitiba

In order to adapt the housing buildings to be developed in Curitiba, to face the effects of the climate crisis, it is proposed here the use of at least three strategies that allow a resilient future for the built urban environment.

Although Curitiba presented, in 2020, the Plan for Mitigation and Adaptation to Climate Change, it is clear that the emphasis given by it to the area of urban planning is in relation to the use of renewable energies; and there are few concerns about the physical characteristics that housing must have to face the effects of climate change.

The requirement for the presentation of studies that guarantee the resistance of the building to the effects of climate change could be added in the approval of projects for new housing and renovations. As mentioned in the plan: "[...] the search for energy efficiency in buildings, both in new constructions and in existing ones, through readjustment (retrofit) of installations, equipment and construction standards is one of PlanClima's emphases" (PlanClima, 2020, p. 79).

This *first strategy* would be in line with Action 5 listed in PlanClima (establish and regulate requirements for buildings adapted to climate threats), mentioned in Chart 3. Thus,

there would be proof of the designer's concern to mitigate the effects of climate change in relation to:

I – material preservation;

II – security;

III – environmental comfort of housing.

A *second strategy* could involve the use of software developed by teaching institutions, as shown in Chart 5, in partnership with the City Hall of Curitiba. Such computer programs could simulate possible future scenarios, influenced by the effects of climate change, such as:

I – extreme heat waves;

II – windstorms;

III – heavy rains; and

IV – flooding.

In these scenarios, the effects of these events applied to housing could help in making design decisions, from the choice of materials to the shape of buildings.

In order not to burden the project approval process, the software could be purchased by the Curitiba city hall and made available for free download to civil construction professionals (architects, engineers and building technicians). Just as the project approval process in Curitiba is done online through the city hall website, through municipal decree n. 799/2020 – Simplified Project, access to the software could also be available on this platform, which presents in a simplified and complete way the information describing the approval process.

In this way, these products, which would be software, would be classified in the concept of innovation policies on the demand side, as Macedo (2017, p. 2) brings us: "[...] government purchases associated with Research requirements, Development and Innovation (RD&I); technological orders".

With regard to social housing, a third strategy, specific to the field of public policies, would be the adoption of the bidding modality through project competitions. In this way, there would be certainty of applying concepts of mitigation and adaptation of housing in relation to climate change, through the specialized technical knowledge of professionals in the area.

Thus, by requiring studies to mitigate the effects of climate change on housing, the role of innovation policies on the demand side would be carried out by the municipal government, and the RD&I sector would be acting in partnership, in an attempt to build a future resilient for the city and its residents.

Final considerations

This article demonstrates that, even with the concern to mitigate and adapt the urban environment built to face the climate crisis, the path to reach the destination is still being traced. The joining of multidisciplinary forces, which must start at the federal level, go through the state level, and reach the municipal field, is an urgent challenge for all countries. When noticing that the main climatic disasters that occur in the metropolis of Curitiba are

windstorms, one realizes the importance of buildings, mainly housing, being designed to resist the effects of these episodes.

The future is still uncertain in relation to the real effects of the climate crisis, but signs of critical scenarios are already showing. The use of multiple resources, such as technological innovations through R&D, allied to federal, state and municipal laws and decrees, as well as the specialized knowledge of professionals, such as architects, engineers and technicians, can result in an urban environment whose dwellings will serve as shelters. resilient to the effects of climate change.

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Referências

BAI, X.; DAWSON, R. J.; ÜRGE-VORSATZ, D.; DELGADO, G.; BARAU, A. S.; DHAKAL, S.; SCHULTZ, S. (2018). Six research priorities for cities and climate change. *Nature Climate Change,* v. 555, pp. 23-25.

BRASIL (1993). Lei n. 8.666, de 21 de junho de 1993. Regulamenta o art. 37, inciso XXI, da Constituição Federal, institui normas para licitações e contratos da Administração Pública e dá outras providências. Disponível em: <http://www.planalto.gov.br/ccivil_03/leis/l8666compilado.htm>. Acesso em: 5 dez 2022.

BRASIL (2009). Lei n. 12.187, de 29 de dezembro. Institui a Política Nacional sobre Mudança do Clima – PNMC e dá outras providências. Disponível em: <https://www.planalto.gov.br/ccivil_03/_ato2007-2010/2009/lei/l12187.htm>. Acesso em: 2 nov 2022.

_____ (2012). Lei n. 12.608, de 10 de abril. Institui a Política Nacional de Proteção e Defesa Civil - PNPDEC; dispõe sobre o Sistema Nacional de Proteção e Defesa Civil – SINPDEC e o Conselho Nacional de Proteção e Defesa Civil – CONPDEC; autoriza a criação de sistema de informações e monitoramento de desastres; altera as leis n.s 12.340, de 1º de dezembro de 2010, 10.257, de 10 de julho de 2001, 6.766, de 19 de dezembro de 1979, 8.239, de 4 de outubro de 1991, e 9.394, de 20 de dezembro de 1996; e dá outras providências. Disponível em: <http://www.planalto.gov.br/ccivil_03/_ato2011-2014/2012/lei/l12608.htm>. Acesso em: 2 nov 2022.

BRASIL (2021). Lei n. 14.133, de 1° de abril de 2021. Lei de Licitações e Contratos Administrativos. Disponível em: <https://www.planalto.gov.br/ccivil_03/_ato2019-2022/2021/lei/l14133.htm>. Acesso em: 9 dez 2022.

CEPED-UFSC – Centro Universitário de Estudos e Pesquisas sobre Desastres. Universidade Federal de Santa Catarina (2013). Atlas brasileiro de desastres naturais: 1991 a 2012 / Centro Universitário de Estudos e Pesquisas sobre Desastres. 2. ed. rev. ampl., v. Paraná. Florianópolis, Ceped-UFSC.

CIDADE DE TORONTO (2019). Código de Resiliência Climática (Climate Resilience Framework). Disponível em: <https://www.toronto.ca/services-payments/water-environment/environmentally-friendly-city-initiatives/resilientto/>. Acesso em: 9 maio 2023.

CIDADE E CONDADO DE SÃO FRANCISCO (2020). Plano de Riscos e Resiliência Climática (Hazards and Climate Resilience Plan). Disponível em: <https://onesanfrancisco.org/hazard/overview>. Acesso em: 9 maio 2023.

EDLER, J.; GEORGHIOU, L.; BLIND, K.; UYARRA, E. (2012). Evaluating the demand side: new challeges for evaluation. *Research Evaluation*. Universidade de Oxford, v. 21, n. 1. Disponível em: <https://academic.oup.com/rev/article-abstract/21/1/33/1642777?redirectedFrom=PDF>. Acesso em: 26 nov 2022.

ESPÍNOLA, I. B.; RIBEIRO, W. C. (2020). Cidades e mudanças climáticas: desafios para os planos diretores municipais brasileiros. *Cadernos Metrópole.* São Paulo, v. 22, n. 48, pp. 365-395.

FIOCRUZ. Observatório de Clima e Saúde (2022). Origens dos eventos climáticos e meteorológicos exteremos. Disponível em: <https://climaesaude.icict.fiocruz.br/tema/eventos-extremos-0#:~:text=Os%20eventos%20clim%C3%A1ticos%20e%20meteorol%C3%B3gicos,de%20processos%20geol%C3%B3gicos%20ou%20fen%C3%B4menos>. Acesso em: 1º nov 2022.

FONSECA, M. N.; FERENTZ, L. M. da S. (2020). Ocorrência de Vendavais no Estado do Paraná: um panorama entre 2013 e 2017. *Revista Nacional de Gerenciamento de Cidades*. São Paulo, v. 8, n. 57, pp. 72-68.

FUNDAÇÃO JOÃO PINHEIRO (2021). *Déficit Habitacional no Brasil 2016-2019*. Belo Horizonte, FJP.

GERHARDT, T. E.; SILVEIRA, D. (2009). *Métodos de pesquisa*. Porto Alegre, Editora da UFRGS.

MACEDO, M. de M. (2017). "Fundamentos das políticas de inovação pelo lado da demanda no Brasil". In: RAUEN, A. T. (org.). *Políticas de Inovação pelo lado da demanda no Brasil.* Brasília/DF, Ipea. Disponível em: <http://www.ipea.gov.br/portal/images/stories/PDFs/livros/livros/politicas_de_inovacao_cap02.pdf>. Acesso em: 9 nov 2022.

MARIMON, A. (2018). *Só 7 municípios brasileiros têm leis específicas de combate às mudanças climáticas.* Núcleo de Estudos e Pesquisas Ambientais. Disponível em: <https://www.nepam.unicamp.br/so-7-municipios-brasileiros-tem-leis-especificas-de-combate-as-mudancas-climaticas/>. Acesso em: 6 maio 2023.

ONU (2015). *Objetivos de Desenvolvimento Sustentável*. Disponível em: <https://brasil.un.org/pt-br/sdgs>. Acesso em: 12 nov 2022.

_____ (2022). *World Cities Report 2022*. Disponível em: <https://unhabitat.org/wcr/>. Acesso em: 13 nov 2022.

PLANCLIMA (2020). *Plano de mitigação e adaptação às mudanças climáticas.* Prefeitura Municipal de Curitiba. Disponível em: <https://mid.curitiba.pr.gov.br/2020/00306556.pdf>. Acesso em: 3 nov 2022.

PLANCLIMA SP (2020). *Plano de Ação Climática do Município de São Paulo 2020-2050*. Cidade de São Paulo. Disponível em: <https://www.prefeitura.sp.gov.br/cidade/secretarias/governo/secretaria_executiva_de_mudancas_climaticas/acesso_a_informacao/acoes_e_programas/planclimasp/?p=315991>. Acesso em: 7 maio 2023.

PREFEITURA DE BELO HORIZONTE (2022). *Comitê de Mudanças Climáticas*. Disponível em: <https://prefeitura.pbh.gov.br/meio-ambiente/comite-de-mudancas-climaticas>. Acesso em: 6 maio 2023.

PUC-RIO (2005). *Fluxovento – Programa para Análise de Ventilação em Ambientes Construídos – Versão 1.0.* Disponível em: <https://www.tecgraf.puc-rio.br/etools/fluxovento/>. Acesso em: 1º dez 2022.

RAUEN, A. T. (org.) (2017). *Políticas de Inovação pelo lado da demanda no Brasil*. Brasília/DF, Ipea. Disponível em: <http://www.ipea.gov.br/portal/images/stories/PDFs/livros/livros/politicas_de_inovacao_cap02.pdf>. Acesso em: 9 nov. 2022.

RORIZ, Engenharia Bioclimática (2022). *Psicrom: Relações Psicrométricas*. Disponível em: <https://roriz.eng.br/downloads>. Acesso em: 2 dez 2022.

SILVA, M. N. da. (2012). *A dinâmica da produção dos espaços informais de moradia e processo de metropolizalização em Curitiba*. Tese de doutorado. Curitiba, Universidade Federal do Paraná.

SOBREIRA, F. J. A.; GANEM, R. S.; ARAÚJO, S. M. V. G. de (orgs.) (2014). *Qualidade e sustentabilidade do ambiente construído: legislação, gestão pública e projetos.* Brasília, Câmara dos Deputados.

TOMINAGA, L. K.; SANTORO, J.; AMARAL, R. (orgs.) (2009). *Desastres naturais: conhecer para prevenir*. São Paulo, Instituto Geológico. Disponível em: <http://www.igeologico.sp.gov.br/downloads/livros/DesastresNaturais.pdf>. Acesso em: 24 nov 2022.

UFSC (2014). Laboratório de Eficiência Energética em Edificações. *Analysis SOL-AR*. Disponível em: <https://labeee.ufsc.br/pt-br/downloads/softwares/analysis-sol-ar>. Acesso em: 1º dez 2022.

UNESP (2013). Faculdade de Ciências Agronômicas. *Escala Beaufort.* Útima atualização em 25 out. 2013. Disponível em: < https://www.fca.unesp.br/#!/instituicao/departamentos/solos-recursos-ambientais/sra/estacao-meteorologica/vento---escala-beaufort/>. Acesso em: 20 nov 2022.

USP (2022). Departamento de Engenharia de Estruturas da Escola de Engenharia de São Carlos. *Ciclone 5.0.1 – Ação do Vento nas Edificações*. Disponível em: <https://set.eesc.usp.br/?page_id=237>. Acesso em: 2 dez 2022.

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