



Research article

The Climate Transition Strategy of the city of Brescia (Italy)

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Abstract: To build climate-neutral, and at the same time sustainable and highly resilient cities, it is necessary to act on their infrastructures and activities that take place in them, which constitutes an operation that requires activating a long and pervasive planning process based on a highly integrated use of the intervention tools available to a municipality. Furthermore, it is necessary to have a specific tool which, in addition to structuring actions to counteract climate change, stimulates and coordinates this integration. A voluntary tool that has established itself in European cities committed to combating climate change is the Sustainable Energy and Climate Action Plan (SECAP), which, subsequently and as a complement to the Sustainable Energy Action Plan, was promoted by the European Union to contribute from below to policies to counter climate change. Currently, one or both instruments have been adopted by around 8,000 municipalities or groups of municipalities. Furthermore, in recent years another tool has been emerging, which is often developed to replace or complement the SECAP to increase the effectiveness of the Municipalities' actions to combat climate change. This new tool, which has taken on different names, is referred to here as Climate Transition Strategy. The experience of the elaboration and the initial implementation of the Climate Transition Strategy of Brescia (Italian municipality of 200,000 inhabitants) is critically described, which was activated together with SECAP to achieve higher levels of mitigation and adaptation to climate change. In particular, the theoretical-methodological characteristics and the initial implementation of this strategy are described, comparing them with the performances required for the adoption of the SECAP and with the experiences that have been had with the latter tools. In this way, the performance of this new tool was compared with that of a consolidated and constantly evolving tool.

Keywords: urban planning; Climate Transition Strategy; climate mitigation and adaptation; 21st century; municipality of Brescia (Italy)

Abbreviations: CTS: Climate Transition Strategy; CTS-BS: Climate Transition Strategy of the city of Brescia; SEAP: Sustainable Energy Action Plan; SECAP: Sustainable Energy and Climate Action Plan

1. Introduction

The highly challenging goals undertaken by most countries of the world to combat climate change on a global level and its effects on a local scale require interventions at various decision-making levels and using all useful tools. A type of tool that can give a significant contribution to this challenge on a local scale is the climate transition strategy (or even plan). With this article we want to give a contribution in this direction, critically describing an innovative experience carried out for an Italian municipality of 200,000 inhabitants.

With Climate Transition Strategy (CTS) we mean a voluntary local-scale instrument, functional to achieve the goals of mitigation and adaptation to climate change assumed by most of the countries of the world [1]. In this regard, the European Union has promoted the Covenant of Mayor initiative as part of climate change mitigation and adaptation policies, to encourage the involvement of municipalities in this process through two intervention tools [2]. The first, which was activated in 2008 to implement climate change mitigation actions, is the Sustainable Energy Action Plan (SEAP), while the second, promoted in 2020 to also implement adaptation actions, is the Sustainable Energy and Climate Action Plan (SECAP). Currently, 7,768 SECAP and SEAP plans have been prepared in the European Union, of which 3,600 have been prepared in Italy [2]. The contents, goals and structure of these plans have been refined and consolidated over time to the point of assuming a very advanced character but, precisely for this reason, it is difficult to fully implement in all situations.

The SECAP, which is the tool that fully falls within the category of CTS defined here, must be developed and implemented by respecting a set of performances aimed at guaranteeing high effectiveness in combating climate change [3,4]. The main of these performances are summarized below in three categories.

The first concerns the exhaustive definition of the strategic aspects of the plan, for which the long-term vision, the objective of reducing CO₂ emissions, the adaptation goals and the way to involve stakeholders and citizens must be indicated. Furthermore, the need to assign human and financial resources, the ways in which possible changes in the strategy are considered over time and the obstacles in the process of implementing the actions must be defined [5].

The second concerns the preparation of emission inventories, which must measure or estimate the annual quantities of final energy consumption and the related CO₂ emissions by energy vector and economic sector to monitor their trends over time.

The third concerns the definition of plan actions, which must implement the general strategy and must be distinguished into mitigation actions and actions to adapt to climate change. The definition of the former requires to indicate the timing, the responsibilities for their implementation, the funds available, the estimate of their impacts and the methods for monitoring their implementation. The definition of the latter must indicate the parameters to be considered (intervention sector, time frame, stakeholders and costs) and the monitoring methods for the period necessary to achieve the goals of increasing the adaptation capacity to the identified climate impacts.

The drafting and implementation of SECAPs and CTSs, but also of SEAPs, has encountered in many cases problems of a theoretical-methodological and decision-making/organisational nature, problems which are often intertwined and whose solution requires the adoption of systemic

approaches [6–10].

Theoretical-methodological problems are the result of some problematic nodes that are difficult to solve, which arise in the elaboration and implementation of a CTS, and which are therefore often developed in an unsatisfactory way [11–14].

The first node concerns the ability to adopt a systemic approach capable of identifying from the outset the main actions and solutions capable of achieving climate neutrality in the area of intervention, overcoming those sectoral approaches that aim to initially resolve the most relevant critical issues and only later to address the other ones [15,16].

The second node concerns the definition of the vision and goals and the deepening of the actions in a shared way with the citizens and the stakeholders. This path requires the ability to quickly implement the numerous interventions and multiple activities necessary to effectively achieve climate neutrality and at the same time to manage the participatory processes, which require longer times, to arrive at shared solutions that better respond to the needs of citizens. Furthermore, since the goals of these strategies have a highly progressive nature, they must contemplate an increase over time in the quantity of actions to be carried out. Therefore, it is necessary to build right from the start the most suitable conditions to favour the dissemination of actions and interventions.

The third node concerns the construction of a good knowledge base on the characteristics and effects of climate change and on the related mitigation and adaptation actions. Indeed, the knowledge base must support the assessments of vulnerabilities, adaptive capacities, potential for mitigation and effectiveness of planned and implemented actions. Furthermore, the knowledge base constitutes a fundamental tool for defining targets, since it is necessary to quantify past trends and predict future scenarios of the various phenomena to be governed, and for the proper functioning of the monitoring system [17–19]. Therefore, given the very short times in which it is necessary to implement the actions of each strategy in the first phase due to the need to reduce the impact factors on climate change as soon as possible, the knowledge base can only be created in parallel with the elaboration and implementation of such actions, which requires finding a difficult balance between acting and knowing.

The fourth node concerns the mainstreaming of adaptation and mitigation goals and actions, in order to be able to include them in ordinary development and management tools and processes, since the transformation of cities into climate-neutral and resilient realities can only be achieved through a coordinated and overall commitment [20,21]. In this regard, this measure should integrate the set of municipal policies, tools and actions functional to combating climate change.

The decision-making/organizational problems of the municipalities are largely attributable to three factors [22,23].

The first problem concerns the lack of qualified human resources for the implementation and monitoring of the CTS and the evaluation of the results of the actions undertaken, and the change of municipal administrators due to the normal succession of municipal elections or local political crises, especially when they have different approaches to problems and solutions related to climate change [24].

The second problem is the fragmentation, among the different departments and sectors of the municipal structure, of data management and skills that are relevant for climate change initiatives, with the consequent difficulty in ensuring a good level of coherence between the measures adopted by the different managers.

The third problem consists in the scarce ability to coordinate the identification and implementation of all the planned actions and in the lack of a political leadership capable of guaranteeing overall coherence in their identification [25].

The CTS elaborated for the city of Brescia (CTS-BS) had to face the problems indicated here, trying to overcome them through the adoption of a holistic and incremental approach that immediately considered the organisational, human and economic resources at its disposition to build over time a theoretical, technical, organizational apparatus capable of achieving the relative goals. The CTS-BS was launched at the beginning of 2020 with a loan from a local banking foundation (Cariplo Foundation) and a public institution (Lombardy Region). Starting from a set of already existing objectives and projects and from the simultaneous elaboration of the SECAP, these two loans have allowed the Municipality of Brescia to develop a solid and exhaustive strategy capable of planning its actions over a period of at least 5 years, with the possibility of projecting them to 2030, the year which constitutes one of the milestones of European and international policies to combat climate change.

2. Characteristics of the climate transition strategy

2.1. The effects of climate change in the city of Brescia

Brescia is a city of 200,000 inhabitants located in the central northern part of the Po Valley and bordered to the north by the pre-Alpine belt that surrounds the northern part of northern Italy (Figure 1).

The municipal territory, whose surface area is approximately 90 km², is mostly flat (altitude of about 150 m a.s.l.), with the exception of the north-eastern side, where the southern slopes of Mount Maddalena (770 m) and the hill Cidneo start to rise. In the western area, the city is crossed by the Mella River.

More than half of the Brescia territory is urbanized (56%), while the remaining part is made up of agricultural areas (24%) and woods and semi-natural environments (19%). Half of the urbanized territory consists of residential areas (48%), for more than a quarter of production areas and infrastructures (21% and 9%, respectively), and the remaining share are green areas (13%) and services (3%).

In the last decade, municipal urban planning has pursued the objective of a strong containment of the urbanization of agricultural and natural soils by focusing on the regeneration of existing urban areas. Currently, the transformations envisage a limited increase in settlement capacity in order to respond to the evolution of housing demand due to the slight increase in the population that occurred in the decade 2010–2020 (+4.7%).

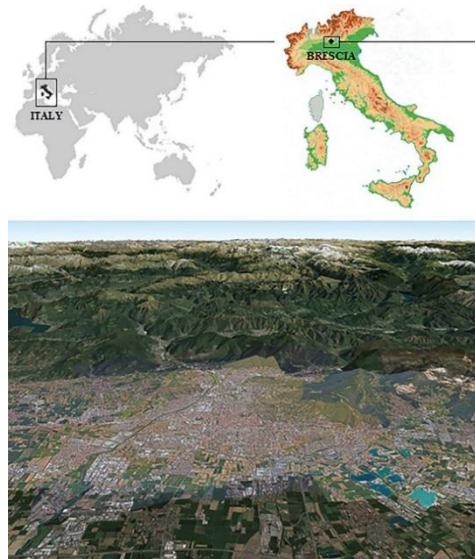


Figure 1. Territorial context of the city of Brescia.

2.1.1. Climate trends and scenarios

In the thirty years 1990–2019 in the Brescia area, the average annual precipitation was around 1,000 mm, while the average annual temperature varied in a range from 12 °C to 16 °C. The absolute maximum annual temperatures often exceeded 35 °C and the absolute minimum annual temperatures fluctuated between 0 °C and –5 °C. Considering the average values of the thirty years, an increase both in temperature, of about 0.5–1 °C, and in precipitation, with an increase in frequency starting from 2008, is observed (Figure 2).

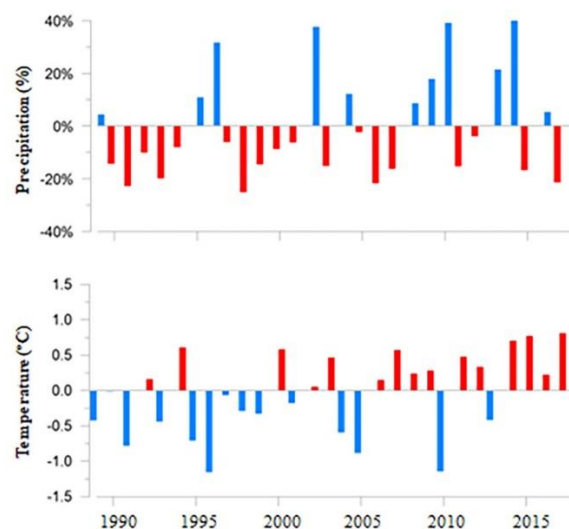


Figure 2. Evolution in the Brescia territory of the anomalies in average annual precipitation (expressed as a percentage) and temperature (expressed in degrees) calculated with respect to the average annual precipitation and temperature in the thirty-year period 1989–2018.

Compared to the previous thirty years (1960–1989), there are no years in which the average annual temperature is lower, with the exception of 1990. Furthermore, the months with the coldest values have decreased, while the intensity and frequencies of the warmest ones have raised, with 2019 being the hottest year in the last 30 years and with an increase in the average annual temperature of about 2.5 °C compared to the average of the previous thirty years (Figure 3).

The increase in temperature in the thirty-year period 1990–2019 corresponds to the progressive decrease in the annual number of Frost Days, the days in which the minimum temperature is below 0 °C, and to an increase in Summer Days, the days in which the maximum temperature has a value higher than 29.2 °C, and Tropical Nights, the days in which the minimum temperature is higher than 20 °C.

The spatial distribution of precipitation is correlated to the orographic characters, so that the higher values, between 1,100 and 1,250 mm, occur in the mountain area and the lower values, between 900 and 950 mm, in the flat area (Figure 4). The spatial distribution of the average annual temperatures shows an increase of about 1 °C in the more urbanized central areas, compared to the municipal average (15.3 °C), while temperatures gradually decrease with the reduction of the urban heat island effect and with the increase in altitude.

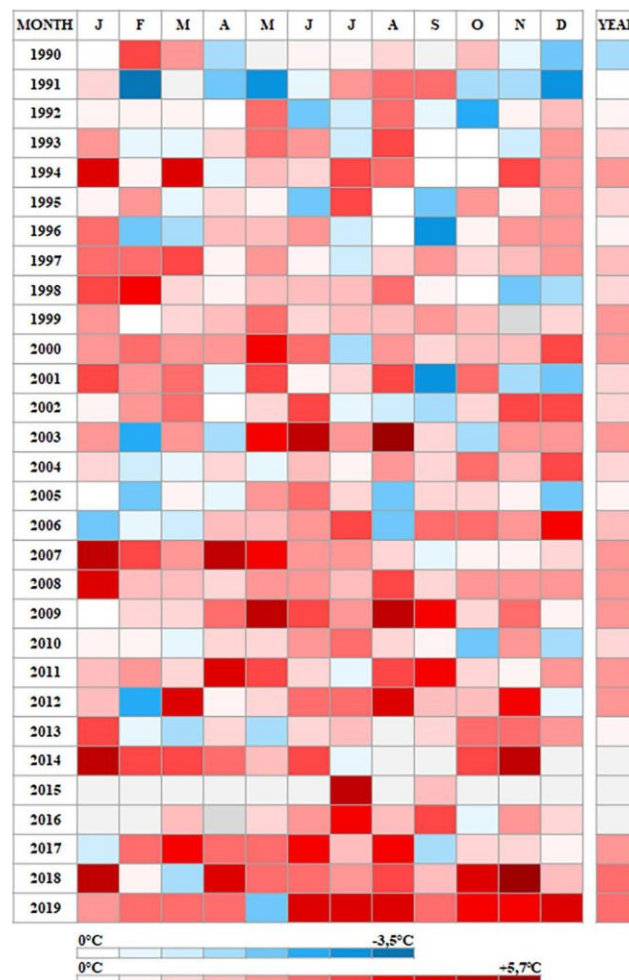


Figure 3. Monthly and annual thermal anomalies for the thirty-year period 1990–2019 compared to the thirty-year period 1989–2018 in the Brescia territory.

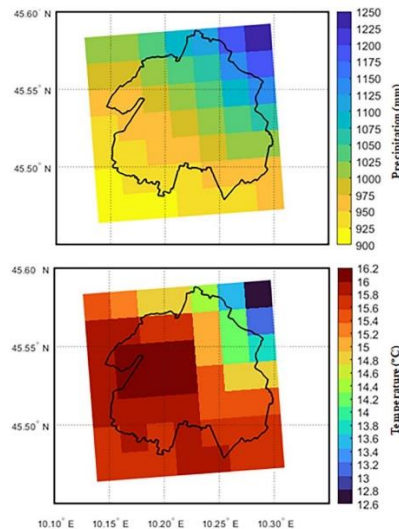


Figure 4. Spatial distribution in the Brescia territory of the average annual precipitation and the average annual temperature, calculated over the thirty-year period 1989–2018.

With the CTS-BS, an estimate was made of the climatic variations expected in the thirty-year period 2021–2050 compared to the reference thirty-year period 1981–2010. The estimate has considered two of the currently available IPCC scenarios, referring to the possible dynamics of the greenhouse gas (GHG) emissions in the atmosphere over time [26]. The first scenario is characterized by a strong mitigation of GHG emissions (RCP4.5), while the second is characterized by a projection of the same emissions of the last thirty years (Business as Usual-RCP8.5).

For both scenarios, there is an increase in precipitation in the wet period (autumn-winter) and a decrease in the dry period (spring-summer), with more marked variations (about $\pm 20\%$) in the RCP8.5 scenario. An increase in the maximum precipitation values is also expected in the winter and autumn periods, especially for the RCP8.5 scenario (+30%).

An increase in minimum, average and maximum temperatures is expected and in particular an increase in average temperatures of around $+1.2\text{ }^{\circ}\text{C}$ for the RCP4.5 scenario and $+1.5\text{ }^{\circ}\text{C}$ for the RCP8.5 scenario, and more significant increases in winter season ($+1.6\text{ }^{\circ}\text{C}$ and $+1.8\text{ }^{\circ}\text{C}$ in the two scenarios) compared to those of the summer season ($+1.3\text{ }^{\circ}\text{C}$ and $+1.7\text{ }^{\circ}\text{C}$).

During the thirty-year period 2021–2050, in the winter seasons a decrease in Frost Days of 10 days in the RCP4.5 scenario and 19 days in the RCP8.5 scenario is forecast, while in both scenarios an average annual increase for Summer Days (approximately +13 days) and for Tropical Nights (approximately +12 days) is expected.

2.1.2. The main criticalities due to climate change

The high temperatures in the summer season are a factor of discomfort for the population of Brescia, in particular for those who live in or frequent the denser urban areas with asphalt surfaces, where the heat island effect is stronger. The occurrence of heat waves of higher duration and frequency increases the severity of the hazard due to heat, with effects on people's health, especially on the most vulnerable subjects (children, the elderly, the disabled and people with cardiorespiratory pathologies). The occurrence of heat waves of higher duration and frequency increases the severity of the hazard due to

the heat, with negative effects on people's health, especially on the most vulnerable subjects (children, the elderly, the disabled and people with cardiorespiratory pathologies). These negative effects further increase during periods in which tropospheric ozone (O₃) is formed, which is a typical phenomenon of this area which occurs during hot days through photochemical processes in the presence of primary pollutants such as nitrogen oxides (NO_x) and volatile organic compounds (VOCs).

The increase in precipitation and extreme events in the rainy seasons exacerbates two types of critical issues existing in the Brescia territory: on the one hand, the floods from surface water bodies, starting from the Mella River, in water basins upstream of the urban areas, on the other hand, urban flooding due to the insufficient capacity of drainage systems to dispose of large quantities of water in a short time. This is because there are a high degree of soils waterproofing and numerous inadequate hydraulic infrastructures, whereby the excess water is mainly disposed of by surface runoff, creating accumulations and flows of water in the streets and in the most depressed areas (road underpasses, underground floors of buildings and metropolitan public transport, etc.).

The reduction in precipitation in dry periods is not so significant as to increase the low levels of forest fire hazard that characterize the Brescia area, but the worsening of drought in some periods of the year may have contributed to increasing the vulnerability of wooded areas and of urban vegetation to episodes of extreme winds that occurred in the recent past, and in the future could make the risk conditions more critical.

2.2. The development of the CTS-BS

2.2.1. The first two phases of the CTS-BS

The CTS-BS was initially developed to participate in a call for funding from the Cariplo Foundation, which is an important local banking foundation whose field of action is the territory of the Lombardy Region, a territory which is in Northern Italy, and which has as its centre the metropolis of Milan. With the funding thus obtained, the CTS-BS, called "Un filo naturale" (A natural thread) [27,28], began to develop towards a long-term scenario characterized by three phases, the first of which was completed in 2021, the second will end in 2025 and the third phase should be completed in 2030, when the conclusion of the European Union package of measures called "FIT for 55" (the 55% reduction in greenhouse emissions compared to 1990), is expected.

The first phase began in 2019 with the elaboration of a proposal characterized by the inclusion in a single framework of the mitigation and adaptation actions to climate change already financed or envisaged by the Municipality of Brescia. In this first phase, the technical and decision-making structure for the elaboration and participatory implementation of the CTS-BS begins to be organised, a structure that will be completed in the second phase.

In particular, the definition of the vision and objectives was the subject of a long elaboration process which ended during the second phase of development of the CTS-BS and was characterized by the organization of numerous meetings in which the municipal institutions (Councillors, Council and Neighborhood Committees), stakeholders, individual citizens and experts were involved in different ways.

The municipal institutions have been supported by the Council for the Environment, which is a consultative body set up by the Municipality of Brescia and made up of representatives of environmental and citizens associations and of productive and service companies and which also

includes researchers, professionals and university professors. Individual citizens were involved through participatory processes managed by a dedicated municipal structure (Urban Center) with the support of experts from the Politecnico of Milano. The expert subjects were the high-level municipal technicians, the professional consultants of the planning tools to be elaborated, the professors and researchers of the Universities of Brescia and Bologna and of the Politecnico of Milano, the Committee of experts specially activated by the Cariplo Foundation for a development innovation of the CTS-BS.

The possibility of adopting a more agile tool than those available in ordinary planning has led the Municipality of Brescia to assign some fields of intervention connected to the climate transition to the CTS-BS, such as the reduction of atmospheric pollution, the construction of resilient communities and the improvement of urban quality.

This first strategy proposal was subsequently reviewed by a group of experts, which includes the two authors of this article, and municipal technicians and administrators, to improve it both from the theoretical-methodological and knowledge points of view, and with respect to the definition of objectives and identifying the actions to achieve them.

In particular, the actions for the dissemination of the pilot interventions were studied in detail, also through participatory courses; the actions to be able to fully achieve the goals of the CTS-BS have been identified; and the accounting of the shares of other municipal instruments that contribute to achieving these goals has been prepared. The goals and actions of the CTS-BS have been reviewed and expanded relying on a parallel deepening of the knowledge base that concerned the mapping of the levels of vulnerability, the modelling of the urban water system and the drafting of the risk and criticality maps due to climate change. The improvement of the knowledge of the possible effects of climate change on the city of Brescia has made it possible to refine the dissemination programs of pilot interventions (green roofs, desealing of urban open spaces, increase in urban drainage, tactical urban planning interventions, planting of greenery, etc.) and has favoured the acquisition of additional funding through local, national and European tenders.

The deepening of the knowledge base has also made it possible to identify the indicators and targets for monitoring the effectiveness of adaptation actions. In particular, the targets were defined starting from the estimate of the baselines of the related indicators and from the greater qualitative-quantitative knowledge of the critical situations and considering the decisions of the municipal administrators and the assessments on the entity of the actions that could have been carried out.

The strengthening of the CTS-BS has also aimed at its systematic integration with the general and sectoral urban planning and building instruments of the Municipality of Brescia, such as the Town Plan, the SECAP, the Sustainable Urban Mobility Plan, the Green Plan and Regulations, the Building Regulations and its Energy Annex, the procedures of the One-Stop Shops for production and construction activities. The prevailing criterion with which this integration was carried out was to try to make the actions as effective and efficient as possible in achieving the goals and targets of the climate transition. Among these tools, the CTS-BS has a symbiotic relationship with the SECAP, since most of the climate change adaptation actions have been attributed to the first instrument, while most of the mitigation actions have been attributed to the second. In this way, the two tools should dialogue systematically to facilitate the achievement of their common goals and to carry out their integrated ongoing verification.

The second phase, which is underway, is characterized by further analytical and planning elaborations, by the continuation of the participatory paths, by the conclusion of the first pilot interventions and by the activation of their first disseminations. These actions will continue until the

available funds are completed and will subsequently rely on additional funds that will be acquired in the meantime.

The analytical and planning activities are developed in parallel with the implementation of the pilot interventions, thus obtaining the information and knowledge useful for improving the identification and planning of these interventions and therefore improving the effectiveness of the CTS-BS in its third implementation phase.

These activities are aimed at developing two types of tools.

Three planning tools belong to the first type, the purpose of which is to favour and stimulate the dissemination of the interventions envisaged by the CTS-BS to be able to fully achieve the related goals and to achieve useful synergies with the other goals of the Municipality of Brescia. The Urban Desealing Implementation Plan and the Strategy for the Diffusion of Green Roofs have first the function of classifying, respectively, the publicly owned paved areas of the city by levels of suitability for the implementation of desealing interventions and the public and private roofs of the city for levels of suitability for the construction of green roofs. Both instruments indicate the priorities for intervention, established considering the indications of municipal administrators and citizens; quantify the potential for intervention to understand their effectiveness in improving climate comfort, reducing the heat island, increasing urban drainage and reducing flooding phenomena; and redefine the goals for the reduction of the heat island and critical issues due to flooding. The Forest Intervention Plan serves to define and apply the intervention and management criteria to enhance the extra-urban wooded areas and to create a satisfactory ecological connectivity in-between the wooded areas and between the wooded areas and the urban green areas.

The second type of tool consists of some digital devices functional to the dissemination of information and knowledge to encourage those behaviours useful for combating climate change. The WebGIS, which has been configured as an open platform, easily accessible to decision-makers and stakeholders, is a tool that connects with the set of databases of the Municipality of Brescia to facilitate the integration of data and information and the elaboration of thematic maps and benchmark indicators to support assessments and decisions on actions to counteract climate change. The One Stop-Shop Desk, functional to support the design and implementation of sustainable building renovation interventions, is a physical and digital place for collecting information and facilitating authorization procedures for stakeholders. The Platform on climate change knowledge in Brescia aims to collect and represent information on monitoring the implementation of the CTS-BS actions and on the achievement of targets and to inform and raise awareness among citizens on the causes and effects of climate change.

2.2.2. The role of the CTS-BS

In defining the role of the CTS-BS, the characteristics of the intervention tools available to the Municipality of Brescia were considered, to outline the framework of the functional and decision-making relationships between these tools to achieve an intervention capacity that is as effective and coherent as possible [29]. In this framework, the CTS-BS is seen as the container and integrative tool of the set of municipal objectives and actions aimed at the climate transition.

It is considered a container tool because it must internally assume, albeit in different ways, all the goals and actions that the Municipality of Brescia is implementing or intends to implement to combat climate change. It accounts in its goals for the performance of the actions also contained in general and

sectoral municipal planning and building instruments, but does not contribute to the planning, implementation and monitoring of these actions, except in cases where it can implement them more effectively.

It is considered an integrative tool because, in addition to indicating the actions to be considered in general and sectoral municipal planning and building instruments, it is designed to integrate the set of policies, intervention tools and municipal actions aimed at directly or indirectly combating climate change. This is because, from the outset, the CTS-BS proved to be a more agile tool than other planning tools, for which the Municipality of Brescia also attributed to it part of the analytical and planning skills that concern some issues connected to the climate transition, such as tackling air pollution not caused by the use of fossil fuels, building resilient communities and regenerating critical areas of the city.

The CTS-BS aims to establish itself as a structured, solid and complete tool projected over an action period of at least 10 years, in order to target 2030, which is the year in which the next intermediate targets are defined at national, European and international levels. The 2030 deadline and the integrated approach have resulted in interest in considering in the CTS-BS those Sustainable Development Goals of the UN Agenda 2030 that are synergistic with the goals of combating climate change.

The CTS-BS has activated, relying on already existing municipal organizational and consultative structures, numerous actions for the widespread and systematic involvement of the population and stakeholders in order to make the interventions more responsive to their needs, favour their best use over time, reduce maintenance costs and support the construction of resilient communities through information, knowledge and awareness of the problems to be faced and possible solutions. In this regard, participatory paths are constantly created both of a decision-making nature, see the identification of the places in which to carry out the interventions or the definition of the type of solutions to be adopted, and of a design nature, see the co-design initiatives. These activities have required the construction of networks of associations and stakeholders, to support, strengthen and enhance the CTS-BS, also promoting a greater awareness in the various subjects of their own capacities for action and, therefore, a change in individual behaviour towards more sustainable models.

To facilitate the implementation of the CTS-BS and coordinate all the activities to be carried out, a specific organizational structure has been set up consisting of: a Climate Transition Manager, who has the task of coordinating and supervising, supported by a group of high level technicians, the implementation of the CTS-BS; a control room, with the task of evaluating any changes to the CTS-BS; those responsible for the implementation of the actions, who have the task of carrying out the actions within the established times and methods.

2.3. The structure of the CTS-BS and the strategic framework

2.3.1. The strategic framework

The CTS-BS adopts a systemic approach, whereby every action finds its place and meaning within a well-defined relationship and performance framework, and is oriented both towards the achievement of progressive conditions of sustainability and towards the strengthening of the capacity for building resilience of the territorial system of Brescia starting from its community. It has a flexible and progressive character to achieve increasingly higher conditions of sustainability and resilience

over time, so it is necessary to verify its effectiveness over time and be able to easily modify it in its various elements (goals, actions, governance, interventions, etc.) to achieve the ambitious and challenging goals [30].

The objectives and actions of the CTS-BS have been identified by relying on a knowledge base in continuous development and updating, for which a dynamic and reciprocal relationship has been triggered, destined to last over time between the knowledge base, partly oriented by the consequent knowledge needs the decisions to be taken and the outcomes of the actions, and the decision-making and planning steps, which are developed with respect to the available information.

The structure of the CTS-BS has been innervated on a Strategic Framework, which constitutes the reference element to support the elaboration, implementation, evaluation and development of the strategy itself, since it allows representation of the logical chains between the impacts of climate change and the goals assumed, the actions envisaged and the results expected following the implementation of the strategy [31].

The strategic framework is structured in 4 components—the vision, the goals, the targets and the actions—whose definition, continuously updated with respect to the evolution of the actions carried out and the objectives to be achieved, took place through a long shared process which tried to harmonize the most effective and innovative solutions of national and international experiences with the specific needs and possibilities of intervention for the city of Brescia.

The vision, which constitutes the description of the long-term scenario that is intended to be achieved for the territorial system of Brescia through the CTS-BS, has the function of transparently declining the aims of the strategy itself, consistently directing and delimiting the related goals. It finds its spatial, action and temporal limits respectively in the municipal area of Brescia, in the purposes indicated for the CTS-BS and in the validity period attributed to the CTS-BS. As indicated, that validity is expected for the end of 2030, even if its definition, of a dynamic type, could be assumed up to the achievement of the climate neutrality objectives indicated for the year 2050 in international, European and Italian policies. It also constitutes a tool for communication and engagement of citizens and for sharing a collective imagination that is intended to be achieved.

The goals indicate the aims and results, expressed in qualitative terms, which are intended to be obtained in the period of validity of the CTS-BS. The achievement of all these goals should make it possible to achieve the conditions described in the vision for the period in question.

Targets are the transposition of goals into measurable performance or conditions over time in sync with the validity period of a strategy. In the CTS-BS, they indicate in quantitative terms the results to be achieved in 2030 or, in some cases, at the end of 2024, when the second phase of implementation of this strategy will end. Through the targets, two fundamental aspects of the correctness of a strategy can be considered, which are the coherence (qualitative aspect) and consistency (quantitative aspect) between vision, goals and actions [32].

The actions indicate the operations that will be carried out to achieve the goals of a strategy, the complete and correct implementation of which must lead to the achievement of the set of goals. Each action contributes to the achievement of one or more goals, while each goal is achieved by the realization of several actions. For greater organizational effectiveness, the actions have been divided into two categories: the activities, which can be managerial, analytical-evaluative, planning, juridical-administrative, participatory and political, and the interventions, which are operations that have as a result the construction of punctually defined works. The activities generally anticipate the interventions, which are preparatory to them, and both must contribute to fully realizing the reference action.

2.3.2. The vision and goals

Having as reference the field of intervention of the vision indicated in point 2.3.1., its definition was carried out by combining a bottom-up approach, based on the visions and goals of the municipal planning tools, with a top-down one, which instead it started from the purposes of the CTS-BS and from the role attributed to it by the Municipality of Brescia. This first definition, of a general order, describes the achievement of three requirements as a result of the transformations of the city to effectively counter climate change: an oasis city, which generates shade and coolness in order to improve the urban microclimate and increase urban biodiversity and the welfare of citizens; a sponge city, capable of restoring space, time and quality to water; a city for people, made up of pleasant and liveable spaces capable of guaranteeing the right to health, slow mobility, sociality and inclusion.

In its operational definition, the vision has been structured with respect to two different types of characteristics, called central and complementary, the achievement of which also allows the achievement of the three requirements of oasis city, sponge city and city for people. This distinction has a slightly hierarchical character, due to the desire to place at the center of the action of the CTS-BS what is within its specific competence, so that the attribution of priorities between the various objectives and actions was consequent to the intervention field of this instrument and not to specific choices of a political nature. This is due to a precise decision-making will of the municipal administrators, whose purpose is to avoid possible conflicts or disharmonies between the various municipal technical-managerial sectors that could lengthen the implementation times of the actions.

The central characters represent the focus with respect to which to identify the main goals of the CTS-BS and concern the two key factors for the fight against climate change: the mitigation of its causes and the adaptation to its effects. These characteristics describe the dynamic conditions that must be achieved by the territorial system of Brescia, the implementation of the CTS being part of an at least thirty-year process in which this system must continue to evolve to be able to achieve increasing performance of goals over time since they have already been defined at world level.

The first factor involves the achievement of a proactive territorial system in continuous and progressive action towards the reduction, to the point of irrelevance, of greenhouse gas emissions. The second factor envisages the achievement of a proactive territorial system in continuous improvement in the management of risks and criticalities due to climate change through a progressive increase in the resilient capacity of a co-evolutionary nature based on integrated actions of a physical, organisational, socio-economic and cultural nature. With co-evolutionary resilient capacity, we mean a constantly evolving process that seeks to transform crises into development opportunities [33,34]. It is not seen only as the ability to be able to recover from natural and/or anthropic crisis situations, but also as a factor of change in the territorial system in the long term. This ability requires that citizens share the objectives of change and be promoters of the change itself and therefore prepare the territorial system to react to potential crises through modifications that anticipate the necessary changes.

The complementary characters represent non-founding elements of the vision and are used to consider in the CTS-BS further conditions, which can be integrated and synergistic with the central conditions, which are intended to be achieved. The achievement of these conditions, such as for example the widespread presence of urban green spaces with high levels of biodiversity or the existence of high levels of quality of life and conditions of well-being for citizens, is never definitive, so they require an active attitude for their maintenance and updating with respect to the evolution of the needs and interests of the community.

The goals of the CTS-BS aim to achieve the central characteristics of the vision as a priority, while taking into consideration the achievement of the complementary characteristics. The goals, and consequently the related actions, have been divided into five types (Figure 5): climate change mitigation, climate change adaptation, governance strategy and organization of the municipal structure, participatory and co-design processes and the financing of the strategy. The first two types concern the contents of the CTS-BS; the next two concern the decision-making and organizational structure to achieve the goals of the first two areas; the last type concerns the identification and activation of the economic resources necessary to achieve the goals of the previous four areas and therefore the strategy itself.

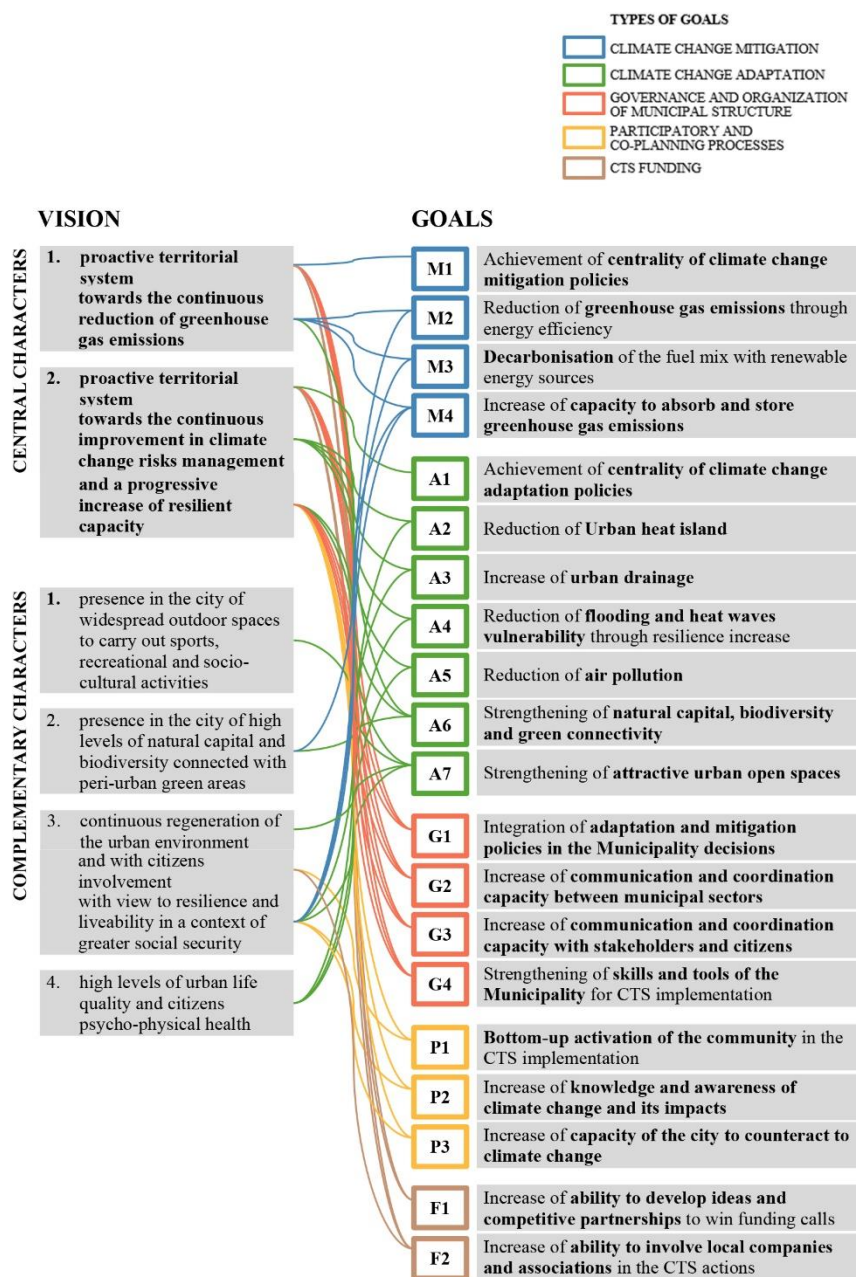


Figure 5. Graph of the relationships between the characters of the vision and the goals of the CTS-BS.

2.3.3. The targets

The definition of the targets was carried out on the basis of complex calculations due to the need to know the extent of the effects of the implemented and planned actions and through a decision-making process that considered several factors such as: the need to reach a reasonable compromise between the capacity of the target indicators to represent the performance and the effectiveness of the CTS-BS and the capacity of the municipal technical structure to monitor them over time; the identification of the actions to be implemented, in addition to those already envisaged, to achieve the established goals; the harmonization and integration of the accounts relating to all the municipal actions envisaged for the climate transition, which required the integration of the CTS-BS accounting with the accounting of the municipal planning and building instruments of a general and sectoral type.

The indicators and targets refer to the municipal area of Brescia and to the set of mitigation and adaptation actions of the CTS-BS and consider a time limit that reaches 12/31/2030 and an intermediate one that reaches 12/31/2024. Indicators and targets were initially established through a discussion with municipal technicians, starting from the criteria for their identification, measurement and evaluation, while the targets alone were subsequently shared with some Councillors and the Council for the environment of the Municipality of Brescia.

For the set of mitigation actions, an overall target was acquired by SECAP, which envisages a 50% reduction in the percentage of per capita CO₂ emissions by 2030 compared to the quantities emitted in 2010, and therefore this percentage was divided between the various mitigation actions in a manner consistent with the estimates of their impacts.

For adaptation actions, numerous indicators have been identified to represent the different aspects on which these actions have an effect. On the basis of the indicators identified, the relative baselines were estimated, the qualitative and quantitative knowledge of the critical situations and the technical-political decisions on the extent of the actions that could and were intended to be implemented were deepened and then the estimates of their impacts were made on the respective indicators by identifying the ranges of possible variability of the targets (Table 1).

Table 1. The most significant targets of the CTS-BS and the related goals and indicators.

Goals	Indicators	Targets
Achievement of centrality of climate change mitigation and adaptation policies	Weighted percentage of instruments in which climate change mitigation and adaptation indications have been integrated	Achievement of 100% of the instruments to be integrated at 12/31/2024
Reduction of greenhouse gas emissions through energy efficiency	Percentage change in annual CO ₂ emissions per capita compared to the 2010 baseline due to energy efficiency	37.5% reduction in per capita CO ₂ emissions in 2030 compared to 2010 due to energy efficiency
Decarbonisation of the fuel mix with renewable energy sources	Percentage change in annual per capita CO ₂ emissions compared to the 2010 baseline due to the replacement of fossil fuels with renewable sources	12.5% reduction in CO ₂ emissions per capita in 2030 compared to 2010 due to the replacement of fossil fuels
Increase of capacity to absorb greenhouse gas emissions	Total number of new trees planted	Planting at least 15,000 new trees by 12/31/2030

Continued on next page

Goals	Indicators	Targets
Reduction of Urban heat island	Percentage change in the Urban Heat Island Intensity Index compared to 2020	Containment of the heat island intensity index below +3% in 2024 compared to the 2020 value
Increase of urban drainage	Percentage of sustainable urban drainage intervention surfaces carried out compared to the public surfaces on which interventions need to be made	Construction by 2030 of 100% of the public surfaces on which it is necessary to intervene with sustainable urban drainage works
Strengthening of natural capital, biodiversity and green connectivity	Variation of the surface of new urban green areas multiplied by the number of jumps in the level of natural quality of these surfaces	Increased 67,750 natural quality points as of 12/31/2024
	Variation of the surface of new extra-urban green areas multiplied by the number of jumps in the level of natural quality of these surfaces	Increased 114 natural quality points as of 12/31/2024
Integration of adaptation and mitigation policies in the Municipality decisions	Weighted percentage of tools in which the indications of the CTS-BS for mitigation and adaptation have been integrated	Achievement of 100% of the instruments to be considered at 12/31/2024
Increase of communication and coordination capacity with stakeholders and citizens	Percentage of subjects supporting the governance of the CTS-BS activated in the period considered	Activation of 100% of entities expected to support governance from 1/1/2022
	Percentage of actions implemented compared to those envisaged in the period considered	Implementation of at least 90% of the actions envisaged at 12/31/2024
Increase of capacity of the city to counteract to climate change	Percentage of CTS-BS targets achieved on 12/31/2024	Achievement of at least 70% of the CTS-BS targets at 12/31/2024

2.3.4. The actions

The actions have been identified both considering what is already foreseen for the fight against climate change, and considering the set of targets assumed, and aiming to implement multi-objective actions to maximize possible synergies. Furthermore, particular attention has been paid to giving precise indications on the methods of integrating the actions of the STC-BS into the general and sectoral planning and building instruments.

To favour the integration and, when useful, a coordinated modification over time of the various actions, each of them is given qualitative information, such as the goals they contribute to achieving and the expected and desired direct and indirect results, and quantitative information, such as the general financial framework, the times for carrying out the activities and interventions connected to them and the indicators for their monitoring.

Below is the list of the main actions envisaged by the CTS-BS, with the most relevant interventions and activities specified (Figure 6).

1. Efficiency improvement of urban energy system: promotion and support for the implementation of retrofitting interventions on buildings and systems and a Zero energy district as a pilot intervention to disseminate this type of intervention in the city.

2. Environmental sustainability increase of urban energy system: support for the spread of photovoltaic systems and pedestrian, bicycle and electric mobility.

3. Natural capital strengthening for GHG absorption and storage and atmospheric pollution mitigation: renewal and enhancement of urban vegetation, extension of the municipal ecological network, increase in biodiversity, improvement of forestry practices in extra-urban wooded areas and expansion of the latter with the formation of new habitat.

4. Urban desealing for urban heat island reduction: reduction of the urban heat island through pilot desealing interventions to be subsequently disseminated through their integration with urban redevelopment and regeneration interventions and renovation of buildings and infrastructures.

5. Sustainable Urban Drainage Systems for flooding and heat wave vulnerability reduction: increase in urban drainage to achieve greater safety from extreme atmospheric phenomena through the implementation of pilot interventions for desealing, green and hybrid roofs and water accumulation and percolation characterized by Nature Based Solutions.

6. Urban planning tool revision to combat climate change: revision of general and sectoral municipal planning and building tools functional to systematically support the implementation of mitigation and adaptation interventions to climate change.

7. Improvement of knowledge and monitoring of climate change and CTS-BS effects: improvement and dissemination of knowledge on past trends of the local climate, on forecasts of future climate scenarios and related criticalities through the implementation of specific studies, the construction of a monitoring system in support of the CTS-BS and the creation of a Climate Change Information Platform.

8. Capacity building and municipality and community engagement for the CTS implementation: increase in the capacity of the municipality and the citizens of Brescia to carry out actions to mitigate and adapt to climate change through a set of actions such as improving the organization and internal communication between various sectors of the municipal structure, the involvement of citizens and stakeholders with co-design activities, experiential and citizen science initiatives, guided tours of pilot interventions and the activation of listening paths to identify places to transform.

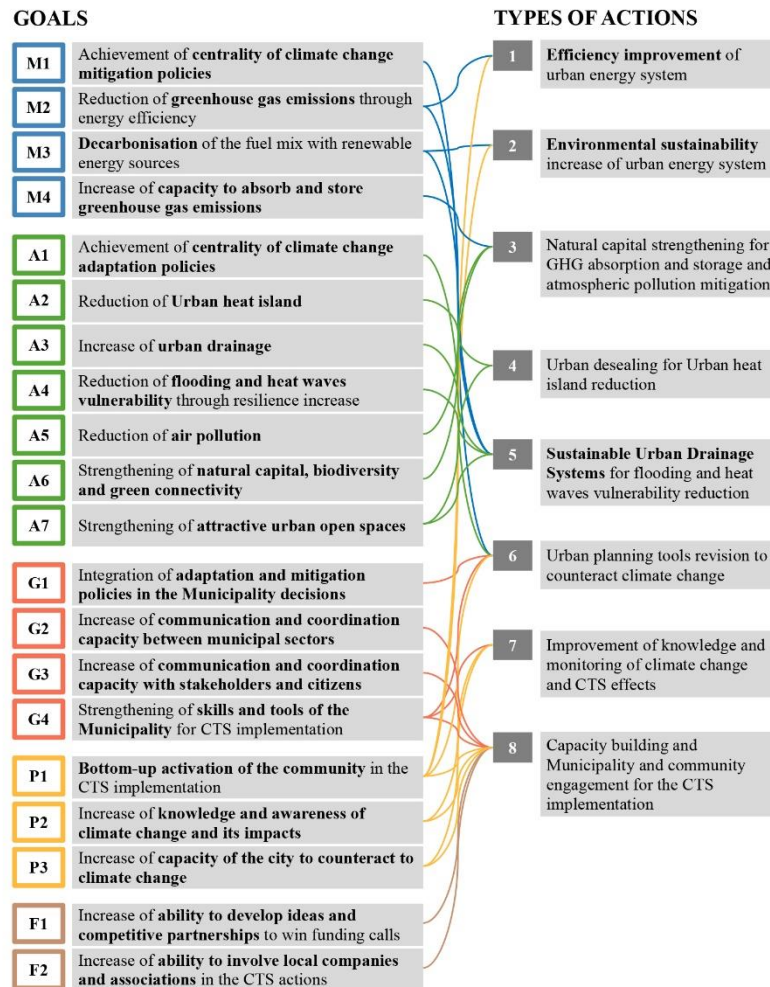


Figure 6. Graph of the relationships between the goals and types of actions of the CTS-BS.

3. The monitoring of the CTS-BS

3.1. Characteristics of monitoring

The monitoring of the CTS-BS was designed to know what, how much of and how the strategy is being implemented and how and how much of the components of the Brescia territorial system are being modified which are the object of intervention by the CTS-BS. Both types of information make it possible to understand the effectiveness and, when useful, the efficiency of the actions of the CTS-BS in achieving the related objectives and, therefore, to make the changes and additions to the strategy itself that are deemed useful. To be able to carry out useful monitoring, it is necessary to build a support system connected to the Strategic Framework in a strong and coherent way, thus managing to effectively and harmoniously bring about the changes that will be defined over time [35,36].

The CTS-BS monitoring system is structured on methodological, organizational and communicative aspects.

The methodological aspects concern the identification of the indicators and the relative relationships that are functional to the representation of interventions, activities, actions, goals and targets contained in the Strategic Framework. Furthermore, the criteria for collecting, measuring,

analysing and evaluating data have a methodological nature.

Monitoring is based on two types of complementary indicators. Indicators of the first type, defined as “direct indicators” because they directly measure what they are intended to describe, serve to represent the progress of the CTS-BS implementation process. In this way there is continuous knowledge of the state of implementation of the activities, of the interventions and therefore of the actions of the CTS-BC, thus allowing identification and understanding of the critical situations from the realization point of view to be able to resolve them promptly. The indicators of the second type, defined as “induced indicators” because they measure the performance and the phenomena induced by the implementation of the actions of a strategy, serve to represent the results achieved over time by the CTS-BS. In this way, we have a good knowledge of the effects of the strategy on the Brescia territorial system in terms of measuring the trends of a multiplicity of factors and characteristics that can be urban, energy, hydraulic, climatic, atmospheric and ecological.

In identifying both types of indicators, a balance has been achieved between the ability of the technical structures of the Municipality of Brescia to measure them and carry out the related processing and the organizational and technical needs for their management capable of supporting communication, verification strategy implementation and performance evaluation.

The use of indicators is carried out in three different ways, characterized by increasing levels of theoretical complexity, processing times and human resources.

The first way concerns the identification and use of direct indicators, which are used to verify the state of elaboration and realization of the products of the analysis, evaluation and planning activities, such as studies, mappings, plans, programmes, projects, guidelines, or to check the progress of the implementation of the interventions. For each direct indicator, the percentages of advance or delay times in carrying out an activity or intervention are indicated, and the consequent judgments are formulated based on the evaluation scale shown in Table 2. These judgments are given with respect to the time planned for their realization and the closer their state of implementation is to that time, the better the judgment attributed to them.

Table 2. Evaluation scale of the state of implementation of activities and interventions.

Judgment	Status of implementation
Very bad	Activity or intervention that can no longer be carried out
Insufficient	Activity or intervention that is more than 10% behind the scheduled time
Unsatisfactory	Activity or intervention that is between 4% and 10% behind the scheduled time
Acceptable	Activity or intervention that is between 1% and 4% behind the scheduled time
Good	Activity or intervention that is less than 1% behind the scheduled time

The second way concerns the identification and use of induced indicators, which are complex operations both from a theoretical point of view, since they require the identification and verification of measurement and evaluation criteria based on lengthy data processing and maps, and from an operational point of view, since there is the need to perform complex operations recursively. The induced indicators are performance-type indicators, which also include the indicators of the targets with which the effectiveness of the CTS-BS in achieving its goals is assessed (Table 1).

The third way concerns the definition of the targets (see point 2.3.3.), an operation which required the activation of a technical-decision-making process that also led to the identification of new actions, to modify the existing ones and to redefine the goals of the CTS-BS. In the coming years, therefore,

the verification of the measures of the targets will be carried out and further actions will be identified on the basis of the indications of the implementing tools of the CTS-BS under development and of the other urban planning and building instruments of the Municipality of Brescia and of the effects of the implementation of the actions currently envisaged.

The organizational aspects concern the subjects involved and the ways in which the process of detection, measurement, analysis, evaluation and communication of monitoring data and information are managed. The subjects identified are the Climate Transition Manager, who has the task of coordinating the various technical managers, the Control Room, who has the task of directing monitoring towards the aspects of greatest interest, the Action Implementation Managers, who have the task of guaranteeing the collection and transmission of data on the implementation of the actions, and the Technical Support Structure to the Climate Transition Manager, which has the task of coordinating the collection of data relating to the actions that will be developed or accounted for in the scope of the CTS-BS.

The communicative aspects are dealt with in the following section, in the description of the ways in which the evaluation of the implementation of the CTS-BS is carried out.

3.2. The evaluation of the implementation of the CTS-BS

The evaluation of the implementation of the CTS-BS relies on two tools, one of an informative nature, the monitoring reports, and the other of a communicative nature, the Platform for information and awareness on climate change.

3.2.1. Monitoring reports

The monitoring reports contain analyses and evaluations on the implementation of the strategy and on the effectiveness of the actions in achieving the goals and indications for modifying the goals, targets and actions. Their preparation constitutes the moment in which the collected data are interpreted, any critical issues encountered in the implementation of the CTS-BS are indicated and the references are given to the Municipality of Brescia to decide whether and which changes to make to the strategic framework or to other aspects of the strategy.

To facilitate the integration of the contents and actions of the CTS-BS with those of the SECAP, the drafting of the monitoring reports of the two tools is synchronized and coordinated. The first Monitoring Report will be prepared at the end of 2023, two years after the approval of the CTS-BS and in synchrony with the SECAP Light Monitoring Report, and will be an expeditious Monitoring Report. After another two years, the second Monitoring Report will be drawn up, to be produced in June 2025, approximately 6 months after the conclusion of the actions financed by the Cariplo Foundation and in synchrony with the complete SECAP Monitoring Report and will in turn be a full tracking. This last report will contain an account of what was elaborated in the first phase of the CTS-BS and indications for the continuation of the strategy itself.

Subsequently, the drafting of expeditious and complete monitoring reports will continue with the following timing: second expeditious report in June 2027, second complete report in June 2029. To evaluate what will have been achieved by the 2030s, in June 2031 a complete and final Monitoring Report could be drafted, accompanied by the elaboration of a new strategy.

The expeditious Monitoring Report will be structured in three sections. The first will be dedicated

to the implementation of the strategy, for which the analysis and evaluation of the direct indicators will be carried out. The second will be dedicated to the evaluation of the effectiveness of the CTS-BS actions in achieving the main targets and goals, for which the accounting of a part of the induced indicators will be represented. The third section will be dedicated to the indications for the modifications to be made to the actions, activities and interventions.

The complete Monitoring Report will be structured in the same three sections as the Expedited Report, while the differences will concern the number and depth of analysis of the milestones and the extent of indications on the development of the CTS-BS. The first section will be substantially the same as that envisaged for the Expedited Report, while the second section will be dedicated to evaluating the effectiveness of the strategy's actions in achieving all the targets and goals and the third section will contain not only indications on any changes to actions, activities and interventions, but may also contain indications on changes to goals and targets.

3.2.2. The Climate Change Information and Awareness Platform

The Platform is an interactive tool for communication and collaboration with the citizens and scientific associations present in the Brescia area. It consists of two parts: a static part, functional for communicating and disseminating information, and a dynamic part, which serves to communicate the monitoring of the implementation of the CTS-BS and its effectiveness in achieving the goals. If the communication of the monitoring results will take place above all through the Platform, the communication will also make use of the ordinary institutional channels, of the co-design initiatives of the interventions and of the public initiatives to promote the strategy.

4. Conclusions

The CTS-BS was developed to maximize the effectiveness of the Brescia Municipality's policies in countering climate change by considering the organisational, human and economic resources available and that will be predictably available over time. Its drafting and its first implementation phase required addressing the problematic nodes indicated in the introduction of this article, to which we tried to find feasible and effective solutions.

First, a systemic and incremental approach was adopted capable of generating over time a theoretical, analytical, planning and organizational apparatus capable of implementing a solid strategy to counter climate change suitable for deploying its capacity for action over a period of at least 10 years. In this way, the CTS-BS can be concluded in 2030, the year which constitutes the next milestone of European and international policies against climate change.

The systemic vision of problems and solutions has required identifying from the beginning the set of possible actions and solutions capable of achieving, within the established times, the intermediate objectives of climate neutrality and attributing to the CTS-BS the role of coordination of all municipal policies and actions to counter climate change. At the same time, the incremental approach aims to immediately identify the most relevant critical issues and opportunities to face and therefore to indicate flexible paths to gradually build the knowledge base and the organizational apparatus necessary to identify and implement the actions useful to achieve the goals of the CTS-BS.

The construction of the knowledge base was focused on the characteristics and effects of climate change in the city of Brescia and on the impacts of all the actions of the CTS-BS and it is developed

in parallel with the elaboration and implementation of the strategy itself. Target definition activities are strongly connected with the knowledge base, since it is necessary to quantify past trends and predict future scenarios of the various phenomena to be governed, and strategy monitoring. It is necessary to know the risks and vulnerabilities resulting from climate change and to identify the criteria for their management based on the adaptation capacity of the territory and the effectiveness of the planned and implemented actions.

The knowledge base was built starting from the use of data, information and knowledge already available starting from the construction of the Municipal Territorial Information System and from what was achieved in the analyses and monitoring of the SEAP, approved in 2012, and in the first analyses for the SECAP, currently under development, and continuing with the analyses necessary to develop the actions of the CTS-BS. At the same time, the integration process for the management of data, information and knowledge useful for all municipal activities was further developed between the various departments and sectors of the municipal structure.

The path for the integration of the knowledge base was linked with the mainstreaming path of the measures to counter climate change, a path that was facilitated by the discrete ability of the municipal machine of Brescia to coordinate the set of actions envisaged, by the presence of a political leadership capable of guaranteeing overall coherence to these actions and by the presence for a decade of a consultative structure through which citizens and stakeholders are systematically involved in the knowledge and evaluation of problems and solutions in the social and environmental fields. The problem of giving continuity, above all in terms of intensity, to the policies to combat climate change by the various municipal administrations that will follow one another over time remains open.

To manage the strategy in an orderly manner, and above all the modification and succession of actions, a strategic framework was elaborated, which structured the fundamental factors of the CTS-BS in a clear and transparent way—such as the vision, the goals, the targets and actions—and their relationships. Furthermore, to anchor the strategy to the actual conditions of intervention, the definition of each action has often indicated a set of information useful for assessing its feasibility such as the timing of the intervention, the municipal entities responsible for their implementation, the budgets available, the stakeholders to be involved, the estimate of their impacts and the methods for monitoring their implementation and the achievement of the targets. In this regard, it has not always been possible to share the definition of the actions, the contents of the activities and the characteristics of the interventions with citizens and stakeholders due to both the need to carry out the interventions within the established times, so as to be able to take advantage of the loans acquired and to respond to the very stringent implementation times, and due to a lack of personnel capable of managing the numerous participatory processes. However, this problem has occurred to a lesser extent for actions that have longer implementation times.

For the allocation of the initially available human and financial resources, the greatest priorities were given to the design and development of implementation plans and pilot interventions and only to a limited extent to the strengthening of the municipal structure, which led to a shortage of personnel in the implementation, monitoring and evaluation of the foreseen actions. This deficiency could worsen in the next few years if, with the acquisition of the resources necessary to carry out the actions envisaged in the subsequent phases of the strategy using sources of financing such as urban implementation plans, municipal funds and funds and tenders local, national and European, this structure is not adequately strengthened.

Finally, the definition of the targets was carried out in a reliable way for the goals for which

sufficient information and knowledge were available to predict the impacts of the envisaged actions with a good level of approximation, while for the other goals the temporary targets or the oscillation intervals were considered, which will be verified over time.

This experience, although still in an initial implementation phase with respect to the long period of duration that has been foreseen for it, constitutes a useful reference for those who have already started or intend to start a climate transition strategy, since it allows sharing of the main problems to be faced, the major construction difficulties and possible solutions. Even more in-depth evaluations can only be carried out at the end of the first phase of implementation of the CTS-BS and, further, after the setting of the second and last phase.

Use of AI tools declaration

The authors declare they have not used Artificial Intelligence (AI) tools in the creation of this article.

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Conflict of interest

The author declares no conflicts of interest regarding this study.

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