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REPERTORIO DI BUONE PRATICHE PER MITIGARE GLI EFFETTI DEL CAMBIAMENTO CLIMATICO E ESPANDERE LA RESILIENZA DELL'AMBIENTE COSTRUITO.

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To Lia Rochink Pante

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ABSTRACT

Il modo in cui abbiamo vissuto negli ultimi anni ha rivelato molto sulle scelte fatte negli ultimi decenni. Queste scelte, soprattutto, som per lo più basate su una struttura socio-economica predatoria, basata sui pilastri dell'antropocentrism e incohercon i principi della sostenibilità globale. La sua struttura e la composizione del consumcausano un notevole degrade environentale e un impatto directto e indirect sui biomi e sugli ecosisti terrestri. Di fronte a questo contesto di impoverimento environentale e di crisi economica, la struttura sociale contemporanea non poteva presentare uno scenario promising. I processi di globalizzazione, ora ancora più intensi e connessi, perpetuano la produione di una società Sempre più eterogenea e fragile, portando all'apartheid sociale. Questo magnifies le disuguaglianze, la violenza urbane, la difficoltà di accesso all'assistenza sanitaria e al diritto alla un alloggio decente, and contributisce ad aumare l'insicurezza idrica, alimentare e nutrizionale, soprattutto nelle economie meno sviluppate e più povere.

La pandemia di Covid-19 del 2020 ha aggravato le prospettive socio-economiche globali, causing effetti positivi e negativi sull'ambiente, come una minuzione del consumo di elettricità e dei livelli di anidride carbonica (CO2) e un Aumdella domanda di produione alimentare e della generazione di rifiuti solidi e ospedalieri. Per decenni il pianeta ha mostrato chiari segni di insostenibilità e di imminente collasso ambientale. Today, viviamo in un contesto di squilibrio, in cui è già posbile osservare: riscaldamento degli oceani e della superficie terrestrial; martamenti nei tassi di piovosità; inondazioni e incendi forestali frequenti e più grandi; siccità prolungate e, in alcune regioni, processi di desertificazione; tra molti altri effetti imminenti. Scelte sbagliate e mancanza di pianificazione per que riguarda: la primorà di una matrice energetica da fonti non rinnovabili; l'unlikely visazione nella gestione dei rischi contro i disastri naturali e le crisi sanitarie; la mancanza di pianificazione di una struttura urbanile sostenibile, l'incipiente gestione delle acque, l'insicurezza alimentare, tra gli altri, producono uno scenario ancora più allarmante. Senza educazione, monetamenti politici, riformulazione del mercato and anche senza azioni concrete ed efficaci per mitigare questi impatti ed effetti sull'ambiente, l'umanità soffrirà di queste trasformazioni rendo l'ambiente in cui viviamo empre più ostile.

In questo scenario, sotto la guida delle *United Nations* (UN), la *United Nations Framework Convention on Climate Change* (UNFCCC) ha promosso incontri annuali dal 1995 per discustere la questionone degli impatti dei changamenti climatici e, attraverso le Conferenze delle Parti (COP), che è l'organo decisionale, monitorare e rivedere l'attuazione delle adottate dalle nazioni nell'UNFCCC. state stabilite nuove linee guida, termini e accordi per guidare il raggiungimento degli obiettivi stabiliti e lo sviluppo sostenibile delle nazioni di fronte al changamento climatico. During the COP21 (2015) è stato firmato l'Acacordi Parigi che ha mobilitato le parti a ridurre le emissioni di gas effetto serra (GHG) e ha incoraggiato lo sviluppo di nuove tecnologie in grade di mantenere il riscaldamento globale al di sotto dei 2°C (preferably 1,5°C) rispetto ai livelli preindustriali prima del 1750 (278)[1].

[1] WMO Global Atmosphere Watch Program (2020). Carbon dioxide levels continue at record levels, despite COVID-19 lockdown. Press Release Number: 23112020 .Available at: <https://public.wmo.int/en/media/press-release/carbon-dioxide-levels-continue-record-levels-despite-covid-19-lockdown>

Tuttavia, anche in questo contesto climatico, alla scala dell'ambiente construito e territoriale, le linee guida per promuovere la decarbonizzazione nel settore delle costruzioni som frammentarie e preliminari. Secondo *The International Energy Agency* - IEA (2020)[2], il settore delle costruzioni è responsabile di più di un terzo del consumo globale di energia e del 40% delle emissioni totali dirette e indirette di anidride carbonica (CO2) nell'ambiente. Oltre all'alto consumo di energia, il settore presenta anche un alto tasso di uso di risorse naturali e idriche in tutta la sua catena di produione e un'alto producimento di rifiuti solidi. Alla luce di tutti questi problemi, il ruolo degli architetti, degli urbanisti, degli ingegneri e dell'industria shall essere ripensato. Rivalutare il tecnologia methodologico di concepzione dei progetti architettonici e urbanistici, riflettenham sulle loro funzioni e tipologie d'uso nella ricera di soluzioni più adatte all'ambiente. Le nuove tecnologie som essenziali per sfruttare questi changamenti, così come la diffusione di buone aprche affrontano soluzioni capaci di mitigare questi effetti e dare più resilienza alle costruzioni di fronte allo scenario climatico attuale. Cercando di creare nuove leggi e standard normativi, migliorare l'efficienza dell'intera catena di produione, attraverso migliori processi industriali a bassa emissione di carbonio, giving priority to all'efficienza energetica, alla razionalizzazione, alla flessibilità, alla reversibilità nei progetti, giving priority to ai methodi di costruzione a basso impatto.

Questo lavoro presenta i principali effetti del change climatico osservati nell'ambiente construito e alla scala territoriale urbane, attraverso una revisione dello stato dell'arte della materia nell'ultimo decennio (2010-2021). Espone anche, dall'analyti qualitativa di studi di casi indiretti, le buone practicche adottate in tutto il mondo per ridurre il tribute del settore alle emissioni di gas serra (GHG), così come Cerca di diffondere gli strumenti, i methodi e le methodologie presently utilizzati. La tesi si decompone il processo progettuale encicinca di identiare come l'architetto e l'urbanista possono mitigare gli effetti del totamento climatico individuato. Sia adattando le strutture esistenti o in progetti *greenfield*, sia promuovem l'espansione della resilienza di questi sisti di costruzione, come risposta allo scenario attuale. Infine, presenta un repertorio di buone pracche per aiutare i professionisti a prendere decisioni progettuali during il procettazione dell'ambiente costruito e territoriale che ha un impatto diretto sullo sviluppo sostenibile della società.

[2] The International Agency (IEA, 2020). Topics Analysis buildings. Available at this site: <https://www.iea.org/topics/buildings>

ABSTRACT IN ENGLISH

The way we have lived in recent years has revealed a lot about the choices made in recent decades. These choices, in their majority, are based on a predatory socioeconomic structure, based on the pillars of anthropocentrism and inconsistent with the principles of global sustainability. Their structure and composition of consumption lead to considerable degradation of the environment and have a direct and indirect impact on terrestrial biomes and ecosystems. Faced with all this context of environmental exhaustion and of economic crisis, the contemporary social structure could not present a promising scenario. The processes of globalization, now even more intense and connected, perpetuate the production of an increasingly heterogeneous, fragile and entailing *social Apartheid*. It increases inequalities, urban violence, the difficulty of access to health care and decent housing, and it also contributes to the increase of water, food and nutritional insecurity, especially in the poorest less developed economies.

The 2020 Covid-19 pandemic has exacerbated the global socio-economic outlook, leading to positive and negative effects on the environment, such as: a decrease in electricity consumption and carbon dioxide (CO2) levels and an increase in demand for food production and the generation of solid and hospital waste. For decades, the planet has been showing clear signs of the unsustainability and the imminent collapse of the environment. Today we live in an unbalanced context, in which it is already possible to observe: warming of the oceans and the earth's surface; alteration of the rainfall indices; floods and forest fires frequent and of greater proportion; prolonged droughts and in some regions the process of desertification; among many other imminent effects. Erroneous choices and the lack of planning as regards: the prioritization of an energy matrix by non-renewable sources; the improvisation in risk management against natural disasters and health crises; the lack of planning of a sustainable urban structure, the incipient water management, food insecurity, among others, produces an even more alarming scenario. Without education, political changes, market reformulation and, still, without concrete and effective actions to mitigate these impacts and effects on the environment, humanity will suffer from these transformations, making the environment in which we live more and more hostile.

Against this background, under the leadership of the *United Nations* (UN), the United Nations *Framework Convention on Climate Change* (UNFCCC) has been holding annual meetings since 1995 to discuss the impacts of climate change and, through the Conference of Parties (COP), which is the decision-making body, monitor and review the implementation of actions taken between nations in the UNFCCC. As a result of these meetings, new guidelines, terms and agreements are being established with the aim of guiding the achievement of established goals and the sustainable development of nations in the face of climate change. During COP21 (2015) the Paris Agreement was signed and mobilized the Parties to reduce greenhouse gas (GHG) emissions, as well as encouraged the development of new technologies capable of keeping global warming below 2 °C (preferably at 1.5 °C) above pre-industrial levels before 1750 (278 ppm)[3].

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[3] WMO Global Atmosphere Watch Program (2020). Carbon dioxide levels continue at record levels, despite COVID-19 lockdown. Press Release Number: 23112020. Available at: <https://public.wmo.int/en/media/press-release/carbon-dioxide-levels-continue-record-levels-despite-covid-19-lockdown>

However, still within this climatic context, on the scale of the built and territorial environment the guidelines to promote decarbonization in the construction sector are fragmented and preliminary. According to *The International Energy Agency* - IEA (2020)[4], the sector accounts for more than one third of global energy consumption and 40% of total direct and indirect emissions of carbon dioxide (CO2) into the atmosphere. In addition to high energy consumption, the sector still has a high rate of consumption of natural resources and water throughout its production chain and a high generation of solid waste. Faced with all this problem, the role of architects, urbanists, engineers and industry needs to be rethought. Re-evaluating the methodological process of designing architectural projects and urban planning, considering their functions and types of uses in the search for solutions more adapted to the environment. New technologies are essential for leveraging these changes, as well as the dissemination of good practices that address solutions that mitigate these effects and give more resilience to buildings in the current scenario. Aiming to create new legislation and regulatory standards, improve the efficiency of the entire production chain, through better low-carbon industrial processes, prioritization of energy efficiency, rationalization, flexibility, reversibility in projects, while favoring low-impact constructive methods.

The present work presents the main effects of climate changes observed in the built environment and in the urban territorial scale, through the revision of the state of the art of the theme in the last decade (2010-2021). It also sets out, from the qualitative analysis of indirect case studies, the best practices adopted worldwide to reduce the sector's contribution to greenhouse gas (GHG) emissions, as well as seeks to disseminate the tools, methods and methodologies currently used. The thesis decomposes the project process seeking to identify how the architect and the urbanist can mitigate the effects of the identified climatic changes. Either by adapting existing structures or *greenfield* projects, or by increasing the resilience of these constructive systems, as a response to the current scenario. Finally, it presents a repertoire of good practices that assists professionals in project decision-making during the process of designing the built and territorial environment impacting directly on the sustainable development of society.

[4] The International Agency (IEA, 2020)Topics Analysis buildings. Available at: <https://www.iea.org/topics/buildings>.

ABSTRACT IN PORTUGUESE

O modo como temos vivido nos últimos anos tem revelado muito sobre as escolhas feitas nas últimas décadas. Escolhas essas, em sua maioria, pautadas numa estrutura socioeconômica predatória, baseada nos pilares do antropocentrismo e incoerente com os princípios da sustentabilidade global. A sua estrutura e composição de consumo ocasionam consideravelmente a degradação do meio ambiente e impactam direta e indiretamente nos biomas e nos ecossistemas terrestres. Diante de todo esse contexto de esgotamento ambiental e de crise econômica, a estrutura social contemporânea não poderia apresentar um cenário promissor. Os processos de globalização, agora ainda mais intensos e conectados, perpetuam a produção de uma sociedade cada vez mais heterogênica, frágil e acarretando em um *Apartheid* social. Aumenta as desigualdades, a violência urbana, a dificuldade de acesso à assistência sanitária e a moradia dignas, contribuindo ainda, para o aumento da insegurança hídrica, alimentar e nutricional principalmente nas econômicas mais podres menos desenvolvidas.

A pandemia de Covid-19, do ano de 2020, agravou a perspectiva socioeconômica global, ocasionando efeitos positivos e negativos no que tange ao meio ambiente, tais como: a diminuição do consumo de energia elétrica e dos níveis de dióxido de carbono (CO2) e o aumento da demanda na produção de alimentos e da geração de resíduos sólidos e hospitalares. Há décadas o planeta dá sinais claros da insustentabilidade e do iminente colapso do meio ambiente. Atualmente vivemos num contexto de desequilíbrio, no qual já é possível observar: aquecimento dos oceanos e da superfície terrestre; alteração dos índices pluviométricos; inundações e incêndios florestais frequentes e de maior proporção; secas prolongadas e em algumas regiões processo de desertificação; dentre tantos outros efeitos iminentes. Escolhas errôneas e a falta de planejamento no que diz respeito: a priorização de uma matriz energética por fontes não renováveis; o improviso na gestão de risco contra desastres naturais e crises sanitárias; a falta de planejamento de uma estrutura urbana sustentável, o incipiente gerenciamento hídrico, a insegurança alimentar, dentre outros, produz um cenário ainda mais alarmante. Sem educação, mudanças políticas, reformulação de mercado e, ainda, sem ações concretas e eficazes para mitigar esses impactos e efeitos no meio ambiente a humanidade sofrerá com essas transformações tornando o ambiente em que vivemos cada vez mais hostil.

Diante deste panorama, sob a liderança da *United Nations* (UN), o United Nations *Framework Convention on Climate Change* (UNFCCC) têm promovido encontros anuais desde 1995 com o intuito de discutir a temática dos impactos da mudança climática e, por meio das Conferencias das Partes (COP), que é o órgão de tomada de decisão, monitorar e revisar a implementação das ações adotadas entre as nações na UNFCCC. Como resultado desses encontros, novas diretrizes, termos e acordos vem sendo estabelecidos com o intuído de nortear o cumprimento das metas estabelecidas e no desenvolvimento sustentável das nações frente as mudanças climáticas. Durante a COP21 (2015) o Acordo de Paris foi firmado e mobilizou as Partes para reduzir a emissão de gases de efeito estufa (GEE), bem como incentivou o desenvolvimento

de novas tecnologias capazes de manter o aquecimento global abaixo de 2 °C (preferencialmente em 1,5 °C) acima dos níveis pré-industriais antes de 1750 (278 ppm)[5].

Porém, ainda dentro desse contexto climático, na escala do ambiente construído e territorial as diretrizes para promover a descarbonização no setor da construção são fragmentadas e preliminares. Segundo *The International Energy Agency* - IEA (2020)[6], o setor é responsável por mais de um terço do consumo energético global e por 40% das emissões totais, de forma direta e indireta, de dióxido de carbono (CO2) na atmosfera. Além do consumo energético elevado, o setor ainda apresenta um alto índice de consumo de recursos naturais e hídricos em toda a sua cadeia produtiva e elevada geração de resíduos sólidos. Diante de toda essa problemática, o papel dos arquitetos, urbanistas, engenheiros e da indústria precisam ser repensados. Reavaliando o processo metodológico da concepção de projetos arquitetônicos e de planificação urbana, ponderando suas funções e tipologias de usos na busca por soluções mais adaptadas ao meio ambiente. Nova tecnologias são essenciais para alavancar estas mudanças, assim como a divulgação de boas práticas que abordem soluções capazes de mitigar estes efeitos e atribuir mais resiliência as construções frente ao cenário atual. Buscando criar novas legislações e normas regulatórias, melhorar a eficiência de toda a cadeia produtiva, através de melhores processos industriais de baixo carbono, priorização a eficiência energética, a racionalização, flexibilização, reversibilidade em projetos, privilegiando ainda métodos construtivos de baixo impacto.

O presente trabalho apresenta os principais efeitos das mudanças climáticas observados no ambiente construído e na escala territorial urbana, por meio da revisão do estado da arte do tema na última década (2010-2021). Também expõe, a partir da análise qualitativa de estudos de casos indiretos, as boas práticas adotadas mundialmente para reduzir a contribuição do setor as emissões de gases de efeito estufa (GEE), bem como procura difundir as ferramentas, os métodos e as metodologias utilizadas atualmente. A tese decompõe o processo projetual buscando identificar como o arquiteto e o urbanista pode mitigar os efeitos das mudanças climáticas identificados. Seja adaptando estruturas existentes ou em projetos de *greenfield*, ou ainda promovendo a ampliação da resiliência desses sistemas construtivos, como resposta ao cenário atual. Por fim, apresenta um repertório de boas práticas que auxilie os profissionais nas tomadas de decisões projetuais durante o processo de projetação do ambiente construído e territorial impactando diretamente no desenvolvimento sustentável da sociedade.

[5] WMO Global Atmosphere Watch Programme (2020). Carbon dioxide levels continue at record levels, despite COVID-19 lockdown. Press Release Number: 23112020. Disponível em: <https://public.wmo.int/en/media/press-release/carbon-dioxide-levels-continue-record-levels-despite-covid-19-lockdown>
[6] The International Agency (IEA, 2020). Topics Analysis buildings. Disponível em: <https://www.iea.org/topics/buildings>.

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INTRODUCTION

The problem of global warming has been observed since the late 19th century, through climate scholars who developed their research in a very empirical and phenomenological way. Among several researchers, we can mention, Jean-Baptiste Joseph Fourier (1824)[7], a French mathematician and physicist, first who discussed why the Earth was hotter than expected considering only solar radiation hitting the planet. Or the work of Tyndall (1861)[8], a British physicist, who experimentally demonstrated that the heat on the earth's surface was directly linked to the absorption of infrared radiation by gases present in the air, such as water vapor (H2O) and carbon dioxide (CO2). Proposing that the increase in the concentration of these greenhouse gases raises the temperature of the Earth's surface. Subsequently, Köppen (1881)[9], a Russian-German geographer and meteorologist, used widespread temperature records to estimate global temperature variability in terrestrial air (HAWKINS, Ed and JONES, P.D., 2013).

Among so many other scientists who contributed to the evolution of this theme, still according to Hawkins and Jones (2013)[10]Only through the work of the English engineer Guy Stewart Callendar (1938)[11] can it be shown through a scientific approach that the temperature of the Earth has increased in the previous 50 years. Callendar further suggested the theory that the concentration of carbon dioxide emissions would have been the main cause of this warming at the time; this effect was known at the time as the "Callendar effect" currently known to modern greenhouse science.

Simultaneously with this period, in the late 19th and early 20th centuries, the world political landscape was marked by constant territorial and economic divergences, triggering several armed conflicts with overwhelming consequences. After the end of the Second World War in 1945, and with all the mass destruction that this war entailed, the need emerged to create an intergovernmental organization that could promote dialog and cooperation among nations and mediate their individual interests from a global point of view. As a response to this demand, this same year, the United Nations (UN) was created. Since then, the UN has played an important role for society and for global sustainable development, working to maintain global security and peace. As well as promoting discussions on the various themes related to the areas of: human rights, governance, environment, violence, racism, conflict management, natural disasters, climate change, among others.

Only in 1972 through the United Nations Conference on the Human Environment, through the holding of the Stockholm Conference - a conference recommended by The

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[7] Fourier, J 1824. Rapport sur la temperature du globe terrestrial et sur les spaces planetaires. Memoires Acad. Royale des Sciences de L'Institut de France 1824: 590-604.

[8] Tyndall. 1861. On the absorption and radiation of heat by gases and vapors, and on the physical connection of radiation, absorption, and conduction. The London, Edinburgh, and Dublin. Philosophical Magazine and Journal of Science. vol.151: 169-194. Available at: <https://www.jstor.org/stable/i207016>

[9] Köppen, W. 1881. Über mehrjährige perioden der witterung-III. Mehrjährige änderungen der temperatur 1841 bis 1875 in den tropen der nördlichen und südlichen gemässigten zone, an den Jahresmitteln. untersucht. *Zeitschrift der Osterreichischen Gesellschaft für Meteorologie*. Bd XVI: 141-150.

[10] Hawkins, E., and P. D. Jones, 2013: On increasing global temperatures: 75 years after Callendar. Fourth. J. Roy. Meteor. Soc., vol. 139: 1961-1963, DOI: 10.1002/qj.2178.

[11] Callendar, G.S. 1938 The artificial production of carbon dioxide and its influence on temperature. Q.J.R. Meteorol. Soc. vol. 64: 223-240, DOI: 10.1002/qj.49706427503.

Economic and Social Council through Resolution 1346 (XLV) of 1968[12] and held in Stockholm, Sweden - did the world propose to discuss the environmental issue and its degradation in a holistic way supporting research related to the theme, establishing the United Nations Environment Program (UNEP). The event was considered a milestone for the time, with over 100 (100) representatives of United Nations member states, aiming to promote environmental discussion on a global scale for the first time and international cooperation permeate individual interests in favor of common interests in pursuit of sustainable development. During the conference, a working group was established to study the issues related to the planning and management of climate-related issues. Discussing topics related to: human settlements, environmental quality and promotion of education on various aspects; management of natural resources; identification and control of pollutants in the global context, among others. As a result of this first discussion, a declaration was drawn up with 26 principles and 109 recommendations with the aim of encouraging the adoption of coordinated environmental actions at international levels between the parties (NATIONS, United, 2012, p. 1).

To support the work developed by The *United Nations Environment Program (UNEP)* and to expand research related to the global climate agenda, beyond the *World Meteorological Organization (WMO)*, was founded in 1988 by the Intergovernmental Panel on Climate Change (IPCC). Both have a mission to promote the transparency of international relations by empowering and providing up-to-date scientific community information on climate issues. It should also keep civil society informed, prepare reports and plan trainings with the aim of subsidizing decision-making by governments and supporting the formulation of public policies, agendas, agreements, social actions and environmental policies to enable global sustainable development.

However, since the *Nations Conference on the Human Environment* nearly 50 years have passed. Several international conferences, summits, terms and agreements were held during this period, but public policies and environmental actions adopted to mitigate the expected impacts on climate and the environment proved ineffective on a medium- and long-term global ladder. The IPCC's fifth assessment report (AR5), published in the year 2014, confirmed the climate collapse scenario already under way:

> *"Warming of the climate system is unequivocal, and since the 1950s, many of the observed changes are unprecedented over decades to millennia. The atmosphere and ocean have warmed, the amounts of snow and ice have diminished, and sea level has risen".* (IPCC, 2013, p. 2)

In 2015, COP21[13] took place in Paris, France, which as a result of the meeting was signed by 196 parties an international treaty on climate change called The Paris agreement with the objective of limiting global warming. The term has been in force since 2016 adopted between the parties, recognizes the irreversible and urgent potential of this problem. Highlighting the

[12] Resolution ECOSOC E/RES/1346 (XLV), 1555th plenary meeting, 30 July 1968. Available at:https://www.un.org/ga/search/view_doc.asp?symbol=E/RES/1346%28XLV%29>

[13] COP: Conference of the Parties

need to reduce greenhouse gas emissions, which are primarily responsible for rising air and ocean temperatures and contemporary climate imbalance:

> *'(...) Recognizing that climate change represents an urgent and potentially irreversible threat to human societies and the planet and thus requires the widest possible cooperation by all countries, and their participation in an effective and appropriate international response, with a view to accelerating the reduction of global greenhouse gas emissions'* (NATIONS, United, 2015).

The Paris Agreement also provides that more developed countries must, in addition to meeting their greenhouse gas emission reduction (GHGs)[14] targets, subsidize and support less developed economies in order to meet the global target set, which is to limit global temperature warming below 2°C, but preferably limit warming below 1.5°C. It also proposes financing policies for the productive sectors to develop new technologies and to update themselves, stimulating cooperation and technology transfer between the parties.

Even with so many studies and research proving the imminent risks and the need for effective action to combat these effects, unfortunately, there is still much neglect, or even denial, of these issues. All this stagnation slows down discussions and the adoption of actions capable of mitigating the problem, and with this, the levels of gases released into the atmosphere only increase. According to *WMO Greenhouse Gas Bulletin n°16* (2020) The gases present in the atmosphere that cause long-term greenhouse effect (LLGHGs)[15] in higher concentrations are carbon Dioxide (CO_2), Methane (CH_4) and Nitrous Oxide (N_2O), which together account for 89% of the total contributions. Most of them come from human, agricultural, economic activities and from systems of production with an energy matrix based on fossil fuels.

More specifically, according to the IPCC's Fifth Assessment Report (AR5) (2013, p. 9), the economic activities that contributed the most to the direct emission of the LLGHGs for the year 2010 were: Electricity and Heat Production contributing 25%, of which 12% related to carbon dioxide (CO_2) emissions from electricity and heat production for Buildings; Agriculture, Forestry and Other Land use (AFOLU) responsible for 24%; Industry responsible for 21% of emissions; Transport responsible for 14%, Buildings with [direct16] emissions of 6.4% and Other Energy with the contribution of 9.6% of global emissions. Also according to the IEA report (2020), it can be said that one of the sectors that emits most greenhouse gases in an incorporated or operational manner is construction, with buildings accounting for one third of global energy consumption and for 28% of the total emissions of carbon dioxide (CO_2) in the atmosphere reaching the historical maximum of 10 $GtCO_2$ in 2019. When evaluating the data on the construction of buildings and buildings together we have the sector responsible for more than one third of the

---

[14] Greenhouse gases (GHGs)

[15] Long-lived greenhouse gases (LLGHGs)

[16] Emissions from the use of electricity in buildings are excluded and are instead covered in the electricity and heat production sector.

global final energy consumption and almost 40% of the total direct and indirect emissions of CO2 into the atmosphere.

We have already suffered from the effects of climate change, according to the first part of the sixth assessment report (AR6) entitled: "Climate Change 2021: The Physical Science Base, Working Group I contribution to the Sixth Assessment Report" (IPCC AR6/WGI) published in August 2021, ratifies this context of climate vulnerability as a result of actions induced by human activities. There is no doubt about its contribution to this crisis.

> *"(...) Human-induced climate change is already affecting many weather and climate extremes in every region across the globe. Evidence of observed changes in extremes such as heatwaves, heavy precipitation, droughts, and tropical cyclones, and, in particular, their attribution to human influence, has strengthened since AR5.* (IPCC, 2021, p. 10)

Also according to IPCC AR6/WGI (2021) climate change has been observed, indicating an increase in extreme heat, precipitation and prolonged droughts throughout the globe. The increase in extreme heat (*hot extremes*) is the most observed alteration as a result of human actions. Of the 45 (forty-five) regions studied, with data observed since the 50s, 41 (forty-one) had an increase in surface temperatures. Of these, 23 (twenty-three) achieved a high degree of reliability (*High Conficence*)[17] and 16 (sixteen) regions with medium reliability contribution index (*medium Conficence*)[18]. Regions with heavy precipitation (*heavy precipitation*) rates increased mainly on the European and Asian continents, with an increase of these rates in 19 (nineteen) regions. Prolonged agricultural and ecological drought (*agricultural and ecological drought*) has seen an increase in occurrences in 12 (twelve) of the 45 regions of the globe studied and the majority are located on the African and Asian continents. (IPCC, 2021, pp. 12-13)

In the face of this hostile and emerging scenario, in which stagnation cannot be tolerated any more, we must systematize in a critical manner the current environmental policies, the dependence on unsustainable energy matrices, the exacerbated consumption with the intention of revising the plans of actions drawn up by the parties and to expand the commitments made so that it is viable for their implementation to revert the current and future scenario. Providing technology transfer, supporting projects that encourage the use of renewable energy matrix, support the financing of research related to this problem as well, the creation of clear guidelines and that can be measured making it possible to control and monitor the actions carried out at a given time.

The effort and relevance of the present work seeks to identify good practices, tools, methods and methodologies of work, correlated with the professional practice of architects and urbanists, that contribute to mitigate the impacts that the construction sector causes in energy consumption and in the emission of GHGs, intervening in the built environment with the

[17] High conficence in human contribution. IPCC. AR5 Uncertainty Guidance Note. Available at: <https://archive.ipcc.ch/publications_and_data/ar4/wg1/en/ch1s1-6.html>
<https://www.ipcc.ch/site/assets/uploads/2017/08/AR5_Uncertainty_Guidance_Note.pdf>

[18] Medium Confidence:

objective of adapting the existing spaces and increase the resilience of these facing climate changes for the next periods.

Engineers, Architects and Designer have a lot to contribute in this context, always having to prioritize decisions that value the: functionality and flexibility of proposed and existing spaces; its constructive tectonics; attention to the specification of high performance materials, besides properly developing the spatial geometry of the building to attribute in the increase of its environmental quality, reducing its impact on the environment and promoting thermal, acoustic and luminous comfort of the users. As well, it is the responsibility of the Urbanists to plan spaces that optimize the local infrastructure, order urban expansion, revitalize degraded and unused areas. Evidencing in their projects sustainable guidelines that mitigate the emission of GHG, that adapt the already existing structure and promote urban and building resilience against adversity, prioritizing not only the well-being of the individual, but the safety of the collective.

The first step towards significant and irreversible change in any context is education. There is a need to democratize and disseminate access to information in a clear and accessible way for the various communities. Subsequently, promote a discussion and identify the skills and knowledge needed to drive this transformation through workshops and workshops with professionals from different fields of knowledge. Document all the actions of the projects elaborated and executed of the most diverse types, as well as their design methodology, the lessons learned during the process (hits and misses) and possible future applications. Documenting what has been achieved is of paramount importance in order to create a detailed database on the theme and make it possible to share this information in an orderly and accessible way.

Subsequently, to develop standards with standardized and more ambitious metrics regarding the environmental performance of new constructions in the face of climate change, requiring performance according to future projections. As well as, minimum environmental performance standards for retrofit and retrofit projects of the existing building stock.

a) STRUCTURE

The research is organized into four main chapters, which address the main theme of the effects of global climate change, its respective impacts on the built environment and urban context. The thesis is also composed of an introductory part and finally, another conclusive part in which it describes itself: a) regarding the theme and the problem of research, it presents preliminary concepts of the area under study, as well as, it exposes the criteria adopted for the development of research and its methodological path; b) The conclusive chapter describes the main challenges encountered in the process of the development of research, limitations found with relation to the data obtained and possible developments for future research. It is expected to contribute to the professional practice of designers, designers and builders, seeking to foster an even more sustainable development based on a circular and resilient economy in what tanje the built environment and the urban space.

The first chapter provides a bibliographical review of the state of the art and its historical chronological evolution, analyzing the following sources and climate models in advance:

- Systemi di classificazione del Climo: Köppen (1936), Miller (1931), Thornthwaite (1948), Köppen Geiger (1961) and Strahler (2005).
- Modelli climatici: Lohmann, et al. (1993), Kottek et al. (2006), Peel et al. (2007), Kriticos, et al. (2012) and Beck et al. (2018). Modelli IPCC AR5 (2014) RCPs and IPCC AR6 (2021) RCPs and SSPs.

For the more specific bibliographical review on the problems of climate change, the main agreements, terms, documents and reports prepared over the last ten years (2011-2021) by global intergovernmental organizations and panels were analyzed. Here we try to identify not only the historical chronology of the theme, but mainly the objective of identifying in these documents whether there are, or not, any guidelines or norms that correlate the problem of climate change and the territorial scale and the built environment with the purpose of promoting sustainable governance (mitigazione, adaptation and resilienza).

- Documenti analyati: The Global New Deal (2009), Il Cinco Report di valutazione (AR5) IPCC (2014), Agenda 2030 (2015), Acacorio di Parigi (2015), European Green Deal e il sesto Report di valutazione WGI, WGII e WGIII (AR6) IPCC (2021), IPCC (2022).

Also in this first chapter, it characterizes the current global climate, presents the main effects of global climate changes and the constant warming of the global average temperature, as for example: the process of acidification of the oceans; increase of the sea level; extreme weather events; increase of average air temperature and prolonged droughts. And it correlates these identified effects and there are likely direct impacts in the context of the urban scale and at the microscale level of the built environment. It also addresses the limits of human tolerance in high temperature range environments and the methodology used by the IPCC in future projections models used in United Nations reports.

The second chapter is intended to characterize the objects of study, being: a) the city of Natal, located in Rio Grande do Norte in Brazil; b) the city of Bologna, located in Emilia-Romana, Northern Italy. Both cities were chosen as the object of study due to the fact that both cities have already reached the surface temperature threshold considered safe and recommended by the Paris Agreement, which is 2 degrees Celsius (IPCC, 2021) and (IPCC, 2022). In addition to the author's professional familiarity with the morphological and normative aspects of these cities. This chapter systematically presents the panorama of greenhouse gas emissions in the two countries (Brazil and Italy), as well as the main physical, climatic and normative aspects related to the problems of research each in its context.

The third chapter deals with the discussions on the theme correlating the effects, the impacts identified on the scale of the built environment and the role of professionals in architecture, urbanism and engineering in the performance of their work activities and within the project process. The fourth chapter presents the objective results in order to build a repertoire of good practices to assist professionals in the area of architecture and engineering in their work routine and in prioritizing choices aligned with the three pillars that make up the face of climate change, which are: the mitigation of GHG emissions, the adaptation of existing infrastructure and the promotion of urban resilience and the built environment through the predictability of effects and impacts and their respective responses to them.

It is expected to give visibility to identified good practices, prioritizing the adoption of more efficient technical solutions and of industrial technologies and processes that mitigate

GHG emissions. As well, revisit adaptation strategies in existing structures in the face of identified physical and sectoral impacts. Valuing actions that increase urban resilience and buildings in the face of the climate changes that we live in today.

So, in an orderly fashion we have the following structure for research:

Search theme:

Climate change, Global warming, Effects of climate change, mitigation, adaptation, resilience of the built environment.

Research Problematic:

How can architects and planners, through the design process, impact on mitigating the emission of GHGs, adapting existing infrastructure and increasing the resilience of the built environment in the face of the effects of current climate change?

General objectives:

The general objective of this research is to understand how the construction sector is inserted in the problem of climate change and to identify, in the literature of the last decade (2011-2021), good practices adopted by the various actors that make up this sector. As a result, a repertoire of good design practices with scaling and replication potential, able to assist architects, urban planners and planners in prioritizing architectural and sustainable engineering solutions, contributing to:

- Mitigate GHG emissions and climate change impacts studied in the built environment (*Greenfield, Greyfield* and *Brownfield*);
- Adapting the existing built environment to climate change (*Greyfield and Brownfield*);
- Increase the resilience of new enterprises and existing urban infrastructure. Collaborating with the implementation of better risk management in the various areas of: Governance, connectivity, adaptive design, flexibility, risk management, etc.

Specific objectives:

- Conduct a bibliographic review of the state-of-the-art research theme, aiming to understand its problematic, main concepts, main existing climate classification systems, future projections models used by the IPCC and local climate characterization.
- Conduct a specific theoretical bibliographic review of the main agreements, terms, agendas, climate documents published in the last decade (2011 - 2021): Global Green New Deal (2009), The 2030 Agenda for Sustainable Development (2015), The Paris agreement (2015) and The European Green Deal (2019). With the purpose of identifying normative policies and/or specific guidelines for urban scale and the built environment (mitigation, adaptation and resilience).
- Elaborate the chronology of the theme and its problems, through:
    a literature review of the state of the art of the theme through open access platforms, with the aim of identifying the main effects of global warming arising

from the greenhouse effect and their respective impacts on the scales of the built environment and the urban system;

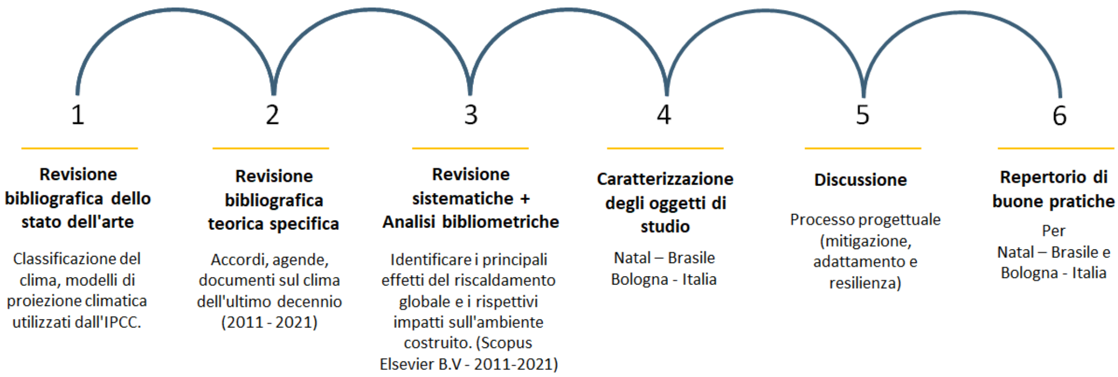
b Systematic review the bibliometric analysis of the data from the literature consulted on the Scopus Elsevier platform, with the objetive of taking science of the scientific and technological evolution of the area in the last decade (2011-2021). Identifying: the main research centers and affiliations between institutions; the thematic trajectory of the area of research over the years and its trend; main authors and existing works; scientific production of a given period, among other metrics that help in this historical construction of the theme.

- Promote a discussion on the presented problems correlating with the importance of the role of the architect and urbanist in the project process from the preliminary stages (mitigation, adaptation and resilience), in the current climate and in the future scenarios for the cities of Natal/RN, located in the northeast of Brazil, and in the city of Bologna, Emilia-Romana located in the northern Italian region.
- Present the results obtained by means of a repertoire of good practices capable of assisting the designers in this project process, exposing that misguided decision-making can have a direct impact on the future climate scenario.

METHODS

The work carried out has a theoretical-explanatory nature obtained through the statistical analytical method with a qualitative approach to the analysis of the selected material within the specific cut-off of the research. The methodological process adopted for the development of the thesis was grouped into five main stages, exemplified in the following figure.

Picture 1: Methodological process of the tesi.



Source: L'autore (2021).

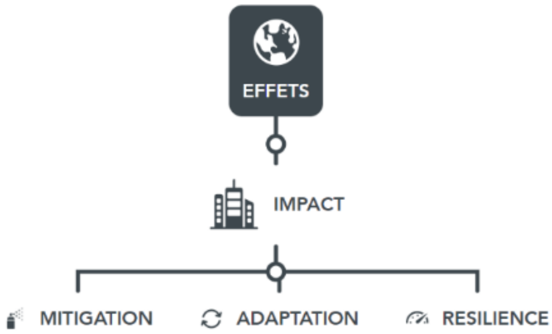
The first stage, besides presenting the delimitation and problematic of the research, consists in the survey of the state of the art existing on the studied theme and its theoretical and specific bibliographic review. It consists of the presentation of the main concepts related to the climate and to the current, future climate models and their derivatives. The next stage, analyzes the main documents, in the last few years (2011-2021), by the main actors who are at the forefront of technical and scientific knowledge about the problem of climate change. They are global technical documents, agreements and climate agendas, discussed in conferences that have not measured efforts since the creation of the United Nations.

The third stage, consists in systematizing the literature drawn from the last decade (2011-2021), obtained through research carried out on the platform Scopus Elsevier B.V and the other platform that are a reference on the theme. Through the systematization of the collected literature, (according to the research cutout following the criteria described to be considered eligible) it was feasible to analyze the bibliometric data obtained through *software* with the R programming language, which identified and sought to evaluate the scientific production of the theme in a quantitative and temporal manner.

To conclude the construction of this theoretical and specific framework begins the fourth stage, which consists in characterizing the formal, morphological, climatic and normative aspects of the objects of study. Discussing the main impacts of climate change on the territorial scale and the built environment, within the context of the current and future scenarios of the proposed clipping, and correlate them to the project process of the architect and urbanist. Always seeking, to make a critical analysis of a phenomenological nature about how the architect and urbanist can anticipate more sustainable solutions in their work processes. Impacting directly on higher environmental quality and on: mitigation[19] of GHGs, promotion of the adaptation[20] of the existing building stock and the attribution of resilience[21] in urban systems and the built environment in the future context and the goals of the Paris Agreement.

All the previous stages build the theoretical and specific foundation needed to analyze the state of the art of the last decade (2011-2021) on the theme and characterization of the study objects. The next step, the fifth methodological step, concentrates on the discussion of the results obtained through research carried out always correlating the effects of global warming and its respective impacts on the built environment, with the physical, climatic and normative aspects inherent in the professional practice of the architect and urbanist.

[19] Mitigation (of climate change): A human intervention to reduce the sources or enhance the sinks of greenhouse gases (GHGs). WGI, II, III (IPCC, 2012, p. 561) (IPCC, 2013, p. 125)
[20] Adaptation: In human systems, the process of adjustment to current or expected climate and its effects, in order to moderate harm or exploit beneficial opportunities. In natural systems, the process of adjustment to current climate and its effects; human intervention may facilitate adjustment to expected climate. (IPCC, 2012, p. 5 and 556)
Adaptation: The process of adjustment to current or expected climate and its effects. In human systems, adaptation seeks to moderate or avoid harm or exploit beneficial opportunities. In some natural systems, human intervention may facilitate adjustment to expected climate and its effects. (IPCC, 2013, p. 118)
[21] Resilience: The capacity of social, economic and environmental systems to cope with a hazardous event or trend or disturbance, responding or reorganizing in ways that maintain their essential function, identity and structure, while also maintaining the capacity for adaptation, learning and transformation5 . {WGII, III - AR05} (IPCC, 2013, p. 127)

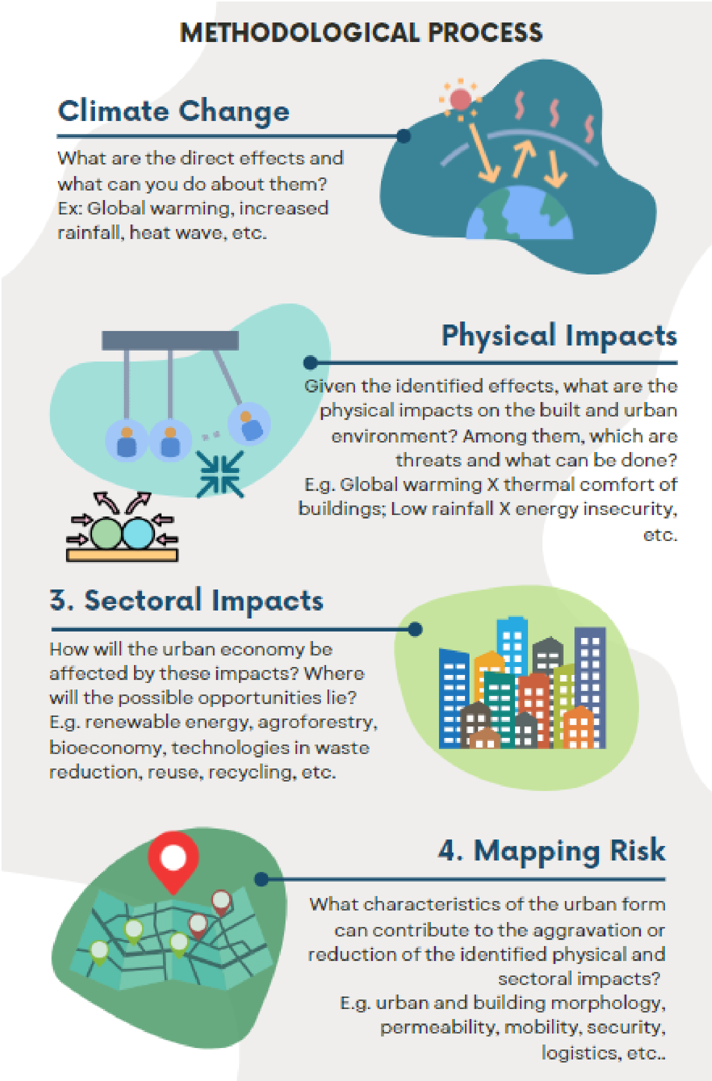


The last methodological step is to systematically organize objective results in order to build a repertoire of good practices to assist professionals in the field of architecture and engineering in their work routines and in the basis of decision making, grouping information systematically according to the impacts identified on the scale of the built environment and classifications of actions (mitigation, adaptation and resilience). The research seeks to contribute to the professional practice of the designers, contributing to the achievement of the climatic targets stipulated in the National Plans specific to each country and by the UN through the Paris Agreement.

Revisione bibliográfica theorica specifica

The review of the specific literature, was built through records of documents, books, articles and periodicals found in the platforms of entities identified as a center of relevance in researches related to the problem of the theme, covering also, the time lapse of the last decade (2011-2020). Among the main bibliographical sources consulted, we can mention: National Aeronautics and Space Administration (NASA); World Meteorological Organization (WMO); publications, agreements, treaties, reports and documents prepared by the United Nations (UN) and the Intergovernmental Panel on Change (IPCC); publications, regulations and documents prepared by the European Commission; technical publications of the International Energy Agency (IEA); Agenzia prevenzione ambiente energia della emilia-romagna (ARPAE); and statistical publications of the Istituto Nazionale di Statistica (ISTAT.com and the Brazilian Institute of Geography and Statistics (IBGE), as well as documents and regulations published by EUR-Lex, European standards (CEN/CENELEC) and the Brazilian Association of Technical Norms (ABNT), among others. A Picture 2 exemplifies the methodological process adopted for the construction of the theoretical framework and specific necessary for the understanding of this comprehensive problem.

Picture 2: Revisione della letteratura theorica e specifica.



Source: L'autore (2021), adattato of: Klimaat effect atlas https://www.klimaateffectatlas.nl/em/how-to-use

Review and empirical analysis of key climate agreements, documents and agendas of the last decade (2011-2021)

After the chronological reconstruction carried out in the UN and IPCC database for the last decade, the documents analyzed sought to identify the existence of guidelines and/or targets in which it makes a direct reference to the problem of climate change and the effect of global warming on the urban territorial scale and the built environment. When identified, the guidelines were classified into seven areas of knowledge, these are:

- Climate Change (effect and impact)
- Sustainability
- Building and renovating
- Affordable secure energy
- Circular Economy
- Governance
- Mobility

Within each area of knowledge the guidelines and good practices observed were grouped into topics framed by strategy: mitigation, adaptation and promotion of resilience.

Revisione systematica con analyi bibliometrica

This methodological step is important for the development of research, as it seeks through conceptual tools in the fields of theoretical studies and of bibliometric metrics, establish criteria of organization, selection, analysis of information related to the problem of the thesis, and later, dissemination.

Arlene Fink (2005) points out that

> *"Numerous motivations for conducting a systematic standalone literature review exist: they can be undertaken to describe available knowledge for professional practice, to identify effective research projects and techniques, to identify experts within a given field, and to identify unpublished sources"*. Apud (OKOLI C., 2015, pp. 882 879-910).

The systematic review of the literature aims to promote the transparency of the method used for the selection of journals and to be analyzed. Through this method of work it is possible to organize the periods obtained in the searches carried out on the adopted platforms, to categorize the criteria for selection, exclusion and quality of texts, besides giving guidelines for the analyzes carried out and quantitative indicators of the results obtained.

Professor Vania Lisboa da Silveira Guedes, from the course of Librarianship and Management of Information Units at the Federal University of Rio de Janeiro (UFRJ), Rio de Janeiro - Brazil, points out that this type of approach to the analysis of citations and literature has its origin in the area of health sciences that seeks to bring together and interpret the statistics related to books and scientific periodicals. But that the use of this tool is also quite widespread in other areas of knowledge. These theoretical and quantitative aspects, when used to develop a literature review and the creation of a composition of Bibliometric indicators, have a positive and fundamental impact on decision-making in the organization, dissemination, evaluation and management of information and knowledge (GUEDES, 2012, p. 75).

Thus, the following work steps and criteria for the systematization of literature were adopted, the first stage in the development of this research.

Scelta della piattaforma da utilizzare per la Fonte di dati ai fini dell'inchiesta:

Search the **Scopus ELSEVIER** platform using the following algorithms (keywords): **"climate change+effect", "built environment+impact", "Building resilience+clichange" and "Urban resilience+climate change".** Record the results of the research carried out in three levels of filters: first at the **global** level **of free access** that comprises all scientific areas, second applying the filter of the scientific area **of engineering and energy,** and later, within this area select only the contents related to the scale of the building and urban scale. Also respecting the preliminary criteria of the research cut-off, selecting only the works published in the last decade (2011-2021).

Criteri adottati per effettuare una revisione systatica della letteratura della tesi:

> *"The process of excluding sources (and including respectively) has to be made as transparent as possible in order for the review to proof credibility. Only then are readers able to assess the exhaustiveness of a review and other scholars in the field can more confidently (re)use the results in their own research".* (VOM BROCKE, 2009, p. 2)

The methodological process adopted for the development of the systematic review and bibliometric analysis of the thesis:

Choice of database: **Scopus Preview ELSEVIER**

1. Establish research algorithms: **"Climate change+effetti", "Built environment+impact", "Building resilience+climate change" and "Urban resilience+climate change";**
2. Perform the research with the algorithms in the selected databases (item 1);
3. Filter the research by delimiting the theme: **last decade (2011 - 2021) and open access;**
4. Carry out the search with the algorithms of the selected databases. For each algorithm limit scientific area: **global, engineering and energy** and **building**.
5. Use the **Zotero**(.ris) **software** to organize the data obtained in the research for each algorithm limit scientific area (item 05) and Systematize the literature;
6. Bibliometric analysis - Software **VOS Viewer** (.cvc) and **RStudio** (.bib);
7. Synthetize results

Table 1: Criteri adottati nella revisione della sistatizzazione e nell'analyi bibliometrica

METHODOLOGICAL PROCESS OF THE SYSTEMATIC REVIEW

Steps	Delimitation of Research
Period to be analyzed	Last decade
Knowledge area	Engineering/Energy/Architecture/Building and construction.
Epistemological approach	Scientific Knowledge
Scientific research method	Quantitative and Qualitative method
Research purpose	basic and applied
Data collection procedure	Bibliographic and systematic research
Origin of date	Journals with international reach
Publication Stage	Final
Publication languages	English, Portuguese and Italian
Data collection instrument	Internet
	https://www.scopus.com/ [22] (ELSEVIER B.V., s.d.)

[22] Scopus Elsevier: Expertly curated abstract & citation database.

	https://www.sciencedirect.com/ [23] (ELSEVIER B.V., s.d.)
Data analysis technique	Bibliometric analysis
Purpose of the review	• Identify in the articles: expected impacts, methods, techniques and the resilient design process (built and territorial environment). • Identify specialists in this area of knowledge
Research objective	Develop a repertoire of good practices and experts on the topic. Benchmarking
Systematization of data collected in the research -	
Title of paper	Check in the database used
Keywords of the paper author	Check in the database used
Indexed Keywords by the platform	Check in the database used
Central theme of the text	Check in the database used
Funding Sponsor	Check in the database used
Document type	Article, Conference papers, review, book chapters, Editorial and Note.
Source Type	Journal, Conference Proceeding, Book, Trade Journal and scientific magazine.
Source (APA)	Check in the database used
DOI	Check in the database used
Publication date	Check in the database used
Number of citations in Scopus	Check in the database used
Number of readings Scopus	Check in the database used
Eligibe Papers (Quality indicators of *papers)*	
Impact of the paper (Citations received)	https://www.scopus.com/sources (ELSEVIER B.V., s.d.)
Journal Rank (Citations/Documents published)	https://www.scopus.com/sources (ELSEVIER B.V., s.d.)
The *paper* must have been reviewed by at least two reviewers	Check in the database used
Presence of a clear and detailed methodology	Check in the database used
Bibliometric analysis - Software VOS Viewer	
Objective: Constructing and visualizing bibliometric networks.	
Bibliometric indicators of papers	
publications by country	Check in the database used
publications by Year	Check in the database used
publications by Key-words: Building, Engineering and Energy	Check in the database used

[23] ScienceDirect: Elsevier's premier platform of peer-reviewed literature.

publications by gender	Check in the database used
Publucations by trends	Check in the database used

L'autore (2020).

Analisi del Piano regolatore dei Comuni di Bologna (IT) and Natal (BR): Governance and territorial

At this stage, the current Master and Regulatory Plans that regulate the commune di Bologna (Emilia-Romania, Italy) and the municipality of Natal (Rio Grande do Norte, Brazil) were analyzed, also with the aim of identifying in these documents and regulations, guidelines, minimum performance required in the territorial scales and the built environment. When identified, the guidelines were classified into seven areas of knowledge, these are:

- Thermal Comfort (mitigation, adaptation and resilience);
    - Temperature
    - Ventilation
- Energy consumption:(Building adaptation, Energy autonomy, envelope efficiency and renewable energy generation).
    - operational energy efficiency of buildings;
    - energy efficiency built into the building;
- Critical events in buildings (mitigation, adaptation and resilience to these events)
    - water resource management (reuse of drinking/non-drinking water and flooding);
    - management of low rainfall (prolonged droughts);
    - fire safety management;
    - air quality management;
- sustainable governance (mitigation, adaptation and resilience);
    - water safety;
    - food and nutrition security;
    - energy security;
    - Urban Mobility;
    - solid waste;
    - health security;

1. THEORETICAL AND SPECIFIC REVIEW

> *"It is unequivocal that human influence has warmed the atmosphere, ocean and land. Widespread and rapid changes in the atmosphere, ocean, cryosphere and biosphere have occurred".* (IPCC, 2021, p. 4)

This chapter, as mentioned above, seeks to carry out a bibliographic review of the state of the art and to expose the main landmarks on the theme, aiming to present in a systematic way, how the problem of climate change has been addressed in the literature of the last decade. It seeks to briefly highlight the main concepts on the theme, constructing the theoretical framework necessary for understanding the theme of research. Evidencing the phenomenon of the Greenhouse Effect, of global warming, identifying its effects and physical impacts on the scales under study, which socio-economic sectors will be most affected in the current climate scenario and in the projected scenario, as well as the impacts on the terrestrial ecosystem in case of non-compliance with the targets stipulated in *The Paris Agreement* (2015).

1.1 Climate: Classification of the climate and future climate scenario

The fifth special report (AR5) published by the IPCC (2014)In his Glossary, he conceptualizes climate through two distinct scenarios:

> *"Climate in a narrow sense is usually defined as the average weather, or more rigorously, as the statistical description in terms of the mean and variability of relevant quantities over a period of time ranging from months to thousands or millions of years. The classical period for averaging these variables is 30 years, as defined by the World Meteorological Organization. The relevant quantities are most often surface variables such as temperature, precipitation and wind. Climate in a wider sense is the state, including a statistical description, of the climate system"* (IPCC, 2013, pp. 119-120).

The globe is divided into climatic zones, each with its specific characteristics, being classified through specific methods that aim to provide a predictability of the climate reducing uncertainties. Because of this need for climate predictability, researchers have developed climate classification systems, each with its own particularities, with advantages and disadvantages and limitations of predictability. Among several systems, the main climate classification systems developed in the last century were: the method used by Köppen (1936)[24]by Miller (1931) [25]by Thornthwaite (1948)[26] and Strahler (2005)[27]. These systems adopted in their methodologies common data obtained through

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[24] Köppen, W. (1936). Das geographisca System der Klimate. Gebr, Borntraeger. 1-44p.
[25] Miller, A. (1931). Climatology. Methuen & Co. Ltd London. 304p.
[26] Thornthwaite, C.W. (1948). Problems in the classification of climates. George. Rev., 33, 233-255p.
[27] Strahler, A.H.; Strahler, A.N. (2005). Physical Geography: Science and systems of the Human Environment. Wiley, New York, 794p.

the areas of knowledge of geography and meteorology. For example, data related to air[28] temperature, air[29] mass, rainfall[30] indices, evaporation[31] indices and native[32] vegetation indices to support the analyzes carried out in order to understand the disparity of existing climatic typologies. Thus these climatic classifications sought to establish correlations between the data analyzes and the local characteristics, zoning into groups and, or regions, with common characteristics and later assigning a classification to this particular climate.

According to Nobrega (2010) The methodology developed by Köppen to classify the climates existing in the terrestrial globe is based on five criteria about a given region, being them: **the temperature of the air, its latitude, solar radiation, rainfall rates and the characteristics of the existing vegetation**. In a simplified way, we can say that this climate classification system uses the temperatures of the coldest and hottest months of the year to determine the climate typologies of a given region. The air temperature in this methodology is a determining factor used in the analyzes, and also ascribes an important role to the vegetation of the place. In Köppen's methodology the plant element is considered an important factor for integration of all the other climatic variables cited and used in the analyzes. For Köppen, the local vegetation is the main indicator used to delimit the areas of frontiers between climatic typologies, acting as a sort of indicator of areas of transition between different climates. All these variants built the Köppen climate classification model.

The model developed by Köppen was perfected by Rudolf Geiger in 1961, originating the Köppen climate classification map, this method of climate classification is still the most frequently used. In a minimalist way, the map is composed of five main climatic groups that generally characterize the region's climate through air temperature. In this macroclassification, each type of climate is represented by a capital letter. The five climate groups in Köppen are: Equatorial Climates (A), Arid climates (B), Warm temperate climates (C), Snow climates (D) and Polar climates (E)[33]. Each climate group, represented by a capital letter, has subdivisions that correlate the data previously analyzed with the rainfall indices of the site. Through the particularities of these indices in each macroregion produce this subdivision of zones, they are: humid, monsoon, summer, winter, Steppe, Desert, Trundra and Frost. All are represented by a lowercase letter immediately after the uppercase letter representing the five major climatic groups.

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[28] Second Nóbrega (2010)However, the temperature fatora proved to be consistent with certain climatic standards. By studying the temperatures of the coldest and hottest months, or even, in the presence or absence and duration of these seasons. Being used as a basis for the identification of climatic groups.

[29] Second Nóbrega (2010), the use of the air mass factor proposed by Strhler (2005) requires a detailed analysis of the types and characteristics of these masses in different parts of the globe. It is easy to apply, since it is not possible to say that the real effects of such mass are identical throughout its course, resulting in a genetic classification based on the causes of these variations.

[30] Second Nóbrega (2010), the use of precipitation indices expresses the relationship between water gain and loss in order to assess the availability of water.

[31] Second Nóbrega (2010), evaporation/evapotranspiration data are scarce. The use of this factor was based on a method for estimating the climate water balance and the water storage capacity of the soil, proposed by Thornthwaite in 1948.

[32] Second Nóbrega (2010)However, the use of the vegetation fatora supposed that vegetation requires different climatic conditions with respect to the climate in order to develop, such conditions can hardly be suitable for another group of vegetation. Using this information to be used to set climate limits.

[33] Equatorial Climates (A), Arid climates (B), Warm temperate climates (C), Snow climates (D) and Polar climates (E).

Over the years, several studies have been developed applying the classification system developed by Köppen, but using other global climate models to improve the results. For example, the study by Lohmann et al. (1993)[34] which applied the Köppen classification system to general atmospheric circulation models and circulation models coupled to the atmosphere-ocean ecosystem. By using these atmospheric circulation models, Lohmann et.al (1993) he compared the models for controlling the current climate and analyzed, through simulations, the warming of the greenhouse gases applied in future scenarios.

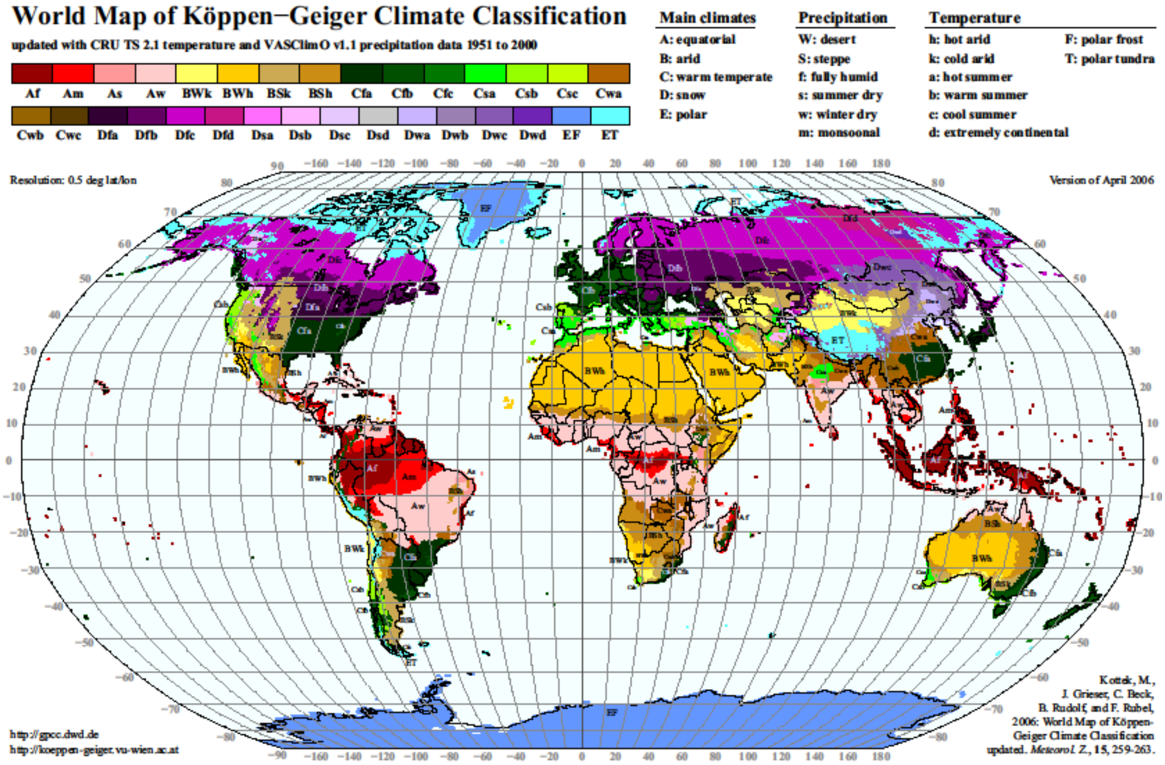
As a result Lohmann et al. (1993) he noted that the process of global warming resulted in a retreat in the *permafrost* regions, as well as an increase in areas with rainy tropical climates and dry climates. The study concluded that the classification developed was adequate for estimating the capacity of climate models to report on the current climate, in the same way that it was adequate for estimating the impact of climate changes on the biosphere. Besides Lohmann et al., other authors have developed critical and comparative research on this subject over the years, we can also cite, Triantafyllou and Tsonis (1994), Kalvova et al. (2003), Wang and Overland (2004), Gnanaderkan and Stouffer (2006) and Kleidon et al. (2000), among others that in their majority had the objetive of assessing the variability of the system proposed by Köppen and its suitability in the face of real data on air temperature and precipitation.

KOTTEK, M. et al (2006) developed a classification system based on observed data. Picture 3 The following is a global map of this Köppen-Geiger classification system updated by KOTTEK, M. et al. (2006). This system is often used with its climatic categories and subcategories. The interesting thing about this map is that its design is based on **data of air temperature and precipitation observed** during the time interval between the years 1951 until the year 2000, represented 31 (thirty-one) climatic typologies through a rectangular grid with resolution of 0.5° latitude x 0.5° longitude, that is, with a grid of approximately 55.55 km, simulated on the basis of observed data and of free access, being for the temperature used the *Climatic Research Unit (CRU)*[35] *and for the precipitation indices the data of the Global Precipitation Climatology Center (GPCC),* which are datasets produced through the research project VASClimO, for the period between 1951 and the 2000s.

[34] Lohmann, U.; Sausen, R.; Bengtsson, L.; Cubasch, U.; Perlwitz, J.; Roeckner, E. 1993. The Köppen climate classification as a diagnostic tool for general circulation models, Clim. Res., 3, 177-193

[35] CRU data sets. Available at: https://www.uea.ac.uk/web/groups-and-centres/climatic-research-unit/data

Picture 3Classification of the climate of Köppen-Geiger aggiornata nel 2006 (with temperature CRU TS 2.1 and precipitazioni GPCC ,VASClimO v1.1, period 1951-2000).



Source: KOTTEK et al. (2006).
Available all'indirizzo: http://koeppen-geiger.vu-wien.ac.at/pdf/kottek_et_al_2006_A4.pdf

Markus Kottek in conjunction with Franz Rubel continued to develop their research based on global data sets (temperature[36] and prescipitation[37]) of climate observations, but also with global climate models (GCMs) capable of showing global trends of future scenarios. These GCMs are statistical and dynamic models that allow us to characterize changes in atmospheric circulation associated with human causes. Using these models and the global temperature and precipitation projections for the period 2003-2010 that were taken from the Tyndall Center for Climate Change Research, TYN SC 2.03 (MITCHELL et al., 2004) data set comprising a total of 20 GCMs (global climate model), added to 4 possible future carbon dioxide emission scenarios described by the SRES (ARNELL et al., 2004), made it possible to prepare global climate classification maps in which represent future projections for the period between 2003 and 2010.

The product of this study was the preparation of the world map of climate classification published in 2010 (RUBEL, F., and KOTTEK, M. (2010), which presents the Köppen-Geiger climate classification projected for a possible future gas emission scenario. A Picture 4 The following presents one of the global maps published in 2010 using the temperature and precipitation scenarios of Tyndall SC 2.03 for the period 2076-2010, and the possible future scenario of A1F1 (more pessimistic) emission of the IPCC, presented in a regular grid of latitude/ longitude equal to 0.5 degree.

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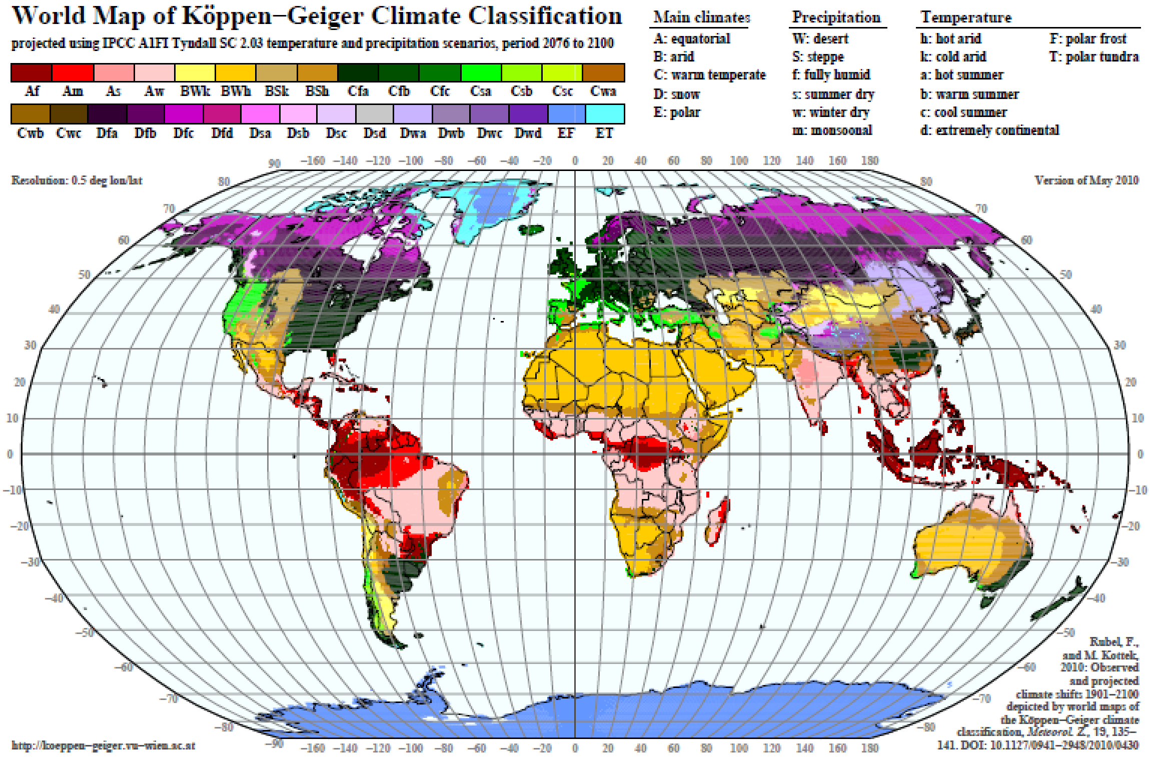
[36] This dataset, referred to as CRU TS 2.1, covers the global land areas excluding Antarctica.
[37] The second dataset, provided by the Global Precipitation Climatology Center (GPCC) located at the German Weather Service, is the so-called GPCC's Full Data Reanalysis Version 4 for 1901-2007 (FUCHS, 2008). This dataset covers the global land areas excluding Greenland and Antarctica.

Picture 4 - Mappa mondiale della classificazione climatica Köppen-Geiger aggiornata nel 2010



Utilizzato gli scenari di ambiente e precipitazioni Tyndall SC 2.03 (MITCHELL et al., 2004) per il periodo 2076-2010 e lo scenario di emissione IPCC A1F1 (pessimistic più).
Source: RUBEL, F., and KOTTEK, M. (2010).
Available all'indirizzo: http://koeppen-geiger.vu-wien.ac.at/pdf/2076-2100_A1FI.pdf

At the same time, still within the context of GMCs and future projections, in the mid-2000s, the IPCC presented four plausible future scenarios that embody future characteristics related to demographic change, economic development, technological change, social trends, global emissions of greenhouse gases and sulfate aerosols, the so-called SRES, the *Special Report on Emissions Scenarios* (Nakicenovic & Swart, 2000), in which they range from a less pessimistic context (Scenario B1) to the more pessimistic scenarios in which fossil fuels continue to be strongly deprecated (Scenario A1). According to Kriticos et al. (2012) some research at the time has already shown that the contexts adopted to represent these future scenarios already underestimated important data in their estimates and spatial dynamics, under an extemporaneous argument for the circumstances of the time, but mainly criticisms that refer to the spacing of the grid of the GCMs (100 km), which becomes inadequate to subsidize analyzes on regional scales.

According to Kriticos et al. (2012)the emission-converter scenarios would no longer be plausible:

> *"... **Rahmstorf*** **et al.** ***(2007)*** *showed that projections from GCMs had underestimated recent global temperature and sea level trends. More recently,* ***Manning*** **et al.** ***(2010)*** *illustrated that since 2000, carbon dioxide emissions owing to fossil fuel use are consistent with the most extreme of the SRES scenarios. These observations, combined with continued failures to agree on legally binding global reductions in greenhouse gas emissions, suggest that the*

conservative emission scenarios are no longer plausible". Kriticos et al. (2012, p. 56).

Peel et al. (2007)[38] It was proposed at the time to update the global classification map of Köppen-Geiger within a scale better suited to climate plots for future trends. The author argued that Köppen's climate classification system was well suited to represent climatic conditions on medium to long-term time scales (regular latitude/longitude grid of 0.5 degrees), but did not consider it appropriate when the climate system was used to characterize a short-term time period, such as annual periods. To analyze within this time scale, the researcher would demand a careful evaluation of the records observed within the short time-lapse. On a short-term scale, temperature and precipitation variables should be measured constantly and at a finer resolution, allowing for a more detailed and accurate evaluation.

Based on the global map developed by Kottel et al. (2006), Peel et al. (2007) elaborated their update using the same criteria as the climatic system used by Koppen-Geiger (1936)with the exception of the temperate (C) to cold (D) climate boundary using the **observed** medium- and long-term variables**.** This cut-off was adopted with the intention of reducing subjective variables during the process of interpolating the observed data. The data records of long-term precipitation and monthly temperature stations, obtained from the data set of the Global Historical Climatology Network (GHCN) version 2.0 in a grid of 0.1 × 0.1 degrees latitude and longitude for each continent (10km), were used to make the final map.

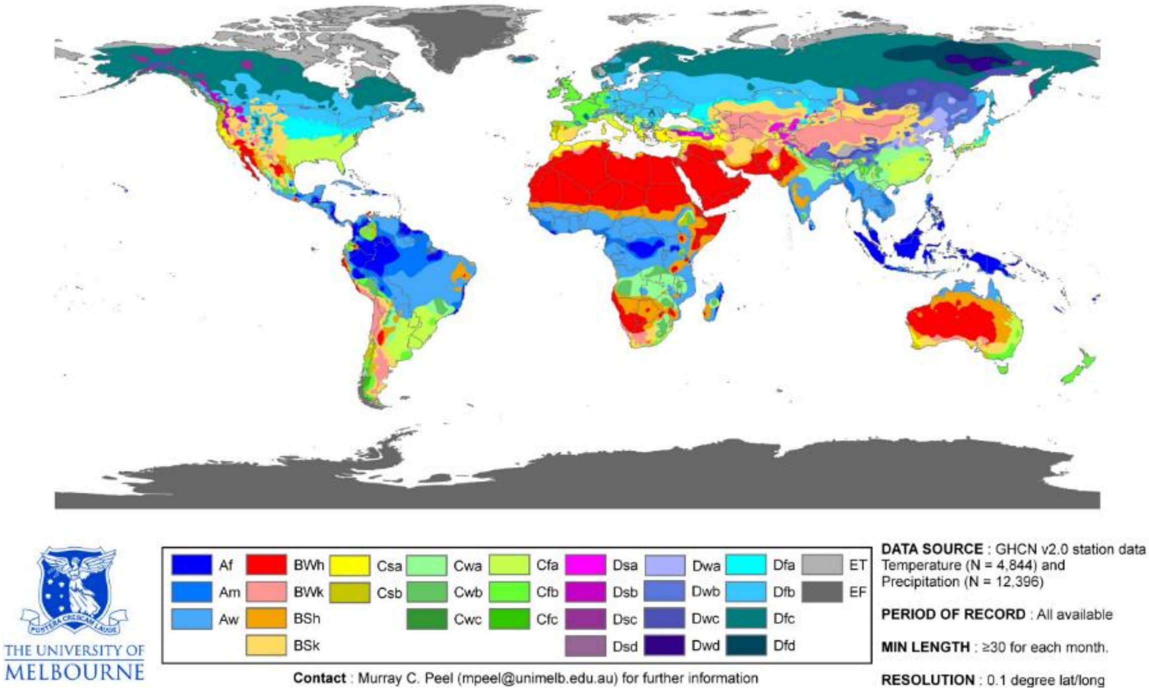
A Picture 5 The following is a global map of Peel et al. (2007), after the interpolation of the analyzed data for the period 1916 to 1992. The author also raised some negative points of the use of this method, they are:

- The failure to represent mountain regions on the map. This is due to the lack of topographical corrections (elevations) in the calculations and analyzes performed, resulting in a deviation of classification accuracy in these areas.
- Another point that should be taken into consideration is the use of a relatively small number of meteorological stations for the collection of data observed for carrying out the analyzes. According to the authors, this resulted in a reduction in the level of reliability of the climate classification to 70.9%, compared to 80% of reliability for the Köppen-Geiger classification map (1980-2016) updated years later by Beck et al. (2018).

[38] Peel, M.C. et al. (2007). Koppen-Geiger climate classification map. Geiger, Hydrol. Terra Syst. Sci., 11, 1633-1644. Available at: https://hess.copernicus.org/articles/11/1633/2007/hess-11-1633-2007.pdf

Peel, M.C., Finlayson, B.L., and McMahon, T.A.: Updated world map of the Köppen-Geiger climate classification, Hydrol. Terra Syst. Sci., 11, 1633-1644, https://doi.org/10.5194/hess-11-1633-2007, 2007. Available at: HESS - Updated world map of Köppen-Geiger climate classification (copernicus.org)

Picture 5: Mappa mondiale della classificazione climatica Köppen-Geiger aggiornata 2007



Utilizzato gli scenari di temperatue precipitazioni dati della stazione GHCN v2 per il periodo 1916-1992, latitudine/longitudine di 0,1 gradi di risoluzione - 10 km.

Source: PEEL et al. (2007)

Available all'indirizzo: HESS - Mappa mondiale aggiornata della classificazione climatica Köppen-Geiger (copernicus.org)

Finally, Peel et al. (2007) concluded that to increase the reliability of the Köppen-Geiger climate classification map and future projections within a short-term scenario, it was necessary to develop a new classification modeling method in which its resolution grid should be further detailed. The author recommended a regular grid with latitude and longitude equal to 0.0083°, which would represent an approximate grid of 1 km. However, it is important to point out that even with a grid with a regular grid resolution of approximately 1km, the predictability of future projections on an urban scale will have a reliability of the data questioned. Since the urban morphology and its compositions are a variable that should not be disregarded within the model or considered in an isolated manner.

Another interesting bias in which this method of climate modeling of future projections was the applicability presented in the work developed by Kriticos et al. (2012)[39]. In this article the authors set out to elaborate a global map of climate classification based on a set of common data (temperature, precipitation, relative air humidity), but including biological variables in their analyzes. This set of climatic data, after interpolation, proved to be capable of representing potential models for the distribution of species, called Species distribution models (SDMs), whose objetive was to apply this modeling in the various areas of study within biology, conservation, the

[39] Kriticos, D.J. et al. (2012). CliMond: global high-resolution historical and future scenario climate surfaces for bioclimatic modeling. Methods in Ecology and Evolution 3, 53-64. Available at: https://besjournals.onlinelibrary.wiley.com/doi/epdf/10.1111/j.2041-210X.2011.00134.x

management of biodiversity, ecology and biological control. According to Kriticos et al. (2012) the aim of this study was to:

> *"The purpose of this paper is to describe the development and testing of a fine-scale global data set uniquely tailored for use in species bioclimatic modeling, including correlative and process-based mechanistic models." Kriticos et al.* (2012, p. 55)

Correlative SDMs basically model the observed distribution of a species as a function of environmental conditions. Mechanistic models, on the other hand, are process-based models, in which they use physiological data of a given species to develop a model capable of forecasting the environmental conditions necessary for its maintenance and survival. These correlative and mechanistic models of species distribution have the potential to assist in the analysis of risk of extinction, management and impacts on biodiversity. This tool has been used in the literature to ensure the physical and geographical conditions favorable to the life or development of a plant or animal species. The aim is to find answers capable of anticipating mitigating actions and adaptive capacity to reduce the impacts of climate changes on the habitat under study.

Over the years, the need to develop a climate classification model to predict climate characteristics in a short time has become a priority and fundamental, with the emergence of the need to update the climate classification model with a more detailed resolution grid, around 1km, equivalent to a regular grid with latitude and longitude equal to 0.0083°. As well, update the data sets and variants that make up the plausible future scenarios, which embody future characteristics related to: demographic, economic development, technological change, social trends, global greenhouse gas emissions. The so-called socio-economic scenarios described in the IPCC literature.

The update of these socio-economic scenarios was presented in the last synthesis report (AR5) produced by the IPCC and published in 2014, in which it was used in its forecasts a set of possible future scenarios of the concentration of GHGs called RCPs (*Representative Concentration Pathways*) designed with the intention of improving climate modeling by improving their future forecasts according to each proposed socio-economic scenario.

According to Beck, H. E. et al. (2018)[40], the main global climate classification maps that existed up to that period were:

- The Global Map of Kottek et al. (2006) produced a map (0.5° resolution ≡ 55,555 km) based on CRU TS 2.123 for temperature and VASClimO V1.124 for precipitation. CRU was based on approximately 7000-17,000 stations (depending on the year) and VASClimO on 9343 stations. (BECK, 2018).
- The global map of Peel et al. (2007) map (0.1° resolution ≡ 11,111 km) was derived from 4,844 air temperature stations and 12,396 precipitation stations. (BECK, 2018).

[40] Beck, H. E. et al. (2018). Present and future Köppen-Geiger climate classification maps at 1-km resolution Sci. Date. 5:180214 doi: 10.1038/sdata.2018.214. Available at: Present and future Köppen-Geiger climate classification maps at 1-km resolution (nature.com)

- The global map of Kriticos et al. (2012) produced a map (0.083° resolution ≡ 9,222 km) based on WorldClim V1 temperature and precipitation datasets[41], which are based on 24,542 and 47,554 stations, respectively (BECK, 2018).

According to Beck et al. (2018), all of the maps cited have a relatively low resolution, with a grid around 10km (≥ 0.1°degrees), being unsuitable for regional analyzes. The map updated by Peel et al. (2007) has not been explicitly corrected for its topography, which influences air temperature and precipitation rates in mountainous regions, reducing its reliability. In addition, the maps of Kottek et al. (2006) and Peel et al. (2007) are based on observed data from a relatively small number of weather stations, which can lead to widespread misclassifications, particularly in regions with low season density and/or strong climate gradients such as mountain ranges. Concomitantly to this, as these maps do not include corresponding uncertainty estimates, they can provide users with a false sense of confidence (BECK, 2018). In other words, we are still in a preliminary process with regard to the development of climate models of future projections on scales capable of adequately representing urban areas (1 km), as well as, to characterize through GCMs statistical and dynamic models that allow us to individualize changes in the air circulation associated with human causes.

In terms of climate models of future projections for the medium and long term, the model adopted by the IPCC covers a set of variables, methods and models with simple and complex approaches capable of anticipating change trends with greater reliability. In the reports that make up the *Fifth Assessment Report (AR5)* published by the IPCC, a new set of data and variants make up the socio-economic scenarios used in the publication, being called **CPRs** (the Representative Concentration Pathways). The ROEs are used in the simulations of climate models developed in the context of the **CMIP** (*Coupled Model Intercomparison Project*) project to predict the possible impacts of future greenhouse gas emissions on the atmosphere, that is, how much there will be to change the energy balance of solar terrestrial radiation. As a result, four projections of socio-economic scenarios were prepared to characterize future projections of GHG emissions, adopting criteria capable of representing the different levels of **reliability X probability** of the global warming potential by the end of the 21st century.

Second the IPCC (2013, p. 29), in the report of *Working Group I to the Fifth Assessment Report (AR5)*, the **CPRs** are identified by their total radiative force (RF)[42] for the year 2100 when compared to 1750. So we have: 2.6 W/m2 (watts per square meter) for **RCP 2.6** (very low level, mitigation optimistic scenario); 4.5 W/m2 (watts per square meter) for **RCP 4.5** (low level,

[41] Hijmans R.J., Cameron S.E., Parra J.L., Jones P.G. & Jarvis A. (2005). Very high resolution interpolated climate surfaces for global land areas. International Journal of Climatology 25, 1965-1978.

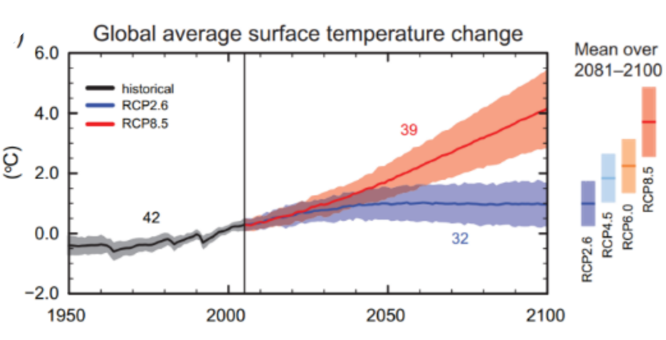
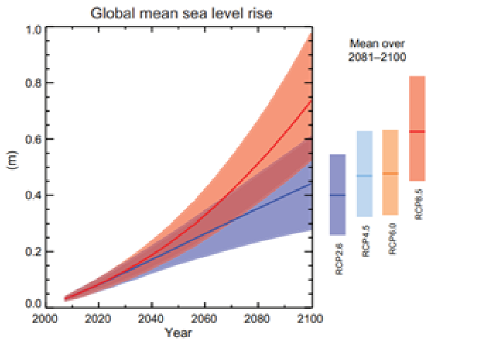
[42] The Radiative forcing (RF) represents the stratospherically adjusted radiative flux change evaluated at the tropopause, as defined in the TAR. Positive RFs lead to a global mean surface warming and negative RFs to a global mean surface cooling Radiative forcing, however, is not designed as an indicator of the detailed aspects of climate response. Unless otherwise mentioned, RF here refers to global mean RF. Radiative forcings are calculated in various ways depending on the agent: from changes in emissions and/or changes in concentrations, and from observations and other knowledge of climate change drivers. In this report, the RF value for each agent is reported as the difference in RF, unless otherwise mentioned, between the present day (approximately 2005) and the beginning of the industrial era (approximately 1750), and is given in units of W m-2, adopted by the Intergovernmental Panel on Climate Change. Forster et al. (2007, p. 131).

stabilization scenario); 6.0 W/m2 (watts per square meter) for RCP 6.0 (intermediate level, stabilization scenario) and 8.5 W/m2 (watts per square meter) for **RCP 8.5** (very high level, pessimistic scenario). According to IPCC-AR5 (2014), the characteristics of each SPC were simulated using the following climate models:

- **RCP 2.6:** was developed by the *Netherlands Environmental Assessment Agency (PBL)'s IMAGE modeling team*. This emission path is representative of scenarios in the literature that lead to very low levels of greenhouse gas concentration. This is a more optimistic "peak-decline" scenario. Its radiative forcing level first reaches a value of about 3.1 W/m2 by mid-century, and returns to 2.6 W/m2 by 2100. To achieve such levels of radiative forcing, greenhouse gas emissions (and indirectly emissions of air pollutants) are substantially reduced over time (Van Vuuren et al. 2007).
- **RCP 4.5:** was developed by the *Pacific Northwest National Laboratory's Joint Global Change Research Institute (JGCRI*) modeling team. It is a stabilization scenario in which the total radiative force (RF) is stabilized shortly after 2100, without exceeding the high level of the long-term radiative forcing (Clarke et al. 2007; Smith and Wigley 2006; Wise et al. 2009).
- **RCP 6.0:** was developed by the AIM modeling team of the *National Institute for Environmental Studies (NIES*) of Japan. It is a stabilization scenario in which the total radiative force (RF) is stabilized shortly after 2100, through the application of a series of technologies and strategies to reduce greenhouse gas emissions (Fujino et al. 2006; Hijioka et al. 2008).
- **RCP 8.5:** was developed using the MESSAGE model and the integrated assessment framework of the *International Institute for Applied Systems Analysis* (IIASA) in Austria. This CPR is a pessimistic scenario and is characterized by increased greenhouse gas emissions over time, representing scenarios from the literature that lead to high concentrations (Riahi et al. 2007).

For each socio-economic scenario described above, it is possible to develop models in which it is possible to simulate future projections of how changes in the energy balance of solar terrestrial radiation could impact the dynamics of the Earth's atmosphere. And with this, what will be their respective effects on the global average surface temperature, the global average air temperature, the air quality index, the sea level rise, ecc. A **Erro! Fonte de referência não encontrada.** The following is the projections of global average surface temperature variation for the years 2050 and 2100 (end of the 21st century) according to the *report* of the IPCC *Climate Change 2013: The Physical Science Basis. Contribution of Working Group I Report to the Fifth Assessment Report*.

Table 2: Predicted change of the global mean surface temperature and and aumdel global mean sea level for the mid to late 21st century compared with the reference period 1986-2005, based on the CMIP5 multiple model.

(I) Global mean surface temperature change	**(II) Global mean sea level rise (IPCC, 2013, p. 26)**[43]
	
(III) The predicted change in global mean surface environment and global sea level AUM in the mid- and late 21st century for the reference period 1986 - 2005 (IPCC, 2013, p. 23) **[44]**	

[43] Le proiezioni dell'aumdel livello medio globale del mare nel XXI secolo rispetto al 1986-2005, ricavate dalla combinazione dell'insieme CMIP5 con modelli basati su processi, per RCP2.6 and RCP8.5. Gli intervalli probabili valutati per la media nel periodo 2018-2010 per tutti gli scenari RCP som indicati come barre verticali colorate, con il valore mediano corrispondente dato come linea orizzontale. (IPCC, 2013, p. (26)

[44] a) basato sull'insieme CMIP5; anomalie calcolate rispetto al periodo 1986-2005. in AR4. In the case of non-som stati valutati intervalli probabili rispetto ai periodi di riferimento precedenti, in quantum non-som generally disposable nella letteratura methodi per combinare le incertezze nei modelli e nelle osservazioni. L'aggiunta delle variazioni previste e osservate non tiene tale dei potentiziali effetti delle distorsioni dei modelli rispetto alle osservazioni, né della variabilità internal naturale during il periodo di riferimento dell'osservazione {2.4; 11.2 Tabelle 12.2 e 12.3}

(b) basato su 21 modelli CMIP5; anomalie calcolate rispetto al periodo 1986-2005. Quest treatment non implies che i contributi in questionone non dipenderanno dallo scenario seguito, ma solo che lo stato attuale delle conoscenze non consente una valutazione quantitativa della dipendenza. Sulla base delle attuali conoscenze, solo il collasso dei settori marini della calotta glaciale antartica, se avviato, potrebbe causare un Aumdel livello medio del mare globale sostanzialismo al di sopra della probabile portata during il XXI secolo. Vi è una media fiducia che questo agricultural contribution non supererebbe diversi decimi di metro di innalzamento del livello del mare during il XXI secolo.

(c) Calcolato dalle proiezioni come intervalli di modelli del 5-95%. Questi intervalli som quindi considers intervalli probabili, tenuto tale di ulteriori incertezze o di diversi livelli di confidenza nei modelli. For the period 2046-2065, il livello di confidenza è medio, in que l'importanza relatà della variabilità internal naturale e l'incertezza in termini di forzatura e risposta alle emissioni di gas non a effetto serra som maggiori rispetto al periodo 2018-2010. questi fattori nelle proiezioni a più lungo termine non stati ficati a causa di una comprehensione scientifica insufficente. {11.3}

(d) Calcolato dalle proiezioni come intervalli di modelli del 5-95%. Questi intervalli som quindi considers intervalli probabili, tenuto tale di ulteriori incertezze o di diversi livelli di confidenza nei modelli. Per le proiezioni relative all'innalzamento medio del livello del mare su scala mondiale il Clime di fiducia è medio per entrambi gli orizzonti temporali.

		2046–2065		2081–2100	
	Scenario	Mean	*Likely* range[c]	Mean	*Likely* range[c]
Global Mean Surface Temperature Change (°C)[a]	RCP2.6	1.0	0.4 to 1.6	1.0	0.3 to 1.7
	RCP4.5	1.4	0.9 to 2.0	1.8	1.1 to 2.6
	RCP6.0	1.3	0.8 to 1.8	2.2	1.4 to 3.1
	RCP8.5	2.0	1.4 to 2.6	3.7	2.6 to 4.8
	Scenario	Mean	*Likely* range[d]	Mean	*Likely* range[d]
Global Mean Sea Level Rise (m)[b]	RCP2.6	0.24	0.17 to 0.32	0.40	0.26 to 0.55
	RCP4.5	0.26	0.19 to 0.33	0.47	0.32 to 0.63
	RCP6.0	0.25	0.18 to 0.32	0.48	0.33 to 0.63
	RCP8.5	0.30	0.22 to 0.38	0.63	0.45 to 0.82

Source: IPCC. Sintesi per i responsabili politici - Contributo del gruppo di lavoro I Relazione alla Quinta relazione di valutazione (WG1/AR5, 2013).

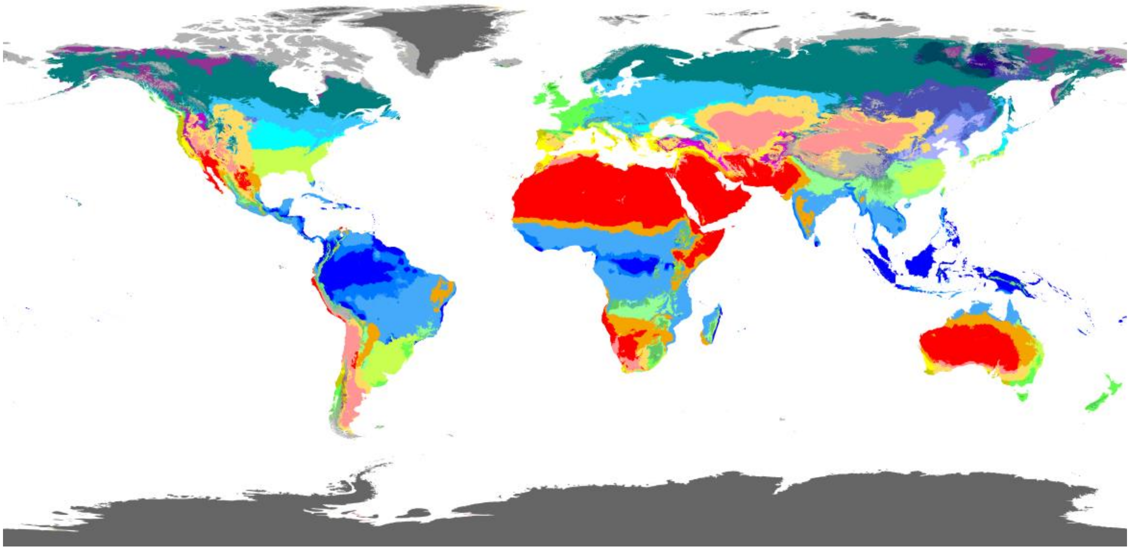
Charts I and II published in 2013 already showed worrying scenarios. Adopting the most pessimistic socio-economic scenario of the IPCC, **RCP 8.5**, the climate model predicts an average increase of 2°C projected for the global average surface temperature and also predicts an average rise of thirty centrimeters (0.30 cm) of the global sea level projected for the year 2050 (medium term). In a long-term forecast, for the end of the 21st century, by adopting the same pessimistic scenario, **RCP 8.5**, one observes a projection of an average increase in the global average surface temperature to 3.7°C and an average elevation of sixty-three centrimeters (0.63 cm) from the global sea level to 2100.

Even with the updating of the socio-economic scenarios present in the IPCC publications, the need to update the climate classification models with a more fine and detailed resolution grid, that is < 0.1° degrees (10 km), forecasting the correction of topographical distortions in mountainous areas is still paramount for improving the predictability of the climate models that we will have in the future. The global map developed by Beck et. al. and published in 2018, proposed to refine this spatial scale by presenting an update of the global Köppen-Geiger climate classification maps, but with a finer resolution with a grid of 1km (0.00083°). Derived from a set of four high resolution climate maps and, unlike the map developed by Peel et.al (2007), with topographical correction in mountainous regions, the proposed update has increased the level of reliability for mountainous regions.

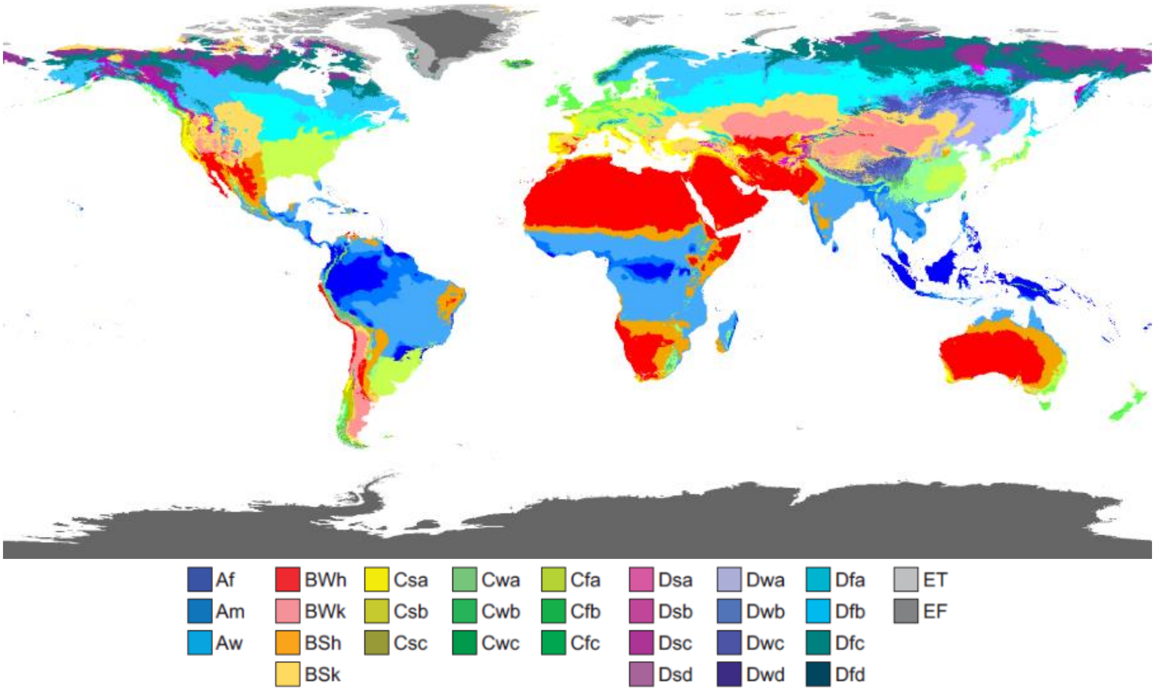
A Picture 6 the following is an update of these classification maps in 2018, covering the period from 1980 to 2016, and the climate classification map with long-term future projections, for the period from 2071 to 2010 (BECK, 2018). The authors adopted the same methodological system used by the IPCC in their reports, adopting the observed database of the GHCN station, version 2 and with CMIP5 coupled model, for the time period between the years 1980 to 2016. To simulate the projections, the socioeconomic scenario **RCP 8.5** (more pessimistic) was used, which is characterized by high levels of GHG emissions.

Picture 6: Classification of the Climate of Today and Future World Map Köppen-Geiger (2018), with latitude/longitude of 0.0083 degree resolution (1 km).

(A) The current map (1980-2016) with color scheme was adopted from Peel et al. (2007). Based on GHCN v2 station data with projected inter-comparison of the coupled model phase 5 (CMIP5) for the period 1980-2016.



(B) The future map (2071-2100) with the color scheme was adopted by Peel et al. (2007).



Source: BECK et al. (2018) Present and future climatic classification Köppen-Geiger a risoluzione di 1 km (figshare.com). Available all'indirizzo: https://www.nature.com/articles/sdata2018214.pdf

In order to improve the socio-economic scenarios to simulate future projections, the second special report published by the IPCC, Climate Change 2021: The Physical Science Basis, prepared by Working Group I, as a contribution to the System Assessment Report (AR6) and published in 2021, presented a new proposal that used the **CPRs** scenarios present in previous reports to simulate future projections of the radiative[45] forces, but additional data was added to these socioeconomic scenarios to represent futures in which the necessary measures to limit global warming provided for in of Paris were hit. As a result, the IPCC WGI Special Report: Climate Change 2021: The Physical Science Basis (2021), presents five new socio-economic scenarios of GHG emissions for climate modeling, called **SSPs** (*Shared Socio-Economic Pathways)* that adopt mitigation and carbon sequestration measures in their data composition. With this, the proposed scenarios make it possible in their models to represent the decline of GHGs emissions up to almost liquid zero.

The creation of these new emission scenarios, the **SSPs** (*Shared Socio-Economic Pathways*), will make possible future climate projections through climate models with low net emissions, or even with negative emissions of GHGs, which will allow the scientific community to draw up future projections capable, for example, of assessing the potential of a given economic and or public policy guideline to be adopted by a Nation and included or not in its National Plan for Adapting to the Climate (NAP). Being a promise of an important tool to assist policymakers and other stakeholders in their decision-making, enabling more assertive choices to achieve the safe injunction set out in the Paris Agreement. Or, by fostering the creation of new carbon capture and storage technologies and in the implementation of the carbon market.

The *Copernics Atmosphere Monitoring Service* (CAMS) and the *Copernicus Climate Change Service* (C3S) served as a database of reanalyzes that supported some findings described in the partial report prepared by the IPCC WGI (2021). As described above, **SSPs** with similar RFs were adopted as presented in the GHG emission RCPs scenarios in their modeling, presenting future projections of short (2021-2040), medium (2041-2060) and long (2081-2100) timeframes. For each **SSPs** scenario, greenhouse gas emission trends (GHGs) are determined, characterizing scenarios from the year 2015 to 2100, in which they include levels of greenhouse gas concentrations different from each other. So we have: 8.5 W/m2 (watts per square meter) for SSP5-8.5 (very high level, very pessimistic scenario with CO2 emissions practically double by 2050 compared to current emissions); 7.0 W/m2 (watts per square meter) for **SSP3-7.0** (high level of emissions, pessimistic scenario with CO2 emissions practically double by 2100 compared to current emissions); 4.5 W/m2 (watts per square meter) for **SSP2-4.5Đ intermediate level, stabilization scenario with CO2 emissions around current levels by 2050), 2,6 W/m2 (watts per square meter) for SSP1-2.60 (low level, CO2-optimistic scenario with zero emissions after 2050 compared to current emissions) and 1,9 W/m2 (watts per square meter) for CO2 emissions (very low level, very optimistic scenario with CO2 emissions declining to zero around 2050 compared to current emissions).**

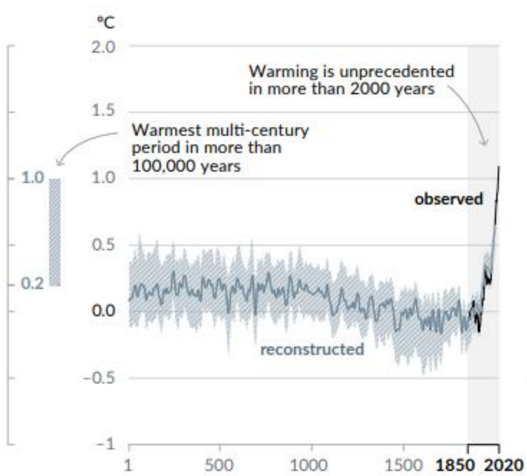
[45] The intensity of the catalysts is quantified as Radiative Force (FR) in watts per square meter (W/m-2) as in previous IPCC assessments. FR represents the change in energy flow caused by a catalyst, and is calculated in the tropopause or upper atmosphere. In the traditional concept of FR employed in previous IPCC reports, the whole surface and tropospheric conditions are kept fixed. In the FR calculations for well-mixed greenhouse gases and aerosols in this report, the physical variables, except for ocean and sea ice, can respond to disturbances with rapid adjustments. The resulting forcing is called Effective Radiative Forcing (ERF) in the underlying report. This change reflects the scientific progress of previous assessments and results in a better indication of the possible temperature response for these catalysts. For all catalysts other than well-blended greenhouse gases and aerosols, rapid adjustments are less well characterized and assumed to be small, and so traditional FR is used (IPCC, 2013).

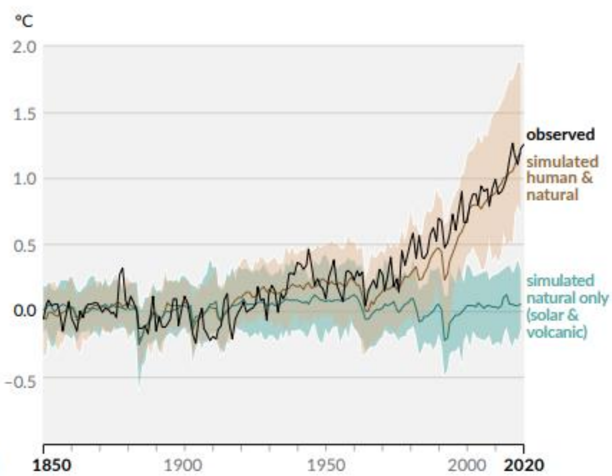
With each of the *Pathway socio-economic* scenarios climate simulations are carried out with the climate model developed by *The World Climate Research Program,* called the *"The Coupled Model Intercomparison Project, Phase 6"*, commonly known as the CMIP6 model. The *Summary for Policymakers In: Climate Change 2021*: *The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report (AR6) of the Intergovernmental Panel on Climate* (2021)These models include new and more reliable representations of the physical, chemical and biological processes of the atmospheric system with better resolution. What it made possible for the first time made an assessment of the impact of each SSPs on global climatic changes, such as the variations in the global temperature of the surface, the warming of the oceans, the thawing and the increase in the level of the sea.

The *Summary for Policymakers In: Climate Change 2021*: *The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report (AR6) of the Intergovernmental Panel on Climate* notes the influence that human activities have directly under the global climate system and highlights that the socio-economic and political patterns adopted throughout the productive chain are the main culprits for the unprecedented impact that we are currently experiencing. In the following figure, published in the report, it is possible to see the worsening global climate warming over the last few centuries.

Table 3: Human influence has warmed the climate at an unprecedented rate for at least the past 2,000 years

(I) Change in global surface metration (10-year average) reconstructed (1-2000) and observed (1850-2020)	**(II) Variation in global (annual mean) observed and simulated temperficiale using fattori umani e naturali e solo naturali (1850-2020)**



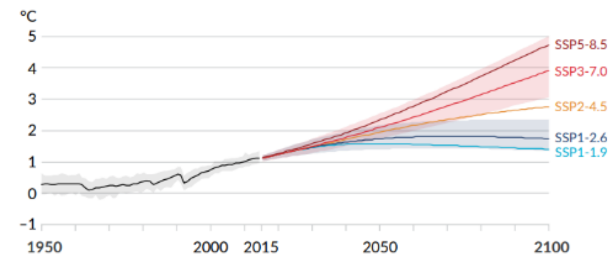
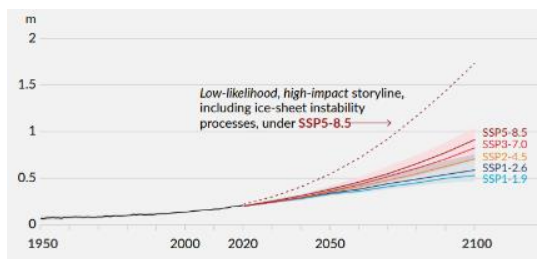


Source: IPCC (2021, p. 6)

When analyzing graph I, one observes the average global warming of the reconstructed surface through the average decenals (*reconstructed*) and the variation of the average global warming of the observed surface, one can see that the reconstructed projections for the pre-industrial period represent a constant range that is between -0.5 degrees celcius and 0.5 degrees celcius. However, the scenario changes dramatically after 1850, when European industrial development began, it can be seen that the change in the global temperature of the observed surface (annual average) is represented by an ascending linear temperature that exceeds 1 degree celcius. Analyzing graph II, which represents the same period as the beginning of European industrialization and seeks to identify and compare the impacts arising from factors: a) human in conjunction with natural factors and b) only natural factors. The study showed that the simulated line for human and natural factors was known with the same pattern as the observed line, showing a global mean surface temperature warming (*observed and human & natural*) between the ascending range of 0.0°C and 1.5°C. This brings us to the safe threshold of warming, which is 1.5°C in the global average, of the Paris Agreement signed in 2013.

The report also presents results for future scenarios and is also not promising. Using the *CMIP6 multi-model* climate model for future projections and the five new scenarios **SSPs** described in this publication, you can see the **Erro! Fonte de referência não encontrada.** The following is the worsening of the climate situation in which we are inserted, when compared to the results presented in the previous report (*Report* of the IPCC: *Climate Change 2013: The Physical Science Basis. Contribution of Working Group I Report to the Fifth Assessment Report).*

Table 4: Predicted change in global surface environment and global mean sea level for the mid- to late 21st century compared with the reference period 1850-1900. Based south multi-model CMIP6.

(I)[46] **Global temperature change from 1850-1900** (IPCC, 2021, p. 22)	**(II)**[47] **World average sea level change since 1900** (IPCC, 2021, p. 22)
	

Source: Sintesi per i politici (IPCC, 2021, p. 22)**,**
Available all'indirizzo: IPCC_AR6_WGI_SPM_final.pdf

Graphic I and II, presented in the previous table, show the climatic projection of the global surface temperature observed between the years 1950 to 2000 for all IPCC scenarios. In a more optimistic scenario (SSP1-1.9) we met the requirements of the Paris Agreement and we would limit the warming to 1.5°C and the projection of the level of the oceans would be + 50 centiments, which is considered safe for the planet. This is if we adopt mitigating policies for the emission of GHGs, adapt our infrastructure for renewable energy sources, implement fiscal and economic policies that favor only the sectors really committed to the low emission of GHGs in all of their productive chain, we can reach the 2°C limit target provided for in the Paris Agreement (optimistic scenario SSP2).

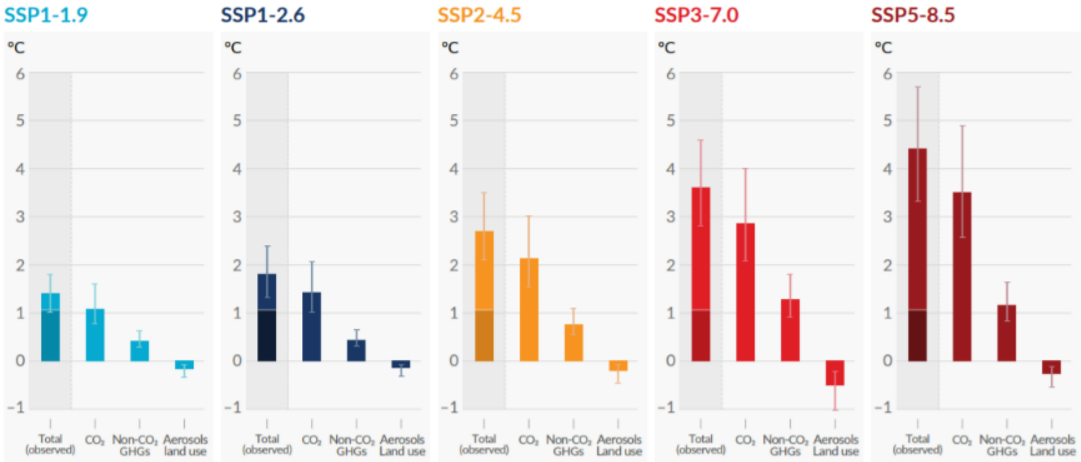
[46] I) Variazioni globali della temperaturiale in °C rispetto al 1850-1900. Le variazioni relative al periodo 1850-1900 basate su periodi medi 20 anni som calcolate aggiungendo 0,85°C (l'increase della metrale globale osservato dal 1850-1900 al 1995-2014) alle variazioni simulate rispetto al periodo 1995-2014. Sono indicati intervalli molto probabili per SSP1-2.6 and SSP3-7.0. (IPCC, 2021, p. (22)

[47] (II) Variazione media globale del livello del mare in metri, rispetto a 1900. I changamenti storici som osservati (dai mareometri prima del 1992 e dagli altimetri dopo), e i totamenti futuri som valutati coherently con i vincoli osservazionali basati sull'emulazione di modelli CMIP, lastre di ghiaccio e ghiacciai. Gli intervalli probabili som indicati per SSP1-2.6 and SSP3-7.0. La curved tratteggiata indica il potentiziale impatto di questi processi profonamente incerti. Shows l'83° percentile delle proiezioni della SSP5-8.5 che includono processi con lastre di ghiaccio a bassa probabilità e ad alto impatto che non possono essere clusi; data la scarsa fiducia nelle proiezioni di questi processi, questa cura non fa parte di un intervallo probabile. Le variazioni relative a 1900 sleep calcolate summing 0,158 m (increase medio del livello del mare osservato a livello globale dal 1900 al 1995-2014) alle variazioni simulate e osservate rispetto al 1995-2014. (IPCC, 2021, pag. (22)

However, in a more pessimistic scenario (SSP5-8.5), in which we maintain the same economic model adopted in recent years, the future long-term forecast (2100) will be an increase in global surface temperature between 4°C to 5°C (in the most pessimistic scenarios SSP3 and SSP5) and the ocean-level related projections, predict that by the end of the 21st century, compared with the level of 1900, it projects an increase of up to one meter of ocean level in the probable scenario (SSP3-7.0). As for the typology of gases emitted in the atmosphere that make up the greenhouse effect phenomenon, note that carbon dioxide emissions are the ones that contribute most to the greenhouse effect and the warming of the earth's surface temperature.

Picture 7: Global surface temperature variation: contribution of warming by different emissions and projections of the change of the global average surface temperature

III)[48] Contributo all'magnifying the surface temperature globale dovuto a diverse emissioni, con un ruolo domindi emissioni di CO2 - Variazione della temperatureale globale nel 2018-2100 rispetto al 1850-1900 (°C). (IPCC, 2021, p. 13)



Source: Sintesi per i politici (IPCC, 2021, pp. 13-14)**.**
Available all'indirizzo: [IPCC_AR6_WGI_SPM_final.pdf]

Graph III presents for each of the five IPCC (2021) scenarios a column graph with pooled data showing the different levels of contribution of GHGs that impact the increase of global surface temperature. With projections for the end of the century of temperature increase in all the scenarios analyzed, they are from the most optimistic to the most pessimistic, when compared with the pre-industrial period (1850-1900). It can be observed that the first columns of each scenario

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[48] (III) I contributi di riscaldamento da parte di gruppi di conducenti antropogenici e per scenario nero indicati come variazione della Temperatureale superficiale globale (°C) nel 2081-2100 rispetto al 1850-1900, con indicazione del riscaldamento osservato fino ad oggi. Barre and baffi rappresentano rispettively valori mediani and l'intervallo molto probabile. All'internal di ciascun plot della barra di scenario, le barre rappresentano: riscaldamento globale totale (°C; tabella SPM.1 - IPCC, 2021, pag. 6); contributi di riscaldamento (°C) derivanti dalle variazioni di CO2 ("bar di CO2") e dai gas a effetto serra diversi dal CO2 (GES; bar "gas a effetto serra diversi dal CO2": ben miscelati (gas a effetto serra e ozono); and raffreddamento netto da altri conducenti antropogenici ("aerosol e uso del suolo" bar: aerosol antropogenici, martamenti nella riflettanza dovuti a Exchange i a nell'uso del suolo e nell'irrigazione, e contraglie dall'aviazione) (see figure SPM.2, pannello c, per i contributi di riscaldamento a oggi per i singoli conducenti). La migliore stima del riscaldamento osservato nel 2010-2019 rispetto al 1850-1900 (see figure SPM.2, pannello a - IPCC, 2021, p. 7) è indicata nella colonna più scura della barra "totale". I contributi di riscaldamento nel pannello b) som calcolati come spiegato nella tabella SPM.1 per la barra totale. Per le altre barre, il contribution da parte di gruppi di conducenti è calcolato con un emulatore fisico del Clio della Temperatureale globale che si basa sulla sensibilità al Clime e sulla forzatura radiativa (IPCC, 2021, pp. 13-14).

show the total warming coming from the gaseous contributions (GHGs), being the heating observed up until the moment presented in dark tones. The second columns show the warming due to emissions from carbon dioxide (CO2). The third columns highlight the global warming of the surface from non-CO2 gases emitted by GHGs, i.e. the total of the other greenhouse gases excluding the carbon dioxide emissions presented in the second column. The fourth and last column shows the projections of the potential for reducing global surface temperatures (cooling), in the case of the adoption of mitigating and adaptive political and economic medicines based on changes in relation to the typology and quantity of aerosols, as well as the way in which the soil will be used for the development of human and economic activities.

(IV) Global surface temperature changes, assessed on the basis of multiple proof elements, for selected 20-year periods (brief term, medium term and long term) to the end of the century, taking such of the five illustrative emission scenarios in WGI/AR6.

	Near term, 2021–2040		Mid-term, 2041–2060		Long term, 2081–2100	
Scenario	Best estimate (°C)	*Very likely* range (°C)	Best estimate (°C)	*Very likely* range (°C)	Best estimate (°C)	*Very likely* range (°C)
SSP1-1.9	1.5	1.2 to 1.7	1.6	1.2 to 2.0	1.4	1.0 to 1.8
SSP1-2.6	1.5	1.2 to 1.8	1.7	1.3 to 2.2	1.8	1.3 to 2.4
SSP2-4.5	1.5	1.2 to 1.8	2.0	1.6 to 2.5	2.7	2.1 to 3.5
SSP3-7.0	1.5	1.2 to 1.8	2.1	1.7 to 2.6	3.6	2.8 to 4.6
SSP5-8.5	1.6	1.3 to 1.9	2.4	1.9 to 3.0	4.4	3.3 to 5.7

Source: Sintesi per i politici (IPCC, 2021, pp. 13-14).
Available all'indirizzo: IPCC_AR6_WGI_SPM_final.pdf

Graphic IV presents estimates of changes in global surface temperature, evaluated on the basis of multiple lines of evidence and compared to the average global surface temperature of the period 1850-1900, the projections were grouped over periods of 20 years (short-term, medium-term and long-term) until the end of the 21st century. Estimates of temperature change take into account the five future SSPs of emissions presented in the special report of the WGI AR6. According to the projections we will overcome global warming by 2°C already in a medium-term context, between the years 2041-2060, which is very likely to happen due to the socioeconomic scenario of emissions used for this projection (SSP3-7.0).

This new context of global warming and increase of surface temperature is a finding, the change of the Earth's climate has been intensifying and extreme critical events are increasingly frequent, with greater intensity and with more serious consequences for humanity. Since AR5 (IPCC, 2014) the IPCC together with the United Nations presents these projections for the 21st century and the IPCC WGI Report (2021) the scenario is even more worrying. According to the report, many of these changes are irreversible over hundreds of thousands of years, and note the need for strong reductions in GHGs to limit global warming. Action that would bring benefits to air quality quickly, however, in relation to stabilization of global temperatures would take from 20 to 30 years and its effects would be felt only in a medium term (IPCC, 2021).

This new climate context that we are in shows projections of even hotter and drier periods, with longer duration and a smaller number of cold days and nights in the course of the year. With prolonged periods of hot days and nights, the heat waves will be more frequent and have directly impacted the rainfall and relative humidity rates, which in turn impacts on crop development and agriculture. There will also be regions in which rainfall will be intense, causing extreme events such as flooding, flooding, tropical cyclones, landslides, among others. Or even, the relative humidity of the air will be high, which will imply directly in the regulation of the sensation of thermal comfort of the human body and in its capacity for maintaining homeostasis.

1.2 Green Deal principale dell'ultimo decennio

In this specific topic of literature produced by the United Nations, using as its sources official documents produced after the various global discussions held at conferences and climate summits, the aim is to identify the main policies, guidelines, tools and methodologies developed in the last decade that aim to: a) promote global sustainable development; b) mitigate GHG emissions; c) adapt the existing infrastructure to reduce the impact of the effects of climate change. As a result of this stage, the construction of a summary framework with the main policies identified in the course of the literary revision that have a direct hit to the built environment. Analyzing these documents provides the contextualization of the concepts related to the theme and facilitating the understanding of the construction of the theoretical foundation and historical evolution related to climate changes inserted in the social, political and climatic conjuncture of the time.

As previously cited, climate-related studies gained notoriety in the early 20th century, the social context in that post-great war period was marked by conflict and socio-economic inequalities. After this great conflict emerged the need to create a regulatory body capable of managing the individual interests of each Nation in a holistic way, favoring the common good and guaranteeing basic rights to the global population. It was then, through the promulgation of the treaty of the Charter of Nations[49] (1945) that the United Nations (UN) was created, with the commitment to take, collectively, measures capable of promoting human development, defending its basic rights, respect for fundamental freedoms, ensuring peace and international security among the Nations in a peaceful manner.

Since then the UN has played an important role in developing relations and promoting international cooperation to solve problems not only in the social context, but also in mitigating global socio-economic inequalities, encouraging the development of integration policies and international rights, as well as cooperation between nations to promote sustainable development. In 1950, the United Nations created the *World Meteorological Organization* (WMO), replacing the first non-governmental climate monitoring organization, the *International Meteorological Organization* (IMO), founded in 1873, with the main objetive of monitoring the global climate, disseminating information and promoting research on climatology, atmospheric sciences, hydrology and geophysics. The establishment of this specialized agency has led to the patronization of concepts, the integration of studies and the transparency of information on the subject.

In the 1970s, concern about the human impact on the environment triggered several discussions on the subject, leading to the creation of non-governmental organizations (NGOs) and the founding of the first green political parties in Europe. In 1972, a major world conference was

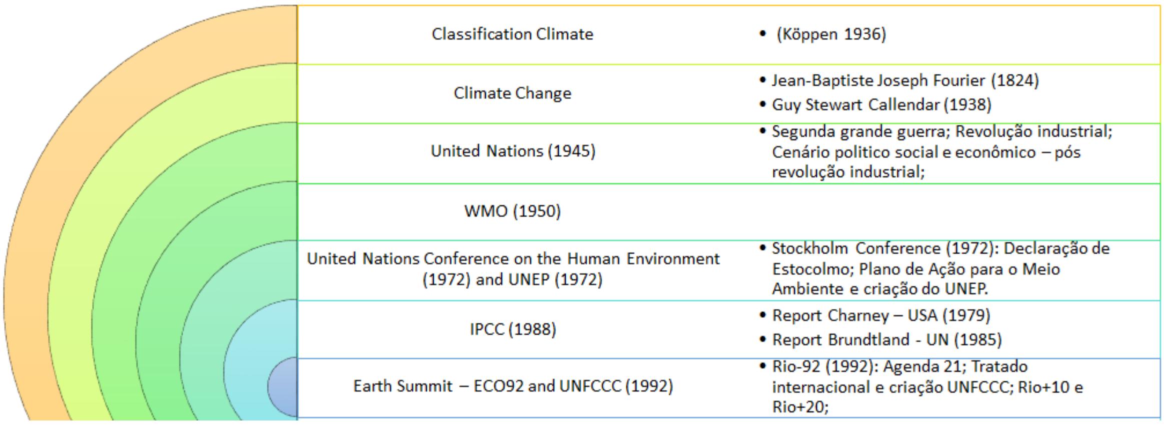
[49] Charter of the United Nations: Statute of the International Court of Justice. Available at: https://treaties.un.org/doc/publication/ctc/uncharter.pdf

held in Stockholm, *United Nations Conference on the Human Environment*. The Stockholm Conference was a milestone not only in its historical context, as it was the first major meeting between the UN and the UN, but mainly for promoting discussion on climate issues, environmental degradation and encouraging sustainable economic development. The meeting culminated in the creation of the *United Nations Environment Program* (UNEP) in the same year (1972) with the aim of coordinating joint international actions to protect the environment. In 1979, the Charney Report (Carbon dioxide and climate: A scientific assessment) was published, a comprehensive document that scientifically evaluated climate and carbon dioxide, and was one of the first publications to address the issues of global warming and climate change (National Research Council, 1979).

At the beginning of the 1980s, the UN resumed this discussion of the effects of man on the environment by setting up a special committee, called *The World Commission on Environment and Development* (WCED) in 1983, with the aim of producing a report on the problems of climate and the environment and possible proposals and strategies for sustainable development. In 1987 this report called *Report of the World Commission on Environment and Development: Our Common Future* and popularly known as *Report Brundtland* was published. At the same time, in 1985 there was the Vienna Convention in Austria, in which the parties discussed the reduction of the protection of the ozone layer and the concern about the impact of man on the worsening of this condition. The event culminated in the drafting of the Montreal Protocol also in 1987, being an international treaty in which countries pledge to reduce greenhouse gas emissions and reduce the use of chemical substances that cause damage to the ozone layer. The Montreal Protocol was ratified in London in 1999, and since then, it has periodically undergone revisions. In the late 1980s, in 1988 *The Intergovernmental Panel on Climate Change* (IPCC) was created by the *World Meteorological Organization* (WMO) and *the United Nations Environment Program* (UNEP) with the aim of being a reference source in scientific studies and production related to environmental and global climate issues. The IPCC produces and disseminates information on this topic in a clear and transparent manner through the periodic publication of climate reports and other documents related to the identification of the effects and impacts of climate change. The material is a reference in the construction of knowledge and proposals for solutions with regard to mitigation, adaptation and resilience and underpins the decision-making of governments all over the globe.

In the 1990s, driven by a period of Brazilian re-democratization, the *United Nations Conference on Environment & Development* (ECO92), popularly known as the Earth Summit, was a conference held in Rio de Janeiro in 1992, being considered a relevant milestone in the international construction of an environmental and climate policy. With a significant participation of heads of state, the event consolidated the important role of the Member States and the United Nations in tackling the environmental problems. As a result of this conference, the first sustainability agenda was drawn up, called Agenda 21, the document addresses non-environmental and climate-related aspects, but on issues related to human rights, women's causes, child welfare, health, food and nutritional security, urban development, among others. Another product resulting from the Earth Summit was the international environmental treaty signed, called the *United Nations Framework Convention on Climate Change* (UNFCCC), which addresses the impacts, risks and areas of vulnerabilities in the face of climate change. The treaty aims to limit GHGS emissions and stabilize their concentrations in the atmospheric system, as well as formalize the collective commitment between the nations to hold the Rio +10 and Rio +20 conferences and to monitor annually the environmental policies under development.

Picture 8: Chronology dell'evoluzione negli studi sul climate



Source: L'autore, 2020.

After ECO92 the environmental issues related to the effects of global warming and climate change gained increasing prominence, during the whole of the 90s important Conferences were held to foster discussion and promote joint international actions to mitigate greenhouse gas emissions. The first Conference of the Parties (COP1) was held in Berlin in 1995, playing an important role in uniting efforts to work out a global agreement with policies to mitigate greenhouse gas emissions in the atmosphere. To this end a team was responsible for developing a preliminary proposal for this document, and after negotiations and revisions to the document, as a result, in 1997 a draft of this agreement, called the Kyoto Protocol, was presented and adopted by the Parties during the third *Conference of the Parties* (COP3) held in Kyoto, Japan.

The Kyoto Protocol[50] aimed to limit and reduce global anthropogenic emissions of greenhouse gases by at least 5% relative to the global levels present in the atmosphere in the year 1990 during the years 2008 to 2012[51]. The protocol was a milestone in climate mitigation policy and entered into force in 2005, having its first meeting (CMP1) held concurrently with the eleventh Conference of the Parties (COP11)[52] in Montreal, Canada. During the COP11 the Nations recognized the seriousness of the problem of climate change, its effects on the environment and the potential risks of its impacts. This has highlighted the need not only to expand the ambition of the targets to limit and reduce the global emission of greenhouse gases, but to structure joint actions in a long-term context in the face of these changes. Already at the first meeting of the Kyoto Protocol, CMP1 (2005), the discussions concentrated on the need for renewing the commitment assumed in 1997 by the Nations beyond 2012, given the dynamics and gravity of the climate problems already at that time.

[50] UNFCCC (1997). Kyoto Protocol. Evaluable from: https://unfccc.int/cop4/resource/docs/cop3/l07a01.pdf
[51] The first commitment period of the Kyoto Protocol.
[52]UNFCCC (2005). Montreal Climate Change Conference (COP11). Evaluable from: https://unfccc.int/sites/default/files/resource/docs/2005/cop11/eng/05a01.pdf

As discussions evolved over the years and during COP18 (2012) in Doha, Qatar, the ambitions regarding the Kyoto Protocol were updated and an amendment called the *Doha Amendment* was adopted by the Parties. New commitments were made there and a new commitment period was established starting in 2013 and ending in 2020. In this second commitment period, the Parties have committed to reducing global greenhouse gas emissions by at least 18% compared to global levels in 1990. In order to promote the achievement of this new target, three market mechanisms have been developed: *Joint implementation* (JI)[53], *Clean development mechanism* (CDM)[54], andEmissions trading (ET)[55]. These mechanisms have provided the starting point for the current Carbon Market proposal.

At the same time, in the early 2000s, the British government commissioned a special report on the effects that climate change could have on the world economy. This report, *Stern Review: The Economics of Climate Change*, popularly known as *Stern Review*, was published in 2006, and opened discussions on the challenges global economies would face if responses to risks were not adopted. The report warned of the economic consequences that the Commission could have on this issue, highlighting the impacts on basic economic sectors related to human survival, such as: in the water resources sector, food production and food safety, health promotion, the environmental sector and biodiversity loss, among others. The report warned about the impacts human activities have in this context, as well as the economic and social impact in case of omission or in isolated actions that would not be able to promote sustainable global socio-economic development. These economic impacts would cost public coffers about five to 20 times more than putting in place a new economy based on intelligent energy use Stern, 2006.

With the 2008 economic recession, one of the biggest crises of the 21st century, the world economy was weakened, with high unemployment rates and millions of people below the poverty line. As a measure to mitigate economic effects, some nations have invested in new technologies based on renewable energy matrices. This decision signaled to the world a change in the economic model for the next few years, based on low carbon. Since then, the European Union (EU), together with the Member States, has been seeking in a coordinated way to support solutions and develop new technologies capable of mitigating these socio-economic impacts.

The following year, in 2009 in Copenhagen, world leaders gathered for the 15th Earth Summit (COP15/CMP5) called the *Copenhagen Climate Change Conference*. According to the UNFCCC, the meeting had wide visibility, being of great political importance for articulating the global efforts necessary to make viable the Clean Development mechanism of the Kyoto Protocol. As a result of this conference the Copenhagen[56] Agreement was produced and the document set targets to limit short-, medium- and long-term global warming for signatories. The agreement clearly expressed the intention of the parties to limit the maximum increase in the global average

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[53] Defined in Article 6 of the Kyoto Protocol.

[54] Defined in Article 12 of the Kyoto Protocol. https://cdm-unfccc-int.translate.goog/index.html?_x_tr_sl=en&_x_tr_tl=pt&_x_tr_hl=pt-BR&_x_tr_pto=sc

[55] Defined in Article 17 of the Kyoto Protocol.

[56] UNFCCC (2010). Copenhagen Accord: The Conference of the Parties at its fifteenth session. Evaluable at: https://unfccc.int/sites/default/files/resource/docs/2009/cop15/eng/11a01.pdf
https://unfccc.int/resource/docs/2009/cop15/eng/11a01.pdf#page=4

temperature to 2 degrees Celsius above pre-industrial levels as a long-term goal, emphasizing the need to limit the increase in temperature by 1.5 degrees Celsius, the safest threshold for the most vulnerable and developing countries. Since then, at each new United Nations conference held on the agenda of climate change, more visibility was gained for the environmental issue before society and with this greater popular support and more signatories were committed to the cause.

In the last decade (2011-2021) discussions have expanded and gained more and more notoriety. During this period, scientific production intensified in line with the evolution of the discussions carried out in the conventions carried out by the UN and IPCC publications. The following was a review of the specific literature of the main documents produced in this last decade with the objetive of identifying guidelines, methodologies and their respective results. As well, to identify the existence rather than climate policies directed at the urban scale and the built environment. The following table presents a summary of the main events over the years and their respective contributions to the evolution of the discussions on the topic.

Table 5: Time line of major conferences in the past decade, with their respective outcomes.

Earth Summit - ECO92 and UNFCCC (1992)	Rio-92 (1992): Agenda 21, International Treaty and creation of the UNFCCC. Commitment to Rio+10 and Rio+20
Berlin Climate Change Conference (1995)	COP1: First Conference of the Parties
Kyoto Climate Change Conference (1997)	COP3: Production of the Kyoto Protocol. Objective: to limit and reduce global anthropogenic greenhouse gas emissions by at least 5% compared to 1990 levels during the years 2008 to 2012. *The protocol only came into force in 2005.
Montreal Climate Change Conference (2005)	COP11: Discussions focused on the need to renew the commitment made in 1997 beyond 2012. The results of this meeting encouraged the drawing up of the Stern Review. In conjunction with the COP11 occurred the first meeting of the Kyoto Protocol - CPM1.
The Economics of Climate Change (2006)	British economist's report on the economic impacts of climate change on the global economy. The report warned of the impacts that human activities bring about in this context, as well as opening up discussions on the challenges that global economies would face if responses to the risks were not adopted.
The Fout Assessment Report AR4 IPCC (2007): Climate Change 2007: Synthesis Report and Economic Recession (2008)	AR4 IPCC 2007: Warming the climate system is unequivocal, generating increased air and ocean tempture, permafrost melting and ocean level rise. Probably due to anthropogenic GHG concentration. Economic recession of 2008: to mitigate the economic effects, there was investment in new technologies with renewable energy matrix, signaling a transition of economic model.

Copenhagen Climate Change Conference (2009) and The Global Green New Deal (2009)	COP15: The Copenhagen Accord signaled the intention of nations to limit GHG emissions as a response to climate change (short and long term). U.S. vs. China make it difficult to adopt a global agreement. The document recognizes that climate change is one of the biggest challenges and that actions must be taken to keep the global temperature rise below 2 °C. The Global New Deal: report "*Rethinking the Economic Recovery: A Global Green New Deal*" that addresses the problem of nations facing carbon dependency in their diverse economic sectors, relating global effects to current impacts.
Cancun Climate Change Conference (2010)	COP16: Stalemates in the formulation of a global climate treaty by the United States, China, Japan and India; Creation of the Green Climate Fund (GCF) financial mechanism to enable mitigation actions and climate change adaptation.
Doha Climate Change Conference (2012) of the Kyoto Protocol	COP18: *Doha Amendment Amendment.* Renewal of the Kyoto Protocol commitment period (2013-2020). They propose three market mechanisms (Joint implementation (JI), Clean development mechanism (CDM) in UN Certified Emission Reductions (CERs), Emissions trading (ET) and emission reduction units (ERUs)). Objective*:* reduce global greenhouse gas emissions by at least 18% compared to 1990 levels.
Chile Climate Change Conference (2014) and The Fifth Assessment Report AR5 IPCC (2014): Climate Change 2014: Synthesis Report	COP20: Proposed emission reduction commitments for each country (Contributions nationally certain NDCs). AR5 IPCC 2014: Human influence on the climate system is clear and is extremely likely to be the cause of warming. The temperature of the air and oceans continue to rise and the oceans absorbed more than 90% of the energy accumulated between 1971 and 2010. Between 2000 and 2010 GHS emissions were higher than in previous decades, with the energy (35%), agricultural and land use (24%) sector emitting the most. Potential impacts: food and water scarcity, increased poverty, people's need for climate immigration and coastal floods. *The construction sector accounts for 6.4%.
Paris Climate Change Conference (2015) and CMP 11, Agenda 2030 (2015)	COP21/CMP11: The Paris Agreements with the aim of limiting the increase in the global average temperature to 1,5°C, not higher than 2°C, compared to pre-industrial levels. Voluntary commitments specified in Article 4: Nationally Determined Contributions (NDCs). *The Paris Agreement comes into force in 2016. Agenda 2030: drawing up the 17 objectives for global sustainable development.
Katowice Climate Change Conference (2018)	COP24: Rules for the implementation of the Paris Agreement; National adaptation plans (NAP); Katowice

	Climate Package; PAWP, *Global Environment Facility*, funding mechanism to help developing countries meet their commitments under the conventions.
Chile/Madrid Climate Change Conference (2019) and The European Green Deal (2019)	COP25: Genre and climate change, discussion on Article 6 of the Kyoto Protocol (market and non-market mechanisms) and Losses and Damage associated with the Impacts of Climate Change (WIM). EU Green Deal: Zero EU emissions by 2050, Climate law
Glasgow Climate Change Conference (2021)	COP26
Sharm el-Sheik Climate Change Conference (2022)	COP27: November 2022

Source: L'autore, 2021; UNFCC, 2021.
Dear: https://unfccc.int/process/bodies/supreme-bodies/conference-of-the-parties-cop

1.2.1 Il New Deal Verde Globale - 2009

Thinking of an economic response to the 2008 crisis, The *Global Green New Deal* (GGND) was drawn up by *United Nations* Environment Programme (UNEP) with international collaboration based on several pre-existing documents, but mainly supported by the research commissioned by UNEP to Professor Edward Barbier of the University of Wyoming, Laramie in the USA. Research produced a final report entitled "*Rethinking the Economic Recovery: A Global Green New Deal*"[57]. This document addresses the economic problem of carbon dependency in its various sectors, relating the global effects and impacts that this economic model can generate, such as: environmental and human vulnerability, loss of biodiversity, the role of the community and global governance in this challenge. The work presents a political, economic and fiscal approach. Generally speaking, it shows the need to think about policies and regulatory means that make possible the construction of a socio-economic system based on green concepts, low carbon and on the reduction of dependence on energy from fossil sources.

The document presents two concepts of economic models, the first called "Greening" economy, which constitute the economic systems that prioritize sustainability and adopt clean energy and low-carbon processes. And the second concept, the "Brown" economy, would be the economic models based on fossil-based energies with high GHG emission rates, and therefore, unsustainable. The document foresees a set of packages and policy measures to stimulate the post-crisis economy to promote its recovery in the short term. It addresses the need for a comprehensive policy reform suggesting the reduction of subsidies to the industrial sector for operations that adopt systems based on the Brown economy, and recommends increasing tax incentives for operations that incorporate systems based on the Greening economy into their processes. The GGDN also recognizes the principle of "*common but differentiated responsibilities*", a principle that proposes mutual support between nations for this transition of economic and political models to take place in a fair and equitable manner. where the more developed countries commit themselves to supporting and assisting the less developed economies during this process.

[57] BARBIER, Edward. (2009). Rethinking the Economic Recovery: A Global Green New Deal of UNEP. Available at: https://www.cbd.int/development/doc/UNEP-global-green-new-deal.pdf

The Global Green New Deal has three general objectives.

> *"It should make a major contribution to reviving the world economy, saving and creating jobs, and protecting vulnerable groups. It should promote sustainable and inclusive growth and the achievement of the MDGs*[58]*, especially ending extreme poverty by 2015. Also, it must reduce carbon dependency and ecosystem degradation - these are key risks along a path to a sustainable world economy"* (UNEP, 2009, p. 1).

In order to achieve these goals, the Green Agreement suggests that the United Nations create national fiscal and policy policies to subsidize the investments needed to support this transition and develop new green technologies, and that it should ensure a large financial investment fund during the years 2009 and 2010 for this purpose. The subsidy would be targeted at technologies that prioritize (a) the energy efficiency of buildings; (b) the production of energy in a renewable way; and (c) a more sustainable mobility system. The document also stresses the need for investments in new technologies that promote better and higher agricultural productivity, better management of water resources and in sanitation, land use and the implementation of urban policies. (UNEP, 2009, p. 6)

The report proposes that governments invest in the *retrofit* of public buildings, as well as in the creation of programs that facilitate access to financing by society to stimulate the renovation of existing real estate stock through green initiatives applied to the climatization systems in buildings (*greening and weatherizing of buildings)*. In the first instance, the efforts would be employed in the renovation of public[59] buildings, with the objetive of achieving their energy efficiency, making possible the implantation of autonomous systems for the generation of renewable energy (*off-grid* system) and to achieve their energy autonomy. Subsequently, the document provides tax incentives for the private sector (commercial and residential) to subsidize reforms to promote the renovation of the enclosure and its insulation, and also, the installation of autonomous renewable energy generation systems and the acquisition of efficient equipment. Recommending the interconnection of autonomous energy systems with the urban network, thus making possible a better management of these resources within the context of urban energy planning. Then, at a second moment, the agreement encourages the public authorities to draw up policies and regulations in which greenhouse gas emissions are reduced to zero.

In the urban mobility sector, the document encourages the use of more energy-efficient transport, which requires less infrastructure and greater connection between the various modal types (air, rail, rail, road and water). It stresses the need to prioritize low-carbon public transport

[58] Millennium Development Goals (MDGs) Development goals set at the Millennium Summit by UN, through the Millennium Declaration published in 2000. In which nations committed themselves to combating poverty, hunger, disease, illiteracy, environmental degradation and discrimination against women. Eight development goals are being drawn up that should be achieved by 2015. Available at: http://undocs.org/A/RES/55/2

[59] To start by 2012 the renovation of existing public buildings to reduce their energy consumption by 40 percent and their GHG emissions by 50 percent. For new offices and public buildings the norm will become 50 kWh/m_/year per year from 2010.

systems through more energy-efficient vehicles, greater hybridization and electrification of the fleet, which would significantly reduce the impact that the sector generates on global emissions.

In a long-term scenario, the document recommended providing investments and credit to make possible the implementation of the principles of *Environmental Accounting* not only in the industrial sector, but also in the commercial area, through carbon pricing and the creation of a possible global carbon market. It also sought to strengthen the development of new technologies and innovations to make other renewable energy sources viable. This would make it possible to reduce the use of fossil fuel energy systems, and to prioritize smarter management systems, clean energy storage and carbon capture.

In the context of agriculture and land use, the GGND highlights the need for the development of technologies that make sustainable growth possible in the agricultural sector, which is the sector that emits the most greenhouse gases and consumes a good part of the natural resources.

> *"Farming is a politically sensitive sector that is affected by virtually the whole array of distortions discussed in this paper, including trade protectionism, perverse subsidies, wastage of water, unsustainable farming practices, and overuse of harmful chemicals"* (UNEP, 2009, p. 8)

In addition to the environmental impact, there is also the social impact on the agricultural sector, as the sector concentrates a large socially vulnerable population that uses the land lease mechanism to develop subsistence agriculture on the ground as the only means of obtaining income and survival. The document emphasizes the need to create fiscal policies that minimize this economic and social disparity, creating conditions of greater equity in the sector. The document prioritizes sustainable agricultural production, suggesting the implantation of clean energy generation technologies (*off-grid* systems) on a small scale and in rural areas. As well as this, it stimulates investments in infrastructure for the production of organic inputs, added value, storage and transportation of production. For the purpose of ensuring food and nutritional security, as well as land conservation and fresh water management (UNEP, 2009).

The GGND suggests the creation or revision of the internal environmental legislation of the Nations and the creation of financial mechanisms capable of subsidizing through incentives, the drafting of taxes and taxes, it is possible to build a new model of sustainable agriculture and fishing. Furthermore, it should prioritize the development of policies and instruments that make producers who pollute the environment responsible and cooperate significantly with their degradation, following the principle it calls in the document of *polluter pays*)[60]. This principle makes the polluter responsible for the environmental damage caused, which in this case is the offender and not the user of a service with a high environmental impact. Also within this context, the document cites, in a referential manner, environmental incentives and taxes that favor companies, products and services that in their productive chain use the concepts of green and sustainability. For example, it

[60] EUROPEAN COMMISSION. The treaty on the functioning of the European Union. Article 191 TFEU 2012. Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:12012E/TXT&from=EN#page86

fosters the need to promote (a) a green tax reform, through the relief of economic and consumer goods that have a low environmental impact; (b) the regulation of the use of vehicles through the allocation of taxes on fuel, vehicles and roads; (c) tax incentives for fleet renewal with low fuel consumption; and (d) investments in public transport infrastructure both motorized and non-motorized. Strengthening the obligation to reformulate or develop clear legislation on land use, title to property, urban planning policies and the right to use and manage fresh water.

In short, the GGND proposed a set of actions, mostly with an economic focus, to leverage the post-recession economic system in a short period of time. With proposals grounded by the central concept of global socio-economic sustainability, underlining the need for a broad discussion to enable more ambitious targets within a medium and long term time context. It emphasizes that the success of the proposed plan would only be achieved, mainly through a strong political articulation and through the commitment of all the parties involved. It proposes a transparent international relationship with the dissemination of periodic and internationally standardized data and information, thus facilitating the monitoring of results. The document served to assist governments in making decisions to promote sustainable development and technology transfer between nations.

1.2.2 Agenda 2030 per lo sviluppo sostenibile - 2015

By recognizing that 70% of the world's population will live in urban centers by 2050, the 2030 Agenda for Sustainable Development set out to foster discussions on the various dynamics existing between the urban system and sustainable development. The text reinforces the need for joint and international collaboration between developed and least developed nations, to promote through technical and financial assistance the construction of a more resilient, inclusive, safe and sustainable society. Strengthening these relations is a key factor in achieving the Sustainable Development Goals (SDGs) proposed in this Agenda.

The 2030[61] Agenda for Sustainable Development, in which it sets objectives, was built at the United Nations General Assembly on the basis of discussions in recent years, referring to work carried out on the mitigation of inequalities, economic, institutional, environmental issues and social vulnerabilities. The Millennium Summit conference organized by the UN in New York in 2000 was the starting point for strengthening the construction of these common goals, two elaborate eight Millennium Development Goals (MDGs), described in the Millennium Declaration, which were to be achieved worldwide by 2015. Agenda 2030 published in 2015 was drawn up on the basis of these eight objectives described in the year 2000, but with the

[61]United Nations. 2030 Agenda for Sustainable Development. Available from: https://sdgs.un.org/2030agenda

https://www.un.org/ga/search/view_doc.asp?symbol=A/RES/70/1&Lang=E

inclusion of new interconnected targets aimed at promoting sustainable development for the period after 2015 (the year in which the deadline for the implementation of the millennium goals would expire). In a participatory manner, Agenda 2030 was drawn up and its final version describes seventeen Sustainable Development Goals (SDGs). In which, each objetive correlates with a given problem within the axes: economic, social, institutional and environmental. Agenda 2030 has more ambitious targets, which should be achieved globally by 2030.

The goals are related to promoting people's quality of life, promoting peace, health, sustainable global development, reducing vulnerabilities, climate mitigation, ensuring the most vulnerable population access to clean energy, education, drinking water and sanitation, food and nutritional security, and actions related to human rights. The objectives set out in Agenda 2030 (2015)are:

_Objective 1. End poverty in all its forms everywhere;

_Objective 2. ending hunger, achieving food security and improving nutrition and promoting sustainable agriculture;

_Goal 3. Ensure a healthy life and promote well-being for all at all ages;

_Goal 4. Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all;

_Goal 5. achieving gender equality and empowering all women and girls;

_Goal 6. ensure the availability and sustainable management of water and sanitation for all;

_Goal 7. Ensure access to affordable, reliable, sustainable and modern energy for all;

_Goal 8. promoting sustainable, inclusive and sustainable economic growth, full and productive employment and decent work for all;

_Goal 9. building resilient infrastructure, promoting inclusive and sustainable industrialization and fostering innovation;

_Goal 10. Reduce inequality within and between countries;

_Goal 11. Make cities and human settlements inclusive, safe, resilient and sustainable;

_Goal 12. ensure sustainable consumption and production patterns;

_Goal 13. take urgent measures to combat climate change and its impacts;

_Goal 14. to conserve and sustainably use the oceans, seas and marine resources for sustainable development;

_Goal 15. protect, restore and promote the sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, halt and reverse land degradation and halt biodiversity loss;

_Goal 16. promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable and inclusive institutions at all levels;

_Goal 17. Strengthen the means of implementation and revitalize the global partnership for sustainable development;

Among all the objectives proposed in Agenda 2030 (2015), we highlight eight objectives that are directly related to the construction sector, the built environment and the urban scale, are:

- Plan in a territorial context food distribution centers in strategic places of the urban network, prioritizing smaller distances and greater modal interconnection.
- Urban community gardens

- Air quality inside buildings
- Thermal comfort and natural ventilation for air renewal;
- environmental quality of the built environment (healthy housing);
- provide for green areas;

- Cities 100% saned;
- Building water management (automation and saving devices);
- reuse of non-potable and rain water;

- installation of clean energy systems and interconnection of the private network with the public network for better management of the energy produced;
- energy efficiency in the building (orientation, thermal properties, watertight, among others);
- Specification of high efficiency equipment;

- Develop new low-carbon technologies throughout the building production chain.
- Logistics;
- Assess the lifecycle of the building (embedded and operational) by prioritizing concepts of circular economy;

- Identification of the effects, impacts arising from climate change and analyze the risks and opportunities for each impact producing an individualized response planning for each identified risk.
- In the event of disasters, provide for a contingency plan to ensure the resilience of installations vital for human survival.

- Nearly zero-emission building (NZEB);
- housing density in areas of good infrastructure (physical, modal, service, outpatient and sanitary);

- Identification of the effects, impacts arising from climate change and analyze the risks and opportunities for each impact producing an individualized response planning for each identified risk;
- energy efficiency in the building (orientation, thermal properties, watertight, among others);
- Air quality inside buildings
- Thermal Comfort and Natural Ventilation for Air Renewal

Source: L'autore, 2021.

Among the goals, object eleven describes specific guidelines for making cities and settlements human. The chapter presents guidelines for sustainable cities and communities, capable of strengthening the development of infrastructure interconnected with environmental and social concerns. In this way, the Agenda prescribes the importance of joint efforts for city consolidation and more inclusive, safe, resilient and sustainable settlements (NATIONS, United, 2015).

The agenda states that by 2030, nations must guarantee their populations access to decent, safe and affordable housing. In order for the houses to have environmental quality, they reinforce the concern for access to basic services with water, sewage and electricity. They also define the importance of developing plans to improve the areas of slums[62], renovating and restructuring these communities (NATIONS, United, 2015, p. 21).

In the next step, he addresses the issue of access to high-quality and sustainable public transport. Therefore, ensure the expansion of the transport network, paving of roads and access routes to public transport, with special attention to the needs of the most vulnerable sections of the population, such as women, children, people with disabilities and the elderly. These measures aim to reduce inequalities in the right to locomotion within national territories, prioritizing those who have difficulty of access (NATIONS, United, 2015, p. 21).

Also on the theme, to provide the development of an inclusive and sustainable urbanization, integrating the communities in the elaboration and management within the context of urban planning policies in all countries. In this sense, there is a quest to democratize the process of urban planning, bringing to it a participatory character, making the community protagonist in the construction of its own city (NATIONS, United, 2015, p. 21).

Despite efforts to promote regional development within nations, action must be taken to protect and safeguard the cultural and natural heritage of countries with a view to ensuring a sustainable environment and the maintenance of the cultural identity of certain peoples (NATIONS, United, 2015, p. 22).

When dealing with the aspects of natural disasters and public calamities, the Agenda recommends the importance of controlling losses in these atypical events by means of actions of predictability and thus significantly reduce the number of deaths and of people affected by these phenomena of a local or even global order. In this way, reduce economic damage with water-

[62] OXFORD dictionary. (2009). Slums: urban area characterized by precarious housing and generally loss-making urbanization infrastructure

related losses, focusing on the protection of the poorest and vulnerable people. This guideline is extremely necessary to guarantee protection for the life and heritage of those most in need who are the main losers in these types of disasters and calamities (NATIONS, United, 2015, p. 22).

The Agenda seeks commitments arising from the adverse per capita environmental impact of cities, with particular attention to air pollution and waste management. The reality of the large global megalopolises with low air quality is a concern increasingly present in the tariffs of sustainable cities, as well as the proper handling of the production of waste that increasingly occupies large spaces in the territory for sanitary landfills. Thus, the reduction in daily waste production per capita should be targeted for by 2030 (NATIONS, United, 2015, p. 22).

By 2030 provide easy access to safe and inclusive public green spaces, in particular for women, children, the elderly and people with disabilities. Free access to public spaces where people can enjoy a balanced environment has also been established as one of the priority goals of Agenda 2030, as access to nature must be universal and an important element of guaranteeing human dignity (NATIONS, United, 2015, p. 22).

The implementation of a positive economic (item 11.a), social and environmental support, establishing links between urban, peri-urban and rural areas for a national and regional strengthening through this deepening in the development strategy and planning of these spaces mutually necessary for the concreteness of a broad structure of the nations (NATIONS, United, 2015, p. 22).

The specific point (item 11.b) establishes that by 2020 the number of cities and human settlements should be substantially increased by adopting the strategy of implementing integrated policies and plans, which together seek the inclusive environment, with efficiency of natural resources, mitigation and adaptation to climate change and promotion of resilience to natural disasters. Prioritizes further that nations develop and implement the disaster risk reduction guidelines (2015-2030) outlined in the Sendai Framework[63], with the goal of holistically managing the various levels of national disaster risk (NATIONS, United, 2015, p. 22).

Supporting the least developed nations (item 11.c) through technical and financial assistance to stimulate sustainable and resilient construction by prioritizing the use of local national materials (NATIONS, United, 2015, p. 22).

To monitor and control the progress of the implementation of the SDGs, global indicators were created for each goal within the overall objective. For the construction of inclusive, safe, resilient and inclusive cities and human settlement the indicators used are:

[63] Sendai Framework for disaster risk reduction (2015-2030): outlines seven clear goals and four priorities for action to prevent new disaster risks and reduce existing ones: (i) Understanding disaster risk; (ii) Strengthening disaster risk governance to manage disaster risk; (iii) Investing in disaster reduction for resilience; and (iv) Improving disaster preparedness for effective response and "Rebuilding Better" for recovery, rehabilitation and reconstruction. Evaluable from: https://www.preventionweb.net/files/43291_sendaiframeworkfordrren.pdf

Table 6: Global indicator framework for the 2030 Agenda for Sustainable Development goals and targets.

GOAL	INDICATOR
11.1	11.1.1: Proportion of urban population living in precarious settlements, informal settlements or inadequate households;
11.2	11.2.1: Proportion of population having adequate access to public transport, by gender, age and persons with disabilities.
11.3	11.3.1: Reason for the rate of land consumption and the rate of population growth. 11.3.2: Proportion of cities with a structure of direct participation of civil society in urban planning and management that operates in a regular and democratic manner.
11.4	11.4.1: Total expenditure (public and private) per capita is spent on the preservation, protection and conservation of all cultural and natural heritage, by type of heritage (cultural, natural, mixed and designated World Heritage Center), level of government (national, regional and local), type of expenditure (current/investment expenditure) and type of private funding (donations in kind, non-profit private sector and sponsorship).
11.5	11.5.1: Number of deaths, missing persons and persons directly affected attributed to disasters per 100 thousand inhabitants. 11.5.2: Direct economic losses in relation to GDP, including damage caused by critical infrastructure disasters and disruption of basic services.
11.6	11.6.1: Proportion of municipal solid waste regularly collected and with adequate final destination in the total municipal solid waste generated, by cities. 11.6.2: Average annual level of inhalable particles (e.g. with a diameter of less than 2,5 µm and 10 µm) in cities (weighted population).
7/11	11.7.1: Proportion of the built-up area cities which is open public space for use by all, by gender, age and people with disabilities. 11.7.2: Proportion of the population subjected to physical or sexual harassment, by sex, age group, persons with disabilities and place of occurrence, in the last 12 months.
11th	11.a.1: Proportion of population residing in cities implementing urban and regional development plans that include population projections and resource assessment, by city size.
11.b	11.b.1: Number of countries adopting and implementing national disaster risk reduction strategies in line with the Sendai Framework for Disaster Risk Reduction 2015-2030. 11.b.2: Proportion of local governments adopting and implementing local disaster risk reduction strategies in line with national disaster risk reduction strategies.

Source: NATIONS, United, (2018).

1.2.3 The Paris Agreement - 2015

Concurrently with Agenda 2030, The Paris Agreement is a climate agreement signed between the Parties in 2015 during the COP21[64] (United Nations Framework Convention on Climate Change (UNFCCC)) held in Paris as a result of the discussions on global warming and the need to limit greenhouse gas emissions. In short, the current agreement recognizes the urgency of the climate issue and its irreversible potential for society and the planet. It highlights the need for a drastic reduction in global greenhouse gas [65](GHG) emissions within a short, medium and long-term context. The agreement highlights, with great concern, the need to create joint public policies and guidelines to elaborate strategies, control tools and innovations to mitigate and limit the emissions that generate this effect. Likewise, the need to provision a financial mechanism to support the development of new technologies, as well as promoting international cooperation to disseminate the actions and good practices that can be replicated.

The construction of the Paris Agreement originated with the Kyoto Protocol. According to the UNFCC The Kyoto Protocol, which remained open for signature for one year (from March 16, 1998 to March 15, 1999) and obtained 83 signatures and 192 participants[66], aimed at a series of objectives that among them in its Article 03, was to reduce the total emissions of greenhouse gases to a level higher, and not less than 5%, comparing to the levels observed in 1990. This was the target for the first commitment period (CP1[67]) which corresponded from 2008 to 2012. The Protocol entered into force only in February 2005, following the instruments specified in its Article 23. Unfortunately, not all the Parties have ratified their contributions to meeting the *Kyoto Protocol* target, until the date of the elaboration and signing of The Paris Agreement. For this reason the *Doha Amendment* established for the Parties a second commitment period (CP2)[68], from 2013 until 2020. Thus, the targets were updated by expanding the initial ambition of 5%, for CP2 the reduction of greenhouse gas emissions should reach 18% when compared to the levels observed in 1990 until 2020[69].

The new commitment period has created a certain global pressure for a global agreement to cap emissions. Thus, upon completion of the work of COP21, the Paris Agreement was signed and remained open for signature in New York (USA) during the period from 22 April 2016 to 21 April 2017. The agreement also highlights the urgency of speeding up the implementation of the amendment The *Doha Amendment to the Kyoto Protocol* published in 2012 with the aim of extending the pre-2020 ambition and mitigating the impacts of climate change. And the signatories made a global commitment to mitigate their respective emissions to limit:

> '*Holding the increase in the global average temperature to well below 2°C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5°C above pre-*

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[64] COP: Conference of the Parties - United Nations Framework Convention on Climate Change (UNFCCC);
[65] Greenhouse gases (GHG).
[66] UNFCCC (1997). Kyoto Protocol. 11 December 1997 Available at: https://treaties.un.org/Pages/ViewDetails.aspx?src=TREATY&mtdsg_no=XXVII-7-a&chapter=27&clang=_en
[67] CP1: First commitment period - Doha amendment to the Kyoto protocol (2012).
[68] CP2: Secund Commitment period - Doha amendment to the Kyoto protocol (2012).
[69] The Doha Amendment entered into force only in December 2020, with the accession of 147 nations.

> *industrial levels, recognizing that this would significantly reduce the risks and impacts of climate change* (NATIONS, United, 2015, p. 3).

The Paris Agreement[70] emphasizes the need for more ambitious and concrete actions to address the issue of climate change, highlighting the importance of joint international cooperation to achieve "climate justice" and the eradication of poverty. With long-term goals the Agreement provides: to reduce global emissions of greenhouse gases to mitigate global warming and limit global average temperature to 1.5 degrees Celsius, and not higher than 2°C, compared to pre-industrial[71] levels. This would ensure the least impact for the most vulnerable communities. The document addresses the mitigation and adaptation capacity of nations in the face of climate change and encourages the promotion of the resilience of sectors in the face of climate (NATIONS, United, 2015).

Emphasizes the need to promote consistent funding to make the transition to a low-carbon economy viable, mainly by supporting developing countries in this endeavor through financial subsidies and technology transfer to strengthen resilience. It is agreed that the signatory Parties shall elaborate and communicate their national targets and contributions to the fulfillment of the global goal (as per Articles 4, 7, 9, 10, 11 and 13) through their respective National Climate Adaptation Plan (NAP). Highlighting the need to draw up an innovative action plan, which reflects its greatest possible ambition, with targets that fall under the threshold of 2 degrees Celsius with a reduction of 40 gigatons. The Parties agreed to review their ambitions, on a periodic basis every five years, of their respective plans. In line with the overall commitments of the Parties (NATIONS, United, 2015, pp. 03 - Art.02), which is to reduce global warming.

The National Adaptation Plan (NAP) is a plan drawn up by national governments that analyzes the current and future climatic risks that their country is facing. It is possible through this process to identify and prioritize which national adaptation actions and strategies can be adopted for a short, medium and long term period. The nationally determined contributions (NDCs), as their name suggests, are the intended contributions that each Nation has committed to reducing GHG emissions in its country, being presented to the UNFCCC during COP21. The NDCs must be updated every five years, and the UNFCCC monitors whether the contributions proposed by the Nations are consistent with the goals of the Paris Agreement.

The agreement also provides that developed economies must commit to reducing GHG emissions absolutely. They also recognize the need to support developing countries and the most vulnerable communities in their respective national contributions so that they are effectively implemented. In the first instance, for these developing nations the transition to a sustainable economy would take place gradually, initially by intensifying mitigatory actions capable of reducing emissions and leading to a scenario of limitation. The document highlights that the targets set in the NDCs should be achieved through the transition between anthropogenic emissions by

[70]UNFCCC (2015). The Paris Argements. Available at: https://unfccc.int/files/essential_background/convention/application/pdf/english_paris_agreement.pdf
[71]Pre-industrial period: 1850-1900

emissions from renewable sources, in addition to expanding the removal of GHGs through sinks by 2050 (NATIONS, United, 2015).

A criticism related to the Paris Agreement is the methodology used to define the time frame of the pre-industrial period, such as the level of comparison with the targets proposed by the Nations. The criterion is that the treaty does not specify what are the pre-industrial levels used in the elaboration of the methodology that defined the projections and targets. Due to the lack of a clear definition, the Agreement adopted the period from 1850 to the 1900s as a time frame. However, he disregarded the previous period, between the years 1700 to 1800, a period in which there was a greater contribution from anthropogenic sources of greenhouse gases (Schurer, Mann, Hawkins, Tett, & Hegerl, 2017)[72]. Also according to the same author, the clear definition of the period called pre-industrial used in the methodology as a benchmark for comparison is of paramount importance for there to be a standardization between methodologies and concepts used by researchers and signatory nations. Further arguing that this action would facilitate the recording, evaluation, control and management of data and comparison between the methodologies of the plans and targets established by the Parties in their respective NDCs.

At the time, another point that generated a lot of disagreement was with regard to Article 06 of this agreement, which deals with the policy of international carbon markets. The central idea of these markets, established in Article 17 of the Kyoto Protocol, is that countries with less ambitious guidelines in their NDCs, which have not yet reached the commitment assumed in this Paris Agreement, could complement their contributions and achieve their commitments through the international purchase of "carbon reduction credits". Credits are from other countries that: a) have promptly achieved their commitment due to a more efficient and ambitious domestic policy; b) have emissions allowed but have not been "used"; c) have their commitment period reserves exceeding 90% of the value assigned by the Nation and continue reducing their domestic emissions generating "negative" emissions values. The regulation of this carbon market initially proposed in the Kyoto Protocol would function as a new commodity, a tool regarded by many as promising, with real power of contribution for the mitigation of the effects of global warming and its climatic impacts projected for the next few years.

The advance of this discussion culminated on two fronts, the first relating to market mechanisms and the second with a non-market approach that encompasses any mechanism of political, fiscal and social cooperation correlated with climate problems. Both mechanisms must be seen as part of the solution to the climate scenario that we are in, and it is extremely necessary to create more ambitious commitments to reach the NDCs assumed to limit global warming.

1.2.4 The Green Deal Europe - 2019

Following the Paris Agreement and the publication of the IPCC's special report on the impacts of global warming, concern has intensified over the growing emission of GHGs and the

[72] Schurer, A. P., Mann, M. E., Hawkins, E., Tett, S. F. B., & Hegerl, G. C. (2017). Importance of the pre-industrial baseline for likelihood of exceeding Paris goals Nature Climate Change, 7(8), 563-567. https://doi.org/10.1038/nclimate3345https://www.nature.com/articles/nclimate3345.pdf

threats that climate change would bring to our ecosystem system. In order to confirm the European commitment to this cause and establish a clear vision of how to make this trajectory, the European Commission (EC) proposed through the pact called A Clean Planet for All (2018)[73], to define this vision in a long-term and spoiled way to achieve climate neutrality by 2050. The document presents a number of directives relating to the EU's economic, climate and energy modernization. The document addresses a set of seven strategic axes to guide this transition. These are:

1. Maximize the benefits of energy efficiency, including zero emission buildings. Since today they are responsible for 40% of the energy consumption (COMMISSION, European, 2018);
2. Implement a renewable energy system, improving the security of energy supply. Since oil and gas imports in 2018 accounted for about 55% of demand, which would also impact on geopolitics; promote the decarbonization of other sectors such as transport and industry through the production of electronic fuels by electrolysis, such as the increase of hydrogen, biomass and renewable synthetic gas (COMMISSION, European, 2018);
3. Maximize the benefits of clean, safe and connected mobility, as transportation accounts for a quarter of GHG emissions in the EU (COMMISSION, European, 2018);
4. Deploying a competitive industry with a circular economy as a key facilitator for this transition (COMMISSION, European, 2018);
5. Develop an appropriate, interconnected intelligent network infrastructure, developing a power transmission and distribution landscape for the future (COMMISSION, European, 2018);
6. Creating carbon sinks and developing alternatives to reap the benefits of the bioeconomy (COMMISSION, European, 2018);

The European Commission has therefore proposed an agreement between the EU's constituent countries, called The European Green Deal (2019)[74], to strengthen the bloc's commitment to these issues. This document, like the previous ones, highlights the concern about current climate changes and the conservation of existing natural resources. The initial proposal put forward proposes a set of policies and strategies to contain climate threats with the aim of promoting equitable and prosperous development in the European Union. Aiming to achieve, beyond the welfare of society, to:

> "*transform the EU into a fair and prosperous society, with a modern, resource-efficient and competitive economy where there are no net emissions of greenhouse gases in 2050 and where economic growth is decoupled from resource use* (COMMISSION, European, 2019, p. 2).

[73] EUROPEAN COMMISSION.A Clean Planet for all - A European strategic long-term vision for a prosperous, modern, competitive and climate neutral economy. COM (2018) 773. Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52018DC0773&from=EN

[74] (COMMISSION, European, 2019). The European Green Deal. Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52019DC0640&from=EN

The agreement adopted in January 2020 by the European Parliament recognizes the challenge of reducing carbon dioxide emissions, and reinforces the idea that concrete results are needed for effective change, which will only be achieved through joint international and inclusive actions. The main actors for the promotion of this ambitious transformation, among so many others, are founded on three basic pillars, are: society, public initiative and private capital. The Roadmap also addresses the concerns and commitments of the European Commission to combat, adopt and implement all necessary climate and environmental measures described in the SDGs of The 2030 Agenda for Sustainable Development[75] published by the United Nations in 2015. The aim of the pact is to promote sustainable development of the bloc, to reduce at least 50% of emissions by 2030, to fulfill the commitments made in The Paris Agreement and to make the European continent the first with Climate Neutrality by 2050.

The bloc proposes to re-endorse and introduce new policies and legislation, prioritizing a circular and innovative economy to give transparency and predictability to investors and society at large. The document reinforces the concern that other international partners agree with this same ambition, so that there is an engagement of all Member States, otherwise all the effort to fulfill their commitments with The Paris Agreement related to the global reduction of emission and maintenance of the global terrestrial temperature below 2°C will not be achieved. Among the strategies and policies suggested to guide this process of socio-economic transformation are: a) the commitment to zero pollution; b) preserving and restoring ecosystems and biodiversity; c) promoting sustainable and intelligent mobility (Smarter transport); d) ensuring access to high-quality food; e) clean energy; f) financial sustainability; g) industrial sustainability; h) promoting a constructive and retraining process based on sustainable methods.

The proposal also emphasizes the need to decarbonize the energy sector, which is responsible for 75% of the EU's greenhouse gas emissions, both on the scale of production and on the scale of consumption. Coal should be unlimited, fossil fuel sources should be avoided and decarbonization of the gas sector should be encouraged. Against this backdrop, priority should always be given to clean and renewable energy sources, as well as demanding the energy efficiency of all systems. The document deals with the importance of combating energy poverty, making a transition to clean energy systems in an affordable and fair manner. Through an intelligent infrastructure and funding programs for its renewal.

According to the published agreement, the industrial sector needs to be renewed, the linear process and the dependence on raw materials causes an impact of more than 90% of the loss of biodiversity and water resources. This is why the entire production chain needs to be restructured through a circular economy, with low solid waste production, low GHG emissions and with the creation of incentives for the use of raw materials of renewable origin, the reuse of discarded materials and when their recycling is not feasible. Automation and the inclusion of new digital technologies are of paramount importance for transforming the entire value chain, as well as promoting decarbonization and modernization of the sector. The design of an integrated market for products from secondary raw materials with recycled components, by-products and reuse of

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[75] (NATIONS, United, 2015). A/RES/70/1. The 2030 Agenda for Sustainable Development. Available at: https://www.un.org/ga/search/view_doc.asp?symbol=A/RES/70/1&Lang=E and publication Available at: https://sustainabledevelopment.un.org/post2015/transformingourworld/publication.

second-hand materials should be provisioned. This transition is expected to lead to the creation of "green jobs" (COMMISSION, European, 2018) in the sector, as well as in the construction, agriculture and forestry and energy sectors. However, it is known that other fossil fuel-based economic sectors must decline and these industries will have to transform themselves, such as: coal mining; oil and gas exploration; the steel, cement, chemical, automobile and fertilizer industries.

Among the various economic sectors, efforts are concentrated on the industrial sectors that contribute most to this impact, directly or indirectly, with the emission of greenhouse gases. They are: the textile sector, the transport sector, the electronics market, the plastics and packaging industry and the construction industry. According to the Green Deal European:

> *"(...) buildings account for 40% of energy consumption. At present, the annual renewal rate for the* building stock varies between 0.4% and 1.2% in the Member States. (COMMISSION, European, 2019, p. 10)"

The agreement reaffirms the commitment of the European Union to finance this economic transition through the InvestEU[76] program lasting from 2021 to 2027. And it is committed to the creation and revision of laws and public policies linked to: a) buildings and renovations of buildings with a focus on energy efficiency (*building and renovating in an energy and resouse efficient way*); b) the generation of clean and safe energy, with affordable preactions (*Affordable secure energy*) and based on the principles of circular economy (*circular economy*). It also ratifies its commitment to the construction and renovation of the existing building stock, since its energy consumption and natural resources are high, as well as its greenhouse gas emissions. The document provides as a mitigating strategy a proposal to rigorously apply legislation related to the energy performance of buildings, to develop the Emission Trading System, as well as to revise the Construction[77] Products Regulation. And recognizes that this topic needs to be widely discussed, to ensure that new buildings and the process of renovating the housing stock are in line with the guidelines of the circular economy, especially in buildings that have social, school and hospital interests.

The agreement states that the transport sector, made up of its various modal types (road, rail, air and water), is responsible for 75% of greenhouse gas emissions, and a 90% reduction in these emissions is necessary to achieve the climate neutrality that the European Union is aiming for by 2050. The transport sector is a strategic sector within the proposed discussion and the transition from the current model to an integrated and sustainable mobility model needs to be accelerated.

According to the document, multimodal mobility needs to be encouraged, the user should be the central pillar of this discussion and the flow of production should be encouraged by waterways (water and sea) and by rail lines. Public transport services need to be interconnected, automated and low-carbon. It also stresses the importance of financing instruments and investments in intelligent traffic management systems and the digitization of the sector, with the

[76] I Invest. Evaluable at: Home (europa.eu)
[77] EUROPEAN COMMISSION. Regulation (EU) No 305/2011 laying down harmonized conditions for the marketing of construction products and repealing Council Directive 89/106/EEC. Available at: EUR-Lex 32011R0305 EN EUR-Lex (europa.eu) and EUR-Lex - 02011R0305-20210716 - EN - EUR-Lex (europa.eu)

aim of reducing congestion and air pollution mainly in urban centers. The production and use of alternative fuels as well as the use of low emission vehicles should be prioritized. It is essential to adopt measures to make it possible to finance the replacement of the fleet and the establishment of the infrastructure needed to supply this market.

With regard to food and nutritional security, the Agreement provides for actions to improve the sustainability of the food system, the fight against food waste and nutritional security. It encourages the implementation of sustainable practices applied throughout the production process, in animal welfare, in soil and nutrient management and in water management. The preservation and restoration of ecosystems and biodiversity need to be protected by legislative and regulatory measures, reaffirming the commitment to combating deforestation, biological diversity in rural areas, in urban, maritime and permanent environmental protection areas (afforestation and sustainable reforestation (blue economy)).

Throughout 2020[78], the European Commission published laws, guidelines and strategic plans to enable this economic transition to the desired climate neutrality. Among them, we can cite for example in:

- January 2020: European Green Deal Investment Plan 79 and The Just Transition Mechanism
- March 2020: public consultation on the proposal of The European Green Deal, draft European climate law[80] and the strategic plans European Industrial Strategy[81] and Circular Economy Action Plan[82];
- May 2020: Farm to Fork[83] Strategy to promote a food system and the presentation of the EU Biodiversity Strategy for 2030[84];
- July 2020: EU Strategy for energy system integration and hydrogen[85], with the aim of decarbonizing the energy sector;
- September 2020: presentation of the 2030 Climate Target Plan (Climate Goal Plan 2030)[86];

[78] EUROPEAN COMMISSION. The European Green Deal. Available at: https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal_pt

[79] EUROPEAN COMMISSION. European Green Deal Investment Plan. Available at: https://ec.europa.eu/commission/presscorner/detail/en/ip_20_17

[80] EUROPEAN COMMISSION. European climate law. Available in: https://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1588581905912&uri=CELEX:52020PC0080

[81] EUROPEAN COMMISSION. European Industrial Strategy. Available at: https://ec.europa.eu/info/strategy/priorities-2019-2024/europe-fit-digital-age/european-industrial-strategy_en

[82] EUROPEAN COMMISSION. Circular Economy Action Plan. Avaiable at: https://ec.europa.eu/commission/presscorner/detail/en/fs_20_437

[83] EUROPEAN COMMISSION. Farm to Fork. Available at: https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal/actions-being-taken-eu/farm-fork_en

[84] EUROPEAN COMMISSION. EU Biodiversity Strategy for 2030. Available at: https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal/actions-being-taken-eu/eu-biodiversity-strategy-2030_en

[85] EUROPEAN COMMISSION. EU Strategy for energy system integration and hydrogen. Available at: https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal/clean-energy_en

[86] EUROPEAN COMMISSION. 2030 Climate Target Plan. Available at: https://ec.europa.eu/clima/policies/eu-climate-action/2030_ctp_en

The interesting thing about The European Green Deal (2019) is its holistic view on the issue of climate change, its direct and indirect effects and impacts on the entire European socio-economic structure. As well, the concern for a joint and coordinated action of the bloc to adapt to the current scenario through public policies, socio-economic and fiscal incentives and financing mechanisms for the promotion of new technologies and innovations.

In order to make possible the commitments signed the Agreement foresees a joint effort by the bloc to make available the necessary amount of investment, the accession of public and private institutions, as well as the accession of other Member States to this project. The report estimates annual investment to facilitate this change,

> *"To achieve the level of ambition set by the European Ecological Pact, significant investments are needed. The Commission has estimated that achieving the current climate and energy targets for 2030 will require an additional annual investment of EUR 260 million, i.e. around 1,5 % of GDP in 2018'.* (COMMISSION, European, 2019, p. 17).

The following Framework systematically lists the main sustainable guidelines addressed in the climate agreements of the last decade, related to the professional practice of designers, architects, planners and engineers and grouped according to the methodology presented.

Table 7Sintesi degli orientamenti in materia di Clima degli accordi sul Clima degli ultimi dieci anni.

	Global Green New Deal 2009	The 2030 Agenda for Sustainable Development - 2015	The Paris Agreement 2015	The European Green Deal 2019
Climate Change	•	• Mitigate GHG emissions	• Recognizes the urgency of the climate problem and its irreversible potentiality; • drastic reduction of global greenhouse gas emissions; • Keep the global average temperature increase well below 2 °C (above pre-industrial levels) and limit the temperature increase to 1.5 °C above pre-industrial levels) goal to 2030; • Reinforces the implementation of the Doha Amendment to the Kyoto Protocol (2012).	• no net emissions of greenhouse gases in 2050; • the drastic reduction of global greenhouse gas emissions; • The Paris Agreement: Keep the global average temperature increase well below 2 °C (above pre-industrial levels) and limit the temperature increase to 1.5 °C above pre-industrial levels) goal to 2030; • Clean Planet for all;
Sustainability	• Preserve and restore ecosystems and biodiversity; • suggests the creation or revision of internal environmental legislation of nations;	• Preserve and restore ecosystems and biodiversity;	• Preserve and restore ecosystems and biodiversity; • follows the sustainability guidelines of Agenda 2030 (Meta13: Climate Action); • To achieve a balance between anthropogenic emissions by sources and removals by sinks of greenhouse gases in the second half of this century;	• Preserve and restore ecosystems and biodiversity, EU Biodiversity Strategy for 2030; • Implement the climate and environment guidelines outlined in The 2030 Agenda for Sustainable Development; • zero pollution; • Preserving and restoring ecosystems and biodiversity; • High-Quality Food; • Directive 2003/87/EC;
Building and renovating	• Easy access policies to society to promote a renovation of the existing; • retrofitting public buildings to promote their energy efficiency, enabling the deployment of autonomous renewable energy generation systems (off-grid);	• Air quality inside buildings • Thermal comfort and natural ventilation for air renewal; • environmental quality of the built environment (healthy housing); • provide for green areas; • Cities 100% saned; • Building water management (automation and saving devices); • reuse of non-potable and rain water;	• Building and renovating in an energy and resouse efficient way;	• Building and renovating in an energy and resouse efficient way; • on-grid systems; • Implement strict legislation related to the energy performance of buildings; • Include the civil construction sector in the Emissions Trading System and review the Regulation of Construction Products; • Circular Economy • Regulation (EU) No 305/2011 — harmonized conditions for the marketing of construction products

Affordable secure	• Renewable energy sources • Systems off-grid and on-grid immigration;	•	•	• Renewable energy sources • on-grid systems; • EU Strategy for energy system integration and hydrogen;
Economy	• based on report data: Rethinking the Economic Recovery: A Global Green New Deal; • economic model: carbon dependency (Brown Economy); • Presents the concept of "Greening" economy; • implementing Environmental accounting principles; • liability for the environmental damage caused, to the polluter and not to the taxpayer. (polluter pays).	•	• developed economies must commit to absolute GHG emission reduction; • recognizes the need to support developing countries to effectively implement national contributions, should intensify their mitigation actions, moving towards a scenario of GHG emissions reduction and limitation.	• The economic growth is decoupled from resource use; • promote decarbonization; • Coal must be unlimited, fossil fuel sources must be avoided; • European Green Deal Investment Plan (InvestEU); • Circular Economy Action Plan; • European climate law;
Territorial sale and governance	• sustainable agricultural production priorities; • Deployment of clean energy generation technologies (off-grid systems) on a small scale in rural areas; • formulation of legislation regarding land use, property title, urban planning policies and the right to use and manage fresh water.	•	•	• Climate Neutrality: • zero pollution; • Smarter transport; • High-quality food
Mobility	• More energy-efficient transportation that requires less infrastructure and greater connection between modal types (air, rail, pipeline, road and waterway) • Hybridization and electrification.	•	•	• Production flow should be encouraged by waterways and railways; • Smarter transport;

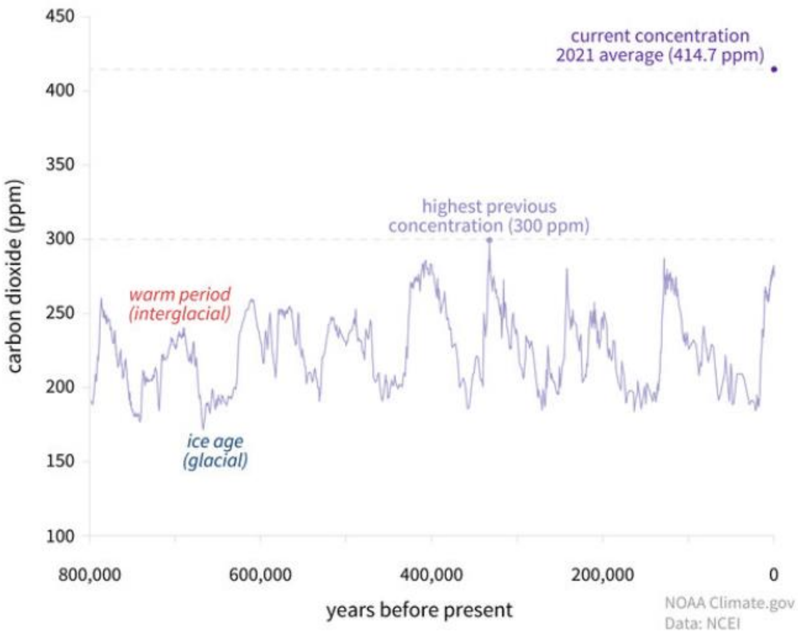
1.3 Main effects of global warming and climate change

This topic seeks to identify within the literature produced the main effects of global warming, correlating them to the current impacts on the urban scale and the built environment. As well, identifying the possible impacts that climate change described in the climate projections of the short (2030), medium (2050) and long term (2100) future scenarios.

The Atmosphere is composed of several gases that make up the planet's energy balance, a system responsible for keeping the heat imprisoned close to the surface of the earth. As mentioned above, the main gases that are part of the composition of the atmosphere are: carbon dioxide, methane, nitrous oxides and water vapor. As carbon dioxide is responsible for the warming effect of the atmosphere, thanks to this effect the global average temperature remains at 15 degrees Celsius. According to NASA[87] scientists, carbon dioxide is important for stabilizing the Earth's atmosphere. Without CO2, the greenhouse effect phenomenon would collapse and the Earth's surface would be about 33 degrees cooler (NASA, 2021).

In the last 800,000 years there have been cycles of concentrations of atmospheric carbon dioxide, with peaks and valleys that have accompanied the glacial (low CO2) and warmer interglacial eras (higher CO2 concentration). However, carbon dioxide has never exceeded the limit of 300 ppm[88]. Since they began measuring global atmospheric carbon dioxide at the Mauna Loa Volcanic Observatory in 1958, concentrations were already 315 ppm. The current concentrations observed in 2021 already account for 415 ppm, characterizing a 100-fold faster increase in the last 60 years than previous natural increases Climate.gov, 2022.

Picture 9: Carbon Dioxide over 800,000 years



Source: Climate.gov, 2022.

[87] NASA. (n.a.). FAQ: What is the greenhouse effect? Climate Change: Vital Signs of the Planet Evaluable from: https://climate.nasa.gov/faq/19/what-is-the-greenhouse-effect/

[88] Before the Industrial Revolution began in the mid-1700s, atmospheric carbon dioxide was 280 ppm or less. NOAA Climate.gov with NCEI data.

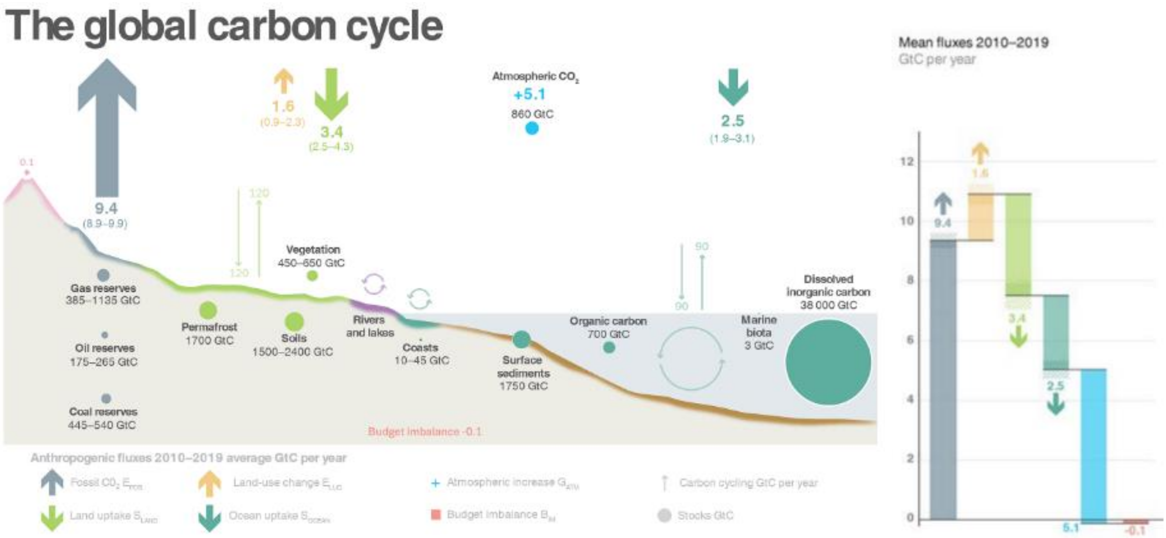
Studies published in scientific journals on this subject show that the increase in carbon dioxide emissions damages the composition of the atmosphere. As a result, the heat present between the earth's surface and the atmosphere does not dissipate into space, resulting in the imbalance of the radiometer energy balance. Within the urban context, this phenomenon, together with the anthropic, physical and morphological characteristics of the cities, generate the effect of the Island of Heat (*Urban heat island - UHI*), accentuating the temperature and reducing the humidity in regions in which the degree of urbanization and density is greater (IPCC, 2013), (IPCC, 2014), (IPCC, 2019) and (IPCC, 2021). In it, the Long Wave Radiation Balance is even more damaged, this happens because normally in urban areas with a high degree of density have a higher level of impermeability of the soil. The materials used in the construction of these floors and accesses, such as asphalt, which is a material with low calorific capacity and which retains the direct solar energy of a short wave, stores it and re-emits all the electromagnetic energy accumulated in the form of a long wave to the atmosphere, raising the discomfort to the heat.

By using the same argument as exemplified in the previous paragraph, however changing the typology of the material, e.g. from alphalt to ocean water, water has to absorb the direct short wave solar energy, and due to its high calorific capacity, it retains the received energy and stores it. Here the re-emission of electromagnetic energy to the atmosphere in the form of long waves does not occur, the energy is retained in the material for having a better calorific capacity, and with this, the temperature of the oceans increases. One of the direct impacts observed in recent years is acidification and the bleaching of corals, for example, which directly impacts the aquatic ecosystem of the oceans and biodiversity.

In the troposphere there is the presence of Atmospheric $_{CO2}$, which does not undergo photochemical destruction, being a gas of continuous emission and necessary to maintain the balance of energy of the atmosphere for the characterization of the microclimate. The gas can be naturally removed by some processes: a) from photosynthesis, becoming organic matter; b) it can be stored by the oceans, but this process causes acidification; c) it can be stored in soil and rocks, but this process is long-lasting. Each year we put more carbon dioxide into the atmosphere, and the current concentration in the atmosphere is the sum of contemporary emissions plus concentrations from previous periods' emission sources (Friedlingstein, et al., 2020).

Friedlingstein et al. (2020) the global carbon cycle for the last decade (2010-2019) is schematically represented by Picture 10 the following image shows global carbon cycle disturbance caused by anthropogenic activities, global average for the period from 2010 to 2019. The average flow of carbon in the atmosphere from fossil fuel emissions was 9.4 GtC (*gigatonnes of carbon*) per year (represented by the color gray). An average of 1.6 GtC per year was observed for CO2 emissions from land use change (represented by orange color). The soil had the capacity to absorb on average 3.4 GtC per year (represented by the color light green) and the Ocean was responsible for the absorption of 2.5 GtC per year (represented by the color olive green). Thus the average final carbon flow evidence that 5.1 GtC per year still remains in the atmosphere, which corresponds to about 46% of the total global emissions of the last decade.

Picture 10: The global carbon cycle (2010-2019)

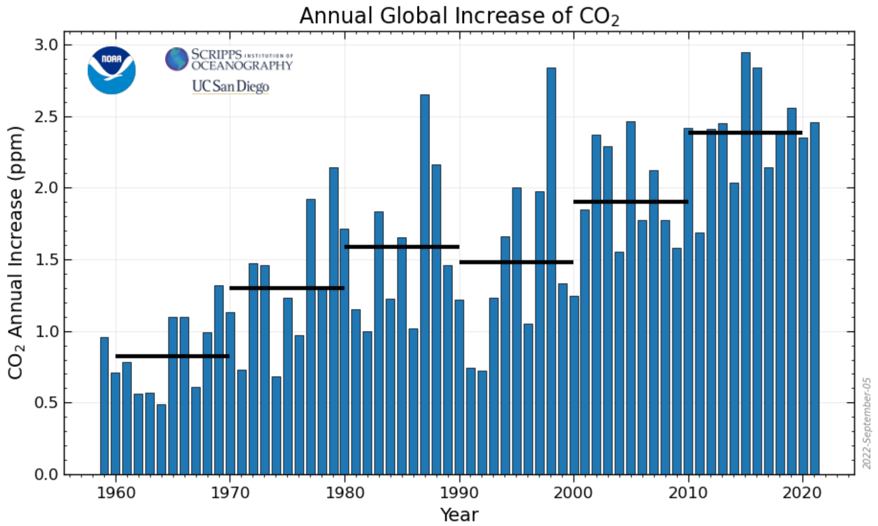


Source: Friedlingstein et al. (2020), Bilancio Globale Del Carbonio 2020. Evaluable at: essd-12-3269-2020.pdf (copernicus.org)

The columns of the chart displayed in the Picture 11 the following shows the annual average growth rates of carbon dioxide emissions, based on overall average marine surface data. Horizontal bars represent average growth rates over the past six decades (averages for the 1960s to 1969, 1970 to 1979, and so on until 2010 to 2019).

Looking at the chart, we conclude that for the last decade, corresponding to years between 2010 and 2019, the global annual average carbon dioxide emissions are approximately 2.4 ppm (*parts per million*) per year, which is equivalent[89] to the research developed by Friedlingstein et al. (2020). This is equivalent to an increase of 200% when compared to the first period analyzed (1960-1969) and there is an average geometric growth rate of 25% per period in the last 5 decades.

Picture 11: Overall annual increase of CO2 and average rate every decade.



Source: NOAA, (2021). Evaluable at: https://gml.noaa.gov/ccgg/trends/gl_gr.html

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89 One part per million (1ppm) of CO2 in the atmosphere is equal to 7.8 gigatonnes (Gt or billions tons) of CO2 or 2.125 Gt of solid carbon. E 1ppm by volume CO2 in atmosphere = 7.80432 Gt CO2 (2.125 GT of C).

The following table presents the major units of quantity and their respective conversions.

Table 8: Convert carbon into multiple units (by convention, unit 1 = unit 2× conversion)

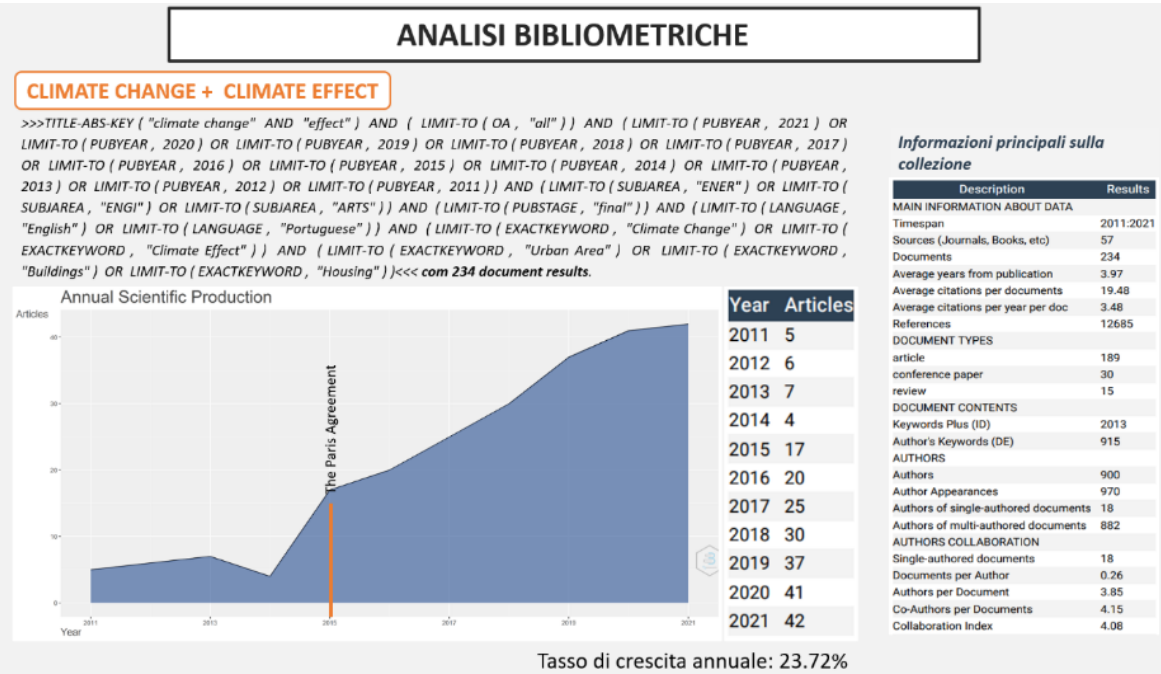
Unit 1	Unit 2	Conversion	Source
GtC (gigatonnes of carbon)	ppm (parts per million)[a]	2.124[b]	Ballantyne et al. (2012)
GtC (gigatonnes of carbon)	PgC (petagrams of carbon)	1	SI unit conversion
$GtCO_2$ (gigatonnes of carbon dioxide)	GtC (gigatonnes of carbon)	3.664	44.01/12.011 in mass equivalent
GtC (gigatonnes of carbon)	MtC (megatonnes of carbon)	1000	SI unit conversion

Source: Friedlingstein et al. (2020).
Prezioso da: ESSD - Bilancio globale del carbonio 2020 (copernicus.org)

1.3.1 Global climate characterization

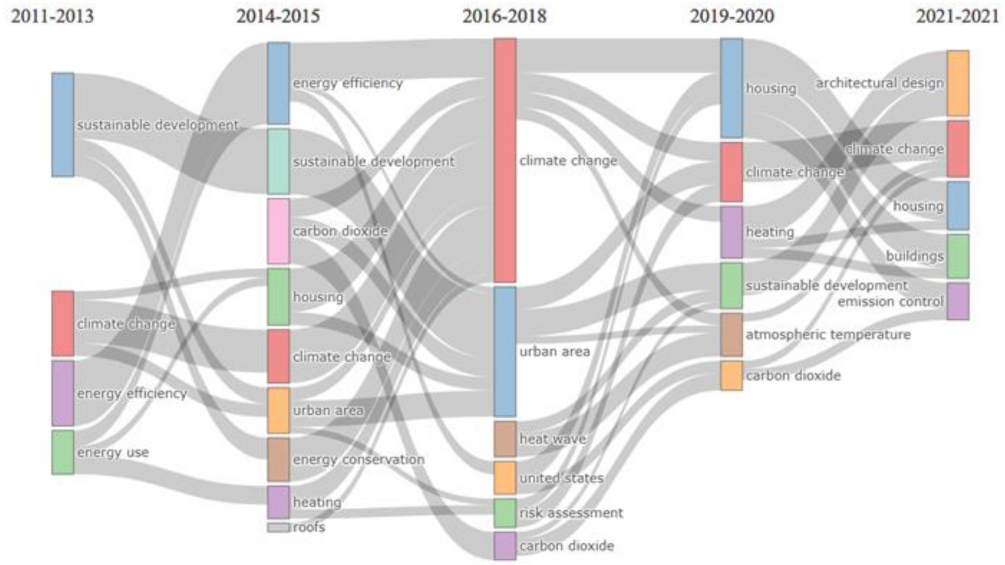
Currently there are several methodologies and tools in which it is possible to obtain information about climate and meteorological characterization on a global and regional scale, and the interest on this theme has increased in recent years. According to the systematic review of the literature and its biliometric analysis, according to the algorithm and methodology presented in the introductory chapter, it was observed that there was at first the production of knowledge on the subject of the effects of global warming and the impacts of climate changes was constant, it is even noted that in the year 2014 there was a small reduction. However, in the year in which COP 21 was held in Paris, which is due to the formulation of the Paris Agreement as its final product, this scientific output grew by an average of 23.72% per year. The analysis shows that the adoption of a public policy has the power to stimulate the development of research and technologies, making a transition to a sustainable model feasible through socioeconomic mechanisms.

Picture 12: Bibliometriche analysis of scientific production: "Climate Change" AND "Effect"



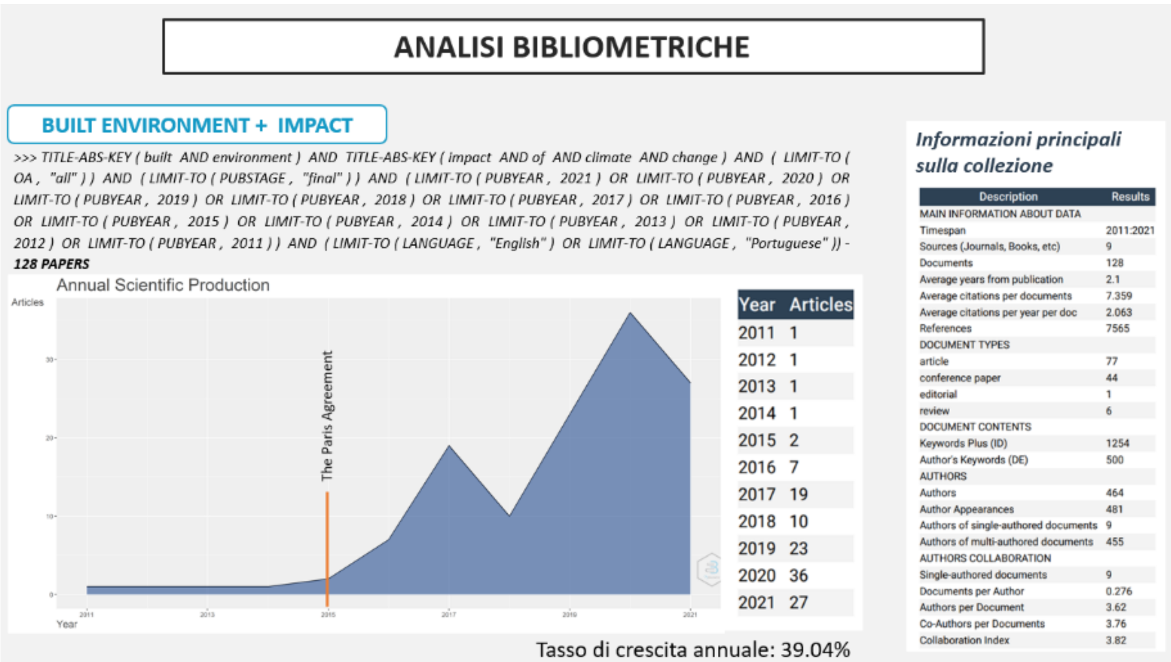
Source: L'autore (2021).

Picture 13 Thematic evolution ("climate change"AND "effet"): Result of the last decade presented by Keywords Plus parameter



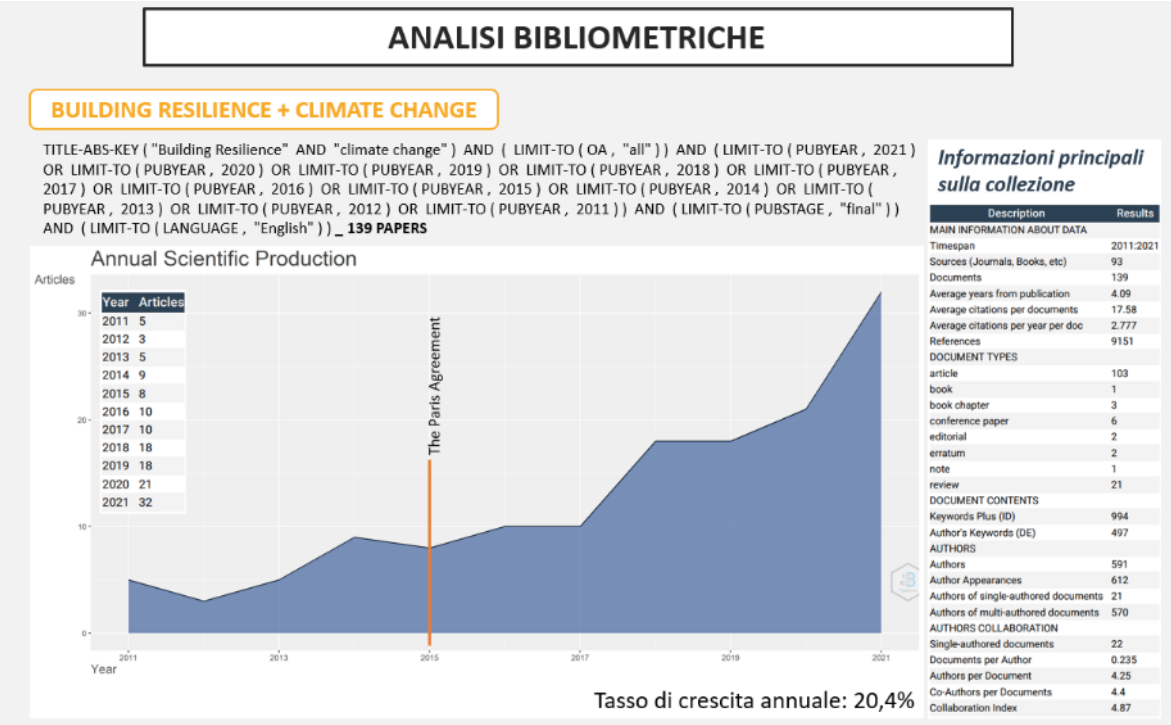
Source: L'autore (2021).

Picture 14: Bibliometriche analysis of scientific production: "Built Environment" AND "Impact"



Source: L'autore (2021).

Picture 15: Bibliometriche analysis of scientific production: "Building Resilience" AND "Climate change"



Source: L'autore (2021).

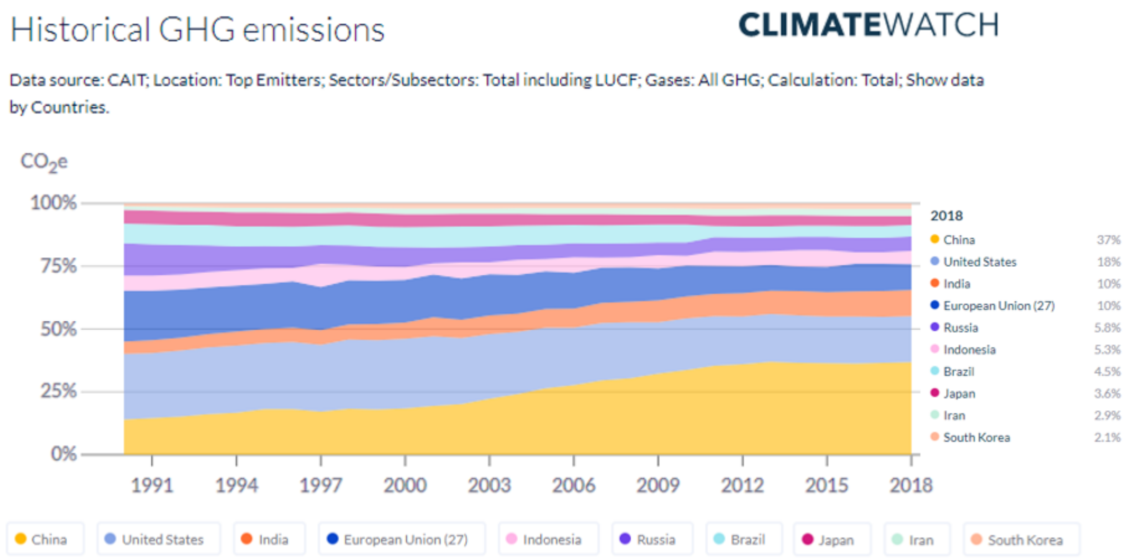
Anthropogenic GHG emissions are responsible for the major part of the contributions within the carbon cycle, and are the one that contributes the most to the effect of global warming and impacts arising from these climate changes. The nations that emitted the most GHGs in the atmosphere in 2018 were: a) China, responsible for 37% of the total emissions; b) the United States, responsible for 18%; c) India, responsible for 10% of the emissions. Together they are responsible for about 62% of the total global emissions of GHGs in the atmosphere, including the LULUCF[90] which is land use, land use change and forestry. LULUCF, Glossary of climate change acronyms and terms (2021) is "*A greenhouse gas inventory sector that covers emissions and removals of greenhouse gases resulting from direct human-induced land use, land-use change and forestry activities*". Being considered a key sector for achieving neutral GHG emissions, since the sector can also function as a carbon dioxide sink. Because CO2 can be absorbed as carbon in the vegetation and soils of terrestrial ecosystems.

As we broaden this analysis and identify which are the ten countries[91] that emit the most GHGs, continuing the list: d) the European Union made up of 27 member countries, responsible for 10%; e) Russia, responsible for 5.8%; f) Indonesia responsible for 5.3%; g) Brazil responsible for 4.5%; h) Japan, responsible for 3.6%; i) Iran, responsible for 2.9% and South Korea, responsible for 2.1%; we will see that their combined contributions correspond to 79.2% of the total of global

[90] Land Use, Land-Use Change and Forestry (LULUCF) also referred to as Forestry and other land use (FOLU).
[91] Emissions from Top 10 contribute 60.6% to global emissions: China 24%; United States 12%; India 6.8%; Russia 4.1%; Indonesia 3.5%; Brazil 2.9%; Japan 2.4%; Iran 1.7%; Germany 1.6% and Canada 1.6% (Global Carnon Atlas, 2020). Evaluable from: http://www.globalcarbonatlas.org/en/CO2-emissions

emissions, while the 1011000000000000000000000000000000000000000000000000in GHGs, they contributed less than 3% of the total GHGs emissions (Global Carnon Atlas, 2020).

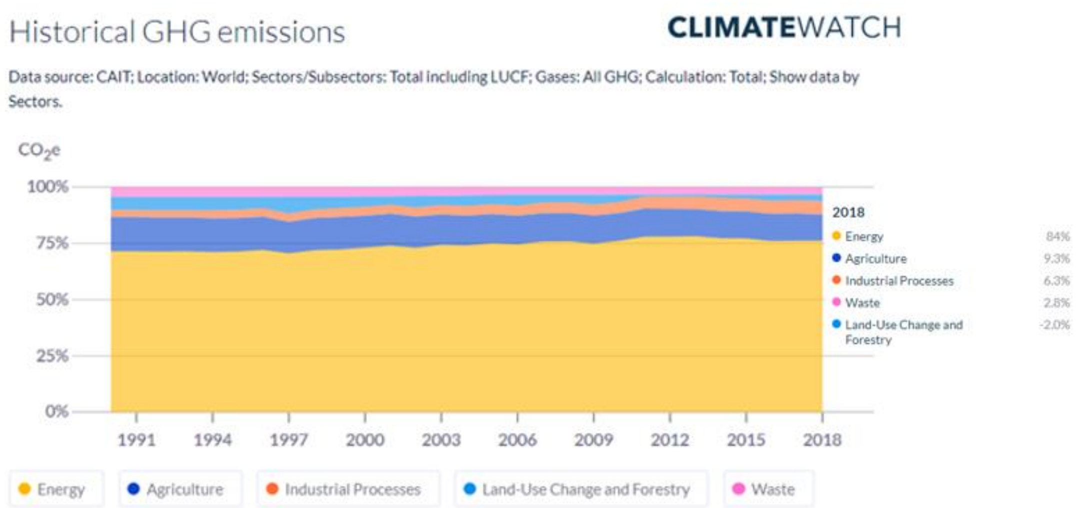
Picture 16: Emissioni storiche di gas a effetto serra (1990-2018) for Countries.



Climate Watch, (2020). Adapted by L'Autore, (2021).

When we analyze the economic sectors that emit the most GHGs, we have to say that the energy sector is responsible for 84%, more than three quarters of the total global emissions. Still within the energy sector, the electricity and heat generation sub-sector is the largest contributor (25%), being considered a key sector for this transition to zero net emissions. Next we have agriculture, forestry and other land uses (24%), industry (21%), transport (14%), waste (2.8%) and land use change and forests (-2%) (ClimateWatch, 2020).

Picture 17: Emissioni storiche di gas a effetto serra (1990-2018) for Sectors



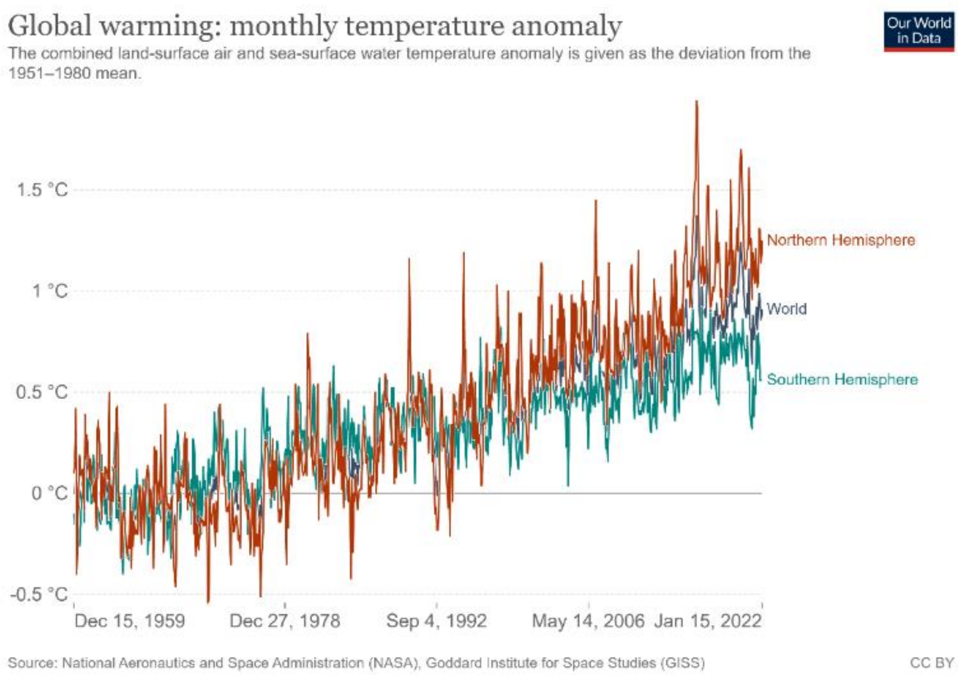
Source: Climate Watch, (2020).

The highest concentrations of greenhouse gases are located in the northern hemisphere (Picture 18). In the Northern Hemisphere, most countries are developed, and for this reason their industrial processes work for a longer time, accumulating more GHGs in the atmosphere over the years, besides that the greater the development of a region, the greater the energy consumption demanded. Also within this context, the Northern Hemisphere is a region with high thermal amplitudes throughout the year. Each season of the year has distinct climatic characteristics, the winters with lower average temperatures when compared to the southern hemisphere. This brings the energy sector a greater demand for energy to provide heating and heat for buildings in general.

In the Southern Hemisphere, most countries have their economies in development, the same phenomenon occurs as in the Northern Hemisphere, but because they have their industrial processes less developed and working for less time, or that is to say, the less the development of a region, the less energy consumption is demanded. This is one of the reasons why the emissions of GHGs accumulated in the atmosphere in the southern hemisphere are lower. Seasons have distinct climatic characteristics in only a few regions. Some of them have winters with lower average temperatures, others with higher temperatures, bringing an impact to the energy sector a greater demand for energy to provide heating and cooling for the buildings.

A Picture 18 the following presents the anomaly of the monthly average temperature and its effect on global warming. When looking at the graph, from the 1960s to the late 1990s the anomaly of the monthly average temperature in both hemiphesarii was characterized by a common ascend line, but from the 2000s this ascend line increased on a larger scale and more rapidly, and in the northern hemisphere, this variable was even higher when compared to the southern hemisphere. This phenomenon can be explained due to the economic context that the world was inserted at the time, it is possible to observe a drop in emissions on the eminence of a global crisis that had its summit in 2008, resuming its growth after the crisis in the mid-2010s.

Picture 18: Globale: anomaly di ambiente mensile



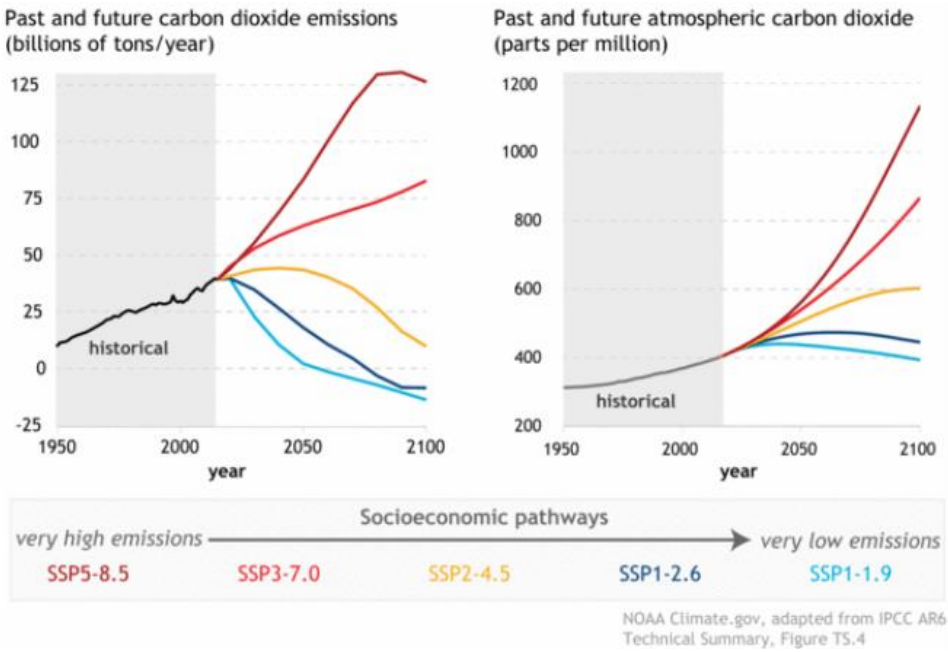
Country	Temperature anomaly °C			
	Dec 15, 1959	Jan 15, 2022	Absolute Change	Relative Change
Northern Hemisphere	0.10 °C	1.25 °C	+1.15 °C	+1,150%
Southern Hemisphere	-0.10 °C	0.56 °C	+0.66 °C	+660%
World	0.00 °C	0.91 °C	+0.91 °C	

Source: NASA, GISS & Our World in Data (2021).

The combined anomaly of air and water temperature on the sea surface is given in the graph as the deviation from the 1951-1980 average. In the Northern Hemisphere this anomaly is already represented between +1 degrees celsisus and +1.15 degrees celsius warmer as compared to pre-industrial indices. In the Southern Hemisphere, this anomaly is also growing, being represented between +0.5 degrees Celsius and +1 degrees Celsius, being close to the global average.

The most recent reports of the IPCC working groups, in relation to future projections for GHG emissions, present simulations built according to each socioeconomic scenario described in their methodology, the SSPs. With SSP5-8.5 being the socioeconomic scenario that characterizes choices based on very high emissions of GHGs, and SSP1-1.9 being the socioeconomic scenario characterized by sustainable models with very low emissions of GHGs. In one of these simulations the report presents two graphs (see figure below) with possible future scenarios for carbon dioxide emissions on the scale of billions of tons per year and another scenario with future projections for carbon dioxide concentrations in the atmosphere on the scale of ppm (pasts per million).

Picture 19: Past and future carbon dioxide emissions



Source: NOAA Chart Climate.gov, 2022, Adapted from the Sixth IPCC Assessment Report - Technical Summary (IPCC, 2022).

The graphs show that to keep atmospheric concentrations of carbon dioxide below 300ppm we have to adopt radical measures based on a socioeconomic model of very low emissions path described by the trajectory SSP1-1.9. If we continue with the current socio-economic model, based on fossil fuels, we will easily achieve concentrations of carbon dioxide in the atmosphere above 800 pmm (path described by trajectory SSS3-7.0). This condition is 266% more than almost observed in the glacial cycles before the industrial revolution. According to Climate.gov (2022):

> *"The last time atmospheric carbon dioxide amounts were this high was more than 3 million years ago, during the Mid-Pliocene Warm Period, when global surface temperature was 4.5-7.2 degrees Fahrenheit (2.5-4 degrees Celsius) warmer than during the pre-industrial era. Sea level was at least 16 feet higher than it was in 1900 and possibly as much as 82 feet higher* Climate.gov, 2022.

The path that would limit global warming to + 1.5°C, the threshold recommended by the Paris Agreement, would be the socio-economic scenario described by SSP1-2.6. In it, the estimated limit of CO2 to maintain this target would be 510 Gt CO2. However, only existing and planned infrastructure based on fossil fuels already emit more carbon dioxide than the limit available to reach this target of 1.5°C. To reverse this situation, there is no more room for non-low-carbon infrastructure with carbon capture and storage technologies (IPCC, 2022).

1.3.2 The limits of human tolerance to exposure to cold and hot environments

Human body heat gain or loss occurs due to two factors: environmental exposure, high or low temperatures, wind, humidity; and due to some physiological process in which the body reacts in response to some atypical condition of the organism. In both cases, the ability of the individual to regulate the central body temperature is compromised, resulting in direct effects on their health, such as insolation, hyperthermia, hypothermia, among others. As well, indirect effects on your well-being, such as air quality, water and energy security, among others.

A study by P. K. Nag et al. (1997) with eleven male volunteers, in a simulated environment assessed the limits of tolerance to the heat of the human being under seven climatic conditions in a climatic chamber. The metrics used to characterize the tolerance limits were dry bulb temperature (°C) and relative air humidity (%), thus obtaining the basic effective temperature ET(B)[92]. Climatic conditions were 38 to 49 degrees C of dry bulb temperature and 45 to 80 percent relative humidity, i.e. 32.3 to 40 degrees C of effective base temperature (ET(B)). During the experiment, volunteers performed ergometric work with duration according to their respective cardiorespiratory response, body temperature and perspiration, there is an intensity of 60 per VO2max[93] center, that is, equivalent to a moderate exercise [intensity (VO2max between 50-74%)94]. According to

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[92] According to the authors, ET(B) values were equated with other indices of thermal stress, for example, WBGT (Wet-bulb Globe Temperature Index) and Oxford Index.

[93] VO2 max (Maximum Oxygen Consumption): is the rate that an individual's organism has to capture and use the oxygen from the air it is inspiring to generate effort/work. VO2max is a good index for us to classify the level of cardiorespiratory fitness, that is, for us to compare with statistical data. All tables of classification of physical fitness were developed from researches carried out on the maximum consumption of oxygen - VO2 Maximum.

[94] As for the intensity rating of the exercise (training from 20 to 60min): Pollock ML, Wilmore JH. Exercise in health and disase: Evaluation and prescription and rehabilitation. 2nd ed. Philadelphia: WB Saunders, 1990.

the American College of Sports Medicine (ACSM) , for healthy non-elderly individuals, an exercise intensity of between 60 and 70% of the estimated maximum oxygen consumption (VO2maxE) or between 70 and 85% of the heart rate measured (FCmaxM) in the stress test (TE).

The study showed that only in extreme heat situations above 35.4 degrees C ET(B), unacceptable levels of physiological and psychophysical reactions were observed. As a result the study suggested as acceptable and tolerable limits for human heat exposure the following weather conditions and time exposures: (i) acceptable, 38 to 38.2 degrees C Tcr (central body temperature) for a tolerance time of 80 to 85 min and (ii) the tolerable short-term limit (40-45 min), at 39 degrees C Tcr, which corresponds to 31.5 and 36.5 degrees C [ET(B)] Nag, K et al. (1997).

A similar study was carried out for a group made up of six women exposed to environmental conditions of 38 to 44 degrees C of dry bulb temperature, with relative humidity of 50 to 80 percent, that is, between 32 to 36.5 degrees C of the normal effective temperature ET(N). During the test, the volunteers performed 50W-intensity ergometric activity on bicycles. The duration of exposure was determined by cardiorespiratory responses, body temperature, and sweating of volunteers, during the study the tolerance limit of central body temperature (CrT) reached more than 38.5 degrees Cr. Demonstrating that in extreme heat situations, in addition to 33.5 degrees ET(N), women presented unacceptable levels of physiological and psychophysical reactions. As a result, the study suggested acceptable and tolerable limits for human heat exposure, characterized by the following environmental conditions: (i) acceptable at 32.0 degrees C [ET(N)] for a time of 43 min; and (ii) tolerable limit of 36.5 degrees C ET(N) for an exposure period of only 16 min Nag, A et al. (1999). Other relevant points that should be considered in environments where there is thermal stress to heat are: (i) the type of clothing the user is wearing; (ii) the characteristics of the site, whether it is an indoor or outdoor environment with or without direct exposure to solar radiation; and (iii) the relative humidity of the environment since the higher the humidity of the air, the less heat is ceded by the human body to the environment through evaporation.

The Occupational Safety and Health Guide published by WorkSafeBC, *Preventing Thermal Stress at Work: OHS[95] Guidelines Part 7: Noise, Vibration, Radiation and Temperature*. There is a specific topic that undergoes the effects and procedures that should be adopted by humans in case of thermal exposure to heat and cold. Describing a method of assessing thermal stress, the method consists of using a dry bulb thermometer and an index called Humidex.

Table 9: G7.29-4 Evaluation of thermal stresses by a thermometer to dry bulb the index of Humidex (Humidex 1). Issued August 1999; Revised January 1, 2005; Revised February 12, 2008 and heat response plan based on Humidex	
(Humidex 1)[96]	**(Humidex 2)[97]**

For lower limits of prescription (60% VO2maxE or 70% FCmaxM) and upper limits (70% VO2maxE and 85% FCmaxM) proposed by ACSM.

95 OHS: occupational health and safety.

96 Humidex 1 corrisponde al limita di azione ACGIH e si applica ai carichi di lavoro moderati (ad esempio spinta e sollevamento) per i lavoratori non climatizzati o ai carichi di lavoro pesanti (ad esempio sabbia delle palette) per i lavoratori condizionati al calore (WorkSafeBC, 2008).

97 Humidex 2 corrisponde al TLV ACGIH e si applica al lavoro moderato per lavoratori acclimatati o al lavoro leggero per lavoratori non acclimatati (WorkSafeBC, 2008).

°C	Relative Humidity (in percent)																		
	100	95	90	85	80	75	70	65	60	55	50	45	40	35	30	25	20	15	10
49																			50
48																			49
47																		50	47
46																		49	46
45																	50	47	45
44																	49	46	43
43																49	47	45	42
42															50	48	46	43	41
41															48	46	44	42	40
40														49	47	45	43	41	39
39													49	47	45	43	41	39	37
38												49	47	45	43	42	40	38	36
37											49	47	45	44	42	40	38	37	35
36									50	49	47	45	44	42	40	39	37	35	34
35								50	48	47	45	43	42	40	39	37	36	34	33
34							49	48	46	45	43	42	40	39	37	36	34	33	31
33					50	48	47	46	44	43	41	40	39	37	36	34	33	32	30
32			50	49	48	46	45	44	42	41	40	38	37	36	34	33	32	30	29
31	50	49	48	47	45	44	43	42	40	39	38	37	35	34	33	32	30	29	28
30	48	47	46	44	43	42	41	40	39	37	36	35	34	33	31	30	29	28	27
29	46	45	43	42	41	40	39	38	37	36	35	33	32	31	30	29	28	27	26
28	43	42	41	40	39	38	37	36	35	34	33	32	31	30	29	28	27	26	25
27	41	40	39	38	37	36	35	34	33	32	31	30	29	28	27	26	25		
26	39	38	37	36	35	34	33	33	32	31	30	29	28	27	26	25			
25	37	36	35	34	33	33	32	31	30	29	28	27	26	26	25				
24	35	34	33	33	32	31	30	29	28	28	27	26	25						
23	33	32	31	31	30	29	28	28	27	26	25								
22	31	30	30	29	28	27	27	26	25	25									
21	29	29	28	27	26	26	25												

Humidex 1 Moderate unacclimatized & Heavy acclimatized	**Response**	**Humidex 2** Moderate acclimatized & Light unacclimatized
25 - 29	Supply water to workers on an "as needed" basis	32 - 35
30 - 33	Post Heat Stress Alert notice; encourage workers to drink extra water; start recording hourly temperature and relative humidity	36 - 39
34 - 37	Post Heat Stress Warning notice; notify workers that they need to drink extra water; ensure workers are trained to recognize symptoms	40 - 42
38 - 39	Work with 15 minutes relief per hour can continue; provide adequate cool (10-15°C) water; at least 1 cup (240 mL) of water every 20 minutes. Worker with symptoms should seek medical attention	43 - 44
40 - 41	Work with 30 minutes relief per hour can continue in addition to the provisions listed previously	45 - 46*
42 - 44	If feasible, work with 45 minutes relief per hour can continue in addition to the provisions listed above	47 - 49*
45* or over	Only medically supervised work can continue	50* or over

* at Humidex exposures above 45, heat stress should be managed as per the ACGIH TLV. The above administrative control measures do not preclude using other means to reduce excessive heat exposures, such as providing additional air conditioners or fans for spot cooling. In fact, engineering controls are the most effective means to control heat stress and should be considered first and in conjunction with the above steps as part of the heat stress ECP. For more examples of control measures, refer to WorkSafeBC publication *Preventing Heat Stress at Work.*®

Source: WorkSafeBC (2008).

The methodology used to obtain the Humidex index evaluates the risk of exposure to humans in certain scenarios with different environmental parameters and risks with regard to: temperature, humidity, type of exposure (direct or indirect), exposure time and type of wearer's clothing, efforts, among others. Through the index identified, finally, the guide proposes procedures that can be adopted as a response to mitigation and protection of the users to the risks observed (WorkSafeBC, 2008).

The proposed method that assigns the Humidex index assumes that workers are wearing regular summer clothes (light shirt, trousers, underpants, socks and shoes). Otherwise, the sum of the following values should be considered in the calculation of the Humidex Index:

- Wear overalls (e.g. cotton jumpsuits) on summer clothes (light shirt, trousers, underpants, socks and shoes): add 5°C to the site's humidex value.
- Wear using Gloves and/or hard hat: add home a 1°C to the humidex value.
- Wear using apron or vest: add home a 2°C to the humidex value.
- In case of direct exposure: to adjust the index to the radiant heat in direct sunlight (between 10:00 and 16:00), add 2°C to 3°C to the Humidex value.
- In the case of indirect exposure: to adjust the index use training, knowledge and experience to adjust set the correction factor for indirect sunlight of 2 to 3°C, estimating whether the exposure is greater or lower than the exposure to direct sunlight.
- In locations with a significant thermal load related to a specific work process (e.g. boilers, ovens, steam lines, etc.) to adjust the index, the WBGT in situ should be measured at various points in the environment and the highest reading98 value should be considered.
- Measurement should be recorded on an hourly basis if Humidex is above 30°C.
- For users who wear encapsulation suits, do not use the Humidex method.

[98]Humidex values should not be based on weather station values or media reports. Use measures taken on site (WorkSafeBC, 2008).

With regard to the limits of exposure to low temperatures, the ACGIH (*American Conference of Governmental Industrial Hygienists*) establishes occupational safety indicators called: TLVs[99] (Maximum Exposure Limits) and EIBs[100] (Biological Exposure Indices) for work activities exposed to low temperatures and risk of Hypothermia. It is considered that normal body temperature for a human being is about 37 degrees celsius. When this temperature reaches 35 degrees Celsius or less, the individual is considered to be suffering from hypothermia. When body temperature reaches levels below 33 degrees Celsius, progressive clinical effects characteristic of moderate hypothermia begin. When measuring body temperature below 30 degrees Celsius, hypothermia is considered severe in which the individual remains in an unconscious state and his heart and respiratory rate are very low. As body temperature decreases from this threshold, the recovery of the individual becomes more and more difficult. Upon reaching 20 degrees Celsius body temperature, the individual suffers cardiac arrest.

The following table presents the maximum exposure limits for cold by correlating these limits to the progressive clinical effects in humans.

Table 10: Clinical and progressive symptoms of hypothermia reproduction by ACGIH (1999)

Temperatura Interna

°C	°F	SINTOMAS CLÍNICOS
37,6	99,6	Temperatura retal normal
37	98,6	Temperatura oral normal
36	96,8	Taxa metabólica aumenta para compensar as perdas por calor
35	95	Calafrio máximo
34	93,2	Vítima consciente e com resposta, com pressão arterial normal
33	91,4	Hipotermia severa abaixo desta temperatura
32 31	89,6 87,8	Consciência diminuída; dificuldade de tomar a pressão sanguínea; dilatação da pupila, mas ainda reagindo à luz; Cessa o calafrio
30 29	86,0 84,2	Perda progressiva da consciência; aumento da rigidez muscular, pulso e pressão arterial difíceis de determinar; redução da freqüência respiratória
28	82,4	Possível fibrilação ventricular, com irritabilidade miocárdica
27	80,6	Parada do movimento voluntário; as pupilas não reagem à luz; ausência de reflexos profundos e superficiais
26	78,8	Vítima raramente consciente
25	77	Fibrilação ventricular pode ocorrer espontaneamente
24	75,2	Edema pulmonar
22 21	71,6 69,8	Risco máximo de fibrilação ventricular
20	68	Parada cardíaca
18	64,4	Vítima de hipotermia acidental mais baixa de recuperar
17	62,6	Eletroencefalograma isoelétrico
9	48,2	Vítima de hipotermia por resfriamento artificial mais baixa de recuperar

Situações relacionadas de forma aproximada com a temperatura interna do corpo. Reprodução da revista de Janeiro de 1982, "American Family Physician", publicada pela American Academy of Family Physicians.

Fonte: ACGIH, ABHO (1999)

According to the *Canadian Center for Occupational Health and Safety* (CCOHS), studies have shown that the response to cold in women can be different from that of men. Although the central body temperature cools more slowly in women, women are generally not able to create as much metabolic heat through exercise or tremors. In addition, the rate of cooling of the extremities of the body is faster among women. As a result, women generally run a higher risk of cold injury (ACOHS, 2019). Besides the low temperature it is important to observe the intensity and the time

[99] Threshold Limit Values (TLV).
[100] Biological Exposure Indices (BEIs).

of exposure to the winds in order to know their real potential for cooling, since depending on the speed of the wind in km/h the equivalent cooling temperature becomes lower than the actual measured temperature. The CCOHs presents a diagram in which it is possible to estimate the cooling power of the air temperature in conjunction with the force of the winds.

The values presented were obtained through studies in which the individual who was being submitted to thermal exposure was not acclimatized by it. There are ways for an individual to acclimatize the new environmental thermal conditions arising from their stressor. The principle of adaptive comfort theory already theorizes about promotion categories of this passive adaptation, and the intention is to make behavioral adjustments in a conscious or inconsistent way, placing one more piece of clothing, opening a window, turning on the heater for example, or inconsistently through physiological adjustments, inherent in the body's thermo-regulating system.

Table 11: Summary of human exposure thresholds to heat and cold.

ESPOSIZIONE UMANA	HEAT (HYPERTHERMIA)		FREDDO (IPOTHERMIA)	
ACCETTABILE	UOMINI 38-38,2°C Tcr (body temperature al cuore) during il tempo di tolleranza di 80-85 min. Pari at 31,5 gradi C di base effective temperature [ET(B)] Nag, K et al. (1997)..	DONNE 32,0°C of the normal and effective temperature (ET(N)) during a period of 143 min. Nag, A et al. (1999)..	UOMO 35-33°C Tcr (body temperature al cuore)	DONNE -
TOLLERABILE THRESHOLD	39 gradi C Trc (corporea centrale temperature) during a brief period di tempo di 40-45 min. Pari a 36,5 gradi C della centro effectiva di base [ET(B)] Nag, K et al. (1997).	36,5°C di normale effective temperature [ET(N)] su un periodo di esposizione di 16 min Nag, A et al. (1999)..	33-30°C Tcr (body temperature al cuore) Ipothermia moderata	DONNE -

Source: L'autore (2021).

Wind also has properties to promote cooling, especially when associated with air temperature and relative humidity. The following table shows the correlation between air temperatures and estimated wind speed, resulting in the equivalent cold temperature that corresponds to thermal sensation.

Table 12: The cooling power of wind (°C)

Estimated wind speed (in km/h)	Actual temperature reading (°C)												
	10	5	0	-5	-10	-15	-20	-25	-30	-35	-40	-45	-50
	Equivalent chill temperature (°C)												
Calm	10	5	0	-5	-10	-15	-20	-25	-30	-35	-40	-45	-50
8	9	3	-2	-7	-12	-18	-23	-28	-33	-38	-44	-49	-54
16	4	-2	-7	-14	-20	-27	-33	-38	-45	-50	-57	-63	-69
24	2	-5	-11	-18	-25	-32	-38	-45	-52	-58	-65	-72	-78
32	0	-7	-14	-21	-28	-35	-42	-50	-56	-64	-71	-78	-84
40	-1	-8	-16	-24	-31	-38	-46	-53	-60	-67	-76	-82	-90
48	-2	-10	-17	-25	-33	-40	-48	-55	-63	-70	-78	-86	-94
56	-3	-11	-18	-26	-34	-42	-50	-58	-65	-73	-81	-89	-96
64	-3	-11	-19	-27	-35	-43	-59	-59	-66	-74	-82	-90	-98
(Wind speeds greater than 64 km/h have little additional effect.)	LITTLE DANGER In < 1 hr with dry skin. Maximum danger of false sense of security.				INCREASING DANGER Danger from freezing of exposed flesh within one minute.			GREAT DANGER Flesh may freeze within 30 seconds.					
	Trenchfoot and immersion foot may occur at any point on this chart.												

Equivalent chill temperature requiring dry clothing to maintain core body temperature above 36°C (96.8° F) per cold stress TLV.

Source: CCOH, (2005). Pubblicato il 1º gennaio 2005 riproduione da CCOH - table G7.33-3.

1.3.3 Projections of future scenarios by IPCC metric

Scientists claim that in addition to global warming, there are other effects that are due to emissions of GHGs by natural or anthropic routes, threatening the entire terrestrial ecosystem. This vulnerability can undermine the social development achieved over the last five decades, a period in which child mortality and rates of extreme poverty throughout the world have been reduced. This scenario will bring about a phenomenon that is being discussed a lot at the moment, called *apartheid-climatico*.

The concept of the term *apartheid* originally referred to a segregationist and racial social regime established in South Africa in 1948, and adopted until 1994, where the minority of the white-born elite population controlled the country, and with this were adopted measures and laws of a discriminatory character that subjugated the local black population, withdrawing their social, economic and political rights. Following the same theoretical ideology the term *apartheid-climatico,* was first quoted in a report published by the United Nations in June 2019[101], referencing the injustice that less developed economies that are also the most vulnerable communities to climate change will suffer in facing the climate crisis when compared to more developed economies. It is problematic that these more developed economies have the privilege of financing actions capable of nullifying these effects and can "pay" to not suffer from the climate impacts generated, while less developed economies have no choice. This will probably have another effect called climate migration of climate refugees.

This scenario could aggravate poverty, health and the quality of human life, leading to a phenomenon of climate migration to a mass scale causing impacts of greater complexity. These impacts are not only related to infrastructure or to the supply of labor, but also to the worsening of water, food and nutritional insecurity, especially in the less developed economies. With a view

[101] UNITED NATIONS (2019). World faces 'climate apartheid' risk, 120 more million in poverty: UN expert. Evaluable at: https://news.un.org/en/story/2019/06/1041261

to mitigation policy, the United Nations, through its various actors, has developed reports, guidelines and tools that aim to inform the community about these socio-economic effects and impacts, and serve as a reference for supporting research and political decisions of the interested parties.

According to the sixth report prepared by the IPCC Working Group I (WGI) (2021) shows that we will probably reach or exceed the threshold stipulated with insurance in the Paris Arrangement of +1.5°C in the next two decades (2020 - 2040). Reaching this threshold is of paramount importance so that the most vulnerable communities do not suffer even more severe impacts on their climate context. To achieve this objective, more aggressive measures would be needed through the more restrictive path, SSP1-1.9, characterized by low-carbon policies and economic models. In addition to ensuring year-to-year emissions decline throughout this decade and committing to achieving zero net emissions by half this century. If we continue with the current model or go in the opposite direction, that is, of the high carbon (SSP5-8.5), the global average temperature may reach + 2.4° C by the middle of the century (2050) and 4.4°C at the end of the century (2100).

Picture 20: Temperature limits that will be reached according to the projected scenario (CMIP6)

*Note: The values given for SSP1-19 (left) and SSP5-8.5 (right) scenarios correspond to central estimates of the values. It is very likely to reach even more critical values, as shown in the table below:

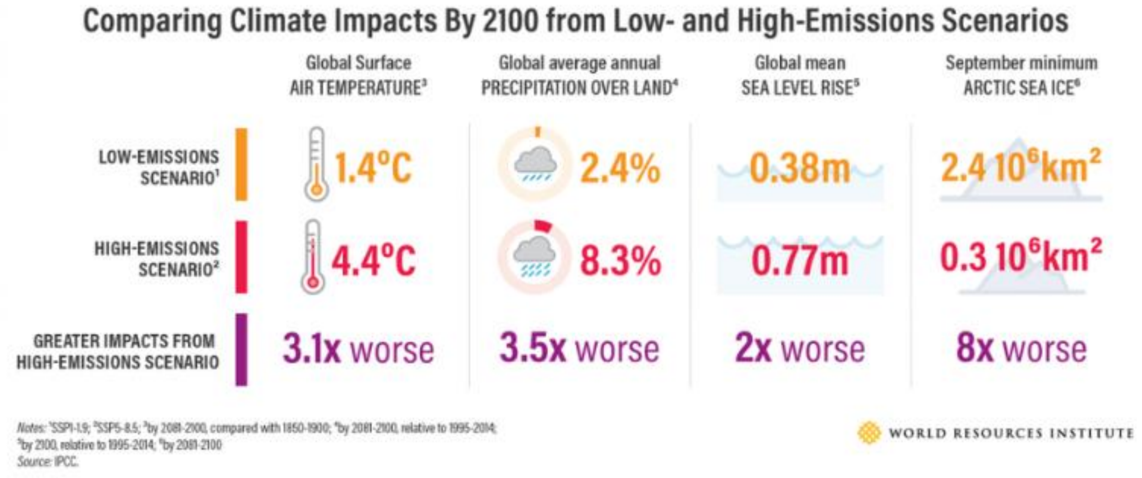
(IV) le variazioni della temperatureale superficiale globale, valutate sulla base di molteplici elementi di proof, per periodi selezionati di 20 anni (brief termine, medio termine e lungo termine) fino alla fine del secolo, tenendo tale dei cinque scenari di emissione illustrativi nel WGI/AR6.

	Near term, 2021–2040		Mid-term, 2041–2060		Long term, 2081–2100	
Scenario	Best estimate (°C)	*Very likely* range (°C)	Best estimate (°C)	*Very likely* range (°C)	Best estimate (°C)	*Very likely* range (°C)
SSP1-1.9	1.5	1.2 to 1.7	1.6	1.2 to 2.0	1.4	1.0 to 1.8
SSP1-2.6	1.5	1.2 to 1.8	1.7	1.3 to 2.2	1.8	1.3 to 2.4
SSP2-4.5	1.5	1.2 to 1.8	2.0	1.6 to 2.5	2.7	2.1 to 3.5
SSP3-7.0	1.5	1.2 to 1.8	2.1	1.7 to 2.6	3.6	2.8 to 4.6
SSP5-8.5	1.6	1.3 to 1.9	2.4	1.9 to 3.0	4.4	3.3 to 5.7

Source: Sintesi per i politici (IPCC, 2021, pp. 13-14)**.**
Available all'indirizzo: IPCC_AR6_WGI_SPM_final.pdf

Adopting carbon removal policies through sinks or technologies can help reduce emissions, but they will not have an immediate effect. Being the IPCC, some impacts such as the melting of the ice sheets, the rising of the seas, the loss of more acidic species and oceans are already irreversible for several centuries, even after the fall of the emissions of GHGs. Comparing the socioeconomic emission scenarios, SSP1-1.9 (***Low emissions***) and SSP5-8.5 (***Very High emissions***) for the period 2081 - 2100 we have the following results presented in the following figure.

Picture 21: Comparing climate Impacts by 2100 from low-and high-emissions scenarios



Source: World Resources Institute, (2021) by data from (IPCC, 2021).

In a low-emission scenario, we would have: a) global air temperature would reach +1.4°C in the long-term scenario (2081-2100) when compared to the global pre-industrial air temperature (1850-1900); b) global average annual precipitation over land increased 2.4% in the long-term scenario (2081-2010) when compared to the relative period between the years 1995-2014; c) rise in the global mean level of the autoceanic sea level It would enter 0.38 meters projected for the end of the century (2100) when compared to the relative period between the years 1995-2014; d) minimum reduction of the area of marine ice in the Arctic (in September) would reduce to 2.4 10^6 km^2 projected for the long-term scenario (2081-210).

In a high-emission scenario, we would have: a) global air temperature would reach +4.4°C in the long-term scenario (2081-2100) when compared to the global pre-industrial air temperature (1850-1900); b) global annual average precipitation over land increased 8.3% in the long-term scenario (2081-2010) when compared to the relative period between the years 1995-2014; c) global average level rise The sea would be 0.77 meters projected for the end of the century (2100) when compared to the relative period between the years 1995-2014; d) minimum reduction of the area of marine ice in the Arctic (in September) would reduce to 0.3 $10^{6\ km2\ 2}$ designed for the long-term scenario (2081-210).

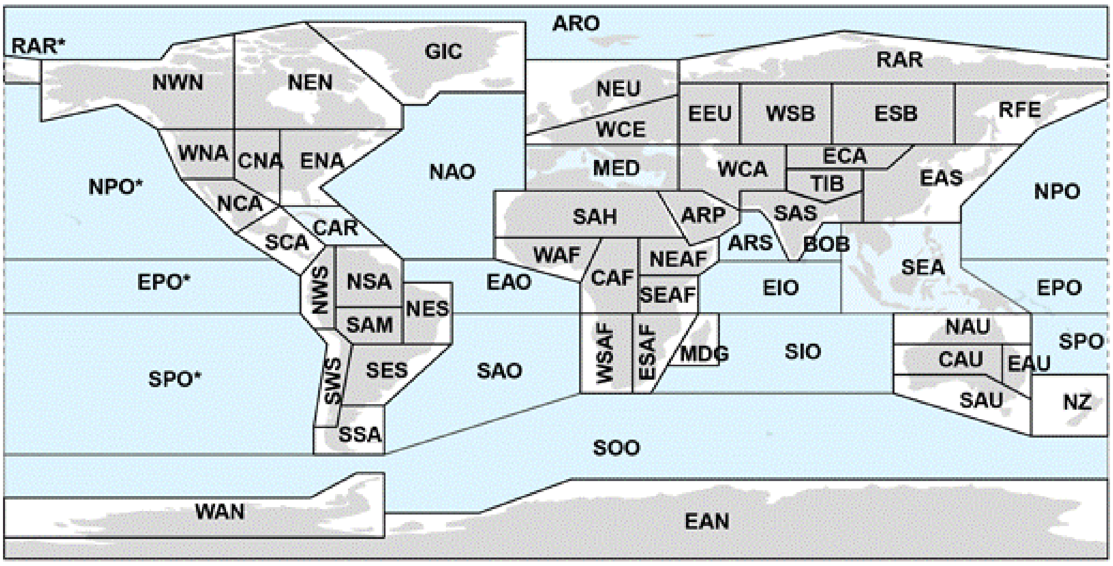
1.4 Main impacts in the territorial context

Among the main effects of global warming identified, we can mention: the increase and intensity of storms; forest fires and soil impoverishment; areas with thermal amplitude, droughts, heat islands; low drainage of the soil and change in the rainfall rates, causing floods; coastal floods, among many other effects observed during the literature review and which will be deepened in this sub-chapter.

One of these tools is the Platform developed by the IPCC, WGI Interactive Atlas, an interactive tool in which it is possible to evaluate the main climatic effects according to the chosen socioeconomic scenario. The platform provides results according to the most current resolution of the simulated projections with the CMIP6 and CORDEX datasets. Respectively with resolutions of 1 degree (111,111 km) and of 0.5 degrees (55,555 km), for a set of 46 reference regions and 14 ocean regions according to the work developed by Iturbide et al. (2020). The following figure is a screenshot of the tool, and shows the interface that the user will find, representing the earth globe in regions.

For this research we will analyze the data related to two specific regions of the Globe, in which are located the cities of: Natal, Rio Grande do Norte, Northeast Brazil and the city of Bologna, Emilia-Romana, located in the Northeast region of Italy. Both will be our object of study and are represented by the regions described on the map by the acronyms NES (Northeast Brazil) and MED (Mediterranean).

Picture 22: Regioni di riferimento IPCC WGI aggiornate (V4)



Source: WGI Interactive Atlas Tool. Iturbide et al., (2020).

The interactive tool developed by the IPCC uses the same climate models used in its reports, and it is possible to persolanize the graphic data outputs to generate a world map with information that the user deems appropriate about the effects projected for each reference region in the updated map (IPCC WGI, 2020). You can also randomly select a particular region on the global map, so the tool presents the main data and effects projected for the area taking into account their respective degrees of confidence. Possible effects and impacts are grouped by environmental characteristics, such as: (a) temperature (hot, cold and snow); (b) humidity; (c) wind action; (d) coastal hazards and a classification called "others" that assigns projections related to air quality, COconcentration and surface radiation.

Using the tool, maps were generated of the graphic data of the effects projected for the reference regions, are: the Northeast Brazil (NES) located in South America and the Mediterranean region (MED) located in the European continent, in which Brazil and Italy are inserted. In the regional synthesis map generated through the Interactive Atlas (IPCC WGI,2020) below, the effects of global warming have been correlated, categorized into six major areas of knowledge and degree of reliability, with the future impacts forecast for the scale of the selected territory, whether they are positive or negative impacts when compared to the current situation.

The first area of knowledge refers to the effects related to **temperature** with heat and cold waves, frosts, increase in the average temperature of the surface. For example, in the question of global average temperature, for the regions of the Brazilian northeast (NES) and for the Mediterranean region (MED) in the European continent, there is the future climate projection of high confidence that in these regions there is the increase of the current indices.

The second area of knowledge refers to the effects related to **precipitation** and water management, in which of the impacts presented in both regions (NES and MED) exhibits a reduction in prescipitation rates and an increase in periods of water scarcity with high growth confidence for the Mediterraneo and average confidence for the Brazilian Northeast.

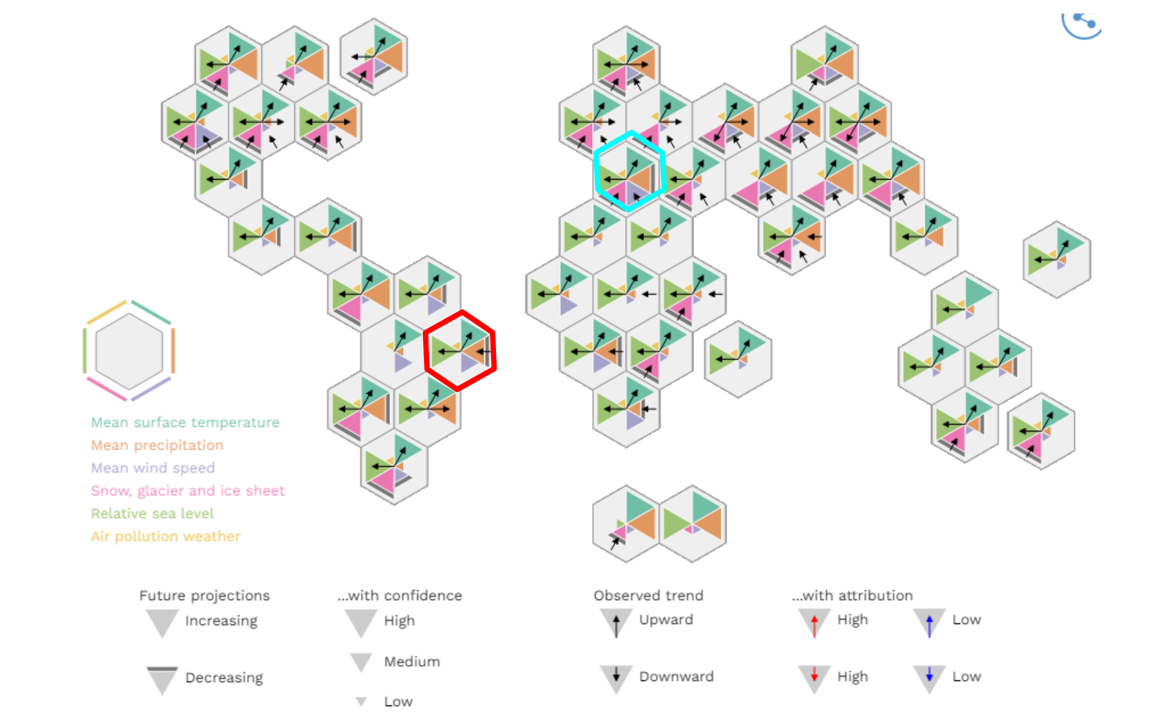
The third large area observed refers to the effects related to the **atmosphere**, where it is possible to observe the relationship between the speed of the wind and the temperature of the thermal mass of the atmosphere.

The fourth area addresses effects related to **glacial** areas **and low temperatures**, for example, in which the degree of reliability is high to reduce the frequency and extent of area where there is Snow, glacier and ice sheet for the Mediterranean region (MED).

The fifth area of knowledge refers to the effects related to the **level of the waters of the sea** and its acidification, in which in both territories there is a high degree of reliability of increase in the levels of the sea and floods with intensification of the oceanic acidity.

The last area of knowledge refers to the effects related to **air quality** and its composition, finding that for both regions there is a high reliability of increased air pollution as impacts from global warming.

Picture 23: IPCC WGI interactive atlas: Sintesi regionale delle 46 regioni con CMIPC6



EFFECT	NORDEST SUD AMERICA (NES) - Proiezioni future	MEDITERRANEAN (MED) Proiezioni future
Media temperature of the surface	→ **elevata** fiducia nella crescita	→ **elevata** fiducia nella crescita
Steep Heat	→ **elevata** fiducia nella crescita	→ **elevata** fiducia nella crescita
Freddo Period (Fredda Wave/Fredda Incantezza)	↓ **elevata** fiducia nella riduz	↓ **elevata** fiducia nella riduz
Ice	]	↓ **elevata** fiducia nella riduz
Precipitazioni medie	↓ **elevata** fiducia nella riduz	↓ **elevata** fiducia nella riduz
Inondazione del fiume	]	↓ **media** fiducia
Forti precipitazioni e alluvioni pluviali	fiducia **media** della crescita	fiducia **media** della crescita
Aridità	fiducia **media** della crescita	→ **elevata** fiducia nella crescita
Siccità idrologica	]	→ **elevata** fiducia nella crescita
Siccità agricola ed ecologica	fiducia **media** della crescita	→ **elevata** fiducia nella crescita
Tempo di fuoco	→ **elevata** fiducia nella crescita	→ **elevata** fiducia nella crescita
Velocità media del vento	fiducia **media** della crescita	↓ **elevata** fiducia nella riduz
Forte tempesta di vento	]	fiducia **media** della crescita
Tropical cyclones	]	]
Tempesta di sabbia and polvere	]	]
Snow, ghiacciaio and ghiacciaio	]	↓ **elevata** fiducia nella riduz
Permafrost (merge)	]	↓ **elevata** fiducia nella riduz
Lake, fiume and ghiaccio marino	]	↓ **elevata** fiducia nella riduz
Grandine	]	]
Snow valanga	]	]

Livello relative del mare	→ **elevata** fiducia nella crescita	→ **elevata** fiducia nella crescita
Inondazioni Costiere	→ **elevata** fiducia nella crescita	→ **elevata** fiducia nella crescita
Erosione del sughero	→ **elevata** fiducia nella crescita	→ **elevata** fiducia nella crescita
Ondata di calore marina	→ **elevata** fiducia nella crescita	→ **elevata** fiducia nella crescita
Accidità oceanica	→ **elevata** fiducia nella crescita	→ **elevata** fiducia nella crescita
Atmospheric Inquinement	]	]
Atmospheric CO2 on the surface	→ **elevata** fiducia nella crescita	→ **elevata** fiducia nella crescita
Radiazione di superficie	fiducia **media** della crescita	fiducia **media** della crescita

Source: Interactive Atlante: Sintesi regionale (2021). Presso availability: https://interactive-atlas.ipcc.ch/.

The effects of global warming made available by the platform were obtained through simulation with projection equal to 1° (111,111 km), providing the user with accessible and relevant information, but preliminary, within the context of empirical analysis on the urban territorial scale. This is because as stated earlier a simulation with a grid of 1 degrees (111,111 km) is not a suitable scale for analyzing the impacts within the scale of the urban microclimate. Since, for example, the city of Natal located in the Northeast of Brazil has a territorial area of 167,401 km² [102], or the Comune de Bologna located in Emilia-Romania in Italy that has a territorial area of approximately 140.86km².

The Atlas is an interesting tool to base thematic discussions and guide leaders in the formulation of mitigating and adaptive policies, proposing guidelines and normatives in the face of this scenario. Combined with other tools, *stakeholders* can identify areas vulnerable to these changes, supporting the development of solutions to expand resilience against them. For example: the identification of areas of risk, identifying areas with a tendency to floods, low percolation, surfaces with low permeability, among others. With these identified areas it is possible to plan actions for implementation of resilient infrastructure capable of mitigating these effects, as well as better manage these climatic events avoiding human losses.

However, when we use the material with the same projection scale to reference the analyzes in the context of the scale of the built environment, the information is even more insufficient. This is due to urban morphology and its built features particular to each city, region and culture. For example, the Comuna di Bologna is a medieval historical city. And as such it possesses particular morphological and constructive characteristics of that region, which together compose characteristics that directly interfere in the local meteorological relationships, constructing a particular microclimate in each neighborhood or quartiere. This limitation shows the need to develop other tools and technologies capable of giving a better precision of these interactions.

Faced with such limitations, the choice was made to classify the approach of this research on two large scales: a) the first macroscale denominated **territorial** one that comprises the urban and peri-urban area, with models of planning and management of cities that show more operational and continuous characteristics; b) the second scale will be here called **constructed**

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[102] IBGE - Brazilian Institute of Geography and Statistics. (2021). Area of the territorial unit of Natal municipality. Evaluable from: https://cidades.ibge.gov.br/brasil/rn/natal/panorama

environment, which comprises the scale of the building itself with a focus on the project process and project management.

Seeking to construct this risk mapping, to identify effect and impacts used as a method the review of literature and state of the art on the theme of research, in which it finds the climate emergency in which we are inserted, it being necessary to adopt joint actions to minimize this impact mainly in the sector of civil construction (large emissions of GHGs incorporated and operational). By means of the literature review of the observed climatic changes added to the literature that addresses the projected changes according to the socioeconomic scenarios or scales of future warming projections.

According to the report of IPCC Working Group I (2021), both the effects and the projections of the main effects attributed to global warming were summarized through a table (see table below extracted from the original text), which presents a summary of the main climatic changes observed since 1950 and their future projections. The table presents the impacts in a time lapse of one short, the medium and the long term and in five scale of reliability of the projections. They are: medium confidence (medium confidence), probable/high confidence (*likely/high confidence*), very likely (*very likely*), extremely likely (extremely likely) and virtually certain (*very*).

Picture 24: Major effects attributed to global warming: projected changes to +1.5°C (SSP1-1.9), +2°C (ssp2-4.5) and +4°C (SSP5-8.5).

Change in Indicator	Observed (since 1950)	Attributed (since 1950)	Projected at GWL (°C) +1.5	+2	+4
Warm/hot extremes: Frequency or intensity	↑	✓ Main driver	↑	↑	↑
Cold extremes: Frequency or intensity	↓	✓ Main driver	↓	↓	↓
Heavy precipitation events: Frequency, intensity and/or amount	↑ Over majority of land regions with good observational coverage	✓ Main driver of the observed intensification of heavy precipitation in land regions	↑ in most land regions	↑	↑ in most land regions
Agricultural and ecological droughts: Intensity and/or frequency	↑ in some regions	✓ in some regions	↑ in more regions compared to observed changes	↑ in more regions compared to 1.5°C of global warming	↑ in more regions compared to 2°C of global warming
Precipitation associated with tropical cyclones	↑	✓	↑ Rate +11%	↑ Rate +14%	↑ Rate +28%
Tropical cyclones: Proportion of intense cyclones	↑	✓	↑ +10%	↑ +13%	↑ +20%
Compound events: Co-occurrent heatwaves and droughts	↑ (Frequency)	✓ (Frequency)	↑ (Frequency and intensity increases with warming)		
Marine heatwaves: Intensity & frequency	↑ (since 1900)	✓ (since 2006)	↑ Strongest in tropical and Arctic Ocean		
Extreme sea levels: Frequency	↑ (since 1960)	✓	↑ (Scenario-based assessment for 21st century)		

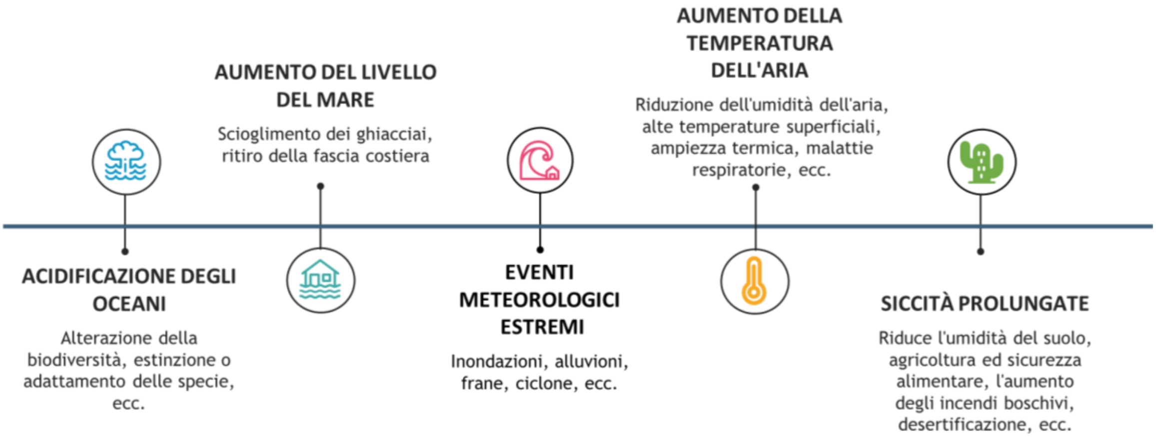
medium confidence · *likely/high confidence* · *very likely* · *extremely likely* · *virtually certain*

Source: (IPCC, 2021). Evaluable at: https://www.ipcc.ch/report/ar6/wg1/downloads/report/IPCC_AR6_WGI_TS.pdf

Second report of the IPCC Working Group II (2022) highlights some impacts related to GHG emissions and the effects of global warming. These are: loss of biodiversity; prolonged droughts, with area in the process of desertification[103]; food and nutritional insecurity; increased fires in forest areas, mainly in Southern Europe; extreme heat, with an increase in the number of days in the year with temperatures above 35 degrees Celsius; increase in sea level, intensified by the process of melting the *permafrost;* increase in the temperature and acidity of the oceans, which impacts on the reduction of coral reefs; extreme climatic events: heat waves all over the globe, but mainly in southern Africa; floods, urban and coastal diseases; air quality.

In addition to the physical impacts, climate change has undoubtedly unleashed socio-economic, political and environmental impacts. After identifying the main effects of global warming through the review of the literature, which are on the territorial scale, effects related to the alteration of biodiversity, air pollution, increase of sea levels, their acidification, increasingly frequent meteorological events of greater impact, increase of the global average temperature and with this the consequences related to water scarcity, among others. We classify which effects in five large areas, as described in the following figure.

Picture 25: Classification of the main effects in the spatial context



L'autore (2020).

1.4.1 Ocean acidification

The first set of effects related to climate change, related to the territorial scale, are the effects related to the absorption of carbon dioxide present in the atmosphere through the upper layer of the ocean, causing its acidification. According to the Special Report on the Ocean and Cryosphere in a Changing Climate (IPCC, 2019), ocean acidification directly and indirectly impacts oceanic and marine ecosystems, forcing species to adapt or causing the loss of marine biodiversity. Since these biomes are many vulnerable and particular to each species.

Among the identified impacts resulting from this effect, we can cite as an example coral bleaching, reef reduction, changes in aquatic biodiversity, changes in weather and sea currents, increased coastal flooding and hangovers, change in coastal landscapes. It also has a socio-

[103] Desertification:" means land degradation in arid, semiarid and dry sub-humid areas resulting from various factors, including climatic variations and human activities" (UNCCD, 1994).

economic impact on coastal communities and human settlements, which depend on this ecosystem for its existence and are essential for the maintenance of life and culture.

1.4.2 Sea level rise

The second group describes the impacts related to the effect of the increase on the level of the sea, intensified by the process of melting the *permafrost,* by the greenhouse effect and concomitantly with global warming. According to the *Special Report on the Ocean and Cryosphere in a Changing Climate* of the IPCC (2019)However, the coastal region is home to about 28% of global human settlements, 11% of which are human settlements that are only 10 meters away, all vulnerable to this effect.

> *Communities living in close connection with polar, mountain, and coastal environments are particularly exposed to the current and future hazards of ocean and cryosphere change. Coasts are home to approximately 28% of the global population, including around 11% living on land less than 10 m above sea level."* (IPCC, 2019).

This effect leads to: (a) exposure to coastal floods; (b) increased risk of coastal erosion; (c) local natural landscape impacts, in addition to being able to cause damage to the existing historical heritage; (d) altering the climate and weather patterns of the site; and (e) has the potential to displace inner communities as well as to promote the disappearance of islands and their biomes.

1.4.3 Extreme meteorological events

The third set of extreme meteorological events, are effects resulting from the change in weather patterns and climate, which cause high rainfall (floods, floods, landslides); low rainfall rates that interfere with the periods of droughts, drought and soil degradation; tropical cyclones, heat and cold waves, thermal amplitude, among others that cause various socioeconomic damage in their respective communities.

Changes in rainfall patterns have influenced the quantity and quality of water resources available for the supply of cities. Urban centers are already responsible for the consumption of 22% of the total water flow captured in Brazil. After this demand, the second largest national demand is that of the agricultural sector through the irrigation of crops. The irrigation system demands equivalent to 55% of the total captured in the Brazilian territory. The alteration of these rainfall regimes had a direct impact on the production of energy. With the forecast of long periods of drought the urban centers will be affected, due to drought, growing demand and the low supply of energy in the country. This is directly linked to the increase in water consumption and unavailability for power generation, as well as the impact this demand will have on the national distribution system UNFCC, (2016). PAGE 12.

We can also mention the increase in the frequency and intensity of storms, forest fires and soil degradation. A degraded soil will cause not only droughts, but also a low percolation rate of the soil, making it difficult for the groundwater to return to its original state. This could aggravate the problem of water and food insecurity.

1.4.4 Increase of the temperature of air

The fourth category of effects on the territorial scale are effects directly related to the global temperature average warming. This is a generalized effect that impacts all scales, whether on global, territorial, urban, built environment or even user scales, the average temperature rise is a critical effect and irreversible consequences.

The latest IPCC report and published in August 2021, "*Working Group I report, Climate Change 2021: The Physical Science Basis* (2021)", recognizes with extreme concern that greenhouse gas emissions from anthropogenic activities were responsible for the increase of approximately 1.1°C of warming in relation to pre-industrial levels (1850-1900). The document also predicts that the average global terrestrial temperature will reach or exceed 1.5°C already at the beginning of the next decade, this being the index established in the Paris Agreement (2015) and considered by many scientists as the Earth's safety threshold. The report further shows that even if there is coordinated planning among nations, with rapid, joint and ambitious actions aiming to significantly reduce GHG emissions, the only noticeable benefit in a short space of time would be the increase in air quality. Furthermore, it would take at least 20 to 30 years for the global temperature to stabilize, otherwise we will reach the global average temperature of 2°C in this century (IPCC, 2021).

This report, also called the "red code for humanity", referred to the main agendas discussed at the last Conference of Nations, COP 26 (UNFCCC, 2021)held in Glasgow, Scotland, in November 2021. The discussions advanced and the main guidelines that were set as priorities in tackling climate change after the debates were: the conclusion of the "Paris Rulebook[104]", with practical guidelines for implementing the Paris Agreement and regulating the carbon market; the commitment of the Nations to update and include in their NDCs more ambitious contributions for 2030 that make it possible to limit global warming by 1.5°; and including a 45% local carbon reduction by 2030 compared to the 2010 level and to reach net zero by mid-2050; Provide more resources to assist developing nations in financing necessary mitigation and adaptation actions, providing 50% of this amount to finance adaptation-related actions.

The major urban centers have diverse and complex climatic characteristics, since the way in which the exchanges of energy (long wave radiation) take place between the atmosphere and the different urban and non-urban systems show their particularities. ZHAO, et.al (2011). The heat island effect is a phenomenon associated with dense areas, with a direct influence on the characterization of the urban climate. As an impact associated with the problem of the Isle of Heat, we can mention the air pollution and floods.

1.4.5 Prolonged drought

Meteorological drought is generally defined on the basis of the degree of safety, which is measured by averaging the "normal" quantity of a given region, in comparison to the dry period. The agricultural drought correlates the characteristics of the meteorological (or hydrological) drought with the impacts that these droughts cause in the agricultural sector. Agricultural drought focuses on studies related to: rainfall scarcity, differences between actual and potential

[104] Paris Rulebook: also known as the Katowice Climate Package or Katowice Rule Book.

evapotranspiration, water deficits in the soil, reduced levels of groundwater or reservoirs and so on. The demand for water by plants depends on the prevailing climatic conditions, the biological characteristics of the specific plant, its stage of growth and the physical and biological properties of the soil. A good definition of agricultural drought should be able to take into account the variable vulnerability of crops during the different stages of crop development, from emergence/emergence to maturity. Deficiency of soil moisture in planting can hinder germination, leading to low plant populations per hectare and reduced final yield.

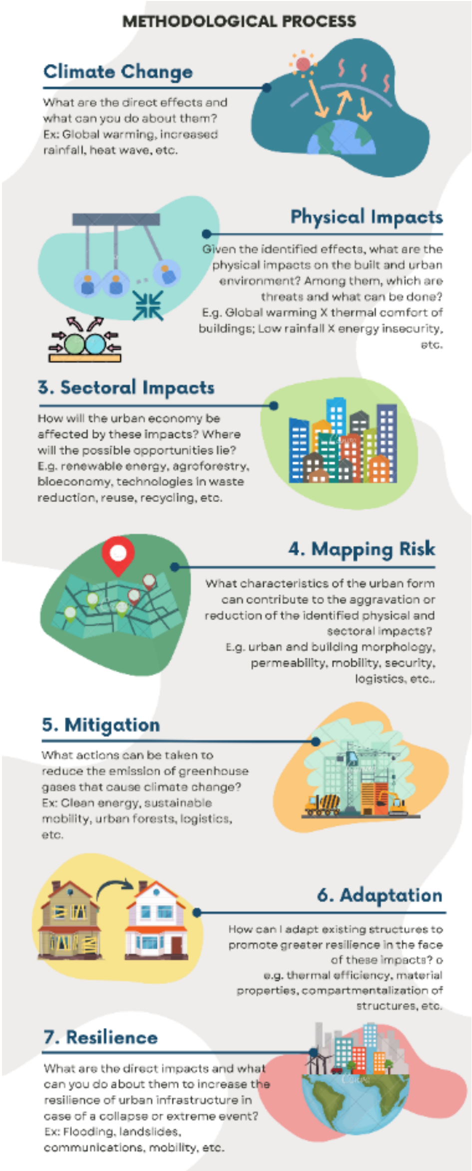
Hydrological droughts, on the other hand, are associated with the effects of periods of precipitation scarcity (including snowfall) on the supply of surface or subsurface water (i.e., flow of current, levels of reservoirs and lakes, groundwater). The frequency and severity of hydrological drought are often defined based on the scale of a river basin. Although all droughts originate with a lack of precipitation, hydrologists are more concerned with how this deficiency manifests itself in the hydrological system. Hydrological droughts generally delay the occurrence of weather and agricultural droughts. It takes longer for precipitation deficiencies to appear in components of the hydrological system, such as soil moisture, flow, and groundwater levels and reservoirs impacting systems in a different way. For example, a rainfall deficiency can result in a rapid depletion of soil moisture that is almost immediately discernible to farmers, but the impact of this deficiency on reservoir levels may not affect hydroelectric power production or recreational uses for many months

As a result, the impact of droughts is generally widespread, reverberating in all sectors that make up a country's national economic economy.

2 CHARACTERIZATION OF OBJECTS OF STUDY: NATAL (BRAZIL) AND BOLOGNA (ITALY)

This chapter aims to correlate the effects of global warming identified within the contexts of the cities of Natal located in the State of Rio Grande do Norte in Brazil and in the commune of Bologna located in the region of Emilia-Romana in Italy. In order to achieve this objective, it is necessary to characterize the objects of the study, to identify later what the possible impacts on the territorial scale of these cities, making possible a diagnosis of exposure to the risk for the site.

Picture 26: Methodology process for developing risk exposure diagnosis



Source: The Author (2021), adapted from: https://www.klimaateffectatlas.nl/em/how-to-use

The methodology adopted in this process was first to categorize what are the direct effects of global warming on the urban territorial scale (previous chapter), to identify after what can and cannot be done in relation to them, afterwards, to identify the direct physical impacts of the effect of global warming on the urban territorial scale and the built environment. As well as the most vulnerable urban systems to these impacts, seeking to obtain resilient responses to this infrastructure essential for the operationalization of the city. Through this mapping of risks and vulnerabilities it is possible to plan and develop strategies within the scale of the built environment to mitigate these impacts, adapt existing structures and promote their resilience to these changes.

To identify the main impacts related to climate change, the European database called Copernicus[105] (*Europe's eyes on Earth*) *was used*. Database providing global satellite-observed data on six main thematic fronts: Atmosphere, Marine, Land, Climate Change, Security and Emergency.

The platform aims to make information available in an accessible and free way to all interested parties, whether they are academic institutions or not, public or private, who wish to carry out research related to the areas of meteorology, hydrology and climatology.

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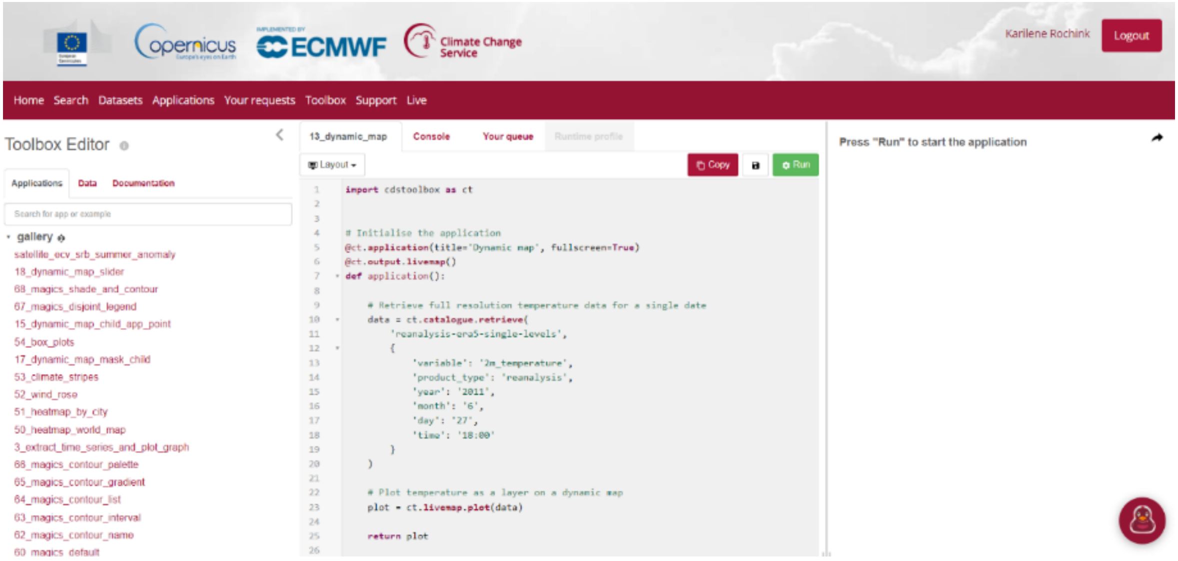
[105] The Climate Data Store: Evaluable from: https://cds.climate.copernicus.eu/#!/home

The *Copernicus Climate Change Service* (C3S) platform was implemented by the European Center for Medium-Term Weather Forecasts (ECMWF) and operated in 2018. To build an EU database to support mitigation and adaptation policies in the face of climate change and global warming. The tool provides, free of charge, reliable information about climatic history, about current climatic conditions and projections of future climate, possible through physical and mathematical models, obtained through Reanalysis[106] Data, also adopted by the IPCC in its reports. The platform allows the customization of data and model inputs, through Pyton programming language, and it is possible to obtain individualized results and graphical outputs.

Picture 27Copernicus: Interface of the Copernicus platform: Il Sistema di memorizzazione dei dati sul Climo (CDS)



Source: Immagine della schermata Copernicus EU dell'autore (2021).

The ECMWF is currently finalizing the production of the global reanalysis data called ERA5 global reanalysis, which is a set of data based on the Cy41r2 integrated prediction system (IFS), which will group together a detailed record of the global atmosphere, the Earth's surface and ocean waves from 1950, replacing the ERA-Provisional reanalysis that covers data from 1979 onwards (Hersbach, et al., 2020). Also according to the same author the ERA5 data will have an improved horizontal resolution of 31km, compared to the previous model of 80 km (ERA-Interim). With this, the platform will provide hourly data outputs, with improved adjustment for variables of temperature, wind, precipitation and humidity in the troposphere[107] , which is the closest layer to the earth's surface at an altitude of between 8 and 14 km.

2.1 Brazil: Natal/RN

Brazil is a country located in Latin America, which is part of the economic bloc of Mercosur. It is a country of continental size, which possesses a vast ecological and biological diversity, divided administratively into five macro-regions: North, Northeast, Center-West, Southeast and South. Due

[106] The ERA5 global reanalysis: Assessed from: The ERA5 global reanalysis: Preliminary extension to 1950 - Bell - 2021 - Quarterly Journal of the Royal Meteorological Society - Wiley Online Library
[107] NASA (2019). The troposphere is the innermost layer of Earth's atmosphere. The troposphere is between 5 and 9 miles (8 and 14 kilometers) thick depending on where you are on Earth.

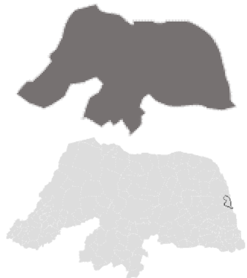
to the extensive geographical and administrative territoriality, it was chosen to work in this research only with the Northeast Region. The choice of this region is justified by the author's familiarity with the aspects related to it and, above all, by being a region extremely vulnerable climatically. Since, according to the last census of the Brazilian Institute of Geography and Statistics (IBGE)[108] of 2010, the Northeast region will be one of the most impacted with the effects of the climatic changes already under way in Brazil. Besides being a region with low levels of human and economic development, lacking investments in all sectors, as well as, devoid of efficient and sustainable public and fiscal policies. Primarily, and unfortunately, in terms of food and nutritional vulnerability, and access to basic infrastructure such as: sanitation (water and sewage), energy and the Internet.

Within the macro-region of the Northeast there are nine administrative subdivisions called States, these are: Tocantins, Piauí, Ceará, Rio Grande do Norte, Paraíba, Pernambuco, Alagoas, Sergipe and Bahia. In order to work with equivalent territorial scales between Brazil and Italy, it was decided to work only with the municipality of Natal, the capital of Rio Grande do Norte. Having defined the object of study, the research sought to identify the effects of global warming and the respective impacts resulting from this climate change, in the current time period and the future projections published by the IPCC, which will afflict the capital of Rio Grande do Norte. The following figure illustrates the clipping of the object of study of the research:

Picture 28: Brazil, Northeash Region and Sub-regions, State of Rio Grande do Norte, city of Natal.

(I)Brazil (II) Northeast (III) State of Rio Grande do Norte

(IV) State of Rio Grande do Norte



(V) Municipality of Natal

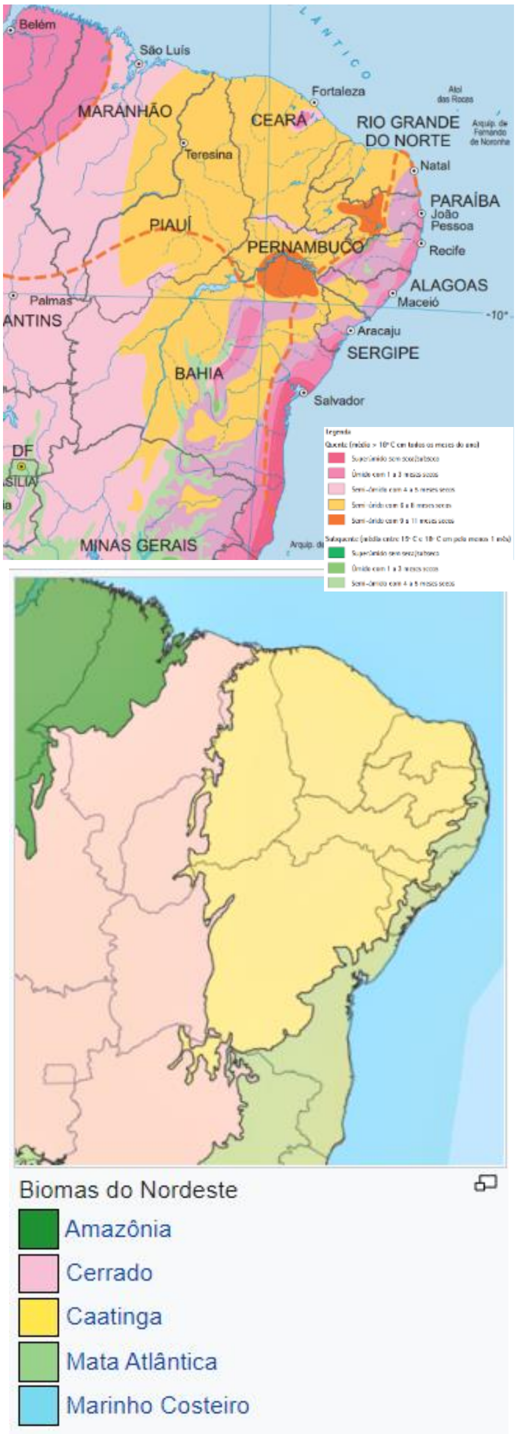
2.1.1 Physical and demographic aspects

Rio Grande do Norte has a territorial extension of 52,809,599 km² (IBGE, 2021). The economy is predominantly based on oil exploration, the establishment of wind farms and tourism.

[108] Brazilian Institute of Geography and Statistics (IBGE). (2010). Evaluable from: https://cidades.ibge.gov.br/brasil/ba/nordestina/panorama

The State Human Development Index (HDI), for the year 2010, is 0.684 and the nominal monthly household income per capita is R$ 1.109 (IBGE, 2021), which is equivalent to U$: 200.54 dollars[109].

Picture 29: Climate characterization of the Brazilian Northeast



Source: IBGE, 2012.

Reflection of a basic education considered as one of the worst in the country, with an IDEB (Index for the development of Basic Education) score of only 4.4 in the year 2019, for the initial years of elementary education of the public school network, being thus the 24th placed within the total of

27 Brazilian states.

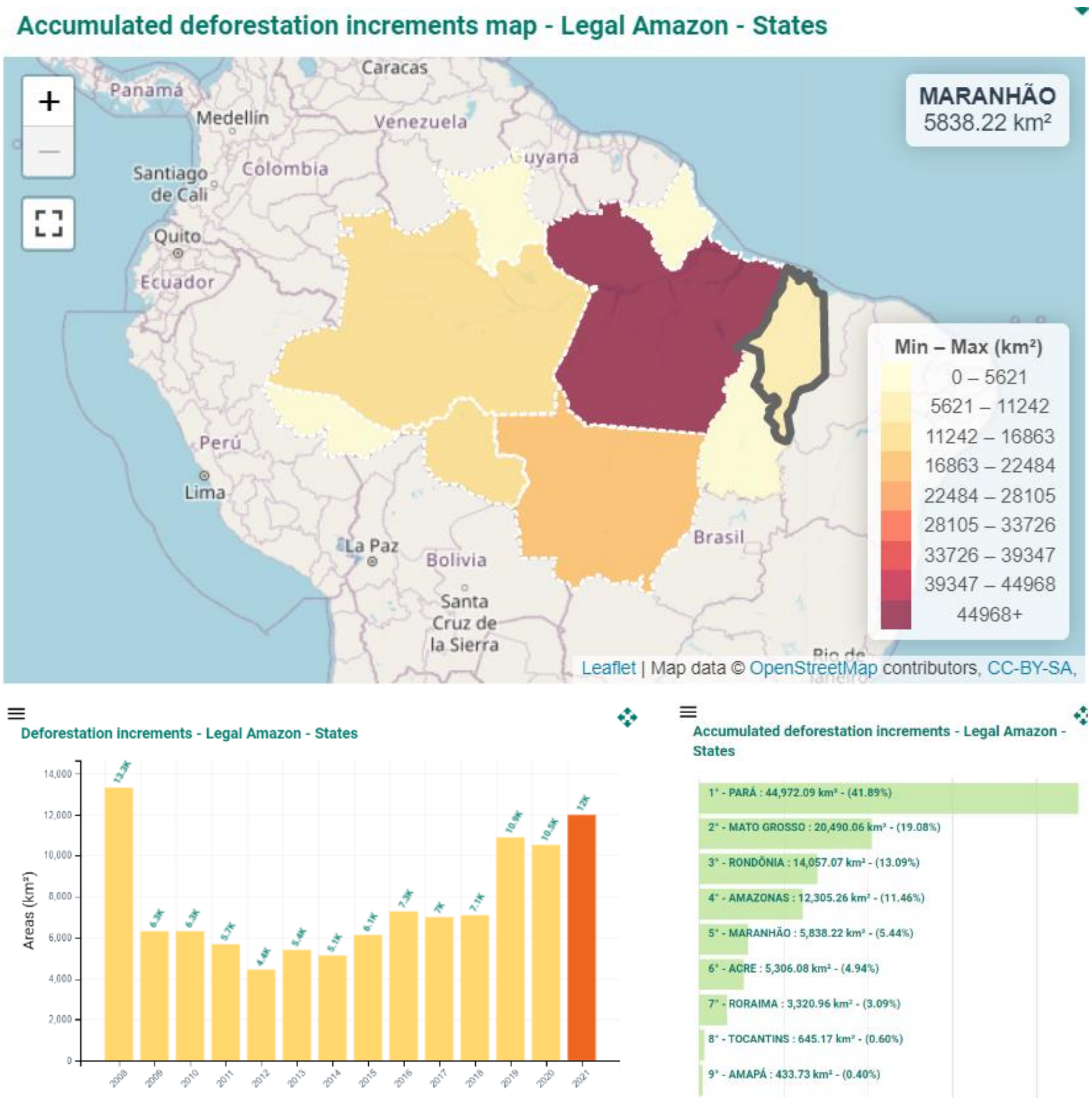
The Northeast of Brazil is composed of four biomes that make up its fauna and flora: the Atlantic Rain Forest, located on the east coast of the state and bathed by the Atlantic Ocean; the region in which the city of Natal is inserted; the Caatinga (from the Tupi: *ka'a* [forest] + *tinga* [white] = white forest), is an exclusive Brazilian biome of extreme fragility that comes from the unsustainable use of its soils and natural resources over hundreds of years of occupation, since the colonial period. Its vegetation is adapted to climates of a lot of aridity, semi-desert being very vulnerable to the process of desertification; the Cerrado is the second largest Brazilian biome that extends from the northeast, passes through the north, through central Brazil, reaching up to the center-west and south. It is composed of a vast biodiversity, but with several species of fauna threatened with extinction, it is a very rich system falling behind only the Amazon forest. With a savannah vegetation, it has been threatened mainly after the 60s due to agricultural expansion, monoculture, still being threatened by criminal fires and by climate changes with high temperatures and low humidity. And finally the biome of the Atlantic Rain Forest, present in the state of Maranhão, which is the largest Brazilian biome rich in biodiversity and extends over the whole territory. A rich ecosystem, fragile climate change and currently suffering from biopiracy, deforestation and illegal burning.

[109] Central Bank of Brazil (2022). Monthly average exchange, for the month of January 2022 = U$:5.53. Evaluable from: http://www.ipeadata.gov.br/ExibeSerie.aspx?serid=38590&module=M

The northeast of Brazil is composed of four biomes that make up its fauna and flora: the Atlantic Rain Forest located on the east coast of the state that is bathed by the Atlantic Ocean, a region in which Natal is inserted; the Caatinga (from the Tupi: *ka'a* [forest] + *tinga* [white] = white forest), is an exclusive Brazilian biome of extreme fragility that comes from the unsustainable use of its soils and natural resources over hundreds of years of occupation, since the colonial period. Its vegetation is adapted to climates with a lot of aridity, semi-desert being very vulnerable to the process of desertification; the Cerrado is the second largest Brazilian biome that extends from the northeast, passes through the north, through central Brazil, reaching up to the center-west and south. It is composed of a vast biodiversity, but with several specifies of fauna threatened with extinction, it is a very rich system falling behind only the Amazon forest. With a savannah vegetation, it has been threatened mainly after the 60s due to agricultural expansion, monoculture, still being threatened by criminal fires and by climate changes with high temperatures and low humidity. And finally, the biome of Mata Atlantica, present in the state of Maranhão, which is the largest Brazilian biome rich in biodiversity and is found throughout the entire territory. A rich ecosystem, fragile climate change and currently suffering from biopiracy, deforestation and illegal burning.

Within the Brazilian Northeastern region there is the gift of the Amazonian biome, represented by the State of Maranhão, which is also part of the legal Amazon. The administrative region in which the Superintendence of the Development of the Amazon (SUDAM) operates, instituted by a federal law dated 2007, has large areas of permanent reserve, made up of nine Brazilian states that also make up the Amazon basin, in this region there is the majority of the indigenous reserves of the country being a population of high vulnerability. The following figure represents the area that comprises the Legal Amazon and the accumulated deforestation by State between the years 2008-2021. The accumulated deforestation in the State of Maranhão alone is 5,838.22 km², which is equivalent to an area twice as large as the territorial extension of the city of São Paulo, which is the largest Brazilian city. In addition to the Amazonico biomes, the region under study presents the Bioma of the Cerrado, Caatinga, Atlantic Rain Forest and the coastal marine biome.

Picture 30: Legal Amazon: Accumulated deforestation by States (2008-2021)



2.1.2 Climate aspects and projections of future scenarios

According to the Köppen-Geiger climate classification map, the Brazilian territory has several climates classified into three climate groups: Equatorial, Arid, Warn Temperate, with the predominant Equatorial climate by territorial extension. Due to the plurality of existing typologies, in this research opted to analyze only the Northeast region of Brazil, in which is located the city of Natal, in Rio Grande do Norte.

The hot and humid climate, typical of the coastal regions of the Brazilian Northeast, presents particularities to be considered in the project process that aims at the comfort of the users. High air humidity makes it difficult for sweat to evaporate, which reduces its action on the body's cooling. On the other hand, the low latitude favors thermal gain by the enclosure, mainly by the covering, which can result in a considerable thermal charge by radiation. Shading significantly reduces thermal gains, while ventilation cools the built-up mass and the human body. The sum of these two strategies is capable of providing comfort for most of the year, and for this reason, they are pointed out as the most suitable project recommendations for the hot and humid climate.

The Brazilian Northeast is characterized by high temperatures, tropical climate and average temperature higher than 18 °C in every month of the year, having three predominant climates: the semi-humid (4 to 5 dry months), the semi-arid (6 to 8 dry months) and dry semi-arid (9 to 11 dry months). In the specific case of Rio Grande do Norte, the semi-arid climate in the interior predominates and is hot and humid on the coast, where the capital is located.

The Christmas/RN climate is characterized by a large percentage of hours of heat discomfort. The fraction corresponding to hours of cold discomfort is inexpressive and only a small percentage points to the climate as comfortable. Among the six categories indicated to alleviate the discomfort effects of the Christmas climate, ventilation alone accounts for approximately 70% of the hours. Added to the categories that combine ventilation with the other strategy, this percentage rises to approximately 84%. Air conditioning is recommended for little more than 1% of hours of discomfort.

Picture 31: Summary of the Christmas/RN climate data

WEATHER DATA SUMMARY

LOCATION: Natal, RN, BRA
Latitude/Longitude: 5.8° South, 35.21° West, **Time Zone from Greenwich** -3
Data Source: INMET 818390 WMO Station Number, **Elevation** 49 m

MONTHLY MEANS	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	
Global Horiz Radiation (Avg Hourly)	476	485	460	449	422	417	439	472	504	520	491	471	Wh/sq.m
Direct Normal Radiation (Avg Hourly)	214	239	203	206	188	176	189	210	249	267	218	195	Wh/sq.m
Diffuse Radiation (Avg Hourly)	215	199	215	194	176	175	177	196	206	209	224	229	Wh/sq.m
Global Horiz Radiation (Max Hourly)	1047	1064	1153	1044	1021	906	839	968	1018	1064	1006	987	Wh/sq.m
Direct Normal Radiation (Max Hourly)	810	839	911	819	737	636	555	730	781	822	748	724	Wh/sq.m
Diffuse Radiation (Max Hourly)	450	458	456	424	400	382	383	412	433	420	440	442	Wh/sq.m
Global Horiz Radiation (Avg Daily Total)	5857	5918	5537	5335	4955	4867	5148	5579	6037	6313	6024	5814	Wh/sq.m
Direct Normal Radiation (Avg Daily Total)	2638	2927	2450	2455	2210	2064	2213	2484	2987	3251	2675	2416	Wh/sq.m
Diffuse Radiation (Avg Daily Total)	2652	2429	2597	2302	2069	2045	2080	2327	2469	2537	2754	2832	Wh/sq.m
Global Horiz Illumination (Avg Hourly)	51219	52249	49711	48226	45097	44344	46909	50660	54309	56166	53035	50668	lux
Direct Normal Illumination (Avg Hourly)	20942	23630	19955	20293	18425	17113	18202	20409	24461	26300	21180	19056	lux
Dry Bulb Temperature (Avg Monthly)	27	27	27	26	26	26	26	26	26	26	27	27	degrees C
Dew Point Temperature (Avg Monthly)	22	22	23	23	23	22	20	20	19	18	19	20	degrees C
Relative Humidity (Avg Monthly)	72	75	78	81	80	78	74	70	65	63	65	66	percent
Wind Direction (Monthly Mode)	30	110	110	120	120	110	110	100	90	90	90	90	degrees
Wind Speed (Avg Monthly)	4	4	3	2	2	2	2	4	5	5	6	5	m/s
Ground Temperature (Avg Monthly of 3 Depths)	26	27	27	27	27	26	26	26	26	26	26	26	degrees C

◉ **ASHRAE Standard 55 and Current Handbook of Fundamentals Model**

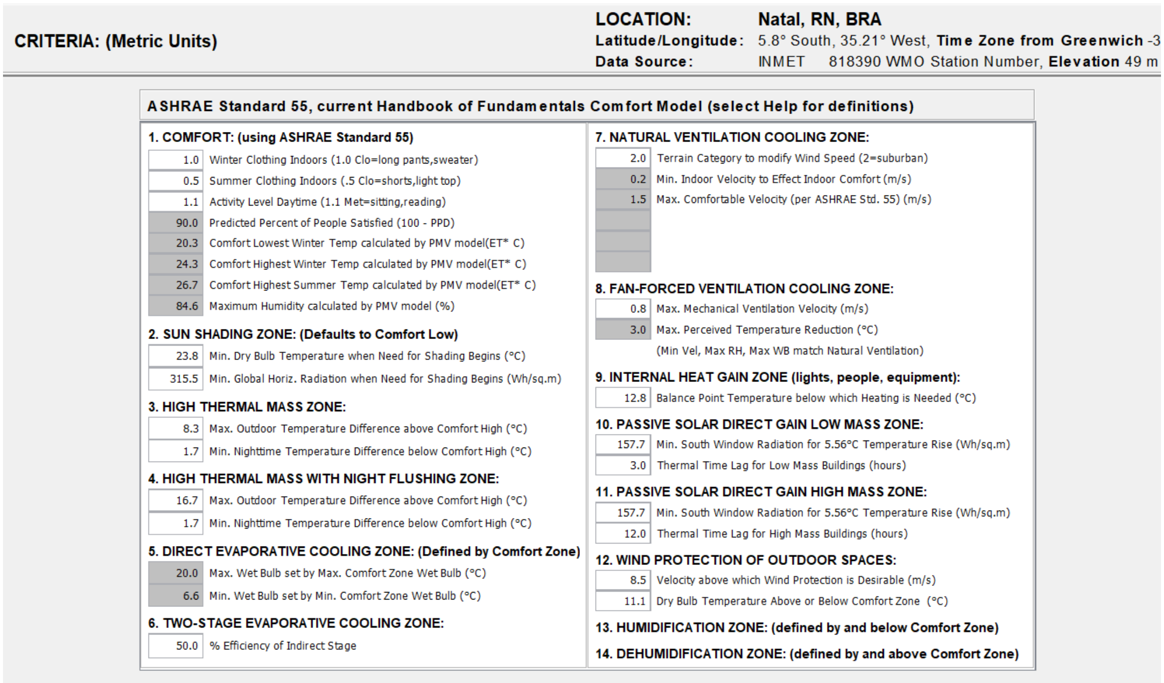
Thermal comfort is based on dry bulb temperature, clothing level (clo), metabolic activity (met), air velocity, humidity, and mean radiant temperature. Indoors it is assumed that mean radiant temperature is close to dry bulb temperature. The zone in which most people are comfortable is calculated using the PMV (Predicted Mean Vote) model. In residential settings people adapt clothing to match the season and feel comfortable in higher air velocities and so have wider comfort range than in buildings with centralized HVAC systems.

Source: ASHREA, 2021.

Considering that the air temperature at Natal/RN is mild for most of the day and is not too high at the hottest times, it is possible to provide thermally comfortable environments without the need for thermo-accumulation strategies. The constant renewal of the air, brought about by natural ventilation, makes it possible to approximate the external and internal temperatures, removing the mass of heated air from the environments, provided that excessive thermal gains are avoided (BONNEAUD, et al., 2001).

Therefore, it is possible to state that the most favorable situation for buildings naturally conditioned in the local climate must present internal temperature lower than the external one, avoid the thermal gains by the envelope (OLIVEIRA, 2006), make use of ventilation to remove the heated air mass and promote skin cooling through air movement. However, it has to be considered that the population of regions of hot and humid climate tend to adapt naturally to the conditions of the environment (BONNEAUD, et al., 2001). There are studies that are dedicated to quantifying the benefit of ventilation over the level of satisfaction of individuals. According to Nicol (2004) the upper limit of the comfort zone may be raised in the event of air circulation, as ventilation increases the tolerance of individuals to high temperatures. This makes it feasible to occupy naturally conditioned environments during periods when the air temperature is high, provided that there is constant ventilation.

Picture 32: Bioclimatic assessment of climate data from Natal/RN
(I)ASHRAE Standard 55, current Handbook of Fundamentals Comfort Model


CRITERIA: (Metric Units)

LOCATION: Natal, RN, BRA
Latitude/Longitude: 5.8° South, 35.21° West, Time Zone from Greenwich -3
Data Source: INMET 818390 WMO Station Number, Elevation 49 m

ASHRAE Standard 55, current Handbook of Fundamentals Comfort Model (select Help for definitions)

1. COMFORT: (using ASHRAE Standard 55)
1.0 Winter Clothing Indoors (1.0 Clo=long pants,sweater)
0.5 Summer Clothing Indoors (.5 Clo=shorts,light top)
1.1 Activity Level Daytime (1.1 Met=sitting,reading)
90.0 Predicted Percent of People Satisfied (100 - PPD)
20.3 Comfort Lowest Winter Temp calculated by PMV model(ET* C)
24.3 Comfort Highest Winter Temp calculated by PMV model(ET* C)
26.7 Comfort Highest Summer Temp calculated by PMV model(ET* C)
84.6 Maximum Humidity calculated by PMV model (%)

2. SUN SHADING ZONE: (Defaults to Comfort Low)
23.8 Min. Dry Bulb Temperature when Need for Shading Begins (°C)
315.5 Min. Global Horiz. Radiation when Need for Shading Begins (Wh/sq.m)

3. HIGH THERMAL MASS ZONE:
8.3 Max. Outdoor Temperature Difference above Comfort High (°C)
1.7 Min. Nighttime Temperature Difference below Comfort High (°C)

4. HIGH THERMAL MASS WITH NIGHT FLUSHING ZONE:
16.7 Max. Outdoor Temperature Difference above Comfort High (°C)
1.7 Min. Nighttime Temperature Difference below Comfort High (°C)

5. DIRECT EVAPORATIVE COOLING ZONE: (Defined by Comfort Zone)
20.0 Max. Wet Bulb set by Max. Comfort Zone Wet Bulb (°C)
6.6 Min. Wet Bulb set by Min. Comfort Zone Wet Bulb (°C)

6. TWO-STAGE EVAPORATIVE COOLING ZONE:
50.0 % Efficiency of Indirect Stage

7. NATURAL VENTILATION COOLING ZONE:
2.0 Terrain Category to modify Wind Speed (2=suburban)
0.2 Min. Indoor Velocity to Effect Indoor Comfort (m/s)
1.5 Max. Comfortable Velocity (per ASHRAE Std. 55) (m/s)

8. FAN-FORCED VENTILATION COOLING ZONE:
0.8 Max. Mechanical Ventilation Velocity (m/s)
3.0 Max. Perceived Temperature Reduction (°C)
(Min Vel, Max RH, Max WB match Natural Ventilation)

9. INTERNAL HEAT GAIN ZONE (lights, people, equipment):
12.8 Balance Point Temperature below which Heating is Needed (°C)

10. PASSIVE SOLAR DIRECT GAIN LOW MASS ZONE:
157.7 Min. South Window Radiation for 5.56°C Temperature Rise (Wh/sq.m)
3.0 Thermal Time Lag for Low Mass Buildings (hours)

11. PASSIVE SOLAR DIRECT GAIN HIGH MASS ZONE:
157.7 Min. South Window Radiation for 5.56°C Temperature Rise (Wh/sq.m)
12.0 Thermal Time Lag for High Mass Buildings (hours)

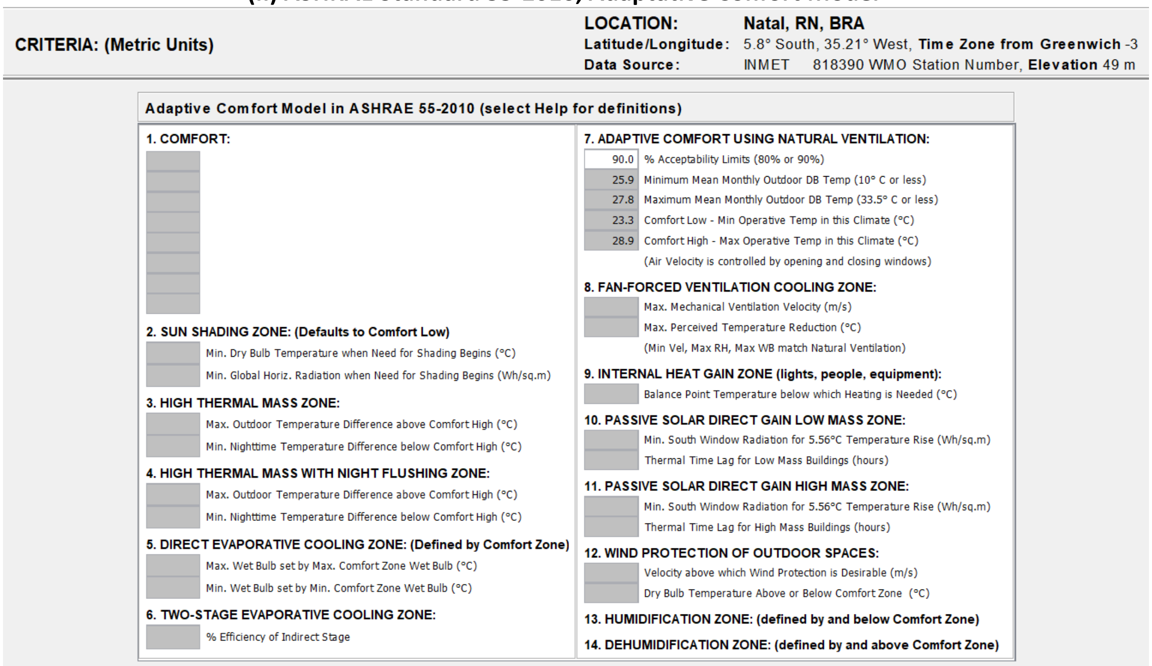
12. WIND PROTECTION OF OUTDOOR SPACES:
8.5 Velocity above which Wind Protection is Desirable (m/s)
11.1 Dry Bulb Temperature Above or Below Comfort Zone (°C)

13. HUMIDIFICATION ZONE: (defined by and below Comfort Zone)

14. DEHUMIDIFICATION ZONE: (defined by and above Comfort Zone)

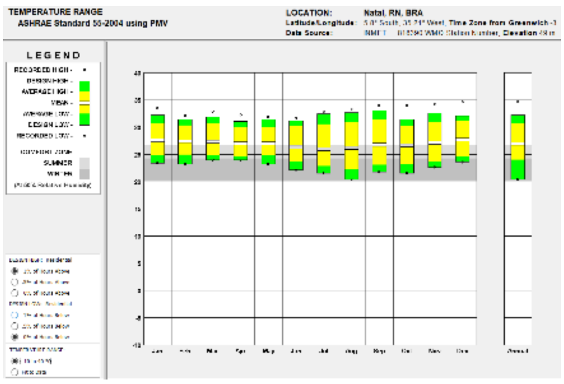
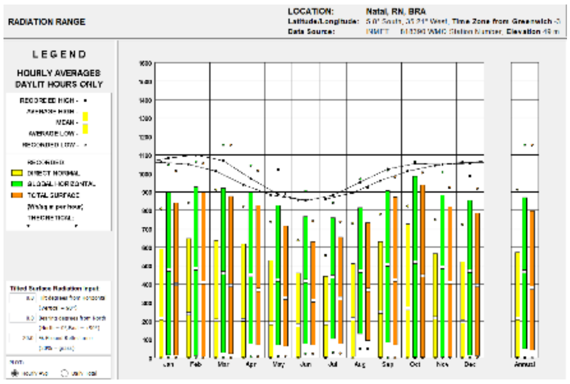
Source: ASHREA, 2021.

(II) ASHRAE Standard 55-2010, Adaptative Confort Model

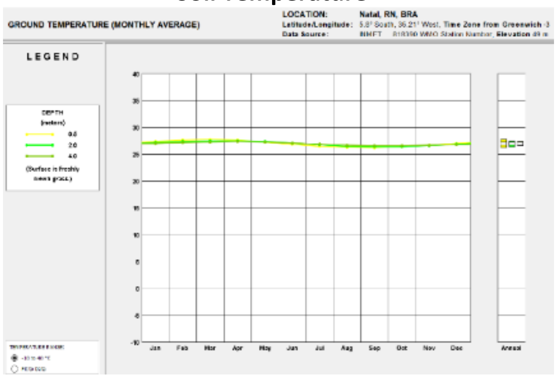


Source: ASHREA, 2021.

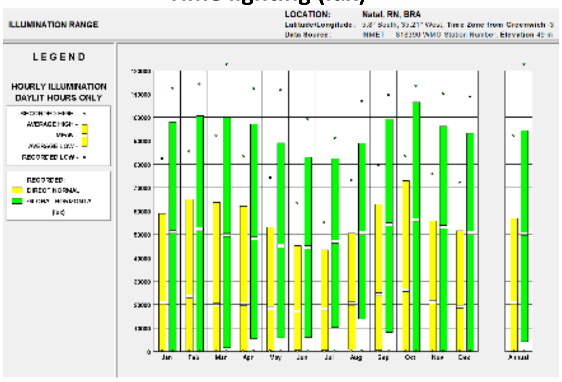
Natural ventilation is characterized by two variables: wind direction and speed at the height of the building openings. The Natal/RN climate data reveal that the range corresponding to the azimuths from 120° to 149.9° is the one that shows the greatest occurrence, followed by the range that goes from 90° to 119.9°. The average of the two intervals is around 135°. However, it is more correct to say that ventilation occurs mainly in the East-South quadrant. As for speed, the interval from 4.0 to 4.9 m/s is the most frequent, accounting for just under a quarter of the year. Next appears the interval from 5.0 to 5.9 m/s, responding by a little more than one fifth, and the interval from 3.0 to 3.9 m/s, which corresponds to something around 18% of the available data. Thus, the range of 3.0 to 5.9 m/s covers 62% of the data.

Table 13: Evaluation of monthly averages of the climate data for Natal/RN	
Monthly average temperatures (PMV) with the comfort zones in summer and winter	**Surface Radiation**
	

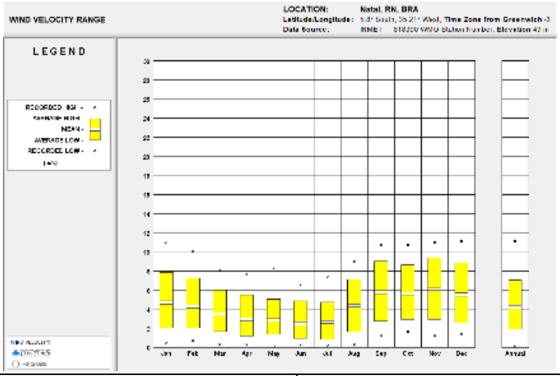
Soil Temperature



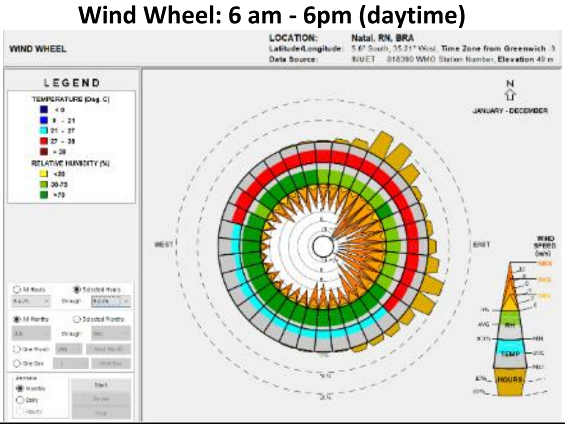
Time lighting (lux)



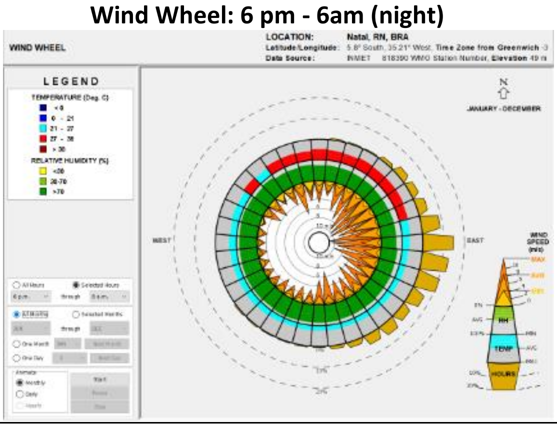
Wind speed



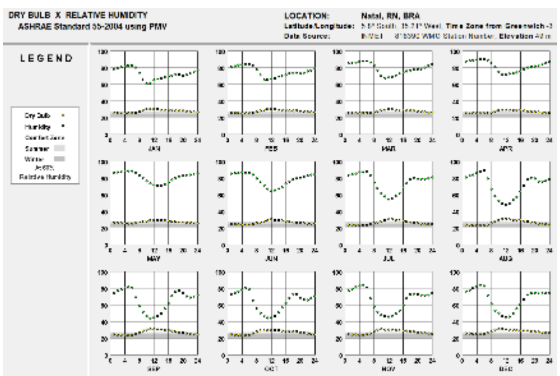
Wind Wheel: 6 am - 6pm (daytime)



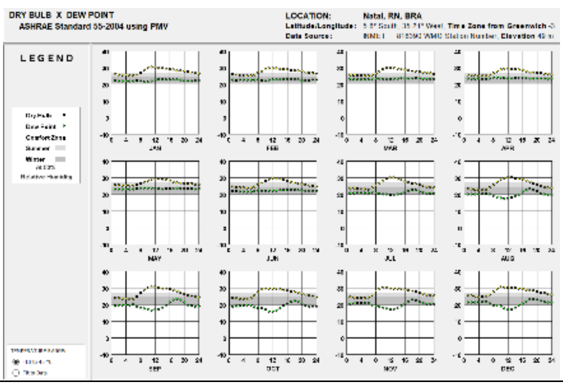
Wind Wheel: 6 pm - 6am (night)

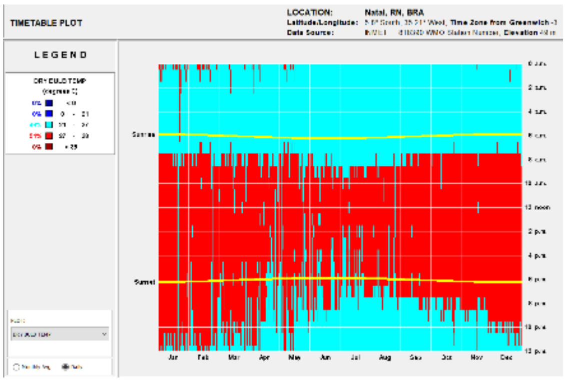
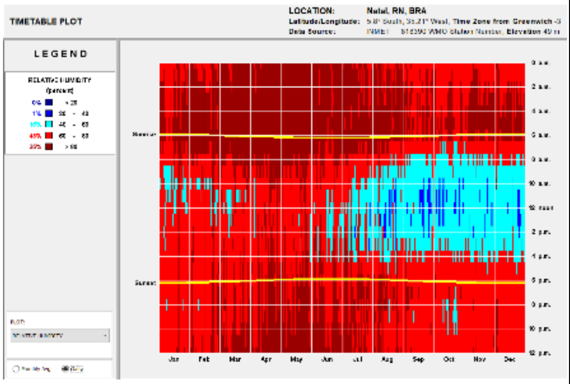


Temperature Dry Buld X Relative Humidity



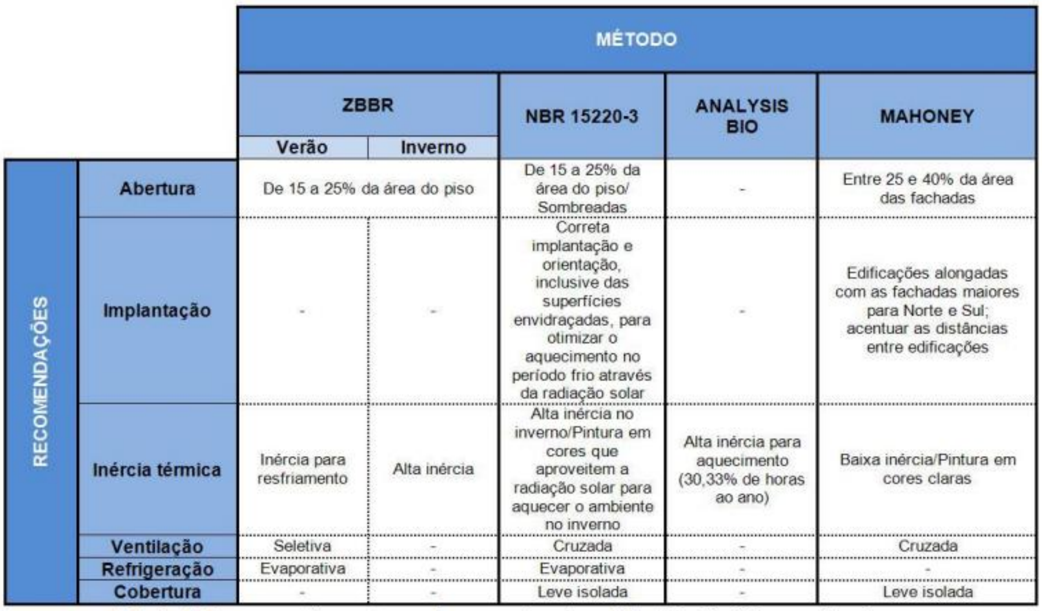
Temperature Dry Buld X Dew Point



Daily temperature chart Dry Bulb (°C)	Daily Relative Humidity Chart Dry Bulb (°C)
	

Attempts to model the effects of environmental variables on user satisfaction, in the way we know it today, go back to the middle of the 20th century. Olgyay (1963) and Givoni (1998) developed comfort zones, graphically depicted on a bioclimatic chart. The comfort zone developed by Givoni was differentiated for developed and developing countries that considered individuals from developing countries adapted to a greater thermal amplitude. However, it is worth remembering that the study was developed from research carried out in Israel, the United States and Europe, considering the temperature expectations in buildings without air conditioning.

Picture 33: Comparative bioclimatic recommendations based on the method



		MÉTODO				
		ZBBR		NBR 15220-3	ANALYSIS BIO	MAHONEY
		Verão	Inverno			
RECOMENDAÇÕES	Abertura	De 15 a 25% da área do piso		De 15 a 25% da área do piso/ Sombreadas	-	Entre 25 e 40% da área das fachadas
	Implantação	-	-	Correta implantação e orientação, inclusive das superfícies envidraçadas, para otimizar o aquecimento no período frio através da radiação solar	-	Edificações alongadas com as fachadas maiores para Norte e Sul; acentuar as distâncias entre edificações
	Inércia térmica	Inércia para resfriamento	Alta inércia	Alta inércia no inverno/Pintura em cores que aproveitem a radiação solar para aquecer o ambiente no inverno	Alta inércia para aquecimento (30,33% de horas ao ano)	Baixa inércia/Pintura em cores claras
	Ventilação	Seletiva	-	Cruzada	-	Cruzada
	Refrigeração	Evaporativa	-	Evaporativa	-	-
	Cobertura	-	-	Leve isolada	-	Leve isolada

Tabela 1. Comparações entre as ferramentas de análise bioclimática analisadas

Source:

The comfort indices have been constantly revised and adapted with the objetive of remedying the limitations found in the traditional models, which can be classified into two groups: those that are based on the thermal balance and the adaptive models. In short, thermal balance consists of adopting the human body as an element that exchanges heat with the surrounding environment and the feeling of comfort is the result of these exchanges. The most widespread index of thermal balance is the PMV/PPD, proposed by Fanger in 1972. Its qualities made it the reference model for the International Standard ISO 7730 a for ASHRAE Standard 55-2004. However, its applicability in naturally ventilated buildings in hot weather has been increasingly questioned in several works because it places little emphasis on user adaptation.

Adaptive models are based on field experiences and relate the thermal sensation to the average monthly temperatures, considering the adaptability of individuals. Adaptability considers the physiological aspects, which make the organism more tolerant to high temperatures in summer and to lower temperatures in winter. Furthermore, it also considers the possibility of the individual interacting with the environment, opening a window, changing posture, changing clothes or choosing more comfortable places. However, because it is a subjective variable, adaptability is studied in an empirical way, which allows the development of several equations relating to the feeling of comfort and average monthly temperature.

The following table presents the observed climate data (2005) of the city of Natal represented by psychrometric chart.

Picture 34: Psychometric chart of the climate data of Natal/RN

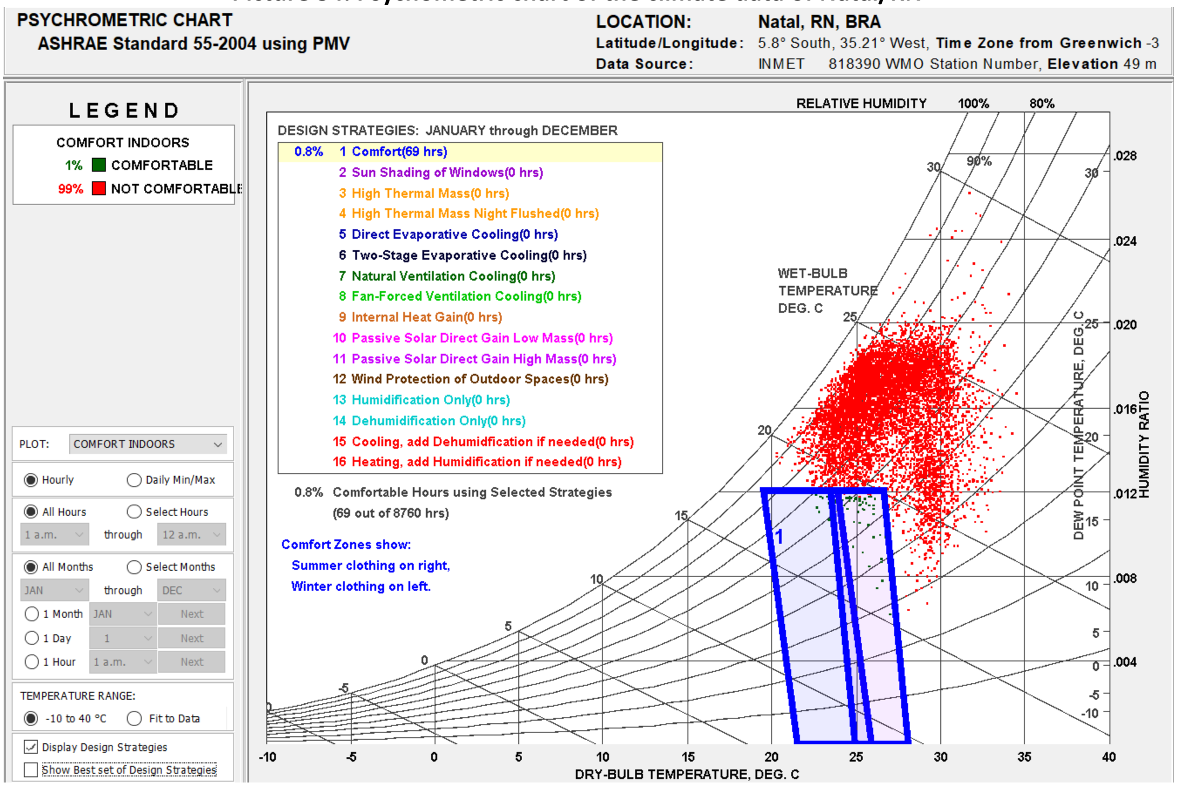
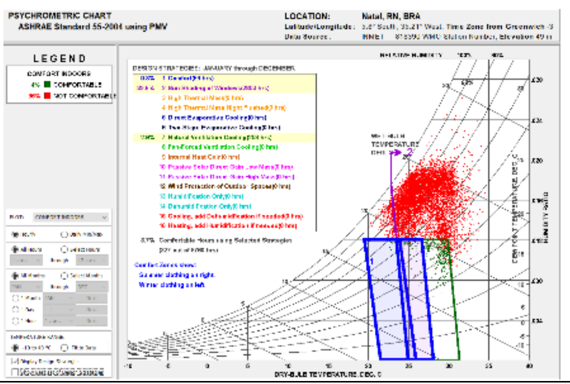
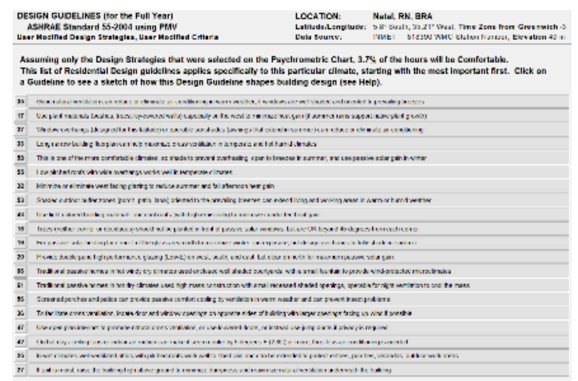
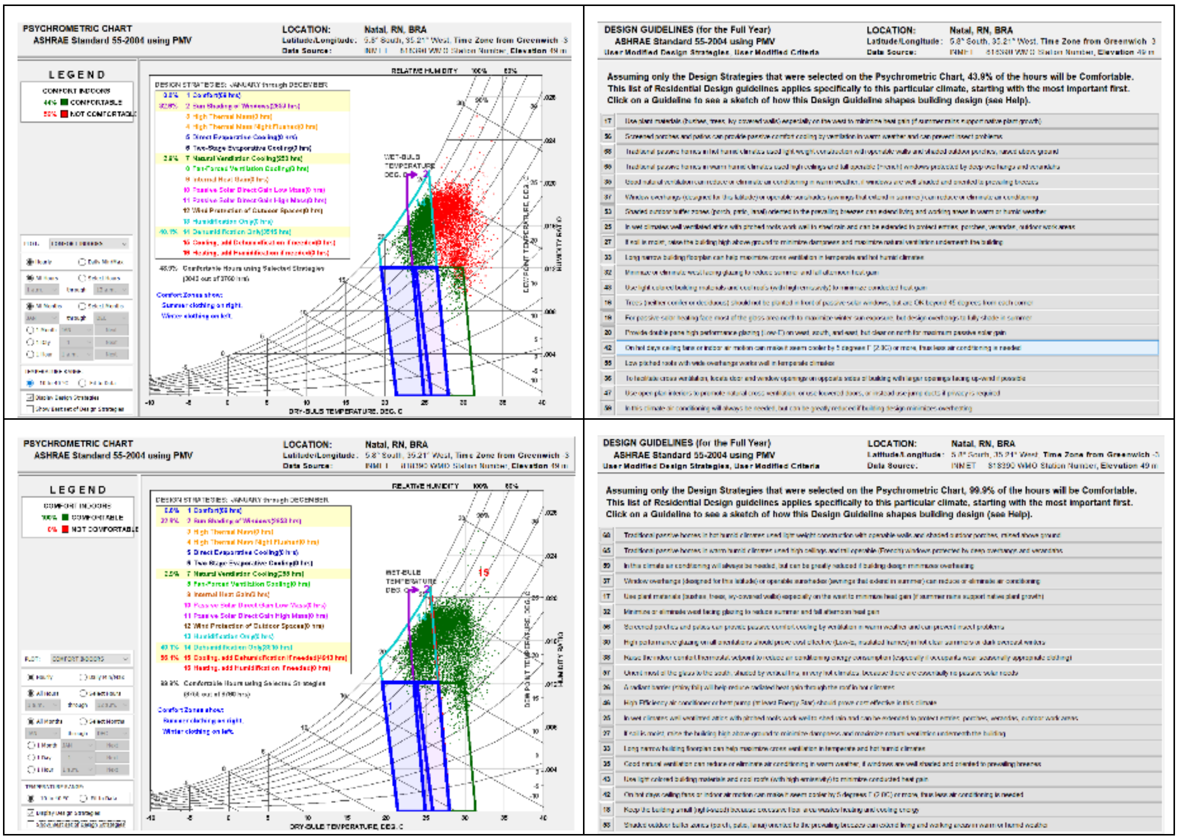


Table 14: Psychometric evaluation of the climate data of Natal/RN

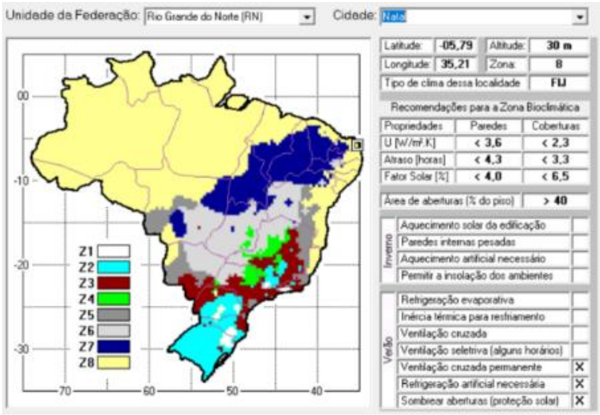
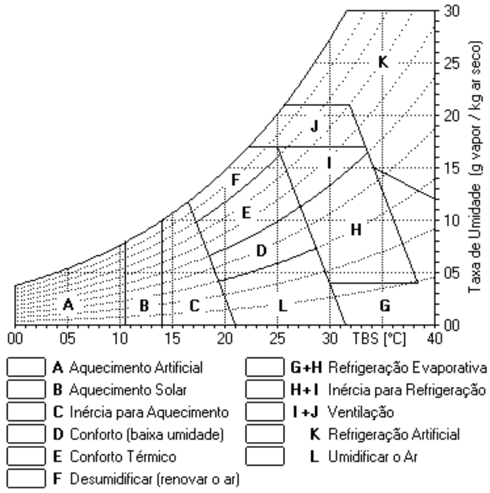





BRAZILIAN BIOCLIMATIC ZONING

The city of Natal/RN, located on the northeast coast of Brazil, is inserted in the Bioclimatic Zone 8, according to ABNT NBR 15.220:2005, which comprises 53.7% of the national territory and covers the city of Natal/RN. The city has an average altitude of 30 meters, with the presence of constant temperatures in the quadrants of the climatic typologies called FIJ of the psychrometric chart. Where F, represents the dehumidification zone (air renewal) and I+J represents the ventilation zone. Thus, the following construction strategies should be considered for proper thermal comfort: large, fully shaded openings, the use of light and reflective walls and roofs; and the use of year-round cross-ventilation. However, the standard warns that only passive conditioning will not be sufficient during warmer hours.

Table 15: Analysis of the Brazilian bioclimatic zoning: ABNT NBR 15200-3,2005.

<table>
<tr><th>Brazilian bioclimatic zoning according to ABNT NBR 15200-3,2005.</th><th>Psychrometric chart and bioclimatic strategies.</th></tr>
<tr><td>
</td><td>
</td></tr>
</table>

Source: ZBBR software according to ABNT NBR 15.220-3:2005 RORIZ, 2004 and ABNT NBR 15.220-3, Annex B (2005, p. 18)

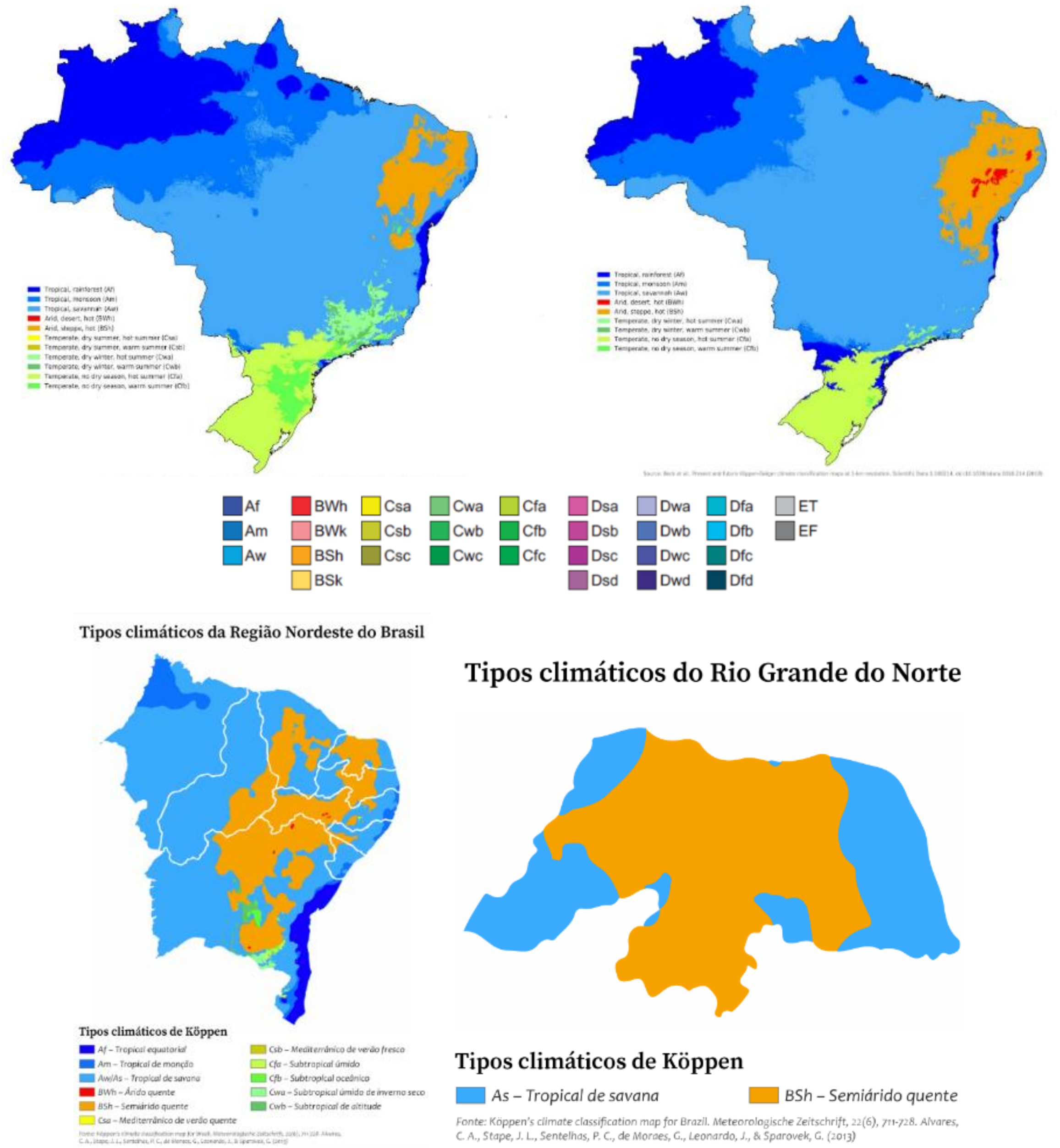
Accordingly, the Standard recommends the use of ventilation by means of openings directed towards the orientation of the prevailing winds and with a useful area of more than 40% of the floor area of the environment, walls and covering of the light and reflective type.

FUTURE CLIMATE CHARACTERIZATION

Analyzes of the present research were based on the proposed climate classification in the global maps by Beck et al. (2018). Two periods were considered: the present moment, based on climate data of **GHCN v2 Station data** for the period between 1980 to 2016; and the future forecast, with the projection of pessimistic conditions of the period from 2071 to 2100, i.e. forecasting an increase in GHG emissions over the years (**RCP 8.5**).

Picture 35 Present-day and future World Map Köppen-Geiger climate classification for Brazil (2018) with latitude/longitude of 0.0083 degree resolution - 1 km and scenario RCP8.5 (pessimistic).

(A) Köppen-Geiger climate classification the present-day map of Brazil (1980-2016)	(B) Köppen-Geiger climate classification the future map of Brazil (2007-2010). The color scheme was adopted from Peel et al. (2007)

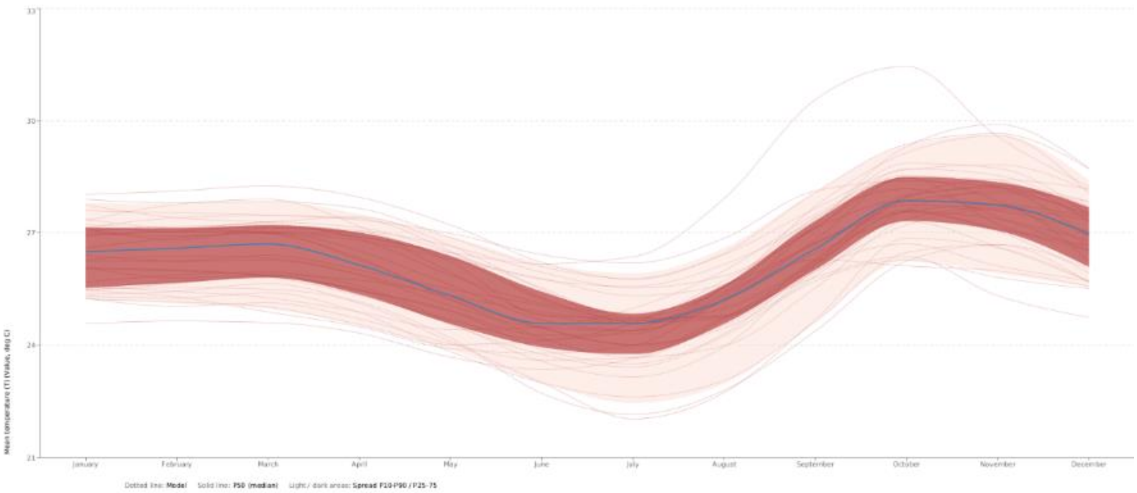


Source: BECK et al. (2018)

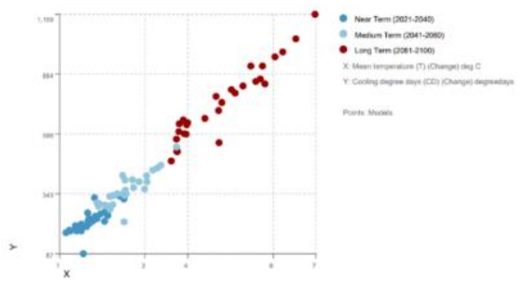
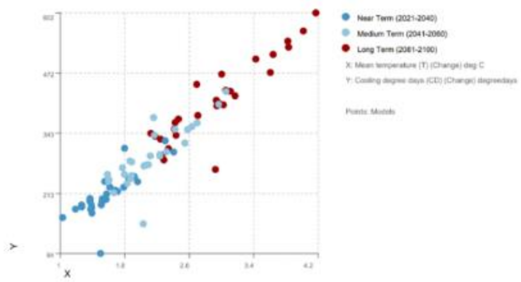
Available at: Present and future Köppen-Geiger climate classification maps at 1-km resolution (figshare.com).https://upload.wikimedia.org/wikipedia/commons/9/9°/Koppen-Geiger_Map_BRA_future.svg

According to the information extracted from the platform developed by the IPCC WGI, Interactive Atlas: Regional information (Advanced), in which it is possible to characterize, through the different climatic scenarios SSPs, the effects of the increase in the emission of GHGs in a given region of the globe, or a global average.

Picture 36: Mean temperature (T) deg C - Warming 2°C SSP5-8.5 with CMIP6 - Annual Cycle (34 models) Regions: North-Eastern South America



Period	Scenario	Median (deg C)	P25 | P75	P10 | P90	P5 | P95
Warming 1.5°C	SSP5-8.5	25.7	25.1 | 26.3	24.4 | 26.7	24.3 | 27.0
Warming 2°C	SSP5-8.5	26.2	25.6 | 26.8	24.9 | 27.2	24.7 | 27.6
Warming 3°C	SSP5-8.5	27.2	26.5 | 27.8	25.9 | 28.2	25.8 | 28.7
Warming 4°C	SSP5-8.5	28.2	27.6 | 28.9	26.7 | 29.0	26.6 | 29.1

SSP5-8.5 (very high emissions, very pessimistic scenario, CO2 emissions nearly double by 2050 compared to current emissions);	SSP2-4.5 (intermediate level, stabilization scenario, CO2 emissions remain close to current levels until 2050).
	

Source: (IPCC, 2021).

2.1.3 Regulatory Aspects

The Statute of the Brazilian Cities (Law n. 10,257/2001) brings in its framework guidelines for public policies for urban development, with the right to a sustainable city and protection of the environment, among others. In a practical way, the Statute instructs the municipal prescriptive order, through the Master Plan and the Codes of Works, to ensure the service of the needs of its citizens in the quality of life.

The Statute stipulates that urban development must be organized around the ideas of the city's social function and sustainability, with respect to the environment and in favor of social justice, values that will be reflected in the objectives, guidelines and actions provided for in the Master Plan. In this context, the city, the expression of nature profoundly altered by man, has as its legal destination the role of promoting the dignified life, the well-being of its inhabitants and the ecological balance."

The following summarizes the guidelines of the Statute intrinsically related to the environment, climate and sustainability that guide urban policy:

> *"I - guaranteeing the right to sustainable cities, understood as the right to urban land, housing, environmental sanitation, (...) and future generations; (...)*
>
> *IV - planning the development of the cities, the spatial distribution of the population and the economic activities of the Municipality and the territory under its influence, in order to avoid and correct the distortions of urban growth and its negative effects on the environment;(...)*
>
> *VI - land use planning and control, in order to avoid: (...)*
>
> *(g) pollution and environmental degradation;*
>
> *(h) the exposure of the population to the risks of natural disasters;*
>
> *VIII - adoption of production and consumption patterns of goods and services and urban expansion compatible with the limits of the environmental, social and economic sustainability of the Municipality and the territory under its influence(...);*
>
> *XII - protection, preservation and restoration of the natural and built environment, cultural, historical, artistic, landscape and archeological heritage;*
>
> *XIII - audience of the municipal Public Power and the population interested in the processes of implementation of enterprises or activities with potentially negative effects on the natural or built environment, the comfort or safety of the population;(...)*
>
> *XVII - stimulation of the use, in land plots and urban buildings, of operating systems, constructive standards and technological contributions that aim to reduce environmental impacts and the economy of natural resources (...)".*

In the light of the above, it appears that the City Statute now requires the creation of a master plan for municipalities susceptible to climate risks. In practice, however, the master plans in general also deal little with the climatic question, since the Brazilian cities tend not to carry out in full the master plans, for lack of qualification or of resources.

CHRISTMAS MASTER PLAN (NATAL, 2022)

Recently the Master Plan of Natal went through a discussion between the years 2017 to 2021 to carry out in a participatory manner the revision of the city's urban plan. The final version of the Christmas Master Plan was endorsed in March 2022, following an extensive review process which followed the following work steps:

- Workshops: Presentation of general data, case studies, maps and legislation specifies the community with collective participation.
- Proposals: Formation of Working Groups, in which they formulated proposals together with the community in the workshops held, through the filling in of printed or online forms.
- Discussions: Meetings were held to promote the discussion of the topics under the guidance of the technical coordination responsible for the revision of the document.
- Prior Consultation: After the previous stages, the material produced was evaluated and systematized by the technical team, being made available for consultation with the population.

The review process has been guided by 5 consecutive steps as detailed below:

- First stage: Initial planning, definition of methodology and schedule of activities, elaboration of the work plan, definition of teams of Technical Coordination, Management Nucleus and Working Groups; meetings of the City of Natal with various segments, elaboration of the internal rules of the review process, public hearings, conference and formulation of rules for election of delegates.
- Stage Two: It involves Technical Reading and Community Reading, which are independent processes, but carried out in the same period. To carry out these actions, training events and workshops will be organized by CT and NG, whose activities will be conducted by the GTs, where data, diagnoses and studies will be presented that allow the population to participate in the formulation of proposals.
- Third Stage: Analysis of the material produced in the workshops and of the proposals sent by the population, which may involve the preparation of new studies by SEMURB. Once the systematization of the proposals is completed, material for Public Consultation will be made available on the Master Plan website and in the Urban Management and Review Room of the Master Plan, with the subsequent realization of Public Hearing for the presentation and discussion of the systematized proposals.
- Fourth Stage: Election of the delegates and the Conference for voting on the draft law. Besides the systematization by SEMURB of the material produced at the conference, sending the bill to the Office of the Mayor and afterwards sending it to the Chamber of Councilors for a final vote.
- Fifth Stage: Covers the post-approval stage of the law in the City Council and the sanction of the law by the Mayor, in which the City Hall of Natal is to structure the management system according to the directives approved in the bill.

Considering that the Master Plan of the City of Natal is the basic instrument of the policy of sustainable urban development of the city, as well as the orientation of the performance of public and private agents, who act in the production and management of the urban space" (NATAL, 2022), it is analyzed following the publication of this publication from the perspective of climate change.

The objectives include:

> *"(...)*
>
> *VIII - stimulating the development and* ***use of technological innovations****, active modes and* ***renewable energies***
>
> *IX - make economic and social development compatible with* ***protecting the climate system*** *and* ***promote the implementation of adaptation and mitigation measures to climate change****;*
>
> *X -* ***preservation, protection and restoration of the environment and the urban landscape****, with a view to* ***ensuring, in addition to the balanced maintenance of natural resources****, quality of life for the inhabitants of the Municipality, encouragement of sustainable economic activity and protection of the cultural and natural heritage of the city;"*

In order to achieve the objectives, the plan sets out the following guidelines:

> *I - Land use and occupation will be submitted to the capacity of the installed urban infrastructure,* ***making environmental conditions compatible****, considering areas where occupation can be intensified and others where it should be limited;*
>
> *XXI - be in compliance with and comply with best* ***practices, policies and international climate agreements****;*

There is therefore the intention to promote sustainable development based on renewable energies with the lowest climate impact. However, the plan itself warns that the implementation of the guidelines requires the regulation of specific laws, in partnership with private enterprise.

In addressing the socio-environmental function of the property, the Master Plan states that:

> *'(...) Single paragraph. Activities* ***of urban interest are*** *those inherent to the social functions of the city, to the well-being of the community and to the preservation of the quality of the environment, such as: housing, production of goods and services, preservation of the natural cultural heritage, movement of people and goods,* ***preservation, active modes, renewable energies, new technologies associated with socio-economic development,***

> ***conservation, adaptation and mitigation to climate change*** *and the rational use of the resources necessary for life and natural resources in general."*

That is, any activity to be carried out in the municipal environment needs to consider the resulting climatic impact, and may even be vetoed by the public authorities if it does not meet this criterion.

The plan sets out ten urban standards, aiming "to guarantee the occupation of the land in a manner appropriate to the characteristics of the physical environment, as well as the climate balance of the city, the following additional urban standards will be observed":

> *I - occupancy rate;*
>
> *II - sealing rate;*
>
> *III - indentations;*
>
> *IV- gaging;*
>
> *V- active ground floor;*
>
> *VI- free spaces of public extension;*
>
> *VII - visual permeability;*
>
> *VIII - public enjoyment;*
>
> *IX - technical standards of accessibility;*
>
> *X - green façade.*

All items contribute in some way to the construction of a more sustainable urban environment with controlled environmental impact. However, from the point of view of thermal comfort and energy performance, the following stand out:

a) load factor: prevents full occupation of the lot by built elements, avoiding continuous built-up massifs;
b) waterproofing rate: mitigate flooding, promote local cooling and recharge the water table supplying the city;
c) indentations: promotes natural ventilation and prevents the spread of fire between buildings;
d) (control of) feedback: It is a tool that aims to protect, besides other characteristics, the quality of life and the climate balance of the city. The PD of Natal includes, besides others, the seafront and the surrounding of the Park of the Dunes, as zones of feedback control
e) free urban sprawl: to ensure the conservation and restoration of environmental and ecosystem services, in particular those related to water security, biodiversity, soil protection and climate regulation;
f) green façades: it favors the lower incidence of direct solar radiation in indoor environments.

From the point of view of resilience, the Plan proposes the Municipal Risk Reduction Policy, which has one of its objetives: to incorporate planning actions relating to climatic and meteorological risks, with an intelligent system or solution that monitors the areas of risk and alerts the communities involved. Starting from the guideline of expanding the dissemination of scientific, technical and traditional knowledge, the opportunity is glimpsed to foster the production, management and dissemination of measures to promote adaptation and the reduction of the climatic and meteorological risk.

The following table summarizes the occurrence of terms linked to the theme of the research in the text of the Natal Master Plan, which allows one to perceive the importance of each one of them in the final wording of the main municipal document of urban planning.

Table 16: Keyword occurrence in the text of the Christmas Master Plan - 2022

KEYWORD	OCCURRENCE
Environment	100
Environmental(ies), environmentally	243
Green(s)	17
Efficient(s), Efficient	4
Sustainability	16
Sustainable	8
Climate, climate	20

Source: The author, (2022).

CHRISTMAS WORKS CODE (Supplementary Law 055/2004)

Complementary to the Master Plan, the Works Code aims to ensure that the built space meets quality standards that meet the minimum conditions of safety, comfort, hygiene and health of users and other citizens, as well as the administrative procedures and technical parameters that ensure these objectives. To this end, the document establishes the minimum dimensions of the elements that make up the building and its surroundings, as well as the rites necessary for the urban and environmental licensing of works of any nature.

From the point of view of environmental comfort, energy efficiency, adaptation to climate change and resilience, the code states that every building compartment must have adequate dimensions and shapes, so as to provide conditions of hygiene, wholesomeness and **environmental comfort**, consistent with its function and habitability.

To this end, the Code reserves a dedicated chapter for the requirements and parameters to be met, aiming to promote the **insolation, lighting and ventilation** of the built environment. The following summarizes the main attributes that a building needs to present, in compliance with the prerogatives of the Code of Works

- All enclosures of the building shall have a direct opening for the patio, patio or backyard;
- The surface of the external opening for insolation, lighting and ventilation shall not be less than one sixth (1/6) of the compartment area in the case of long-use environments and may be reduced to one eighth (1/8) in the case of transient environments;
- Enclosures shall not be considered to be ventilated or illuminated if they are more than three (3) times their right foot deep from the place where the illumination is provided;

However, since this legislation has been published for more than ten years, it can be seen that the Code of Works for Christmas has little or no mention of the terms coined by the current concern with the effects of climate change, as can be seen in the following table survey:

Table 17: Occurrence of keywords in the text of the Christmas Works Code - 2022

KEYWORD	OCCURRENCE
Environment	1
Environmental(ies)	60
Green(s)	1
Efficient(s), Efficient	0
Sustainability	1
Sustainable	1
Climate	1

Source: The author, (2020).

THERMAL PERFORMANCE OF BUILDINGS: ABNT NBR 15220:2005.

Brazil has a housing deficit of 5.8 million (Fundação João Pinheiro, 2019). The vast majority of these houses are houses with precarious constructive quality, normally self-built, without the technical advice necessary to guarantee the environmental quality of the project and its execution in accordance with the current standards. To mitigate this market context, Caixa Economica Federal (CEF) together with the Financier of Studies and Projects (Finep) have developed the Standard of Performance of housing construction (ABNT NBR 15.220:2013) being the only prescriptive tool that evaluates the final performance of buildings and applies to new works, renovations, retrofit of buildings and ephemeral buildings.

THE ABNT (2013) it sets minimum requirements for safety (structural safety, fire safety, safety in use and operation), habitability (leakproofness factors; thermal, acoustic and light performance; health, hygiene and air quality; functionality and accessibility, tactile and anthropodynamic comfort) and sustainability related to the final performance for housing buildings. It is subdivided by building systems, divided into six parts. Performance is measured by two approaches: the first approach is simplified as measured by the prescriptive method, the second is more elaborate and should be applied by the simulation method. It is of paramount importance that the architect and urbanist have knowledge and make applicability already in the preliminary stages of the project design.

The Brazilian Standard of Thermal Performance NBR 15220-3 (ABNT, 2005) recommends for the Bioclimatic Zone n° 8, which comprises 53.7% of the national territory and covers the city of Natal/RN, the use of ventilation by means of openings aimed at the orientation of the prevailing winds, with a useful area higher than 40% of the floor area of the environment and the shading of the openings. While recognizing the importance of ventilation, the Standard in question did not make recommendations on the types of window frames or leaked elements would be the most suitable for the different bioclimatic zones, and does not suggest the use of wind collectors or deflector elements, as well as information on the loss of load caused by the shutters or any other architectural element that could obstruct the passage of air. For the types of seals, light and reflective vertical seals (Thermal transmittance of U≤ 3,6 W/m².K) and light and reflective horizontal seals (Thermal transmittance of U≤ 2,3.FT W/m².K) are recommended, with the aim of lowering the thermal load within buildings (2005, pp. 10-12). With respect to air quality, no minimum recommended values are cited to promote air renewal or a sufficient ventilation rate to satisfy the minimum standards of thermal comfort and wholesomeness.

The Brazilian thermal performance standard has a more focused approach in determining the minimum limits necessary, referring to the thermal properties of the construction systems of the envelope, to satisfy the thermal comfort of the users. Although the standard assigns minimum performance requirements, it has several limitations in both approaches. Sorgato et al (2012) already highlighted in a technical note referring to the assessment for the standard three points to be discussed: the analysis is limited to a typical day, disregarding the climatic variations throughout the year; the rate of renewal of the air of the environment is constant, disregarding the possibility of bioclimatic solutions and underestimating the effects of natural ventilation; and the occurrence of internal thermal loads is not considered. In addition to these limitations the requirements attributed to the standard do not consider the life cycle of the building (50 years), not considering: the degradation of the materials and their relationship with absorbance; future climate projections; in the case of bioclimatic zones 08 (hot climate) absence of area limits of glass in facades with direct exposure; absence of thermal emission[110] limits for the surfaces of the envelope for buildings in temperate climates present in bioclimatic zones 1 to 3 (Perreira, 2014).

2.2 Italy: Bologna/ EM-R

Italy is situated on the European continent, in the Mediterranean region and is part of the European Union's economic bloc. It has a vast ecological and biomass diversity, being divided into five administrative regions: Northwest, Northeast, Central, South and Insular. Within each region the territory is subdivided into provinces, which in turn are subdivided into communes. The following figure illustrates the clipping of the object of study of the research.

[110] Emitance is the term used to characterize the amount of energy emitted by a surface compared to an ideal black body (ABNT, 2005).

Picture 37: Italy, Northeash Region, Capoluogo Emilia-Romagna, Provincia di Bologna ed Comune di Bologna.	
Northeast Region	**Capoluogo Emilia-omagna**
	
Pronvice di Bologna	**Comune di Bologna**
	

For the development of this research, it was decided to work only with the Northeast Region of Italy, in the capollutogo of her Emilia-Romagna, within the province of Bologna, where the Comune de Bologna is located. The choice of this region is justified by the author's familiarity with the aspects related to it and also by being an extremely vulnerable region climatically. Since, according to Berkeley Earth (Berkeleyh Earth, 2020) the Italian territory, like the Brazilian one, has already exceeded the warming threshold of the air temperature of +1.5 degrees celsius stipulated by the Paris Agreement. Being a region that already feels the effects of climate change.

Having defined the object of study, the research sought to correlate the effect of global warming and climate change with the impacts identified, within the current context and in the future projections published by the IPCC through the SSPs.

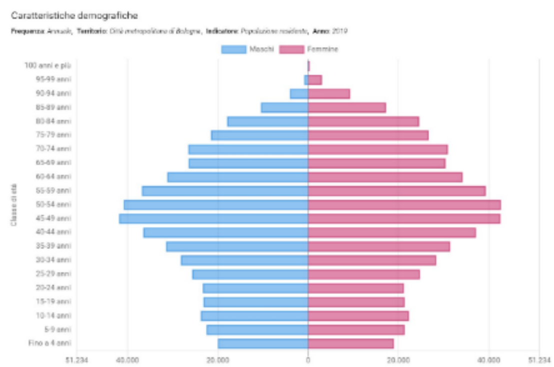
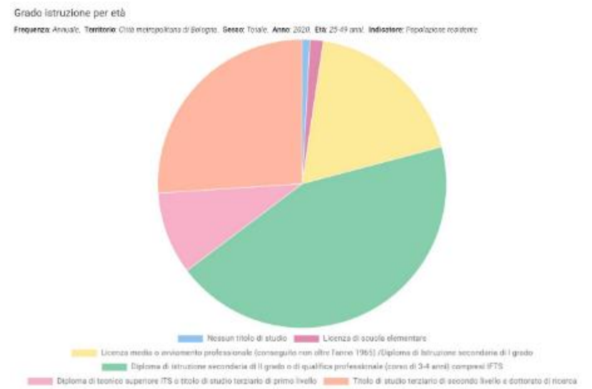
2.2.1 Physical and demographic aspects

The province of Bologna located in Emilia-Romagna is located in the Padada Pianura near the Tuscan-Emilian Appennino. It is about 50 meters above sea level, a temperate humid climate with summers (beginning at the end of June and ending in September) very hot and humid, very cold and humid winters, with the possibility of snowfalls. With high relative humidity ranging from 818% in December to 52.73% in July (Climatedata.org) and winds predominantly from the north, and the average annual precipitation rates of 800mm.

According to the Istituto Nazionale di Statistica, it has a surface area of 3,702.53 km² and a resident population of approximately 1 million inhabitants in 2016, being 51.76% female and

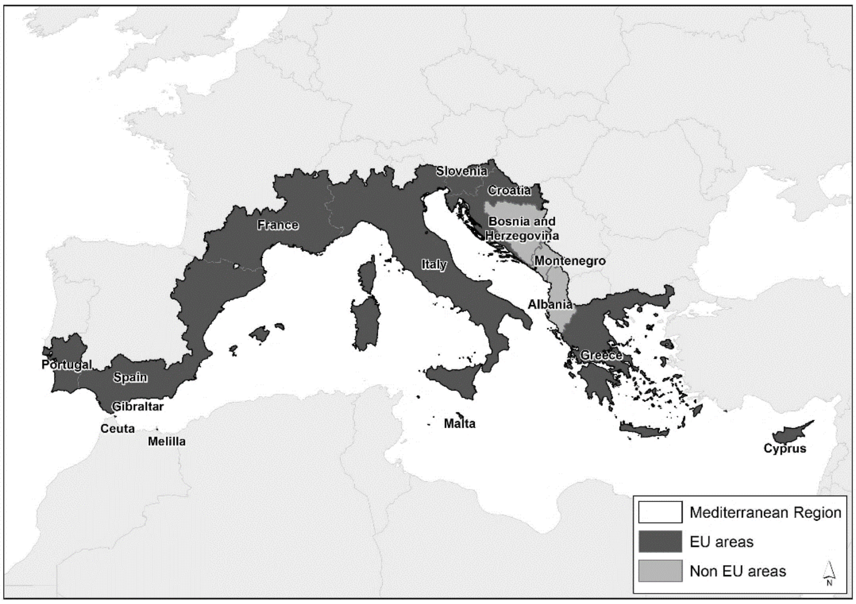
48.23% male, and an average annual income of 19 thousand euros. The Comune de Bologna has a surface area of 140.86 km², a population of 388,367 in 2016, being 52.67% of the resident population of the female genus, 47.33% of the resident population of the male gender and an average annual income of 20,000 euros, being still the commune with the highest percentage of foreign citizens (15.4%).

Table 18Subject: Province of Bologna: demographic characteristics

Demographic characteristics	Education/age
	
Source: (2019). Evaluable from: [Permanent growth della popopolazione e delle abitazioni (istat.it)]	

In the last two decades, the Italian territory has undergone changes in the use of the soil that have resulted in an increase in forest areas, an increase in the area of urban expansion, and also in the reduction of areas dubbed for cultivation and of pasture areas, when compared to the year 1990. Italy is part of the Mediterranean region, and is also part of the "Forest" category, which accounted for about 31% of the national land area in 2015. Although forest expansion has decreased during the last decade, the Italian forest area is expanding due to the abandonment of farming practices, mainly in mountain areas, and the natural conversion of cultivated land and grazing into forests.

Picture 38: Mediterranean Region



Italy is characterized by a vast natural heritage of animal and plant specimens, both in terms of the total number of specimens and in the high rate of endemic[111] species. In addition, fifty-seven (57) Italian sites are recognized as wetlands of international importance and are listed in the Ramsar[112] Convention, which has an area of 73,982 hectares.

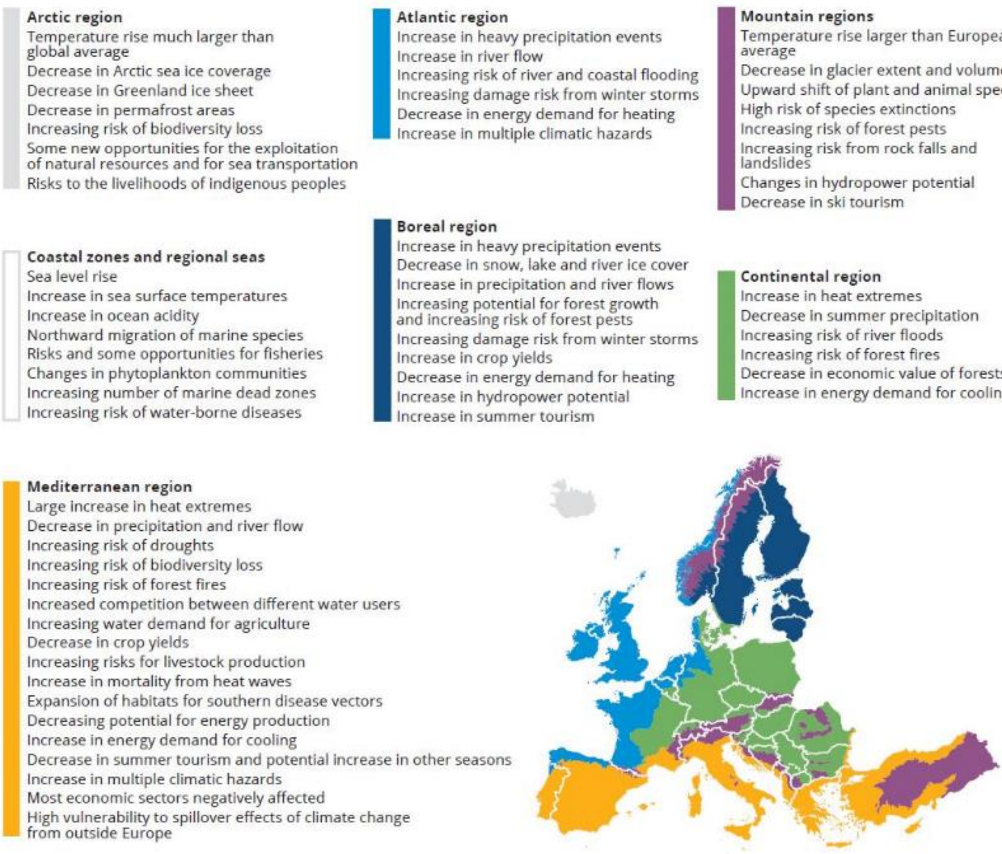
According to the 2019 census of the Istituto Nazionale di Statistica[113], Italy has 60.3 million inhabitants and has a declining birth rate of 0.67, that is, for every 100 people who die only 67 children are born, in the last decade this scenario was 0.96 (out of every 100 people who die 96 children are born). The fertility rate (2019) is 1.27 children per woman and the average age of women who become pregnant at the time of childbirth is around 32.1 years. The average resident population is 45.7 years old, with 91.1% of this population being Italians and 8.9% being foreigners. The life expectancy of the country, as well as in other countries that make up the European Union, is high. Life expectancy for women is 85.3 years and for men 81 years. With this aging rate increasing every year, between 2018 and 2020 this increase was 5 percentage points, reaching 179.3 elderly for every one hundred young people on January 1, 2020.

With regard to mobility and transport, still according to the 2019 census, in the same year 10.1% of the employees were working in public transport, against 69.7% of the employees who used the car as a means of transport. Also in 2019, the motorization rate was 663 cars per thousand inhabitants, the research found that the car is the most used modal. Students travel more frequently on foot, representing 27.5%, or on public transport, corresponding to 32.4%). Although the road fatality rate has been steeply reduced over the years, since 2014 the trend has fluctuated, with an average of 9 victims per day.

According to A Clean Planet for all, the impacts of climate change in Europe are described in the following figure. Especially in the Mediterranean region, it predicts a great increase in temperature, causing extreme heat, reduced rainfall, greater risk of droughts, loss of biodiversity, greater risk of forest fires, greater demand for water, increasing its competition, reduced crop production, increased mortality from heat waves, lower energy production potential, expansion of habitats capable of harboring disease vectors, reduction of tourism in the summer, among others (COMMISSION, European, 2018).

[111] An endemic species is an animal or plant species that occurs only in a given geographical area or region.
[112] RAmsar Platform (2022). Evaluable from: https://www.ramsar.org/
[113] Istituto Nazionale di Statistica (2019). Evaluable from: https://www.istat.it/it/files//2020/02/indicatori-demografici-2019.pdf

Picture 39: Impact of climate change in Europe.



Source: A Clean Planet for all (COMMISSION, European, 2018). Evaluable at: EUR-Lex - 52018DC0773 - EN - EUR-Lex (europa.eu)

2.2.2 Climate aspects and projections of future scenarios

According to the platform [114]ClimateADAPTa Italia is located in the northern hemisphere, in the Mediterranean region which has a topography with particular characteristics, with the presence of mountain ranges (Alps and Apennines), plains and a coastline with unique and diverse ecosystems. Due to these characteristics the effects of global warming and its impacts on the territory have a real potential risk to vulnerability. Its climate system is influenced by the arid climate of North Africa and the temperate and rainy climate of Central Europe. By analyzing the climate data (ewp) of the city of Bologana through the Climate Consult software, using ASHRAE Standard 55 and Current Handbook of fundamentals Model, we obtain graphic outputs with daily, monthly and annual data organized by themes.

[114] ClimateADAP Platform (2022). Evaluable from: https://climate--adapt-eea-europa-eu.translate.goog/countries-regions/countries/italy?_x_tr_sl=en&_x_tr_tl=pt&_x_tr_hl=pt-BR&_x_tr_pto=sc

Picture 40: Summary of climate data from Bologna/ER

WEATHER DATA SUMMARY

LOCATION: Bologna-Borgo Panigale, -, ITA
Latitude/Longitude: 44.53° North, 11.3° East, **Time Zone from Greenwich** 1
Data Source: IGDG 161400 WMO Station Number, **Elevation** 49 m

MONTHLY MEANS	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	
Global Horiz Radiation (Avg Hourly)	113	150	211	286	352	372	385	344	278	186	101	91	Wh/sq.m
Direct Normal Radiation (Avg Hourly)	57	101	129	222	233	252	290	262	213	144	66	48	Wh/sq.m
Diffuse Radiation (Avg Hourly)	93	105	136	140	183	183	171	162	147	115	77	76	Wh/sq.m
Global Horiz Radiation (Max Hourly)	268	418	610	885	897	888	965	895	657	452	296	210	Wh/sq.m
Direct Normal Radiation (Max Hourly)	368	559	582	868	834	763	869	845	691	513	397	385	Wh/sq.m
Diffuse Radiation (Max Hourly)	194	236	299	348	372	379	376	354	325	272	207	162	Wh/sq.m
Global Horiz Radiation (Avg Daily Total)	1023	1534	2493	3803	5166	5703	5770	4764	3434	2001	953	792	Wh/sq.m
Direct Normal Radiation (Avg Daily Total)	526	1038	1544	2946	3417	3874	4344	3620	2630	1545	620	419	Wh/sq.m
Diffuse Radiation (Avg Daily Total)	841	1066	1607	1859	2685	2800	2564	2244	1823	1241	726	661	Wh/sq.m
Global Horiz Illumination (Avg Hourly)													lux
Direct Normal Illumination (Avg Hourly)													lux
Dry Bulb Temperature (Avg Monthly)	1	3	8	12	17	21	23	23	19	13	7	2	degrees C
Dew Point Temperature (Avg Monthly)	0	2	4	7	11	15	15	16	13	9	5	1	degrees C
Relative Humidity (Avg Monthly)	93	91	78	75	71	71	62	65	69	79	89	90	percent
Wind Direction (Monthly Mode)	230	160	60	50	140	30	170	210	110	50	30	210	degrees
Wind Speed (Avg Monthly)	1	1	1	2	2	1	1	1	1	1	1	1	m/s
Ground Temperature (Avg Monthly of 3 Depths)	6	5	5	7	11	15	18	20	19	17	13	9	degrees C

◉ ASHRAE Standard 55 and Current Handbook of Fundamentals Model

Thermal comfort is based on dry bulb temperature, clothing level (clo), metabolic activity (met), air velocity, humidity, and mean radiant temperature. Indoors it is assumed that mean radiant temperature is close to dry bulb temperature. The zone in which most people are comfortable is calculated using the PMV (Predicted Mean Vote) model. In residential settings people adapt clothing to match the season and feel comfortable in higher air velocities and so have wider comfort range than in buildings with centralized HVAC systems.

Source: ASHREA, 2021 Climate Consult.

Picture 41Subject: Bioclimatic assessment of climate data from Bologna/ER

(I)ASHRAE Standard 55, current Handbook of Fundamentals Comfort Model

ASHRAE Standard 55, current Handbook of Fundamentals Comfort Model (select Help for definitions)

1. COMFORT: (using ASHRAE Standard 55)

1.0	Winter Clothing Indoors (1.0 Clo=long pants,sweater)
0.5	Summer Clothing Indoors (.5 Clo=shorts,light top)
1.1	Activity Level Daytime (1.1 Met=sitting,reading)
90.0	Predicted Percent of People Satisfied (100 - PPD)
20.3	Comfort Lowest Winter Temp calculated by PMV model(ET* C)
24.3	Comfort Highest Winter Temp calculated by PMV model(ET* C)
26.7	Comfort Highest Summer Temp calculated by PMV model(ET* C)
84.6	Maximum Humidity calculated by PMV model (%)

2. SUN SHADING ZONE: (Defaults to Comfort Low)

23.8	Min. Dry Bulb Temperature when Need for Shading Begins (°C)
315.5	Min. Global Horiz. Radiation when Need for Shading Begins (Wh/sq.m)

3. HIGH THERMAL MASS ZONE:

8.3	Max. Outdoor Temperature Difference above Comfort High (°C)
1.7	Min. Nighttime Temperature Difference below Comfort High (°C)

4. HIGH THERMAL MASS WITH NIGHT FLUSHING ZONE:

16.7	Max. Outdoor Temperature Difference above Comfort High (°C)
1.7	Min. Nighttime Temperature Difference below Comfort High (°C)

5. DIRECT EVAPORATIVE COOLING ZONE: (Defined by Comfort Zone)

20.0	Max. Wet Bulb set by Max. Comfort Zone Wet Bulb (°C)
6.6	Min. Wet Bulb set by Min. Comfort Zone Wet Bulb (°C)

6. TWO-STAGE EVAPORATIVE COOLING ZONE:

50.0	% Efficiency of Indirect Stage

7. NATURAL VENTILATION COOLING ZONE:

2.0	Terrain Category to modify Wind Speed (2=suburban)
0.2	Min. Indoor Velocity to Effect Indoor Comfort (m/s)
1.5	Max. Comfortable Velocity (per ASHRAE Std. 55) (m/s)

8. FAN-FORCED VENTILATION COOLING ZONE:

0.8	Max. Mechanical Ventilation Velocity (m/s)
3.0	Max. Perceived Temperature Reduction (°C)

(Min Vel, Max RH, Max WB match Natural Ventilation)

9. INTERNAL HEAT GAIN ZONE (lights, people, equipment):

12.8	Balance Point Temperature below which Heating is Needed (°C)

10. PASSIVE SOLAR DIRECT GAIN LOW MASS ZONE:

157.7	Min. South Window Radiation for 5.56°C Temperature Rise (Wh/sq.m)
3.0	Thermal Time Lag for Low Mass Buildings (hours)

11. PASSIVE SOLAR DIRECT GAIN HIGH MASS ZONE:

157.7	Min. South Window Radiation for 5.56°C Temperature Rise (Wh/sq.m)
12.0	Thermal Time Lag for High Mass Buildings (hours)

12. WIND PROTECTION OF OUTDOOR SPACES:

8.5	Velocity above which Wind Protection is Desirable (m/s)
11.1	Dry Bulb Temperature Above or Below Comfort Zone (°C)

13. HUMIDIFICATION ZONE: (defined by and below Comfort Zone)

14. DEHUMIDIFICATION ZONE: (defined by and above Comfort Zone)

(II) ASHRAE Standard 55-2010, Adaptative Confort Model

CRITERIA: (Metric Units)

LOCATION: **Bologna-Borgo Panigale, -, ITA**
Latitude/Longitude: 44.53° North, 11.3° East, **Time Zone from Greenwich**
Data Source: IGDG 161400 WMO Station Number, **Elevation** 49 m

Adaptive Comfort Model in ASHRAE 55-2010 (select Help for definitions)

1. COMFORT:

2. SUN SHADING ZONE: (Defaults to Comfort Low)

Min. Dry Bulb Temperature when Need for Shading Begins (°C)
Min. Global Horiz. Radiation when Need for Shading Begins (Wh/sq.m)

3. HIGH THERMAL MASS ZONE:

Max. Outdoor Temperature Difference above Comfort High (°C)
Min. Nighttime Temperature Difference below Comfort High (°C)

4. HIGH THERMAL MASS WITH NIGHT FLUSHING ZONE:

Max. Outdoor Temperature Difference above Comfort High (°C)
Min. Nighttime Temperature Difference below Comfort High (°C)

5. DIRECT EVAPORATIVE COOLING ZONE: (Defined by Comfort Zone)

Max. Wet Bulb set by Max. Comfort Zone Wet Bulb (°C)
Min. Wet Bulb set by Min. Comfort Zone Wet Bulb (°C)

6. TWO-STAGE EVAPORATIVE COOLING ZONE:

% Efficiency of Indirect Stage

7. ADAPTIVE COMFORT USING NATURAL VENTILATION:

90.0	% Acceptability Limits (80% or 90%)
10.0	Minimum Mean Monthly Outdoor DB Temp (10° C or less)
25.0	Maximum Mean Monthly Outdoor DB Temp (33.5° C or less)
18.4	Comfort Low - Min Operative Temp in this Climate (°C)
28.0	Comfort High - Max Operative Temp in this Climate (°C)

(Air Velocity is controlled by opening and closing windows)

8. FAN-FORCED VENTILATION COOLING ZONE:

Max. Mechanical Ventilation Velocity (m/s)
Max. Perceived Temperature Reduction (°C)
(Min Vel, Max RH, Max WB match Natural Ventilation)

9. INTERNAL HEAT GAIN ZONE (lights, people, equipment):

Balance Point Temperature below which Heating is Needed (°C)

10. PASSIVE SOLAR DIRECT GAIN LOW MASS ZONE:

Min. South Window Radiation for 5.56°C Temperature Rise (Wh/sq.m)
Thermal Time Lag for Low Mass Buildings (hours)

11. PASSIVE SOLAR DIRECT GAIN HIGH MASS ZONE:

Min. South Window Radiation for 5.56°C Temperature Rise (Wh/sq.m)
Thermal Time Lag for High Mass Buildings (hours)

12. WIND PROTECTION OF OUTDOOR SPACES:

Velocity above which Wind Protection is Desirable (m/s)
Dry Bulb Temperature Above or Below Comfort Zone (°C)

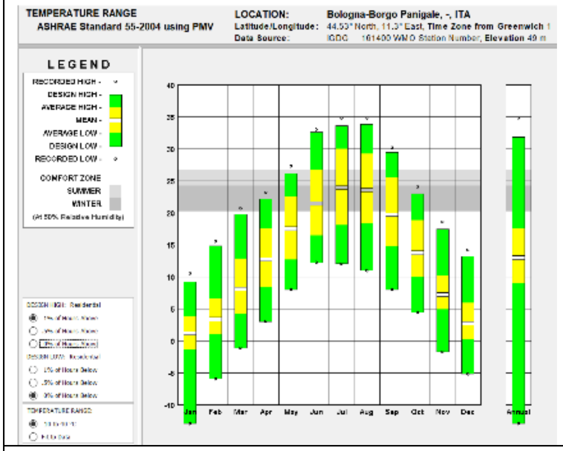
13. HUMIDIFICATION ZONE: (defined by and below Comfort Zone)

14. DEHUMIDIFICATION ZONE: (defined by and above Comfort Zone)

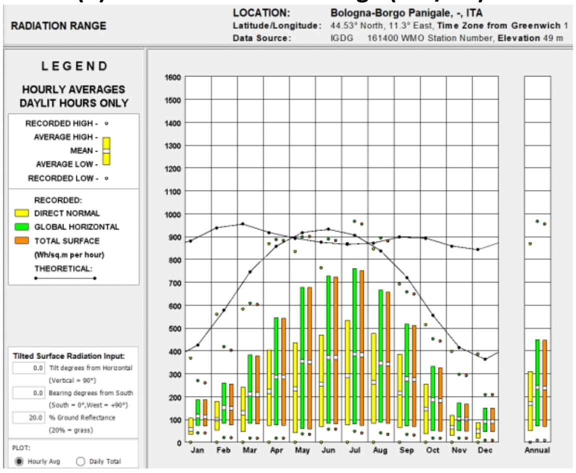
Source: ASHREA, 2021

Table 19: Evaluation of monthly averages of the climate data for Natal/RN

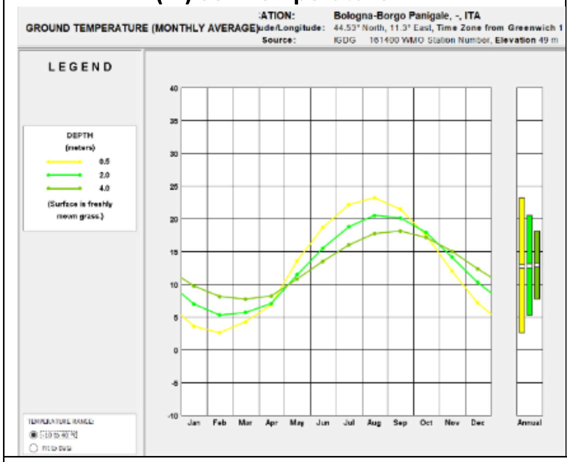
(I)Monthly average temperatures (PMV) with the comfort zones in summer and winter



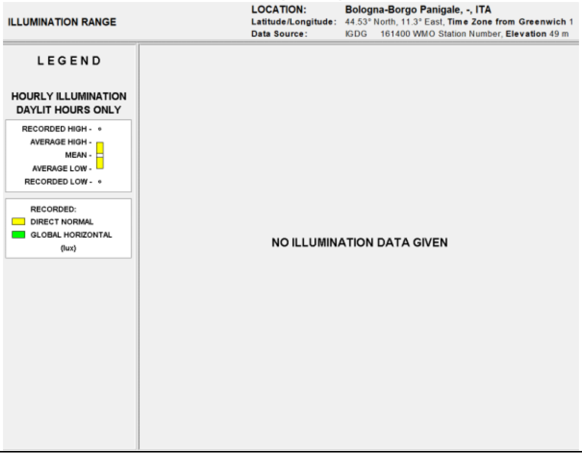
(II) Surface Radiation Range (Wh/m²)



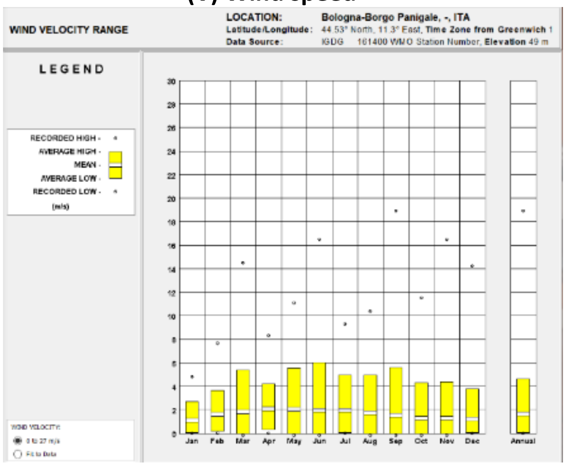
(III) Soil Temperature

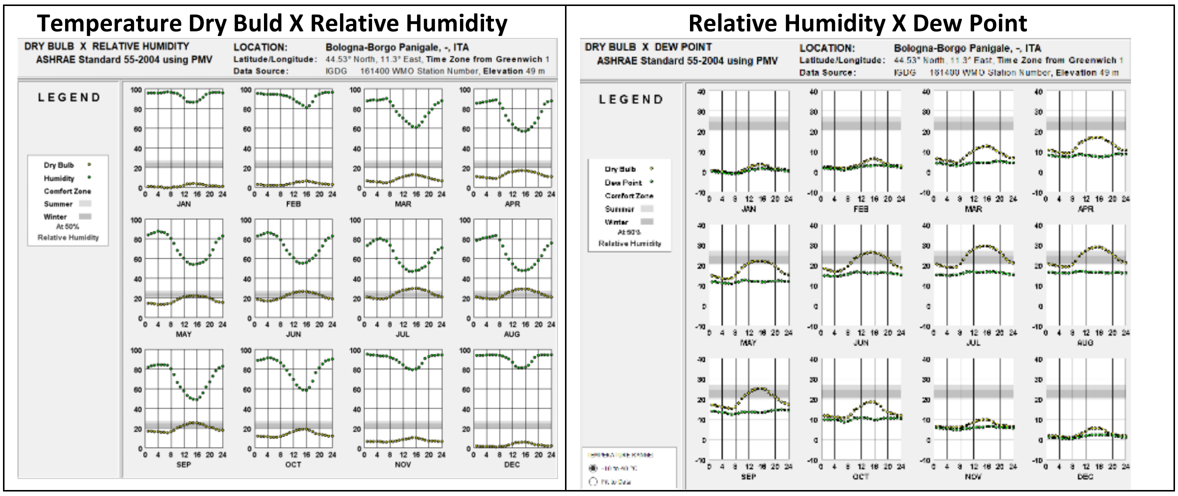


(IV) Time lighting (lux)



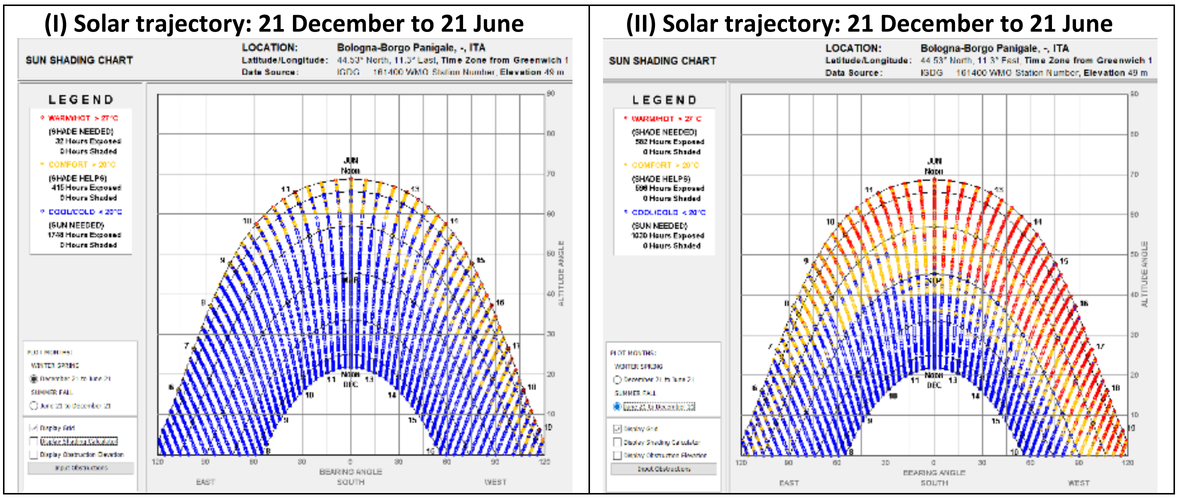
(V) Wind speed



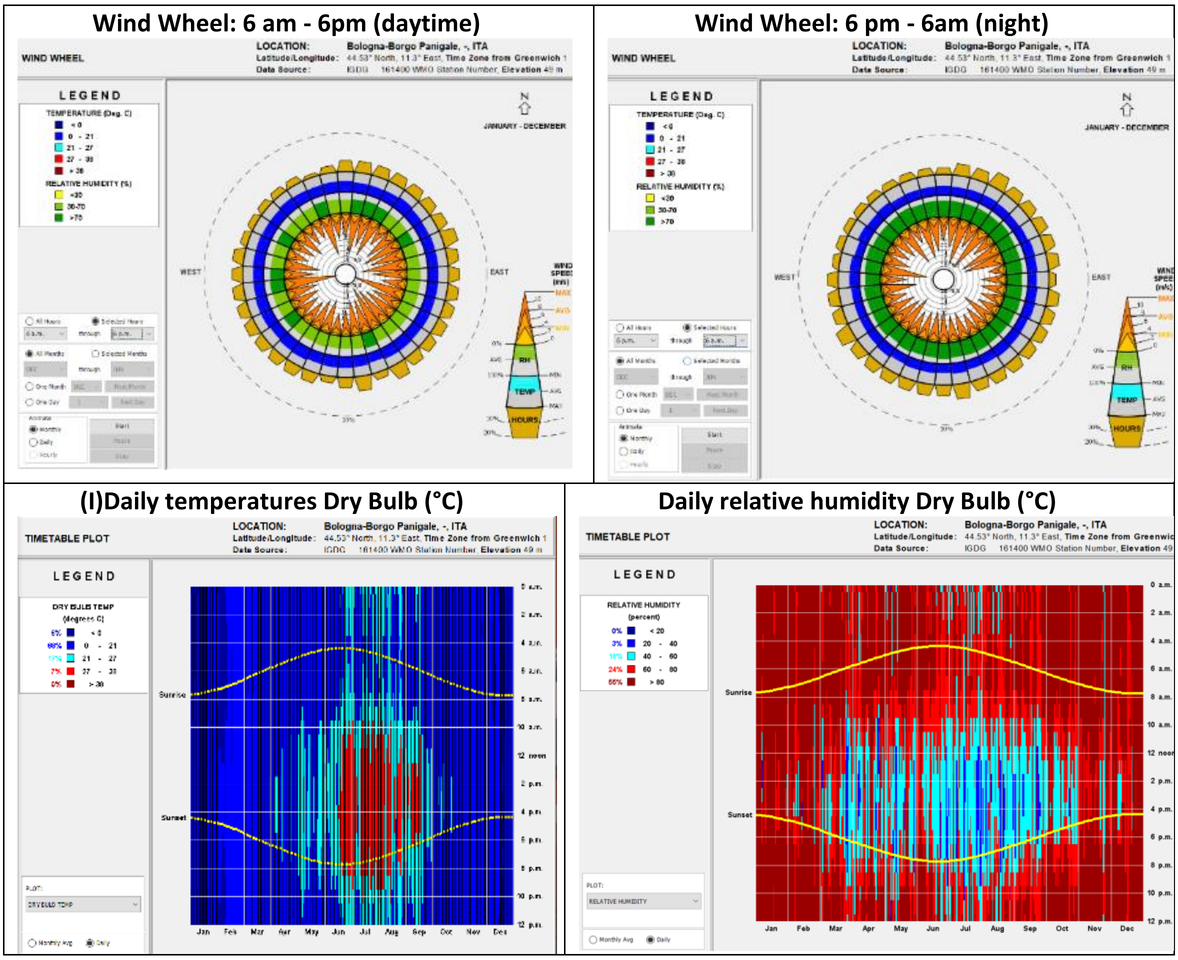


Source: ASHREA, 2021

The image on the left (I) below represents the trajectory of the solar to the city of Bologna, horizontally and vertically (altitude), showing through the colored points the temperature observed during the period from December 21 to June 21, temperature measured every 15 minutes. Showing total hours in heat discomfort 32 hours, total hours in comfort 415 hours and all hours in cold discomfort 1748 hours. The image on the right (II) below represents the trajectory of the solar to the city of Bologna, but showing through the colored points the temperatures observed during the period from June 21 to December 21, measuring the temperature every 15 minutes. Showing total hours in heat discomfort 582 hours (>27 degrees celsius), total hours in comfort 596 hours (> 20 degrees celsius and <27 degrees celsius), as well as hours in thermal discomfort by cold 1030 hours (< 20 degrees celsius).



Source: ASHREA, 2021

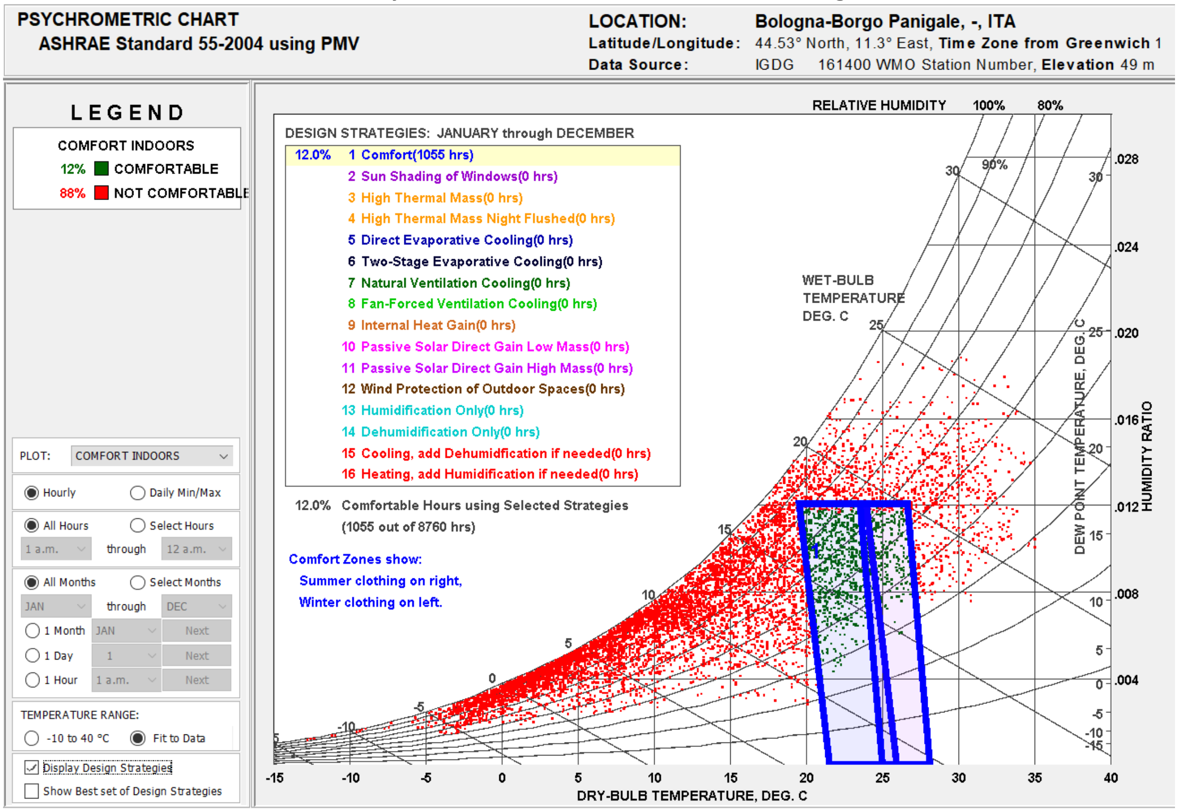


Source: ASHREA, 2021

Adaptability considers the physiological aspects, which make the organism more tolerant to high temperatures in summer and to lower temperatures in winter. Furthermore, it also considers the possibility of the individual interacting with the environment, opening a window, changing posture, changing clothes or choosing more comfortable places. However, because it is a subjective variable, adaptability is studied in an empirical way, which allows the development of several equations relating to the feeling of comfort and average monthly temperature.

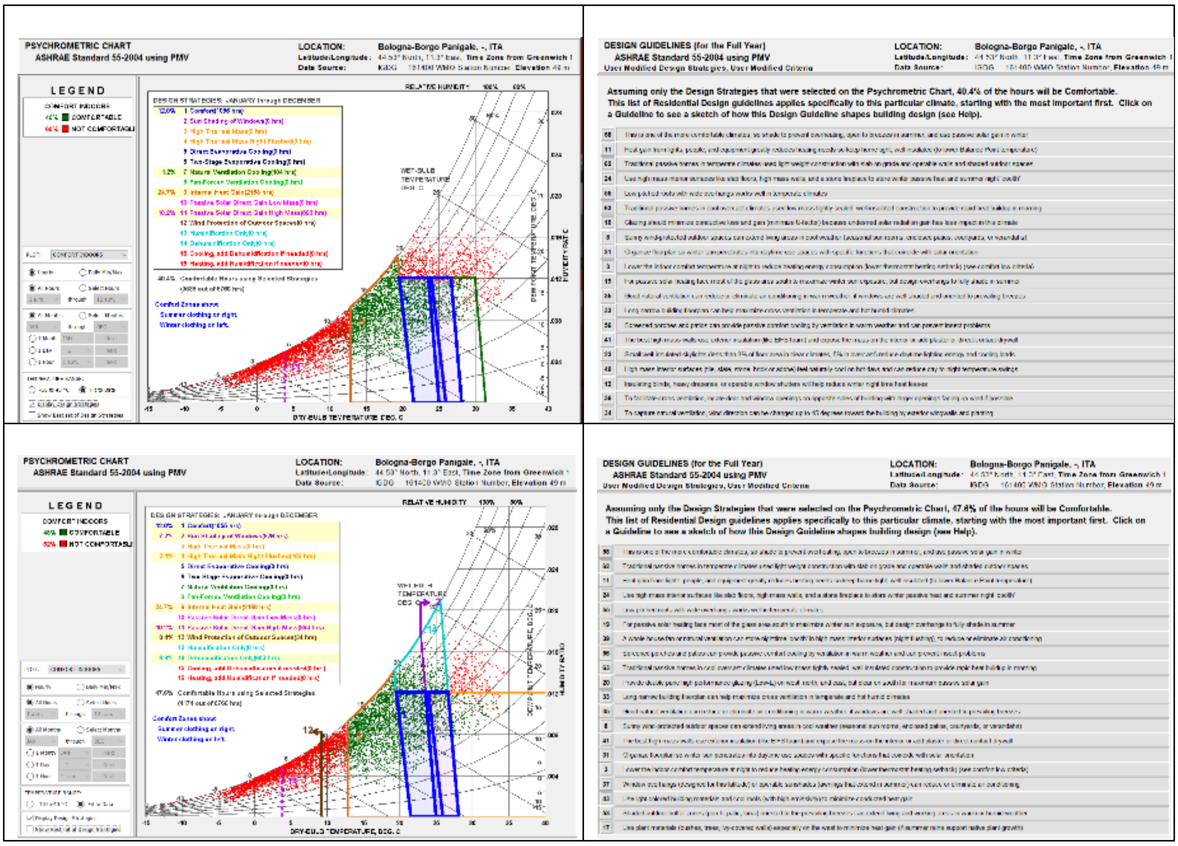
The following table presents the observed climate data (2005) of the city of Natal represented by psychrometric chart.

Picture 42: Psychometric chart of climate data of Bologna/ER



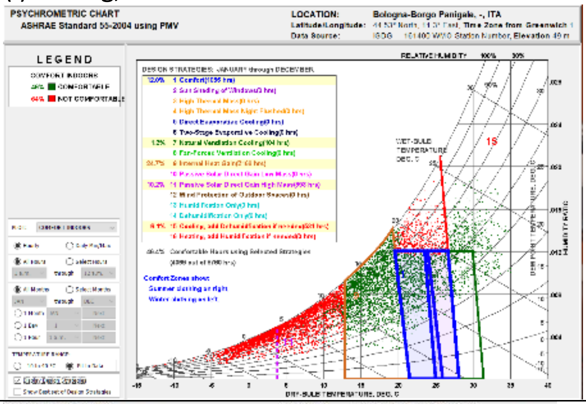
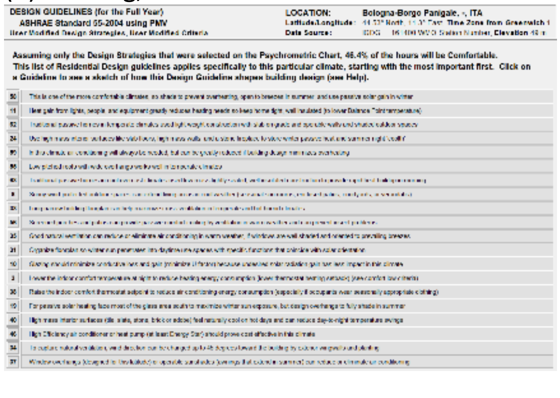
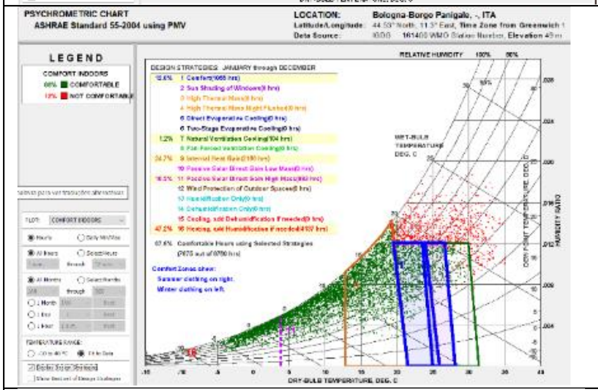
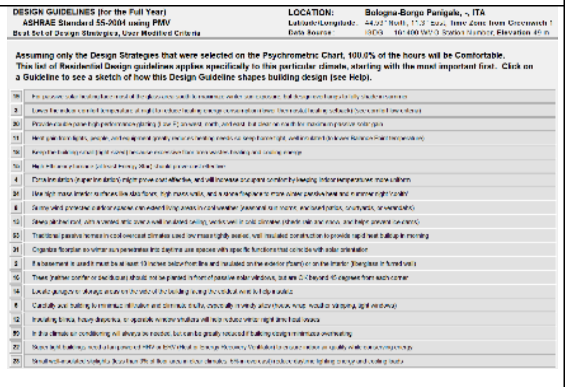
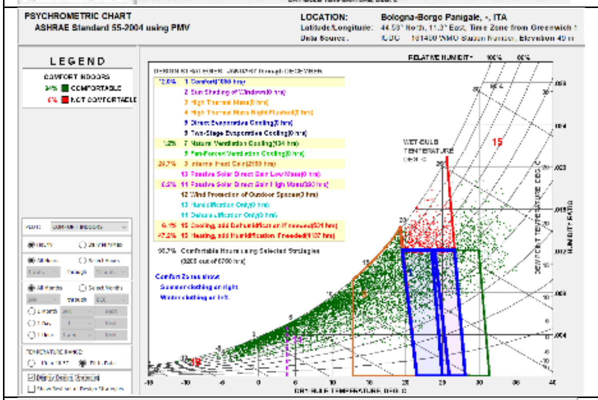
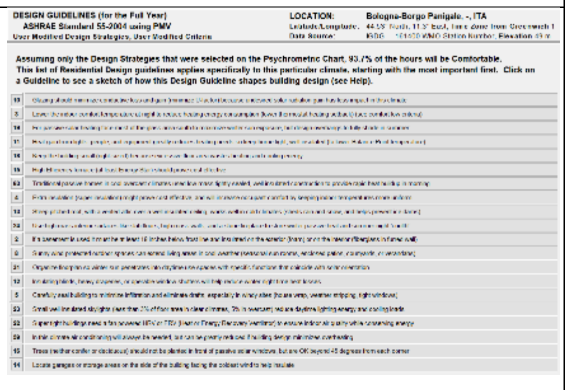
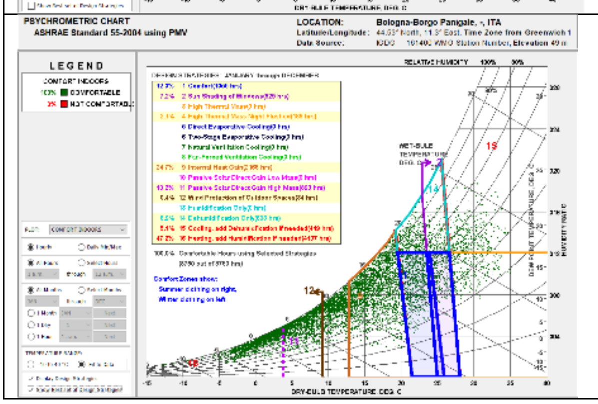
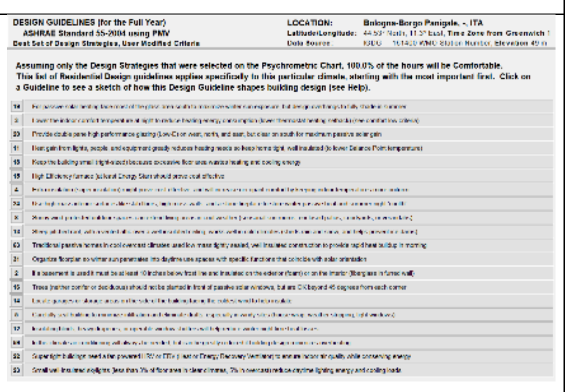
Source: ASHREA, 2021

PASSIVE STRATEGIES



Source: ASHREA, 2021

PASSIVE STRATEGIES + (ARTIFICIAL) COOLING AND HEATING MECHANICS

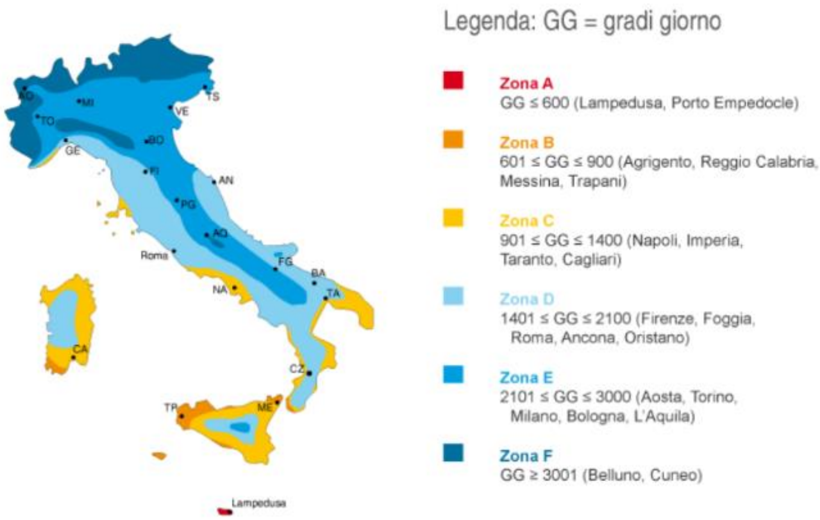
(i)cooling, add deshumidfication	(II) Heating, add humidification if needed
	
	
	
	

Source: ASHREA, 2021

ITALIAN BIOCLIMATIC ZONING

According to the Italian bioclimatic zoning, there are three main climatic zones present on Italian territory: hot temperature climate, snow climate and polar climate. Subdivided into six zones that are classified according to the observed variables (air temperature, precipitation indices) by the amount of degree-days[115] that a given region, regardless of the geographical location. These thresholds are specified according to the Decreto del Presidente della Repubblica n. 412 del 26 august 1993 and successivi aggiornamenti fino al 31 ottobre 2009.

Picture 43Subject: Classification of Italian climatic zones according to degrees - days

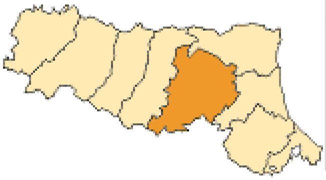


Zona climatica	*Gradi-giorno*	*Periodo*	*Numero di ore*
A	comuni con GG ≤ 600	1° dicembre - 15 marzo	6 ore giornaliere
B	600 < comuni con GG ≤ 900	1° dicembre - 31 marzo	8 ore giornaliere
C	900 < comuni con GG ≤ 1.400	15 novembre - 31 marzo	10 ore giornaliere
D	1.400 < comuni con GG ≤ 2.100	1° novembre - 15 aprile	12 ore giornaliere
E	2.100 < comuni con GG ≤ 3.000	15 ottobre - 15 aprile	14 ore giornaliere
F	comuni con GG > 3.000	tutto l'anno	nessuna limitazione

Source: (DECRETO DEL PRESIDENTE DELLA REPUBBLICA 26 August 1993, n. 412, 1993)

Also according to the Decree of the President of the Republic n. 412, the province of Bologna is inserted in the Climate Zone E, with 2,259 degree-days. In which the period of operation of the heating systems are from: 15 October to 15 April (14 hours daily).

[115] Degree-days (GG) is the sum, for all days of the year, of the difference (only positive) between indoor air temperature and outdoor daily temperature. In other words, the higher the GG index, the climate is more rigid, with temperatures below 20°C for many days of the year.



Zona climatica E	Periodo di accensione degli impianti termici: dal 15 ottobre al 15 aprile (14 ore giornaliere), salvo ampliamenti disposti dal Sindaco.
Gradi-giorno 2.259	Il grado-giorno (GG) di una località è l'unità di misura che stima il fabbisogno energetico necessario per mantenere un clima confortevole nelle abitazioni. Rappresenta la somma, estesa a tutti i giorni di un periodo annuale convenzionale di riscaldamento, degli incrementi medi giornalieri di temperatura necessari per raggiungere la soglia di 20 °C. Più alto è il valore del GG e maggiore è la necessità di tenere acceso l'impianto termico.

Source: Classificazione climatica di Bologna (BO) (tuttitalia.it)

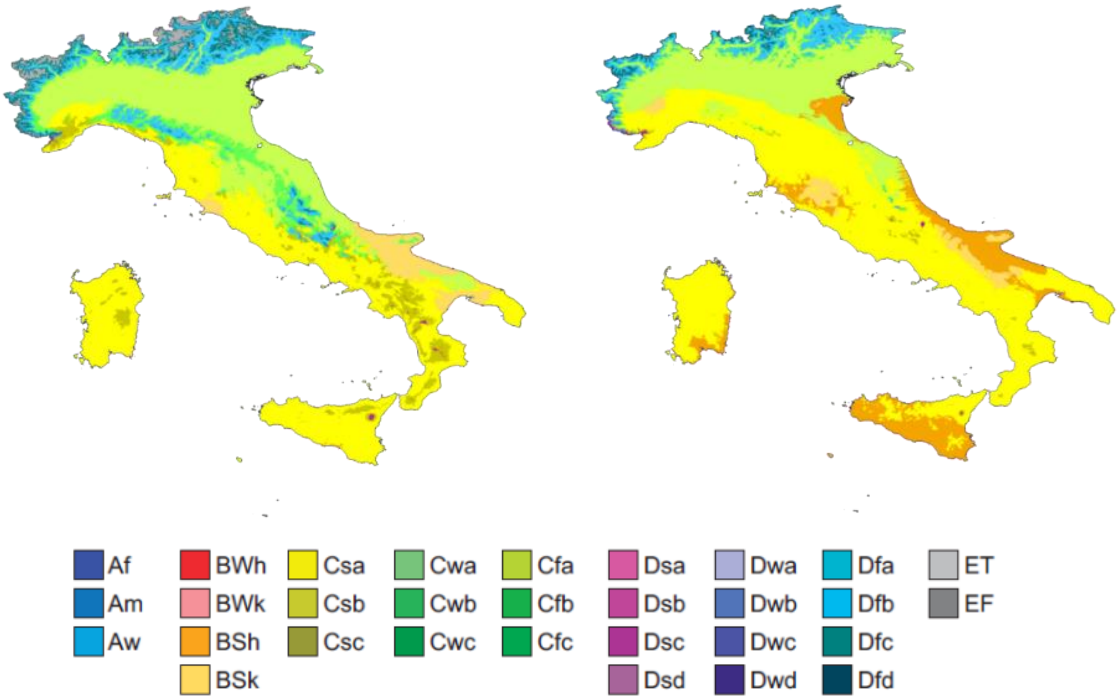
FUTURE CLIMATE CHARACTERIZATION

For the analyzes concerning the Italian territory, the climatic classification presented in the global maps of Beck et al. will be adopted. (2018). These maps, drawn on the basis of the climate data of GHCN v2 Station data, for the present period used the data between the years 1980 to 2016 and for the future forecast the data between the years 2071 to 2100.

Picture 44: Present-day and future World Map Köppen-Geiger climate classification for Italy (2018) with latitude/longitude of 0.0083 degree resolution - 1 km and scenario RCP8.5 (pessimistic).

(A) Köppen-Geiger climate classification the present-day map of Italy (1980-2016)

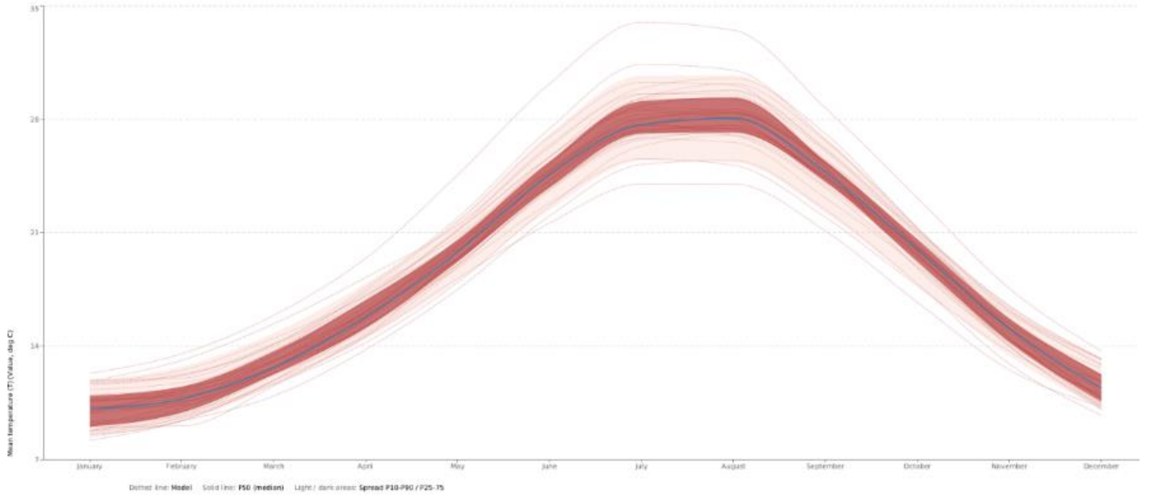
(B) Köppen-Geiger climate classification the future map of Italy (2007-2010)



The color scheme was adopted from Peel et al. (2007)
Source: BECK et al. (2018)
Available at: Present and future Köppen-Geiger climate classification maps at 1-km resolution.

Interactive Atlas: Regional information (Advanced), in which it is possible to characterize through the different SSP climate scenarios the effects of the increase of the emission of GHGs in a given region of the globe or a global average. According to the information extracted from the platform developed by the IPCC WGI using the most pessimistic socio-economic scenario SSP5-8.5, the Mediterranean region

CMIP6 - Mean temperature (T) deg C - Warming 2°C SSP5-8.5 - Annual Cycle (34 models)
Regions: Mediterranean



Period	Scenario	Median (deg C)	P25 | P75	P10 | P90	P5 | P95
Warming 1.5°C	SSP5-8.5	17.9	17.2 | 18.5	16.7 | 19.2	16.3 | 19.7
Warming 2°C	SSP5-8.5	18.5	17.7 | 19.2	17.3 | 19.8	16.8 | 20.4
Warming 3°C	SSP5-8.5	19.6	18.8 | 20.3	18.4 | 20.9	18.2 | 21.6
Warming 4°C	SSP5-8.5	20.5	19.9 | 21.2	19.6 | 21.6	19.4 | 21.8

Source: (IPCC, 2021).

2.2.3 Regulatory Aspects

According to the Decree of the President of the Republic n.412 (1993), a regulation laying down rules for the design, installation, operation and maintenance of thermal systems in buildings for the purpose of containing energy consumption, buildings are classified according to their purpose and use, according to criteria described in its Art.3:

1. Buildings are classified according to their purpose of use in the following categories:

E.1 Buildings used as dwellings and the like:

E.1 (1) continuous residential housing such as civil and rural houses, colleges, convents, prison houses, barracks;

E.1 (2) residential households with occasional occupation, such as holiday homes, weekends and the like;

E.1 (3) buildings used as hotels, pensions and similar activities;

E.2 Buildings used as offices and similar: public or private, independent or adjacent to buildings also used for industrial or craft activities, provided that they are separable from the effects of thermal insulation;

E.3 Buildings used such as hospitals, clinics or nursing homes and the like, including those used for the hospitalization or care of minors or the elderly, as well as facilities for the care and rehabilitation of drug addicts and other matters entrusted to public social services;

E.4 Buildings used for recreational, association or cult activities and similar activities:

E.4 (1) as cinemas and theaters, meeting rooms for congresses;

E.4 (2) as exhibitions, museums and libraries, places of worship;

E.4 (3) as bars, restaurants, dance halls;

E.5 Buildings used for commercial and similar activities: such as shops, wholesalers or retail stores, supermarkets, exhibitions;

E.6 Buildings used for sports activities:

E.6 (1) swimming pools, saunas and the like;

E.6 (2) gyms and similar;

E.6 (3) support services for sports activities;

E.7 Buildings used for school activities at all levels and assimilable;

E.8 Buildings used for industrial and craft activities and assimilable.

The decree in question also assigns requirements and sizing of heating systems (Art.05), Minimum efficiency of heat generators (Atr.06), Operation and maintenance of heating systems and controls (Art.11). In Annex D, the decree establishes technologies for the use of renewable energy sources suitable for production listed by constructive category of public property or public use. Besides this decree others bring pertinent guidelines to the buildings as for example:

- DECRETO DEL PRESIDENTE DELLA REPUBBLICA 16 aprile 2013, n. 74 Recante regulation definizione dei criteri generali in materia di esercizio, conduione, controllo, manutenzione e ispezione degli impianti termici per la climatizzazione invernale ed estiva degli edifici e per la Preparazione dell'acqua calda per usi igienici sanitari, a norm dell'articolo 4, comma 1, lettere a) e c), del Decreto Legislativo 19 Aug 2005, n. 192.
- LEGGE 9 gennaio 1991, n. 10, Norme per l'attuazione del Piano energetico nazionale in materia di uso razionale dell'energia, di risparmio energetico e di sviluppo delle fonti rinnovabili di energia.
- LEGISLATIVE DECREE 19 August 2005, n. 192 Attuazione della directive 2002/91/EC on energy efficiency nell'edilizia.

EU DIRECTIVES

Regulation (EU) No 305/2011 of the European Parliament and of the Council of 2011, regulating harmonized conditions for the marketing of construction products (CPR, EU/305/2011), which lays down seven Basic Requirements for construction products:

- mechanical strength and stability,

- fire safety,
- Hygiene, health and the environment,
- safety and accessibility in use,
- noise protection,
- Power savings and heat retention and
- Sustainable use of natural resources.

The Regulation provides that construction works as a whole and their separate parts must be suitable for their intended use, taking into account in particular the health and safety of the persons involved throughout the life cycle of the works.

DIRECTIVE 2002/91/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 2002 on the energy performance of buildings - EPBD

Article 09 of this directive ensured that by the end of 2020 all new buildings would be nearly zero energy buildings (NZEB). It is proposed that in the revision of the thermal regulation a target should be set which would require a significant reduction in the average primary energy consumption, which would hopefully have a maximum value of 10 kWh/m2.ano (equivalent to that defined in Denmark) for heating, AQS, ventilation, air conditioning and lighting purposes.

DIRECTIVE 2010/31/EU OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 2010 on the energy performance of buildings (European Union, 2010)

The recent EU Directives 2010/31 and 2012/27 set near-zero energy building standards for new buildings, aiming at a better quality of the built environment through the adoption of high performance solutions.

DIRECTIVE (EU) 2018/844 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 30 May 2018 amending Directive 2010/31/EU on the energy performance of buildings and Directive 2012/27/EU on energy efficiency (Text with EEA relevance)

UNI EN 15232-1:2017 can be used both for the design of new buildings and for the verification of existing buildings. Presenting guidelines for control, building automation and technical building management capable of contributing to the energy performance of buildings. Unfortunately this standard does not have free access, but according to specialized websites it references and complements a whole series of standards that, specifically, for each individual type of system, define an analytical calculation method to determine the energy savings. These standards belong to the EN15000 and EN12000 series and cover the following types of systems:

· Heating (BACS/HBES)

· Cooling (BACS / HBES)

· Ventilation and conditioning (BACS/HBES)

· Hot water production (BACS/HBES)

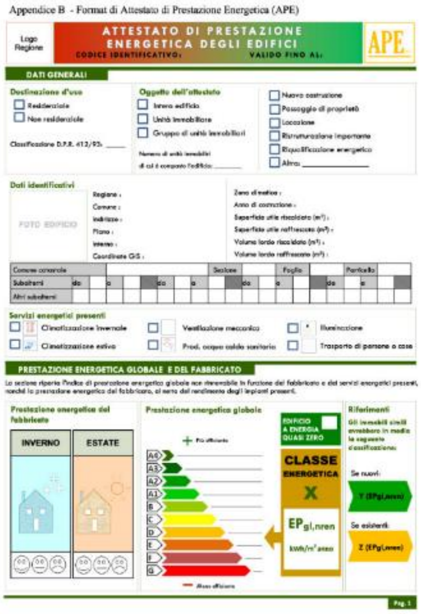
· Lighting (BACS/HBES)

· Solar shading control (shutters and ambient light) (BACS/HBES)

· Centralization and integrated control of the different applications (TBM) or Diagnostics (TBM)

· Detection of consumption/improvement of automation parameters (TBM)

ENERGY PERFORMANCE CERTIFICATE



Appendice B - Format di Attestato di Prestazione Energetica (APE)

Logo Regione

ATTESTATO DI PRESTAZIONE ENERGETICA DEGLI EDIFICI

CODICE IDENTIFICATIVO: VALIDO FINO AL:

APE

DATI GENERALI

Destinazione d'uso
- ☐ Residenziale
- ☐ Non residenziale

Classificazione D.P.R. 412/93: ____

Oggetto dell'attestato
- ☐ Intero edificio
- ☐ Unità immobiliare
- ☐ Gruppo di unità immobiliari

Numero di unità immobiliari di cui è composto l'edificio: ____

- ☐ Nuova costruzione
- ☐ Passaggio di proprietà
- ☐ Locazione
- ☐ Ristrutturazione importante
- ☐ Riqualificazione energetica
- ☐ Altro: ____

Dati identificativi

FOTO EDIFICIO

Regione :
Comune :
Indirizzo :
Piano :
Interno :
Coordinate GIS :

Zona climatica :
Anno di costruzione :
Superficie utile riscaldata (m²) :
Superficie utile raffrescata (m²) :
Volume lordo riscaldato (m³) :
Volume lordo raffrescato (m³) :

Comune catastale								Sezione			Foglio			Particella		
Subalterni	da		a			da		a			da		a			da		a		
Altri subalterni																

Servizi energetici presenti
- ☐ Climatizzazione invernale
- ☐ Climatizzazione estiva
- ☐ Ventilazione meccanica
- ☐ Prod. acqua calda sanitaria
- ☐ Illuminazione
- ☐ Trasporto di persone o cose

PRESTAZIONE ENERGETICA GLOBALE E DEL FABBRICATO

La sezione riporta l'indice di prestazione energetica globale non rinnovabile in funzione del fabbricato e dei servizi energetici presenti, nonché la prestazione energetica del fabbricato, al netto del rendimento degli impianti presenti.

Prestazione energetica del fabbricato

INVERNO	ESTATE

Prestazione energetica globale

Più efficiente

A4 A3 A2 A1 B C D E F G

Meno efficiente

EDIFICIO A ENERGIA QUASI ZERO

CLASSE ENERGETICA

X

$EP_{gl,nren}$

kWh/m² anno

Riferimenti

Gli immobili simili avrebbero in media la seguente classificazione:

Se nuovi: Y ($EP_{gl,nren}$)

Se esistenti: Z ($EP_{gl,nren}$)

Pag. 1

The Energy Performance Certificate (EPA) is a document that certifies the energy performance and energy class of a building and indicates the most cost-effective improvements. Through the EPA, citizens learn about characteristics such as the energy requirements of the building or construction unit, the energy quality of the building, carbon dioxide emissions and the use of renewable energy sources, which affect the operating costs and environmental impact of the building, and are guided by an informed choice in the event of purchase, rental or renovation (renovation or upgrade).

Energy performance is the amount of energy needed to meet the standard use needs of a building for heating, cooling, ventilation, domestic hot water and, in non-residential buildings, also for lighting, elevators and escalators. As of October 2015, the EPA has a standard format across the country.

BOLOGNA URBAN REGULATION

According to the General Plan of the Urban Regulation of the city of Bologna, there is the forecast of guidelines for microclimatic well-being that should be satisfactory to guarantee the comfort of the users. This action seeks to contribute to mitigating the effect of "heat island" in urban space, and to prioritize constructions and interventions in the built environment that respect the principles of sustainable design.

According to the regulation, a building that respects these principles takes into account not only the particularities of the place where it will be inserted, but mitigates the effects of the solar radiation incident in its surroundings, using urban morphology and the use of vegetation to improve the urban microclimate and consequently the comfort of the users, mainly in internal spaces. The designer must adopt integrated solutions that are able to control the summer sun simultaneously, promote direct sunlight during the winter, thus optimizing passive performance of buildings and introduce climate adaptation (PUG[116]).

The following requirements shall be ensured:

- Microclimati wellness index (BM);
- Coefficient of reflection of external horizontal surfaces - Albedo.
- treatment of external fences of the building and introduction of solar energy into the building;

Control of the solar power supply to the building. In interventions of new constructions or demolitions and reconstruction (NC, RE), RI guarantees in the summer, shading/darkening of each transparent closures (windows, skylights, etc.) of the spaces of the construction unit used for the main activity and adequate protection of the roofs against solar radiation, including with external shading systems. They are particularly suitable in this regard are green walls, green coats, innovative shading systems, energy production shading of walls with power production (as per Art. 61 >>) and passive climate control technologies such as green roofs or free cooling systems (as per Art. 65 >>). Those parts of flat roofs not affected by green green roofs or installations for the production of energy from renewable sources shall be treated in such a way as to ensure an albedo of at least 80% (cool roof), unless otherwise prescribed in these Regulations (Comune di Bologna, 2020).

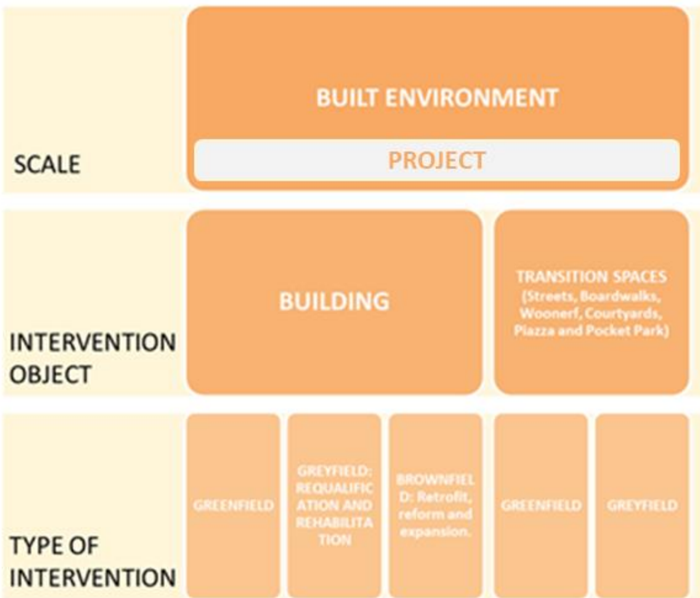
[116] PUG... Disciplina del Piano_ADO.pdf (comune.bologna.it)

3 DISCUSSION

Within the cut-off of the built environment, scale of the building, residential typology, to facilitate the process of analysis of the multidisciplinary information correlating with the collected data (observed and projected), it was concerned to better structure the method used for the Overview of this work with the intention to systematize the analyzes of possible strategies that would have good performance in mitigation, adaptation and expansion of resilience. As a framework proposal, the work scales were categorized, later the object that would undergo the intervention and then the type of inversion.

Intending to analyze the effects of climatic changes on the microscale of the user, as a final proposal, the decision was taken to work with two objects of intervention: the building itself and the transition areas, internal or external areas that are spaces whose function is to converge public and private spaces with architectural and environmental quality. As for the type of intervention to be carried out on the object, it was classified on three fronts, and could be: *greenfield*, which are new projects in which there is total freedom of proposing solutions (mitigating and expanding their resilience); *greyfeld* which are existing buildings and space in which they have undergone processes of requalification and rehabilitation where the project solutions are more restricted seeking to adapt the structure in the face of future scenarios assigning it resilience, and finally theBrownfield which would be buildings already existing usually obsolete or ambandonadas, which in their operation possessed industrial, which is planned in a very restrictive way and based on particular technical aspects, a regeneration process of these areas, with retrofits of infrastructure, renovations and expansions to meet a new architectural programming. Here the management of multidisciplinary projects should be efficient promoting their reuse in an adaptive way, improving environmental quality and expanding their resilience. A **Erro! Fonte de referência não encontrada.** the following is an example of this proposed classification:

Picture 45: Proposed classification of scales, objects and types of interventions



Source: The author (2020).

After identifying scales, objects and types of intervention, it is necessary to identify vulnerabilities and opportunities for each effect that exist so that the planning of the response to these risks is more effective. On the user's micro scale, it will be possible to evaluate the built environment, plan response actions and manage them in a structured manner. According to the PMBOK® Guide (2021)[117], project[118] risk management includes in its structure the processes to assist in the conduct of these analyzes, are: identification, analysis, response planning, implementation of responses and monitoring of risks in a project.

When carrying out risk[119] management in a project, one must first identify which types of interventions are in fact projects and which are part of their operationalized one, since for each one the responses to the effects will be diverse. Both will be run by people, with limited resources, processes and have a final goal. However, within the concept disseminated by the PMBOK, the Project is a temporary action, with a focus on producing something, with limited resources and a portion destined to the production of a product with a focus normally on expanding the business. The concept of Operation brings the action on a continuous basis, with a focus on maintaining something, with limited resources, but with contributions per function and time (monthly) destined to maintain the business.

All the risk is formed by three main components, these are: the **event itself associated with its root cause** (cause and impact), the **probability** of occurrence associated with the event and the overall impact of the event if it does not have an impact identified the PMBOK methodology characterizes these events to uncertainties and not to PMBOK risks, (2017) and (2021).

De Camprieu et al. (2007), proposed the reduction of these three components in a mathematical model taking into account the diversity of theories among different areas of knowledge, be they project, administrative, economic, among others. According to the authors, the future environment is determined by various facts that may or may not occur. A successful project will depend on the real state of the future environment, as the real state is intangible, what will prevail will still be uncertainty. In order to mitigate the uncertainties within the risk management of a project, the authors developed the following mathematical equation described by the density function that combines the probability and impact amplitude of the various events to describe the risk, given by the density function **h(x,y) = g(x/y).f(y)**. Where, f(y) is the function corresponding to the problem, and g(x/y) is the amplitude of the event if it occurs. Both functions are conditioned, that is, we can only assess the effects of the risk [g(x)] if it has actually occurred [f(y)].

The concept of exposure to Risk (Boehm, 1991) is a version of the risk density function, where P(Xi) is the probability of an undesirable event occurring (i) and C(Xi) is the consequence of that undesired event (i) for the affected parties. Risk exposure, according to the author, is defined by the relationship between:

---

117 PMBOK: Guide to the Project Management Body of Knowledge from PMI

118 According to PMBOK (2017), Project is a temporary effort undertaken to create a unique product, service or result.

119 According to the PMI, (2013). Risk is an uncertain event or condition that, if it occurs, has a positive or negative effect on one or more objectives of a project.

$$\text{Risk Exposure} = \sum_{i=1}^{n} P(X_i) * C(X_i)$$

Identifying the risk exposure index for each impact identified by predicted effect, independent of the method chosen, makes with such variables that were previously subjective, be qualified in a quantitative manner, reducing uncertainties, which facilitates the classification process and makes possible the prioritization of actions to be adopted within the context of risk management.

Within the various methods and methodologies for carrying out risk management in projects (PMI, 2013), among them we will adopt the risk management process described by the *Project Management Institute* (PMI), at PMBOK, composed of the following steps: planning, identification, analysis (quantitative and qualitative), planning of responses, monitoring and control of the identified risks (PMI, 2013). That summarizes the planning phase, the step that consists of describing all the processes and classification methodologies that will be adopted to manage the identified risks. The next step encompasses the stages of identifying the risks, their respective impacts (root cause) and classification to make possible the next step, the qualitative and quantitative analysis of each impact (root cause) described above and relating possible responses to each undesirable effect should the impact occur. Afterwards, one must make possible metrics capable of monitoring the physical and climatic conditions of the place where the impact is to occur, being possible through tangible metrics to monitor the exposure to risk and its tolerance to critical events. Afterwards, it is important to control impacts and, above all, to document them so that it is possible to develop a process of continuous improvement of risk management.

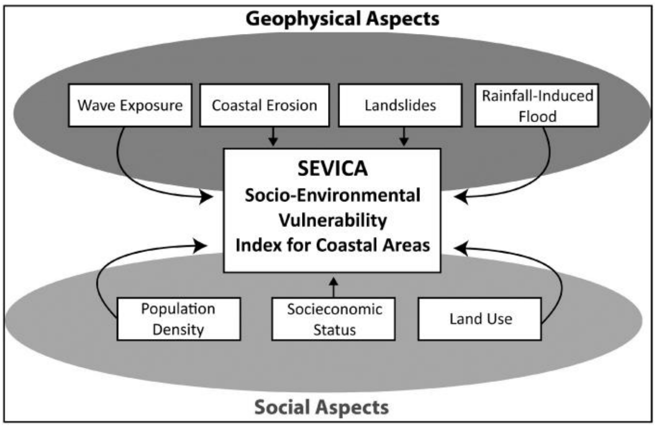
Another very important indicator for risk analysis is to identify the level of vulnerability of a given region to the risks in which it is inserted. Vulnerability according to IPCC is described by the degree of susceptibility of a system to the adverse effects of climate change, or its inability to manage these effects, including climatic or extreme variability (IPCC, 2014).

> *"Vulnerability is a function of the character, size and rate of climatic variation to which a system is exposed, its sensitivity and capacity for adaptation* (IPCC, 2014)*."*

To determine the vulnerability index of a front region as described by IPCC, PMI, PMBOK, among others described. It is proposed to determine an index of socio-environmental vulnerability, so that, in conjunction with the risk exposure index, it is feasible to obtain a "final" index diagnosing the variables risk and vulnerability, but mainly, relating the physical data obtained also in the social, environmental and economic context in which a communities and region of high vulnerability is inserted. With the ultimate goal of an attempt, perhaps naive, to promote equity between such divergent quantities.

First, as described by Segundo Zanetti et al. (2016), geophysical and socio-environmental aspects need to be assessed and diagnosed. The authors propose a risk index composed of multiple factors, four of which have geophysical characteristics, are: floods, landslides, coastal erosion and exposure of waves. With three socioeconomic factors, they are: Socio-economic status, population density and land use.

Picture 46: Aspects analyzed according to Zanetti et al. (2016)



Source: (Zanetti, de Sousa Junior, & de Freitas, 2016).

Among the approaches used by Zanetti ei al, (2016), to reference the analyzes of the different concepts and indices of vulnerability existing in the literature to formulate the Social and Environmental Vulnerability Index of Brazilian Coastal Areas for the city of Santos/SP - Brazil, we highlight as table next.

Table 20: Examples of different approaches to measuring vulnerability

VULNERABILITY CONCEPT	INDEX	VARIABLES/PARAMETERS/ FACTORS	REFERENCE
Geophysical	CVI	Relief, geomorphology, rock type, vertical sea level movement, shoreline displacement, tidal range, wave height.	Gornitz, V. (**1991).** Global Coastal Hazards from Future Sea Level Rise. *Palaeogeogr. Palaeoclimatol, 89*, 379-398.
	SI	Relief, rock type, geomorphology, sea level tendency, shoreline displacement rate, mean tidal range.	Shaw, J.; Taylor, R.B.; Forbes, D.L.; Ruz, M.-H.; Solomon, S. (**1998).** Sensitivity of the Coasts of Canada. *Geol. Surv. Can. Bull*, *505.*
	CVI	Geomorphology, coastal slope, relative sea-level rise rate, shoreline erosion/accretion rate, mean tide range, mean wave height.	Thieler, E.R.; Hammar-Klose, E.S. *National Assessment of Vulnerability to Sea-Level Rise: Preliminary Results for the U.S. Atlantic Coast*; United States Geological Survey: Reston, VA, USA, 1999.
	CSI	CVI (Thieler and Hammar-Klose, 1999).	Karymbalis, E.; Chalkias, C.; Chalkias, G.; Gigoropoulou, E.; Manthos, G.; Ferentinou, M. Assessment of the Sensitivity of the Southern Coast of the Gulf of Corinth (Peloponnese, Greece) to Sea-Level Rise. *Cent. Eur J. Geosci.* **2012**, *4*, 561-577.
Social	SoVI	Personal Wealth, age, density of the built environment, single-sector economic dependence, housing stock and tenancy, race—African American, race—Native American, race—Asian, occupation, infrastructure dependence.	Cutter, S.L.; Boruff, B.J.; Shirley, W.L. Social Vulnerability to Environmental Hazards. *Soc. Sci. Q.* **2003**, *84*, 242-261.

	CsoVI	Poverty, age, development density, Asian and immigrants, rural/urban dichotomy, race and gender, population decline, ethnicity (Indian) and farming, infrastructure employment reliance, income.	Thieler, E.R.; Hammar-Klose, E.S. *National Assessment of Vulnerability to Sea-Level Rise: Preliminary Results for the U.S. Atlantic Coast*; United States Geological Survey: Reston, VA, USA, 1999.
Socio-Environmental	PVI	CVI (Thieler and Hammar-Klose, 1999) + CsoVI.	Boruff, B.J.; Emrich, C.; Cutter, S.L. Erosion Hazard Vulnerability of US Coastal Counties. *J. Coast. Reg. West Palm Beach* **2015**, *21*, 932-942.
	N.A (Not defined)	Flood-risk zones, population, housing units, females, ethnic population, young (under 18), elderly (age over 60), single mother households, renter-occupied housing units.	Wu, S.Y.; Yarnal, B.; Fischer, A. Vulnerability of Coastal Communities to Sea-Level Rise: A Case Study of Cape May County, New Jersey, USA. *Clim. Reg.* **2002**, *22*, 255-270.
	N.A (Not defined)	Flooding risk, population and structure, differential access to resources.	Chakraborty, J.; Tobin, G.A.; Montz, B.E. Population Evacuation: Assessing Spatial Variability in Geophysical Risk and Social Vulnerability to Natural Hazards. *Nat. Hazards Rev. Am. Soc. Civ. Eng.* **2005**, *6*, 23-33.
	N.A (Not defined)	Socio-economic index, land use index, eco-environmental index, coastal construction index, disaster-bearing capability index.	Li, K.; Li, G.S. Vulnerability Assessment of Storm Surges in the Coastal Area of Guangdong Province. *Nat. Hazards Earth System. Sci.* **2011**, *11*, 2003-2010.
	N.A (Not defined)	Sea level rise, storm surge, number of cyclones in the last 5 years, river discharge, foreshore slope, soil subsidence, km of coastline, population close to coastline, percentile of disabled persons, shelters, cultural heritage, awareness and preparedness, km of drainage, growing coastal population, recovery time, uncontrolled planning zones, flood hazard maps, institutional organizations, flood protection.	Balica, S.F.; Wright, N.G.; van Der Meulen, F. A flood vulnerability index for coastal cities and its use in assessing climate change impacts. *Nat. Hazards* **2012**, *64*, 73-105.

Source: (Zanetti, de Sousa Junior, & de Freitas, 2016)

Once the main possible impacts in a given region have been identified, it is necessary to relate the impacts to tangible parameters, capable of characterizing these impacts through quantitative and qualitative metrics. Subsequently, one must also classify and assign weights so that it is possible to identify which areas are more vulnerable in relation to others, and finally, to choose in which databases the specific information of a municipality, region, rural area, among others, taking into consideration the availability of these data, will be taken. Finally, the vulnerability matrix should be developed to obtain the final rate of vulnerability to climate change. Espresso through the mean value of the parameters considered being calculated by the arithmetic mean, described by the following equation (Zanetti et al., (2016):

$$\text{Fator}_{v} = (P_{1} + P_{2} + P_{3} + \ldots + P_{n}) \times n^{-1}$$

Where: Impact v = Impact Vulnerability;

$P_{1\text{-}n}$ = Parameters characterizing this impact;

n = number of parameters considered

After identifying the values of vulnerability of each impact, in order to obtain the final index of vulnerability to climate change, one must calculate the weighted average of the factors, according to the following equation (Zanetti et al., (2016):

$$\text{SEVICA} = (\text{F.}\_p_1 + \text{L.}\_p_2 + \text{CE}.p_3 + \text{NÓS}.p_4 + \text{SS}.p_5 + \text{PD}.p_6 + \text{LU}.p_7) \times \left(\sum_{eu=1}^{7} p_{eu}\right)^{-1}$$

Where:

F = flood impact index;

L = sliding impact index;

CE = erosion impact index;

WE = Impact of wave exposure index;

PR = Risk of human settlement

BS = impact index for access to basic services;

SS = socioeconomic impact index;

LU = land use impact index;

P = weight for each impact;

Table 21: Vulnerability matrix: Identified impacts x parameter classification x weight assignment (between 1 and 5). Source: (Zanetti, de Sousa Junior, & de Freitas, 2016).

IMPACTS	SORT PARAMETER	1	2	3	4	5	DATABASE
Landslide	Number of extreme events in the last 10 years (SEN)	≤3 events	≤10 events	≤20 events	≤36 events	>36 events	Adapted from [7]
	Soil Geotechnical Classification (SCG)	Rocky base	Non-expansive tertiary soil, fractured rock with rough surface	Laterite soil, sandy soil	Alluvial rock (quaternary), fractured with clean ruptures filled with clay	Body of coluvius and talus, expansive soils	Expert Elicitation
	Tilt (S)	≤20%	≤ 40%	≤60%	≤80%	>80%	Adapted from [25]
Flooding	Number of extreme events in the last 10 years (SEN)	≤3 events	≤10 events	≤20 events	≤36 events	>36 events	Adapted from [7]
	Tilt (S)	≥ 80%	≥ 60%	≥ 40%	≥ 20%	<20%	Adapted from [25]
	Water body proximity (WBP)	>150 m	>100 m	>50 m	>20 m	≤10 m	Adapted from [26]
	Permeability index	>80%	≤80%	≤60%	≤ 40%	≤20%	
Exposure to waves	Sea level rise (SLR)	≤0 m	≤0.3 m	≤ 0,5 m	≤0.7 m	≤0.9 m	Adapted from [25]
	Relief (R)	> 50m	>20 m	>10 m	>5 m	≤1 m	Adapted from [24]
	Distance from coast (DC)	>150 m	>100 m	>50 m	>20 m	≤10 m	Adapted from [26]
C o a s	Sea level rise (SLR)	≤0 m	≤0.3 m	≤ 0,5 m	≤0.7 m	≤0.9 m	Adapted from [25]

IMPACTS	SORT PARAMETER	1	2	3	4	5	DATABASE
	Geomorphology (G)	Rocky, high cliffs, walls	Medium cliffs and cut-off coast, bulkhead	Low cliffs, floodplain	Cobblestone beach, estuary, lagoon	Sand beach, mud plain, delta	Adapted from [25]
	Tidal Height (TH)	≤ 0,5 m	≤1 m	≤ 1,5 m	≤2.0 m	≤2.5 m	Adapted from [15]
Risk of human settlements	Density (HAB/KM²)	≤5000	≤10,000	≤50,000	≤100,000	>100,000	
	Age (A)	25-35 years	35-40 years	15-20 years and 40-50 years	5-15 years and 50-60 years	0-5 years and over 60 years	Adapted from [6]
	Number of Permanent Local Domiciles						
	Degree of Urbanization						
Access to basic services	Access to medical/hospital care						
	Access to drinking water						
	Access to sanitation						
	Access to public transport						
S o c i	Income (I)	>20 LMW	up to 20 LMW	up to 10 LMW	up to 5 LMW	up to 2 LMW	Adapted from [8]

IMPACTS	SORT PARAMETER	1	2	3	4	5	DATABASE
	Education Level (EL)	Graduate or higher	Graduate	Faculty	High school	Elementary school or less.	Adapted from [8]
Land Use	Land Use (USE)	Industrial Area	Environmental protection area or natural habitat	Rural area	Commercial Area	Residential area	

MITIGATION STRATEGIES

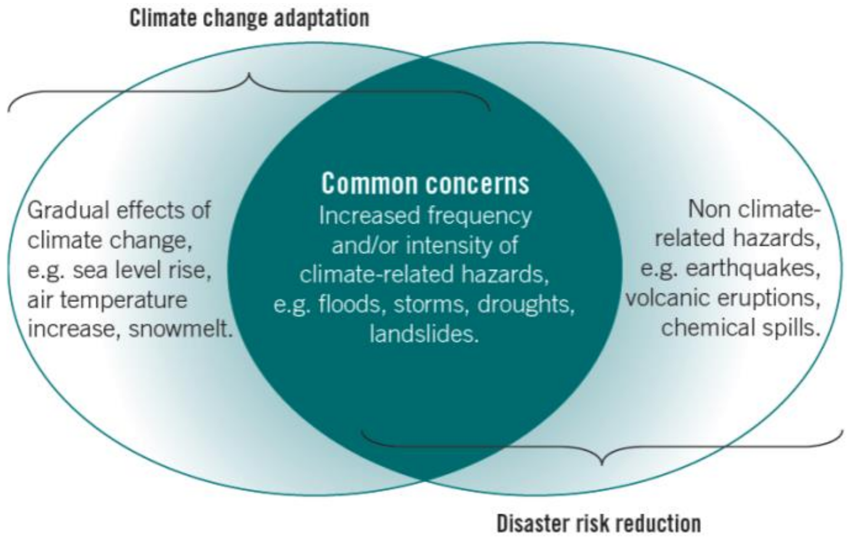
Climate change mitigation is achieved by limiting or preventing greenhouse gas emissions. As well, to privilege solutions that, instead of emitting GHGs, remove these gases from the atmosphere. Greenhouse gases originate from various types of sources and the mitigation of these emissions can be applied in all socio-economic sectors, from the adopted energy matrix to a number of sources and to activities that include: use of renewable energy, the transport sector, construction and operation of buildings, industry, waste management, agriculture, forestry and other forms of land management (IPCC, 2022).

When planning mitigation and its application, joint actions with short and long term goals should be proposed.

ADAPTATION STRATEGIES

Second European Commission (2013), in *Guidelines on developing adaptation strategies*, governance should address common concerns across the areas of climate change adaptation and extreme event risk reduction:

Picture 47Subject: Common concerns among areas of climate change adaptation and risk reduction



Source: European Commission, (2013, p. 13).

One of the measures that can assist in mitigating and expanding the adaptive response of the existing infrastructure is to draw up a contingency plan and manage the risks of these events. For each event, identify:

- climate risks, climate-related risks (temperature increase, floods, snowfalls, etc.) and non-climate-related risks that will not be addressed in the research (earthquakes, volcanic eruptions, chemical accidents, etc.) that a given region has;
- its effects and links them in the short, medium and long term contexts in the various sectors of a country (economic, environmental, social, etc.);

- the probability that each risk has to occur, and also, if it does, what impacts it causes (economic, environmental, health, social, etc.);
- the frequency, intensity and consequences of climate risks;
- The determinants of climate risks, as well as, allocating functions and responsibilities to the various actors that make up the public and private sectors. Developing risk reduction strategies and actions to be taken before, during, and after the event.

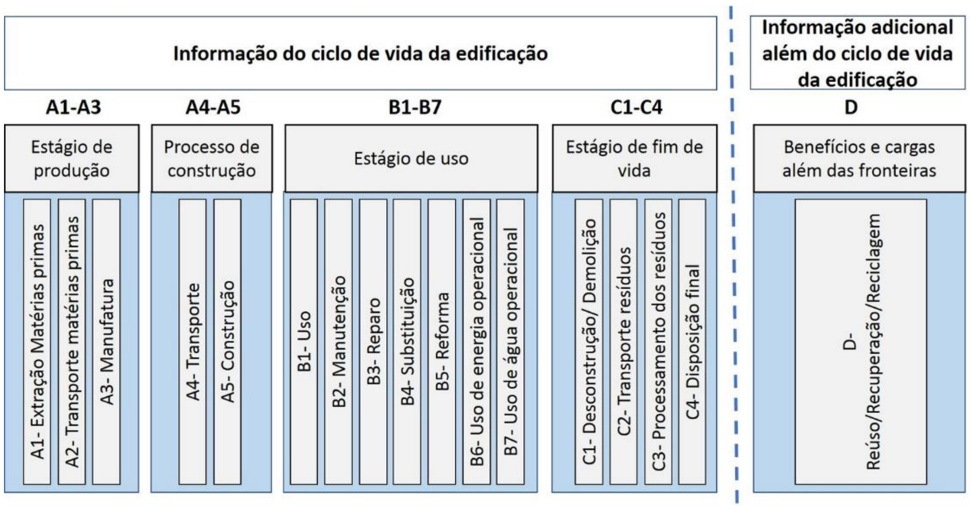
EXPANDING RESILIENCY

Increasing your resilience means assuming "the ability to adapt to changing conditions and maintain or regain functionality and vitality in the face of stress or disturbance" (Wilson A., Building Resilience in Boston, Boston Society of Architects, 2013).

Questo articolo descrive l'approccio di progettazione integrata sviluppato dall'Unità di Ricerca del Dipartimento di Architettura dell'Università di Bologna (UK) con l'obiettivo di individuare scenari di azione resilienti per la riforma degli edifici e dei distretti esistenti, nonché di definire criteri efficaci di progettazione delle riforme a livello di distretto. Questo approccio integrrato combines soluzioni e tecnologie efficienti sotto il profilo energetico che hanno un impatto positive e sostenibile sull'ambiente con strategie orientate ai clienti per Garantire sia i vantaggi che le aspettative e le esigenze dei clienti.

L'articolo evidenzia: il legame tra le strategie di mitigazione e l'ambiente edificato; l'attuazione della posta di un approccio integrrato alla progettazione (IDA) nel contesto reale del distretto di Bologna (Bolognina, TI); il rapporto tra la valutazione del cicleta di vita (LCA), le misure di mitigazione e l'IDA; analyi dei risultati, degli impatti e delle funzionalità della replica.

Picture 48: Life cycle stages of a building according to EN 15978:2011

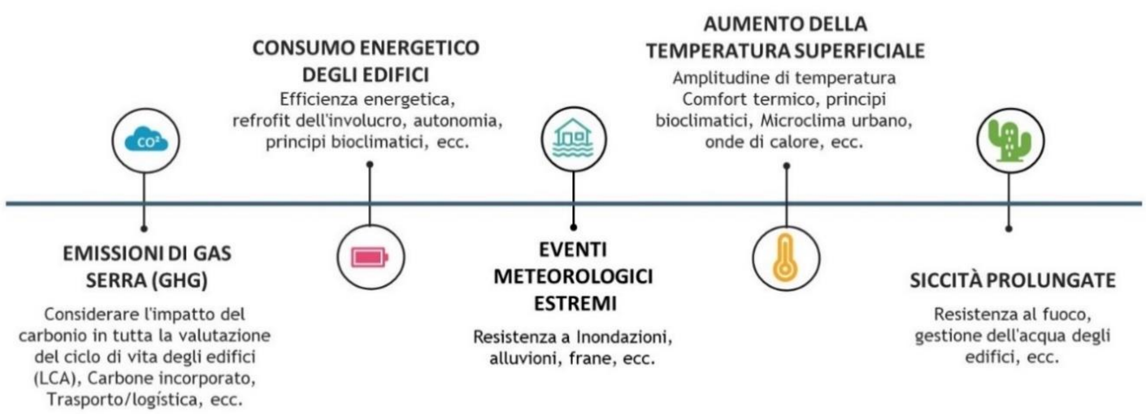


MAIN IDENTIFIED IMPACTS

After identifying them, for each climatic and meteorological event it is recommended to elaborate a **probability** matrix **X impact** so that it is possible to prioritize the events cataloged according to their degree of gravity. Prioritized, one must analyze through risk management tools, such as the **SWOT** tool, what the threats, opportunities, strengths, weaknesses of each previously listed event, as well as their economic impacts. Subsequently, assess the identified and prioritized risks by elaborating a risk management agenda, containing mitigating, adaptive and pontentializing actions in case of identification of opportunities in identified events. After that, you must plan responses that promote infrastructure resilience by drawing up a **contingency plan** for each event in the event of an event, through tools, strategies, processes and provisioning of resources appropriate to the impacts. In addition to this contingency plan, it is of paramount importance to draw up a **communication plan** covering the three phases of exposure to risk: pre-event, during the event and post-event. This plan has the function of preventing noise in communication during the occurrence of the event. Through constant training, it is expected that the community will always be informed about what actions should be taken at the moment, such as what to do, where to go, what to take, among others. Finally, **prioritize systems that promote the resilience** of existing infrastructure so that in the event of an extreme event, the event response is responsive and coordinated.

Among the effects identified and described in the inner capitals within the scales of the built environment, we have: The emission of greenhouse gases due to the energy matrix adopted today; the problem of energy consumption in buildings, its lack of efficiency in the wrap-around and in the specification of more energy efficient materials and equipment; the extreme events caused by the increase of global temperature media, which brings climatic, hydrological events and putting the population at risk in vulnerability; the increase of global average temperature, increases the thermal discomfort with heat and cold waves, low humidity, prolonged periods of drought, leading to increased health risk and aggravating the vulnerability of the communities.

Picture 49: Main impacts identified



Source: The author (2020).

Therefore, new buildings and urban spaces will have to be designed to deal with the impacts arising from the effects of climate change. In this context it is of paramount importance that during the design process of the architect and urbanist there is the adoption of mitigating metrics to reduce the vulnerability of the users, besides forecasting the increase of the resilience of the constructions designing structures capable of adapting with time, of registering during extreme events and to overcome the post-event impact. To do so, it will be necessary to expand the performance of buildings, as regards thermal comfort, energy efficiency, adaptability to retrofits and requalifications, tightness, incorporation of new technologies, properties and resistance of materials and construction methods.

The results presented here are within the urban context of the cities of Natal, located in the state of Rio Grande do Norte located in the Brazilian Northeast and the city of Bologna, located in the region of Emilia Romana located in the northern Italian region, on the scale of the built environment, sub-scale of the building of residential typology. Both cities with different climatic characteristics and impacts.

Table 22: Proposal to plan Risk Management: Description and categorization of the causes, effects, consequences/impacts and risk exposure index: Probability matrix (by type of risk) and impact (by type of objective) identified - cause is the emission of GHGs

	CAUSE	IDENTIFIED EFFECTS	PRIMARY IMPACT	SECONDARY IMPACTS	TERTIARY IMPACTS	PROBABILITY (P(XI))	CONSEQUENCE OF THE EVENT (C(XI))	RISK EXPOSURE INDICE	VULNERABILITY INDEX
Related to Climate	GHGs Deforestation	Thermal Confort	Thermal amplitude	Human exposure to high temperatures and radiation	Risk of hyperthermia and death				
				Air quality	Cardiorespiratory disorders (heart attacks, strokes, dehydration, etc.)				
				Moisture	Spiratory Diseases				
					Increased thermal discomfort				
			Wave of heat and cold	Human exposure to high temperatures	Risk of herthermia and death				
				Air quality	Cardiorespiratory				
				Moisture	Respiratory				
					Increased thermal discomfort				
			Ventilation	Air quality	Cardiorespiratory				
		Energy	Energy Security	Increased demand	Cut in supply,				
					Increased cost of production				
				power dependency	Diversify the energy mix, prioritize renewable sources,				

					energy-efficient buildings and equipment.				
				Reduction of wind power generation capacity					
				Increased solar power production capacity					
		Critical Events	Hydrological	Coastal Floods	collapse of structures, deaths, coastal and soil erosion,				
				Floods (Waterways)	Collapse of structures, deaths, floods, erosion of the margins				
				Flooding (Rainwater)	Collapse of structures, Deaths (drowning or burial), floods				
				Landslides	Collapse of structures, Deaths by burial,				
			metereological	Dried	Food safety, lack of supply, cardiorespiratory diseases,				
				Cyclones	Collapse of structures, Deaths by burial,				

				Earthquakes	Collapse of structures, Deaths by burial,				
			Security	Spread of fire	Collapse of structures, Deaths by burial and CO2 inhalation				
		GHG emissions	Dermolitions	Removal without need	Erosive processes, amount of solid waste and increased demand for landfills or recycling, change of flow regimes, landscape change,				
			Mitigation of emissions in the incorporated carbon footprint	Choice of subjects	High carbon footprint (use of concrete), low tightness,				
				Choice of constructive methods	High carbon footprint (concrete use), low thermal, acoustic and energy performance.				
				Project management	Construction site (environmental impact of the project, solid waste, water consumption and high electricity), air pollution, water and subsoil pollution, noise emission,				

					occupation of public roads.				
					Logistica (carbon footprint), impact on surrounding traffic,				
			Mitigation of emissions in the operational carbon footprint	Energy Efficiency of the Enclosure					
				Near Zero Energy Buildings (NZEB)					

Metrics adopted to obtain the exposure index through quantitative and qualitative assessments of identified impacts relating them to existing and accessible publications and metrics

Metrics	IPCC Projection	Tolerance bands	Index	
Likelihood of an undesirable event occurring [P(XI)] (Boehm, 1991)	↓- **low** reduction confidence	< 10%	0,05	Very (Low relevant)
	↓+ **low** growth confidence	between 11% - 20%	0,10	Low
	↔ **mean** reduction confidence ↔ **mean** growth confidence	between 21% - 50%	0,20	Moderate
	↑- **high** confidence of reduction	between 51% - 80%	0,50	High
	^+ **high** growth confidence	above 81%	0,80	Very high
Impact consequence (by object type) (C(XI)) (Boehm, 1991)		<10%	0,1	Very Low
		between 11 - 30%	0,3	Low
		between 31 - 59%	0,5	Moderate
		between 61 - 89%	0,7	High
		above 90%	0,9	Right to occur
Weight impact generated by the effect identified in the community (collectivism)	Pollution, air quality, preservation and recovery of natural resources, landscape, erc.	Environmental	2	Chronic Stress Factor: Situation to Improve. Plan the intervention.
	Investment, Employment, Service, Value Generation, etc.	Economical	1	Chronic stress factor: Material situation. Plan the intervention.
	Shelter, health, health, education, etc.	Social	3	Chronic stress factor: Situation to be corrected, intervention soon time. Adopt control measures until the situation is eliminated.
	Water and food, Energy, communication, mobility and logistics.	Basic Infrastructure	4	Shock Factor: Critical situation, immediate intervention.
Time period (The Paris Agreement)	Targets for 2030	Short-term	3	2,030
	Targets for 2050	Medium term	2	2,050
	Targets for 2100	Long term	1	2,100
Frequency Days/year	1 d up to 36 d/year	< 10%	0,05	Very Low (Irrelevant)
	37 d up to 73 d/year	between 11% - 20%	0,1	Low (Sporadic Exposure)
	74 d up to 182 d/year	between 21% - 50%	0,2	Medium (Uncommon exposure)
	183 d up to 292 d/year	between 51% and 80%	0,5	High (Frequent exposure)
	293 d up to 365 d/year	above 81%	0,8	Very high (Continuous exposure)

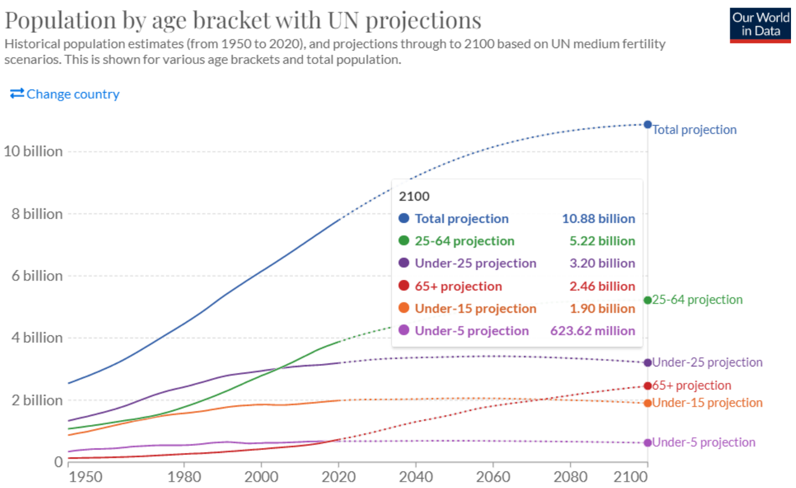
3.1 The relationship between the design process, the effects of global warming and the impacts on the built environment

The design process does not present a single problem solution, but is a process that consists of training the eyes to observe and then analyze. It must be possible to identify not only the intrinsic needs of each project, but also to evaluate its urban-functional (place and surroundings) articulations and compositions, and especially to know how to synthesize them from a broad and integrated multidisciplinary perspective.

Currently the world population is composed of 4.3 billion people living in cities and metropolitan areas and 3.4 billion in rural areas (World Bank based on the UN World Population Perspectives (2020)), with population growth cities have followed this trend by demanding even more urban infrastructure, more natural resources and mainly energy. According to UN projections and taking into account the increased life expectancy and fertility rate per woman, it is expected in the long term, for the year 2100, that the global population will be approximately 10.8 billion people (UN & Our Worldi n Data, 2019). 90% of these people lived in urban centers in less developed regions (IPCC, 2021). All the demands in general will be expanded, which is why there is a need to develop new technologies that are sustainable and with low emission or zero emission. These, and so many other variables, are the components that characterize the exposure to risk and uncertainties that urban areas are embedded in.

> *"In cities, global warming is just one of several issues on the local agenda. Governments are also confronted between current priorities and long-term risks, and this situation is compounded by the uncertainties that may involve the occurrence and severity of climate-related impacts in a city" (ROSENZWEIG et al., 2011b).*

Picture 50 Population by age bracket with UN projections.

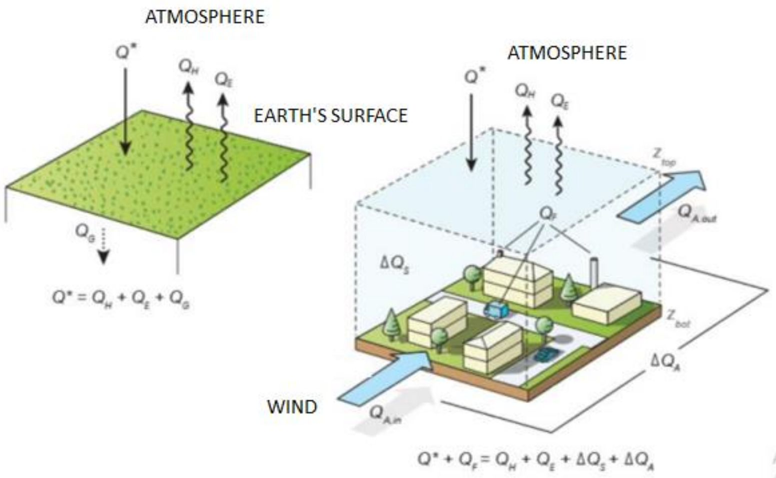


Source: Our World in Data, (2020).

In order to map the existing vulnerabilities in an urban environment, it is necessary to understand the different climatic conditions that make up the environment, for example: meteorological conditions of the open sky, night conditions, energy balance, air temperature, surface temperature, evapotranspiration, urban geometry, among others. Identifying, analyzing and evaluating all these variables together with the meteorological difficulty of characterizing the climate on a real scale makes this task complex, requiring multidisciplinary expertise. One way of quantifying this data is to use models with empirical, physical and mathematical bases capable of simulating these conditions.

In order to study the urban microclimate, it is necessary to know the components that make up its energy balance. Oke's (1978) equation of energy balance in urban areas has been used as the basis for studies of urban microclimate change synthesizing how energy is transferred to the surface of the Earth. According to Oke (1987), the thermal changes related to the energy balance - soil-atmosphere interface - can be of the dry kind that occur through conduction, convection and radiation, or by exchanging humid ones that occur by the evaporation process.

Picture 51Subject: Land energy balance flow



Source: Adapted from Kowalski, L. (2019).

In an area without urban mesh, the liquid radiation (W.m^{-2}) is described by the sum of the sensitive heat [(W.m^{-2}) flux between the surface and the atmosphere], latent heat [(W.m^{-2}) resulting from the evaporation processes and involving phase changes] and soil energy flow (W.m^{-2}) that measures the change in soil[120] temperature. In areas where there is an urban grid the energy balance is expressed in a different way, where the liquid radiation (W.m-2) added to anthropogenic heat (W.m-2) is equal to the sum of sensitive heat (W.m-2) plus latent heat (W.m^{-2}) plus the heat flow stored by the urban grid (W.m-22) and plus the variation of horizontal convective circulation [warning (W.mHeat-22)], simplified by the following equation (Erell et al., 2011):

$$Q^* + QF = QH + QE + \Delta QS + \Delta QA$$

Where: $Q*$: Liquid Radiation (W.m-2)

[120] It depends on factors such as soil cover, soil type, present water content, crop development or not, among others.

QF: Anthropogenic heat (W.m-2)

QH: Sensitive Heat (W.m-2)

QE: Latent heat (W.m-2)

QS: Heat flow storage by urban mesh (W.m-2)

QA: Variation of horizontal convective circulation (advection) (W.m-2).

Anthropogenic heat (QF): is the heat flux originating from combustion processes of fuels and, or, activities of human activities, towards the atmosphere. In a study conducted for Beijing climate conditions, it was shown that the average temperature increased with the increase of the *anthropogenic heat release* (AHR), and more frequent extreme heat events were produced, with an annual increase of 0.02-0.19 days, as well as less frequent extreme cold events, with an annual decrease of 0.26-0.56 days, based on seven extreme temperature indices in the city center (Liu, et al., 2021).

Sensitive Heat (QH) is the amount of heat required for a unit of mass of a substance to change its temperature through dry exchanges without changing its state of aggregation. An example of this kind of situation is a piece of metal that heats up when it is placed close to the fire, but remains in a solid state. The definition of sensitive heat is related to the concept of Thermal Capacity, which corresponds to the amount of heat that the total mass of a body needs to receive or lose for its temperature to vary 1ºC.

Latent Heat (QE) is the amount of heat that, when supplied or removed from a body through humid exchanges, does not alter its temperature, but causes change in its state of aggregation. It tells you how much heat per unit of mass you need to supply or remove from an object to change its aggregation state (solid, liquid, gaseous).

The factors that most influenced the energy balance on a given surface are the elements of roughness, surface albedo[121], thermal[122] diffusivity and emissivity[123]. presents the main values of albedo and surface emissivity (Oke, 1978; Alves & Vecchia, (2012). The structure of the urban environment absorbs and emits a greater amount of energy in relation to rural areas, due to the fact that the typical materials of an urban surface present, on average, lower albedo, lower thermal capacity and greater heat conductivity (LANDSBERG, 1981). In addition, the air masses over the city move more slowly than over the rural area, due to the increased roughness of the soil that alters the speed of the winds which modify their flow, giving them peculiar characteristics (ARAÚJO; SOUZA, 2010).

Table 23: Radiant properties of the surface of some materials

SURFACE	ALBEDO	EMISSIVITY

[121] Albedo: The albedo indicates the ability of materials to reflect solar radiation, is the ratio of the amount of radiation reflected by a body to the amount received by it, usually expressed as a percentage (OKE, 1987; Alves &Vecchia, (2012).

[122] Thermal diffusivity: diffusivity is an important indicator for evaluating the ease of penetration and duration of energy in objects (OKE, 1987; Alves &Vecchia, (2012).

[123] Emissivity: is the material's ability to emit the absorbed radiation (OKE, 1987; Alves &Vecchia, (2012).

Soil	0,05 - 0,40	0,90 - 0,94
Grass	0,16 - 0,26	0,90 - 0,95
Forest	0,13 - 0,23	0,97 - 0,99
Water	0,08 - 0,10	0,85 - 0,95
Concrete	0,10 - 0,35	0,90 - 0,96
Asphalt	0,05 - 0,20	95
Brick	0,20 - 0,40	0,90 - 0,92
Rock	0,20 - 0,40	0,85 - 0,95
Gravel	0,08 - 0,18	0,92
Ceramics	0,10 - 0,35	0,9

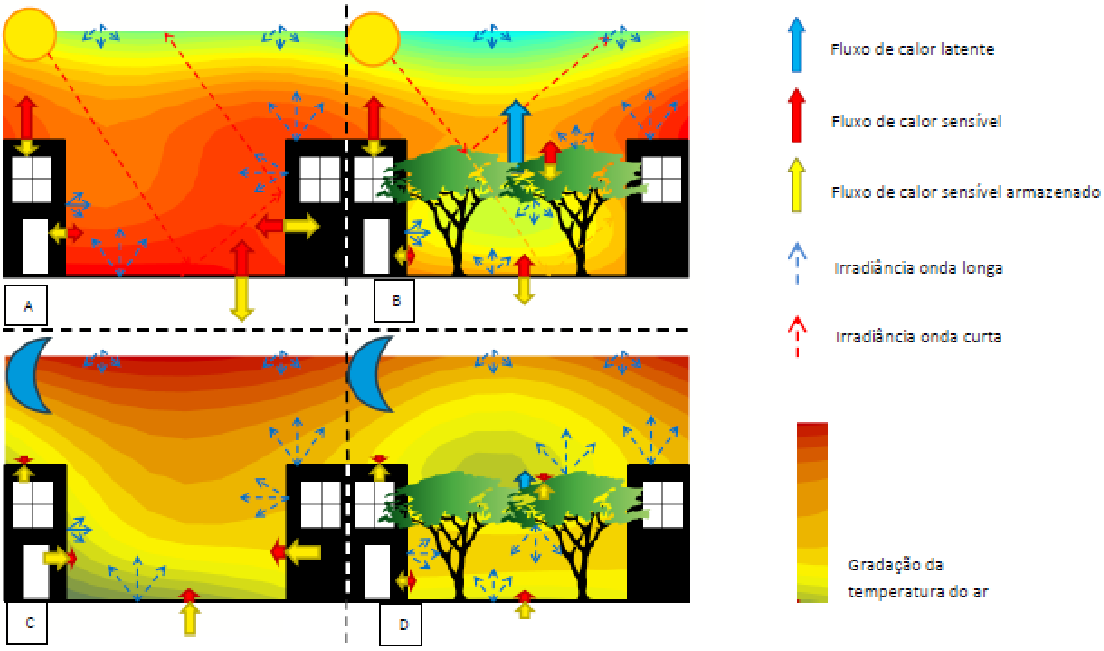
Source : Alves & Vecchia, (2012).

Within the energy band there is also the exchange of humids being an important quantity for measuring the temperature of the air. The intensity of evapotranspiration is directly related to the availability of water in the soil (Erell, Pearlmutter, & Williamson, 2011). For the calculation of the temperature of the air, as the process of evapotranspiration occurs in the upper part of the vegetal[124] canopy, where a good part of the transfer of vapor occurs above the trees, the process has low interference in the air close to the surface. In the area below the canopy there will be an influence of soil evaporation. The vegetation intercepts the long wave radiation (indirect radiation), making the area immediately below the canopy not heat with the same intensity as in areas where there is no such vegetation cover, acting as a natural barrier to direct radiation, that is to say, short wave radiation (2019). In spite of this small decrease in temperature in very dense urban areas, the use of vegetation can provide a significant reduction in the temperature of the surface, which would reduce the emission of radiation from long waves and improve the comfort of the pedestrian at the height (2019). The less heated the surfaces release less long wave radiation, decreasing the heating of the air (QIU et.al., 2013).

A **Picture 52** it gives a schematic example of the effect of evaporanstiration on the urban microclimate. In which during the diurnal period, due to the predominance of short wave radiation from the sun hitting the surface, there is an accumulation of expressive heat. However, during the night period, due to the predominance of long wave radiation emitted by the heated surfaces, the accumulated heat makes the reverse flow back into the atmosphere.

[124] Vegetable canopy: continuous cover, formed by the canopies of the trees that touch each other in a forest, mall, street, among others.

Picture 52Subject: Effect of evapotranspiration on soil evaporation in the urban context (ENVI-met Software).
Radiative and energetic interactions of the urban microclimate by day (A and B) and night (C s D) for a street without vegetation (A and C) and with vegetation (B and D). [Coutts (2015) and Oke et al. (2017)



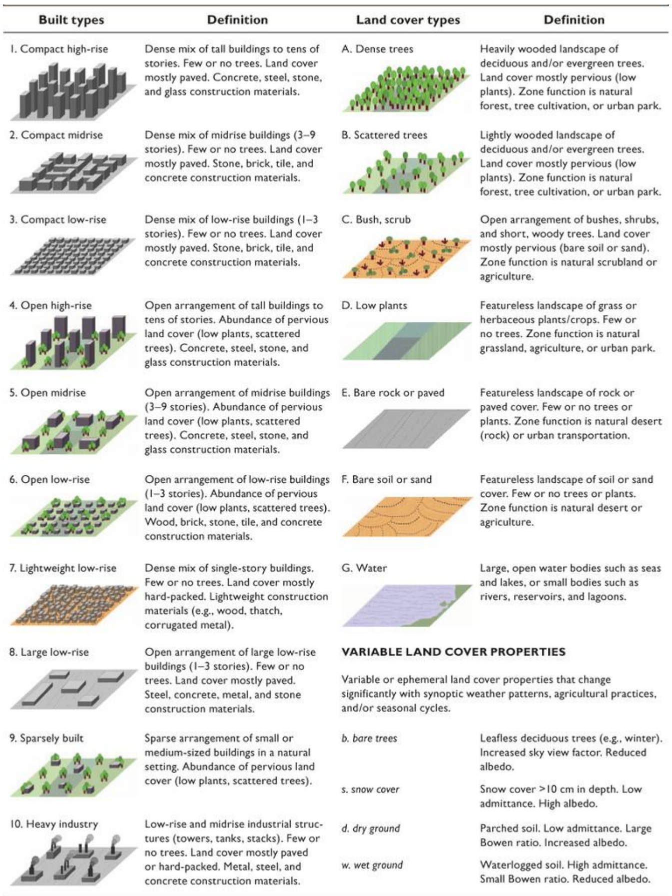
Source: Ferreira, L. S., (2019)

Vegetation plays an important role in the social sphere, reducing atmospheric pollutants (NOWAK, 1994), removing or immobilizing soil contaminants (MORINAGA, 2007), rainwater retention and infiltration (MAGNOLI, 1982), lowering the speed of surface runoff (EPA 2003) and as a support for biodiversity. As well, plays decision within the flow of energy balance, its extension produces effects beyond the area below the canopy. Recent research shows that its influence on the reduction of air temperature is only local in scope (FERREIRA, 2019). However, its effect can be significant for the climate in urban areas when a larger number of small green areas are forecast in the urban grid, or rather large green areas with concentrated dimensions (Stewart & Oke, 2012).

The urban form is affected primarily by the dimensions and spacing of buildings, but also by the characteristics of artificial surfaces and the amount of green spaces (Erell, Pearlmutter, & Williamson, 2011). Due to population growth projects up to 2100, cities will need to adapt to this new reality, in addition to meeting the demand for housing and mobility, urban settlements will need to adapt and develop a way to articulate the mitigation, adaptation and expansion of resilience against the impacts that high density and increased global warming corroborate on the urban microclimate and its environmental quality.

Studying the effect of urban development on the local climate is a widely discussed topic, to try to describe the physical composition of areas described as urban and rural (Oke, Initial Guidance to obtain representative meteorological observations at urban sites, 2004)have developed a classification system called Local Climate Zones (LCZ) to reduce the discrepancy between the urban-rural description. This system consists of seventeen types of covering that characterize the human surface and activity. Being an interesting tool to standardize and facilitate the comparison between locations with diverse structures and their temperature observations, how to understand the dynamics of urban heat islands and the effects of climate change, being a model quite widespread nowadays. Knowing the urban context and identifying the effects of its morphology in conjunction with the climate is fundamental for designing space with higher environmental quality and thermal comfort.

Picture 53Definitions for local climate zones (LCZ)



Built types	Definition	Land cover types	Definition
1. Compact high-rise	Dense mix of tall buildings to tens of stories. Few or no trees. Land cover mostly paved. Concrete, steel, stone, and glass construction materials.	A. Dense trees	Heavily wooded landscape of deciduous and/or evergreen trees. Land cover mostly pervious (low plants). Zone function is natural forest, tree cultivation, or urban park.
2. Compact midrise	Dense mix of midrise buildings (3–9 stories). Few or no trees. Land cover mostly paved. Stone, brick, tile, and concrete construction materials.	B. Scattered trees	Lightly wooded landscape of deciduous and/or evergreen trees. Land cover mostly pervious (low plants). Zone function is natural forest, tree cultivation, or urban park.
3. Compact low-rise	Dense mix of low-rise buildings (1–3 stories). Few or no trees. Land cover mostly paved. Stone, brick, tile, and concrete construction materials.	C. Bush, scrub	Open arrangement of bushes, shrubs, and short, woody trees. Land cover mostly pervious (bare soil or sand). Zone function is natural scrubland or agriculture.
4. Open high-rise	Open arrangement of tall buildings to tens of stories. Abundance of pervious land cover (low plants, scattered trees). Concrete, steel, stone, and glass construction materials.	D. Low plants	Featureless landscape of grass or herbaceous plants/crops. Few or no trees. Zone function is natural grassland, agriculture, or urban park.
5. Open midrise	Open arrangement of midrise buildings (3–9 stories). Abundance of pervious land cover (low plants, scattered trees). Concrete, steel, stone, and glass construction materials.	E. Bare rock or paved	Featureless landscape of rock or paved cover. Few or no trees or plants. Zone function is natural desert (rock) or urban transportation.
6. Open low-rise	Open arrangement of low-rise buildings (1–3 stories). Abundance of pervious land cover (low plants, scattered trees). Wood, brick, stone, tile, and concrete construction materials.	F. Bare soil or sand	Featureless landscape of soil or sand cover. Few or no trees or plants. Zone function is natural desert or agriculture.
7. Lightweight low-rise	Dense mix of single-story buildings. Few or no trees. Land cover mostly hard-packed. Lightweight construction materials (e.g., wood, thatch, corrugated metal).	G. Water	Large, open water bodies such as seas and lakes, or small bodies such as rivers, reservoirs, and lagoons.
8. Large low-rise	Open arrangement of large low-rise buildings (1–3 stories). Few or no trees. Land cover mostly paved. Steel, concrete, metal, and stone construction materials.	**VARIABLE LAND COVER PROPERTIES** Variable or ephemeral land cover properties that change significantly with synoptic weather patterns, agricultural practices, and/or seasonal cycles.	
9. Sparsely built	Sparse arrangement of small or medium-sized buildings in a natural setting. Abundance of pervious land cover (low plants, scattered trees).	*b. bare trees*	Leafless deciduous trees (e.g., winter). Increased sky view factor. Reduced albedo.
		s. snow cover	Snow cover >10 cm in depth. Low admittance. High albedo.
10. Heavy industry	Low-rise and midrise industrial structures (towers, tanks, stacks). Few or no trees. Land cover mostly paved or hard-packed. Metal, steel, and concrete construction materials.	*d. dry ground*	Parched soil. Low admittance. Large Bowen ratio. Increased albedo.
		w. wet ground	Waterlogged soil. High admittance. Small Bowen ratio. Reduced albedo.

Source: Oke, et al. (2004).

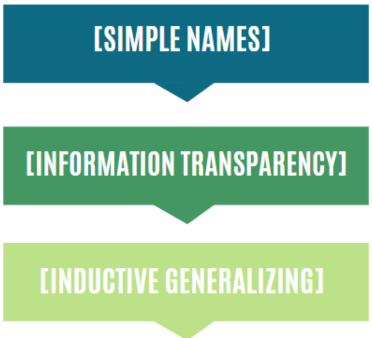
In this scenario, promoting thermal comfort on the scale of the built environment is a multi-degree task that involves variants with environmental and human characteristics. Among the environmental variables we have: Temperature of the air (Temperature of dry bulb); Temperature radiant media (temperature of the globe thermometer); Speed of the air [Anemometer of palettes (external) and anemometer term (internal) - m/s] and Relative Humidity of the air (Rotary psychrometer of dry and humid bulb -%). As the temperature rises the organism increases its elimination by evaporation increasing the humidity of the medium, which in turn, the higher the relative humidity the lower will be the removal of heat in the environment. The air velocity within this context promotes heat exchange through the processes of convection and evaporation, the greater the pain the air velocity, the greater the feeling of heat loss.

With regard to human variables: inherent to metabolism, age, sex, weight, height, race, food habits and thermal resistance offered by the body's clothing (clo) or acclimatization, among others. For an individual to feel in thermal comfort with the environment, it is necessary that the internal temperature of the human organism remains practically constant at 37 degrees Celsius (ranging only between 36.1 degrees Celsius and 37.2 degrees Celsius). The limits for human survival are between body temperatures of 32 degrees Celsius and 42 degrees Celsius (Lamberts, et al., 2016).

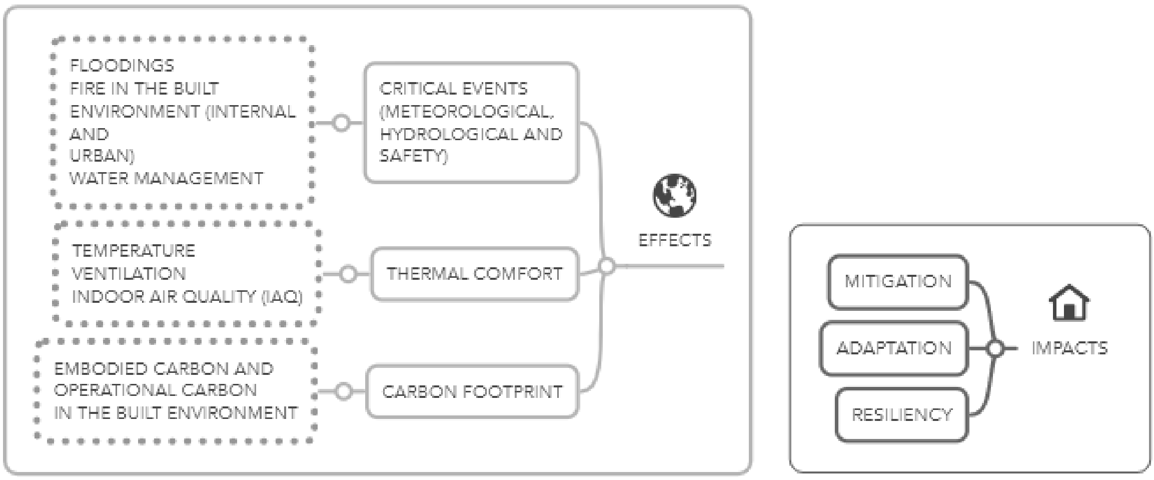
4 RESULTS

Best Practice Directory

To set up the final structure of the good practice repertoire, he appropriated the concepts of logic, method and theory of classification, developed by Grigg (1965). In this article the author refers to criteria that a system must meet. Among them, we have: (1) it must have a simple and logical nomenclature by which objects can be named and described clearly aggregating acceptance; (2) a classification system must facilitate the transfer of information associating real-world objects with an organized system of generic classes, capable of making comparative statements about the members belonging to each classification group; (3) this condition has led the author to establish the criterion of inductive generalization. A properly constructed classification system should simplify the objects/areas under study and subsequently promote theoretical statements about their properties and relationships. The classification created for the good practice repertoire follows the following structure.



Picture 54 Mental map of the classification structure of the good practice repertoire

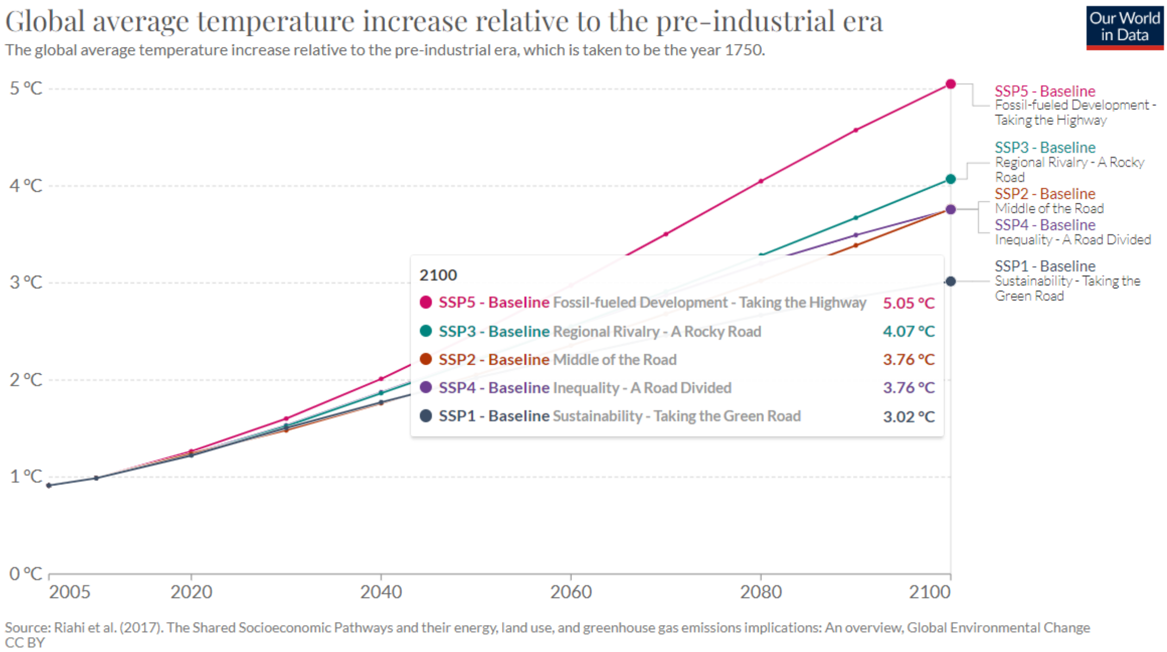


Source: The author, (2022).

4.1 Thermal Comfort

Scenarios are an essential part of climate change research and assessment. They help us understand the long-term consequences of short-term decisions and allow researchers to explore different possible futures in the context of fundamental future uncertainties (Riahi, et al., 2017). The world has already reached an increase of 1.3 degrees Celsius in its global average temperature (Berkeleyh Earth, 2020). Projections of future scenarios according to shared socio-economic cumin (SSPs: *Shared Socioeconomic Pathways*) show an incremental global average temperature path in five different contexts. Using the CMP6 climate model (IPCC, 2021). The projections are based on sustainable baselines, in which mitigation and adaptation strategies provide a low radiative force limiting warming to 3 degrees Celsius. The projections evolve in their radiative forces until they reach high values, which means that the mitigation and adaptation strategies have failed to describe a future still based on fossil fuels, in this critical context, the projection of an increase in the global average temperature is 5 degrees Celsius.

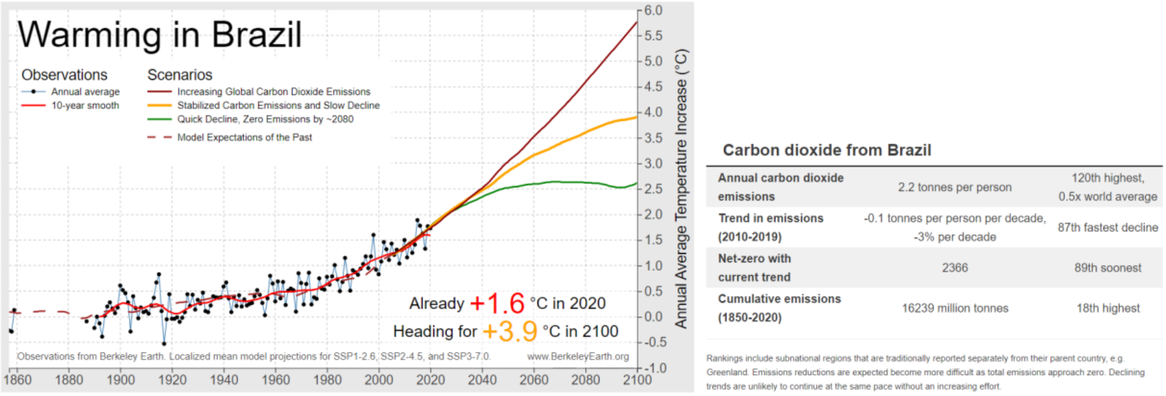
Picture 55: Global Average temperature increase



Source: Our World in Data, (2017).

The average temperature of Brazil in its territory reached in 2020 the mark of 1.6 degrees Celsius when compared with pre-industrial levels, exceeding the limit considered ideal for reducing vulnerability to serious events. The forecast is to reach 2 degrees Celsius considered safe by the Paris agreement in 2027. The following figure presents the projections according to the scenarios SSP1-2.6, SSP2-4.5 and SSP3-7.0, that is, it leaves out the most pessimistic scenario among the SSPs, which corresponds to the SSP5. For 2030, the Brazilian expectation is to reach the mark of 2.2 degrees celsius and 2100 the mark of 3.9 degrees celsius of local average temperature (SSP2-4.5), which can reach up to 5.8 degrees celsius in the scenario SSP3-7.0. However, this scenario may worsen considerably, since the emissions of GHGs of the last decade in Brazil fell only -3%. Following this trend, it is estimated that Brazil only attains climate neutrality (Net-zero) in 2366 (Berkeleyh Earth, 2020).

Picture 56: Warming in Brazil



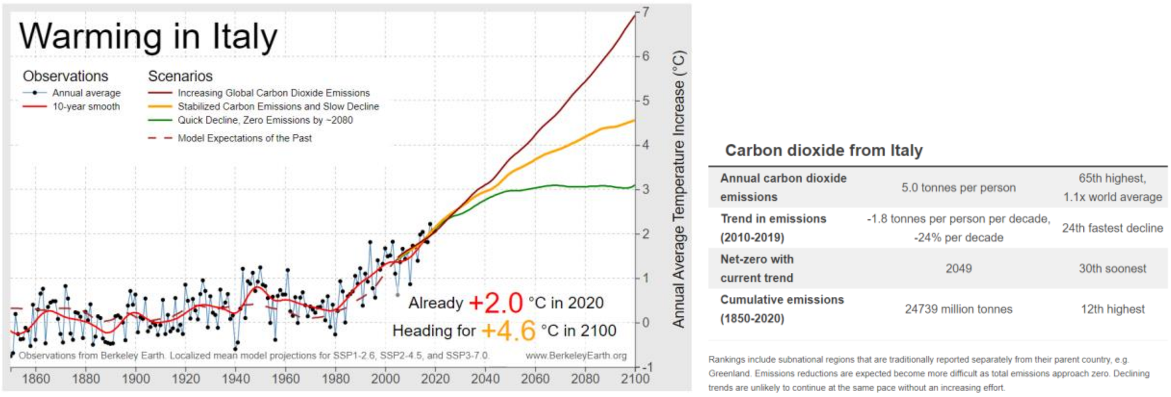
Annual carbon dioxide emissions	2.2 tonnes per person	120th highest, 0.5x world average
Trend in emissions (2010-2019)	-0.1 tonnes per person per decade, -3% per decade	87th fastest decline
Net-zero with current trend	2366	89th soonest
Cumulative emissions (1850-2020)	16239 million tonnes	18th highest

To analyze the climatic context in which the municipality of Natal was inserted used the Climate Consultant software, software that uses annual observed climate data of EPW format that are made available in an open way for local climatic characterization.

ITALY

With Italia the scenario is even worse, since the country has already reached the 2 degrees Celsius mark considered the safe heating threshold according to the Paris agreement (2015) in the year 2020. The following figure presents the projections according to the scenarios SSP1-2.6, SSP2-4.5 and SSP3-7.0, that is, it leaves out the most pessimistic scenario among the SSPs, which corresponds to the scenario SSP5. For 2030, the Italian expectation is to reach the mark of 2.6 degrees Celsius of average temperature, and in the long term, in 2100 the mark of 4.6 degrees Celsius of local average temperature (SSP2-4.5) could reach up to 6.9 degrees Celsius in the scenario SSP3-7.0. The good news is that the GHG emissions of the last decade fell by -24%, following this trend, it is estimated that Italy will reach Net-zero by 2050, as stipulated by the European Union (Berkeleyh Earth, 2020).

Picture 57 Warming in Italy



Annual carbon dioxide emissions	5.0 tonnes per person	65th highest, 1.1x world average
Trend in emissions (2010-2019)	-1.8 tonnes per person per decade, -24% per decade	24th fastest decline
Net-zero with current trend	2049	30th soonest
Cumulative emissions (1850-2020)	24739 million tonnes	12th highest

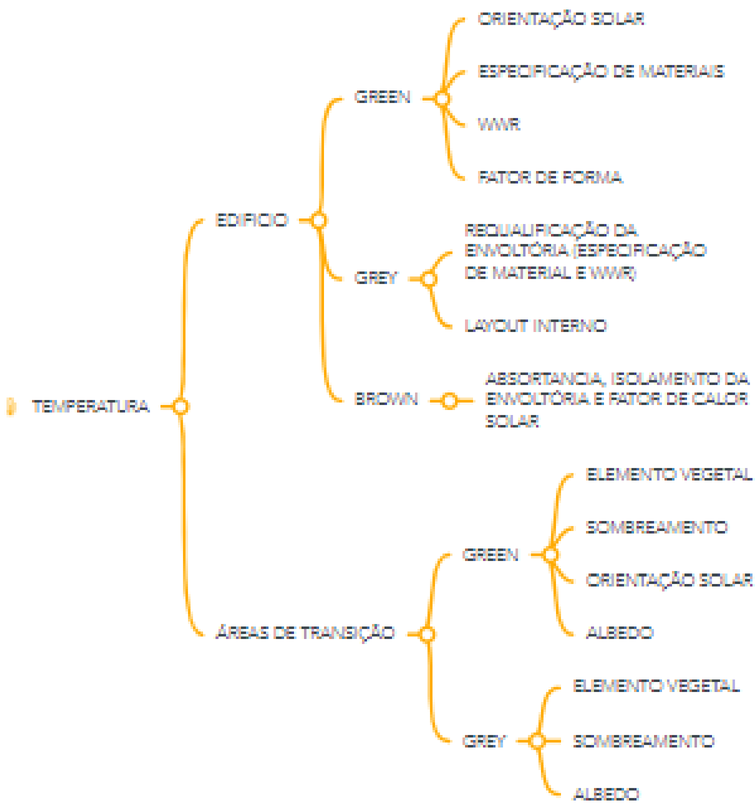
With a current climate scenario, in which we are already at +2°C in comparison to the global average temperature of the pre-industrial period. And that most of the existing real estate has not yet been built, it is necessary that the parameters adopted in the current technical standards and guidelines are updates already consider a projected socio-economic scenario consistent with the current path. In other words, we are today designing a small portion of the buildings that will be in operation in the long term, but these same buildings are not adapted to achieve adequate performance in the future.

4.1.1 Temperature

Due to the difficulty of measuring the temperature of the air (lack of infrastructure), many works use the temperature of the surface as a study variant. The use of Surface temperature is due to the ease of access to remote sensing data (orbital and portable), as well as better correlation between land use typologies and greater scale of coverage. (HU; JIA, 2010; WENG, 2009)

In dense urban areas the land (permeable areas) is scarce, often favoring the specification of waterproof surfaces. With this, wooded areas such as urban parks and plant elements on public tours are increasingly rare, directly impacting urban climate and recurring critical events. Vegetation can be a type of strategy for adapting the urban network in the face of climate change, minimizing temperatures, besides playing the role of being a sink of carbon dioxide. Boon Lay Ong (2003) proposed an architectural metrics called "green plot ratio" (GPR) based on a common biological parameter called "The leaf area index" (LAI), to determine.

Picture 58Subject: Structure of the Mental Map used to categorize good practice repertoire related to thermal comfort



Source: The author, (2021).

THERMAL COMFORT ON THE URBAN SCALE AND THE BUILT ENVIRONMENT

Strategies to mitigate the effects of district heating:

- Decrease heat gain: work well the building envelope with more reflective materials, thermal insulation and shading (wrap geometry and landscaping)
- increase heat loss: increase ventilation of spaces and evapotranspiration (water loss to the atmosphere in the form of vapor-see latent heat and sensitive heat);
- Plan in the urban grid green spaces with smaller proportion, however in larger quantities. As well as, tree streets, avenues, transition areas to create a microclimate.

THERMAL AMPLITUDE IN URBAN SCALE AND BUILT ENVIRONMENT

On the metropolitan scale, the impact of vegetation on the urban surface temperature should not be neglected. The different strategies and technologies for adaptation of the natural and built environment should be analyzed. The plant element in the urban context, with green roofs and walls, as well as the use of water-based technologies, cold roofs and cold floors should be encouraged and prioritized. It also seeks to discuss policies and interventions to promote the mitigation of urban heat and the creation of urban sinks. The role of vegetation both in the attenuation of surface temperatures and in its resilience to extreme situations of high temperatures and low precipitation (Ferreira y Duarte, 2019).

In the more urbanized areas, the surface temperature of the day and night is higher than the less urbanized areas, and the urbanized area is not homogeneous: areas with higher rates of vegetation and/or higher buildings have lower surface temperature than other urban types in the day period and areas with high buildings and low vegetation rates have higher night surface temperature, a characteristic compatible with the surface heat island standard. Areas that had extensive vegetation losses and urban interventions, such as the implementation of paving, showed an increase in surface temperature (Ferreira y Duarte, 2019).

On the scale of the built environment the high thermal amplitude is an indication of the need for specifications of materials with property for vertical and horizontal seals with high thermal inertia, as well as for the materials used in the building envelope. Seeking to know and to know how to differentiate the thermal properties of each material, besides verifying the angle of incidence of solar radiation (solar altitude and azimuth) and analyzing the hararium s of greater insolation through the solar chart.

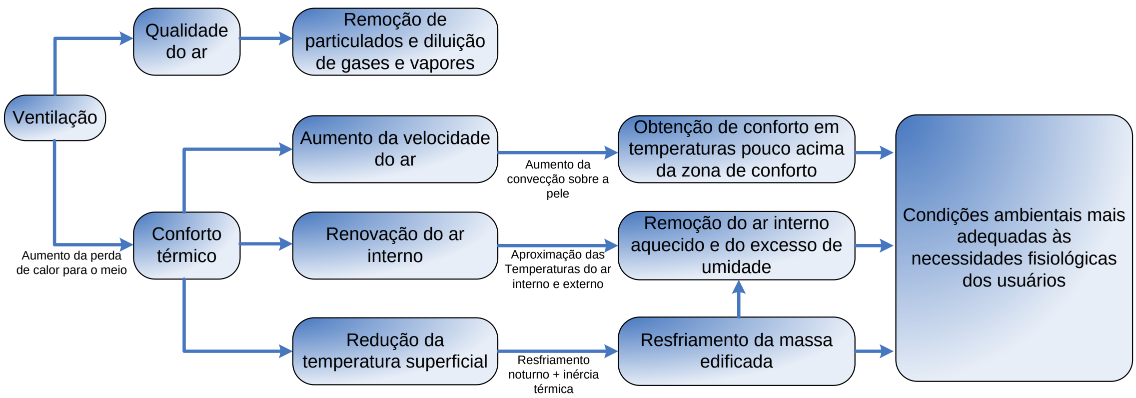
On the local scale, based on the field measurements and the calibration of the model for the local conditions, scenarios were simulated with afforestation on the roads and field brains around an urban park of 1ha, in a central vertical and densely constructed area. Due to the quality of the shade and evapotranspiration provided by the trees, there was a reduction in air temperature of up to 1.7°C and surface temperature of up to 8.5°C, with an increase in air humidity, improving the feeling of pedestrian comfort at about 3°C (Shinzato et al., 2019).

Green walls can have a positive impact on thermal comfort inside buildings, but the result is practically imperceptible in the sense of comfort in the urban environment, even with increments of the leaf area index (Silva y Duarte, 2018). Built density studies, including urban form and materials employed on building facades, show distinct day and night results, compatible with the island pattern of atmospheric heat, quantifying the positive and negative impacts of verticalization, built mass, colors and glazed surfaces on district heating and, consequently, on the thermal comfort of the pedestrian (Gusson y Duarte, 2018).

4.1.2 Ventilation

Natural ventilation is the most recurrent bioclimatic strategy when it comes to the quality of the space built in the hot and humid climate, such as that of Natal/RN, by means of the renovation of the air and increase of comfort (**Erro! Fonte de referência não encontrada.** following**Erro! Fonte de referência não encontrada.**). Air renewal is recommended for all climates, for promoting the hygiene of the built environment and the health of the occupants. Therefore, it should be stimulated in a natural or mechanical way. Natural ventilation has advantages over mechanical systems: the cost of installation is much lower, they do not consume energy and maintenance is minimal. However, when making use of natural ventilation, attention should be paid to the quality of the external air, which, depending on the occupation of the surroundings and the traffic of vehicles, can show high levels of pollutants. In specific cases, caution is recommended when adopting natural ventilation as a single resource for continuous and efficient ventilation (COSTA, 2005).

Picture 59: Flowchart of natural ventilation functions.



Source: CUNHA, 2010.

Small ventilation rates are also sufficient for the dispersion of odors and other domestic pollutants from respiration, cooking and chemicals. The adoption of the renovation rate to prevent the appearance and growth of mold and sufficient to satisfy the other ventilation demands.

Table 24: Ventilation rate for pollutant control

Situation	Ventilation rate (liters air/ second/ person)
Minimize mold growth	7.0
Control of Volatile Organic Compounds	6.5
Body odor control	3.5
Control of nitrous oxides coming from cooking	3.0
Provide oxygen	1.0

Source: Built from EST (2006)

Besides improving environmental quality, the capture of air from the external environment with a temperature lower than the internal environment favors the conditions of comfort in places with a tropical climate, since it cools the occupants and the built up mass. Cooling of the built-up mass is a resource used mainly in arid climate locations characterized by large thermal amplitude, where the cold night wind is allowed between the environments, but the hot day wind is barred. This strategy, coupled with the high thermal inertia of the envelope, favors the formation of a milder internal microclimate in relation to the external one.

In addition to the removal of heat resulting from renovation, the movement of air around the individual influences the feeling of comfort, as it facilitates the loss of heat to the environment by convection and favors the evaporation of sweat. Thus, by allowing constant air flow between environments through cross-ventilation, it is possible to provide users with satisfactory conditions in places where the external temperature is just above the comfort range and below the human body temperature.

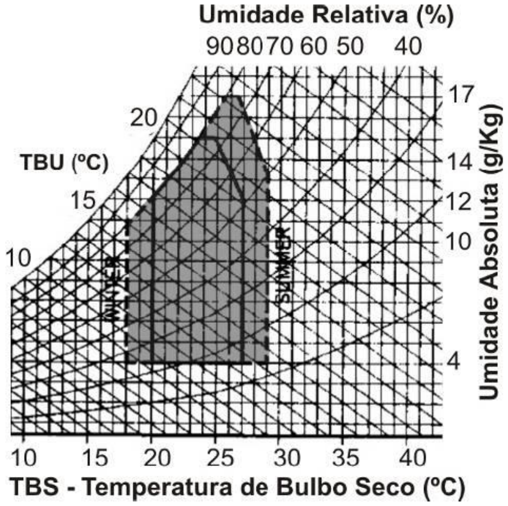
In the indoor environment natural ventilation can be obtained basically in two ways: through the 'chimney effect' or by wind pressure. The chimney effect corresponds to the flow of air generated by the vertical gradient of temperature. This strategy is useful for maintaining air quality in countries with a cold climate and/or in a low-occupancy and low-permanence environment. Natural ventilation caused by wind effect occurs when there are differences in air pressure in the vents. Cross-ventilation occurs when there are openings in separate walls and preferably on opposite faces and the intensity of the airflow is proportional to the difference in pressure and the size of the openings.

VENTILATION AND THERMAL COMFORT

Attempts to model the effects of environmental variables on user satisfaction, in the way we know it today, go back to the middle of the 20th century. Olgyay (1963) and Givoni (1969) developed comfort zones graphically depicted on a bioclimatic chart. In both cases, the amplitude was influenced by ventilation, typically expanding the upper limit of the comfort temperature. The comfort zone developed by Givoni was differentiated for developed and developing countries that considers individuals from developing countries adapted to a greater thermal amplitude (line dashed in the **Erro! Fonte de referência não encontrada.**).

However, it is worth remembering that the study was developed from research carried out in Israel, the United States and Europe, considering the temperature expectations in buildings without air conditioning. Therefore, considering the climate of the countries analyzed and the constraints imposed by the methodology adopted, it is necessary to observe the results obtained with caution to avoid drawing hasty conclusions.

Picture 60: Representation of the comfort zone developed by Givoni.



Source: Elaborated from Givoni (1969).

The comfort indices have been constantly revised and adapted with the objetive of remedying the limitations found in the traditional models, which can be classified into two groups: those that are based on the thermal balance and the adaptive models.

In short, thermal balance consists of adopting the human body as an element that exchanges heat with the surrounding environment and the feeling of comfort is the result of these exchanges. The most widespread index of thermal balance is the PMV/PPD[125], proposed by Fanger in 1972. Its qualities made it the reference model for the International Standard ISO 7730 a for ASHRAE Standard 55-2004. However, its applicability in naturally ventilated buildings in hot weather has been increasingly questioned in several works because it places little emphasis on user adaptation.

Adaptive models are based on field experiences and relate the thermal sensation to the average monthly temperatures, considering the adaptability of individuals. Adaptability considers the physiological aspects, which make the organism more tolerant to high temperatures in summer and to lower temperatures in winter.

Alongside the development of comfort rates, there are studies that are dedicated to quantifying the benefit of ventilation over the level of satisfaction of individuals. Second NICOL (2004) the upper limit of the comfort zone may be raised in the event of air circulation, as ventilation increases the tolerance of individuals to high temperatures. According to this author, it is possible to increase the upper limit of the comfort zone with 1 m/s ventilation by more than 3 °C.

VENTILATION AND ARCHITECTURAL DESIGN

The project process is being explored by researchers and designers who defend different positions as to the sequence of actions that describe the development of the project. Practice

[125] "Predicted Mean Vote - PMV" and "Predicted Percentage of Dissatisfied - PPD" is a method of quantifying both the thermal performance of environments and the percentage of dissatisfied users. PMV ranges from -3 (cold) to +3 (heat), with zero being the condition of neutrality.

shows that each professional develops his own way of designing, making the process personal and difficult to systematize. However, it is possible to describe the process in broad outline as a linear sequence of steps, composed of successive tasks and decisions to be made. The characterization of the phases makes it possible to suggest approaches compatible with decision-making (PEDRINI;SZOKOLAY, 2005). In bioclimatic architecture, the thermal performance of the building, and by extension the effectiveness of natural ventilation, is the result of architectural decisions taken still in the sketch phase.

The hot and humid climate, such as that of Natal/RN, presents particularities to be considered in the project process that aims at the comfort of the users. High air humidity makes it difficult for sweat to evaporate, which reduces its action on the body's cooling. On the other hand, the low latitude favors thermal gain by the enclosure, mainly by the covering, which can result in a considerable thermal charge by radiation. Shading significantly reduces thermal gains, while ventilation cools the built-up mass and the human body. The sum of these two strategies is capable of providing comfort for most of the year, and for this reason, they are pointed out as the most suitable project recommendations for the hot and humid climate.

The analysis of the climate data reveals that the climate of Natal/RN is characterized by a large percentage of hours of heat discomfort. The fraction corresponding to hours of cold discomfort is inexpressive and only a small percentage points to the climate as comfortable. Therefore, it is possible to provide thermally comfortable environments without the need for thermo-accumulation strategies. The constant renewal of the air, brought about by natural ventilation, makes it possible to approximate the external and internal temperatures, removing the mass of heated air from the environments and promoting cutaneous cooling through the movement of the air, provided that excessive thermal gains are avoided (BONNEAUD, et al., 2001; OLIVEIRA, 2006).

Therefore, in addition to the correct orientation of the openings and the proper dimensioning of the frames, the use of architectural elements of composition of the envelope should be stimulated, which are capable of increasing the thermal performance of the building. These elements shall be designed to act as a filter for weather conditions, barring or at least minimizing unwanted weather such as high temperatures, direct solar radiation and high intensity wind gusts. The Netherlands (1976) he already brought in his script the need for free layout, leaked walls, cross ventilation and ventilated sill. These strategies are easily incorporated into the project without the need for standardization of solutions.

It is of paramount importance to consider that the design process tends to underestimate the potential of natural ventilation, disregarding the benefits that passive cooling can bring to the living space. The construction and shape of the building alter the local wind pattern by creating different pressure zones around the building. The specificities of air flow and climatic variables make it difficult to predict natural ventilation with a low degree of uncertainty, even in small-scale projects (CHEN, 2004). Ventilation, when contemplated in the elaboration of the project, is usually represented by vectors that suggest the path of the wind in the interior and in the surroundings of the building. This prediction follows the designer's intuition and has a reduced degree of reliability, since the correct estimate of the airflow requires in-depth knowledge about the physical phenomenon.

Despite the complexity, the use of natural ventilation in projects developed for the hot and humid climate becomes indispensable in view of the benefits obtained. Using well-founded recommendations to enhance the efficiency of natural ventilation during the design process, aided by appropriate tools, significantly increases the likelihood of making the right decisions

There are simple and accessible recommendations from the drafting stage that should be used in the absence of a tool or more elaborate methods. It was found that the algebraic methods make it possible to estimate, with reasonable precision, the rate of renewal and the speed of the internal air from the climatic data and the dimensions of the environments and the openings. The development of an electronic spreadsheet makes it easier to compare multiple options for the orientation and size of the openings, providing quantitative arguments for the decisions taken. However, a prediction, still at the design stage, with a lower degree of uncertainty can only be obtained by means of computer simulation of fluids (CFD), which involves a high level of complexity and theoretical knowledge that is not compatible with the project practice and the training of the architect.

4.2 Energy consumption in the built environment

In order to mitigate the effects of climate change, European energy policy has given great attention to the energy efficiency of buildings due to their potential.

4.2.1 Operational Energy Efficiency of the Building

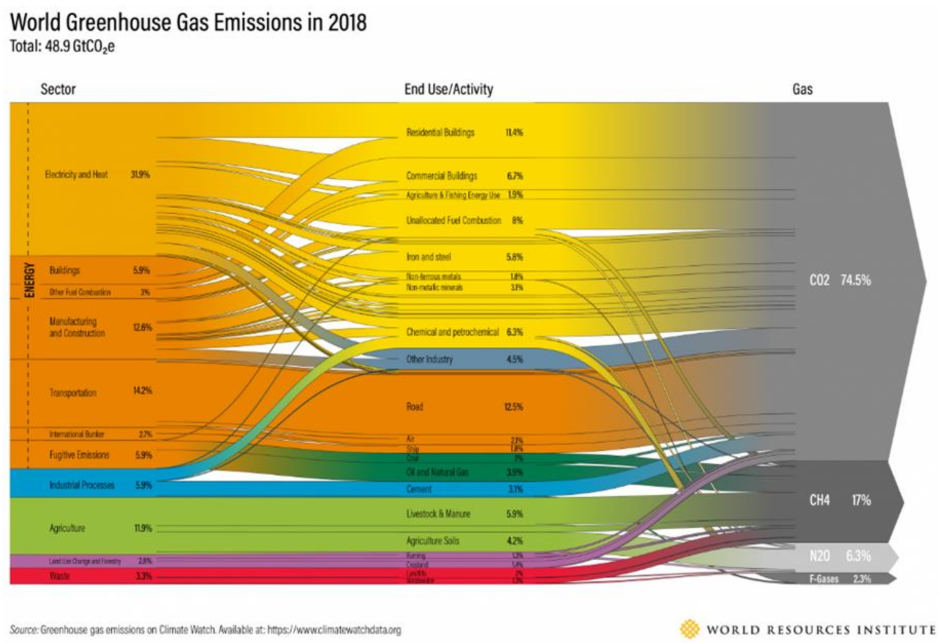
The lack of an architectural design focusing on the thermal and energy efficiency of the building envelope causes the energy consumption of the building to be high, both to promote its cooling and its heating. The orientation of the openings in the facades as well as the specification of materials and coatings with low thermal absorbance and high reflectance should be prioritized. In addition, we must prioritize the specification of construction systems that make possible a thermal insulation of the whole envelope. The proposed pact foresees the need to create new financing policies and investments in the sector to make possible the renovation of the building stock, through urban regeneration projects, *retrofit* and renovation of public and private buildings.

Sustainable architecture according to Corbella and Yannas (2003) can be described as:

> *"Sustainable architecture is the most natural continuity of bioclimatic, also considering the integration of the building to the whole environment, in order to make it part of a larger set. It is the architecture that wants to create buildings aiming to increase the quality of life of the human being in the built environment and its surroundings, integrating the characteristics of local life and climate, consuming the least amount of energy compatible with environmental comfort, to bequeath a less polluted world for the next generations"* (Corbella & Yannas, 2003, p. 17).

Therefore, as mentioned by the authors, sustainable architecture is directly related to the social, economic and mainly environmental context. The study of bioclimatology when applied in the methodology of architectural design produces knowledge and climatic guidelines of the place where the building will be or is inserted, which can contribute to indoor thermal comfort and mitigate the impacts of the building in the urban mesh. Therefore, the designer must take advantage of this prior knowledge acquired to direct decision-making for the purpose of mitigating, adapting and expanding resilience in the built and territorial environment (Rochink, 2017, p. 38).

According to the Climate Watch Data website of the World Resources Institute (WRI), the energy sector is the one that produces the most greenhouse gas emissions, accounting for 76% (48.9 GtCO2) of global emissions in 2018. The heat and electricity generation sector accounts for 31.9% (15.6 GtCO2) of this total. Within this sector residential buildings account for 11.4% of the total (per end-use activity), commercial buildings account for 6.7% of the total and the construction sector for 0.5% of the total (per end-use activity).



According to Lamberts, Dutra and Perreira (2014), energy efficiency in architecture can be understood as follows:

> *"Energy efficiency in architecture can be understood as an inherent attribute of building representing its potential to provide thermal, visual and acoustic comfort to energy-efficient users* (Lamberts, Dutra, & Perreira, 2014, p. 15)*"*

The design decisions directly affect the performance of the building, both in terms of the construction process, as well as its useful life and operation. In order for the final product to have good thermal, energy, acoustic, luminous and low carbon footprint performance, it is necessary to have a deep multidisciplinary background knowledge that must be applied in all the project phases and with a focus on the entire building life cycle. The energy consumption of the building is closely related to the projectionist's design decisions already in the early stages of the shape and volumetric studies. Understand the context in which the building is inserted and promote the best thermal performance through passive strategies of ventilation, form, opening, shading or not, privilege natural lighting through direct and indirect openings, evaporative cooling, among so many other strategies that collaborate directly in the promotion of thermal, luminic and acoustic comfort of the user.

Efficiency, as well as the promotion of thermal and acoustic comfort depend on another important variant, tightness. It is obtained by deep knowledge of the tectonics of materials employed in construction, which are responsible for reducing or not reducing operational consumption throughout the building's life cycle. Designing and building truly sustainable buildings taking into account the three main aspects: the environmental, the economic and the social, and yet, low-carbon footprint is an emerging and little exploited need to face climate change and combat the waste of natural resources such as water and energy.

Some countries have already established a national plan to promote the low carbon transition, such as the United Kingdom, which in 2009 published "*The UK low carbon transition plan: national strategy for climate and energy*" which requires an 80% reduction in GHG emissions by 2050, housing being one of the ways to reduce these emissions. According to the study on the different types of variables that explain annualized electricity consumption in residential buildings in the UK, developed by researchers (Huebner, Shipworth, Hamilton, Chalabi, & Oreszczyn (2015)showed that among the predictor categories which have the greatest impact on energy consumption in residential buildings. The research concluded that the building compactness factor has a direct impact on its energy consumption, it was observed that the size of the housing units were oversized for the family composition that resided in the place, favoring the under-occupation of rooms. This contributes to the increase in energy consumption of lighting, cooling and heating systems.

The compactness of the project is strongly related to the economy in both horizontal and vertical planes (external perimeter), elements that represent the highest costs of the building. Being a good strategy to mitigate the waste of natural resources and feed the efficiency of the envelope, from the thermo-energy point of view. It is estimated that the total cost of a work is decomposed between: horizontal plans that correspond around 25% of the total value, vertical plans that are equivalent to 45%, costs with installations in general that correspond to 25% and construction site and other works that consume around 5% of the budget of the work (MASCARÓ, 2010). Vertical planes have a higher cost due to the composition of the materials and construction systems specified for their construction, increasing the cost of the square meter of the wall. As well as the internal dimensioning of the environments, which can be a determining fatora, since the greater the quantity of partitions the greater the square meter constructed. The choice of the shape of the compartments and the volume of the building also has a quantitative influence on its index of compactness and on the square meter constructed (MASCARÓ, 2010).

The compactness index of a project, defined by Rosso (1978), is expressed by the relationship between the perimeter of a circle of equal area of the project, and the perimeter of the external walls of the project. The closer to the maximum value of the index, which is achieved with the geometry of a circle (IC = a 100), the lower the construction costs would be. The compactness index is expressed by the following equation (ROSSO, 1978):

$$IC = \frac{2\sqrt{Ap.\pi}}{Pp} x100$$

Where,

CI = compactness index;

Ap = project area;

Pp = perimeter of the exterior walls of the project.

In this case, for existing buildings, one way of promoting the adaptation of these housing units is through the process of improving the watertight environment. As well, to know the physical and thermal properties of the materials used in the facades so that substitutions or additions of materials with thermal capacity and their energy performance can be made by choosing more assertive with regard to the materials used in the facades. Among the main items that should be noted are:

- Prioritize natural lighting over artificial lighting, which in addition to the benefit of energy saving, is the benefit of physical and psychological well-being obtained through communication between indoor and outdoor environments, the quality of natural light and its impact on the cardiac cycle and the quality of sleep;

Besides working the form of the building in relation to its with compactness, it is the role of the designer since the preliminary studies of the design process to develop an integrated design approach, adopting technical and volumetric solutions capable of promoting the thermal comfort of the building and the greater energy efficiency.

4.2.2 Building Autonomy

The recent EU Guidelines 2010/31 and 2012/27 provide near-zero energy building standards for new buildings, aiming at a better quality of the built environment through the adoption of high performance solutions. In the future, cities are expected to be the main driver of development, supporting the impact of population growth and increasing demand for energy. To expand urban and built-environment resilience, it is closely correlated with the energy efficiency of systems. To improve the ability to adapt to changing dynamics, buildings and districts have to increase their resilience, assumed as "the ability to adapt to changing conditions and to maintain or recover functionality and vitality in the face of stress or disturbances" (Wilson A., Building Resilience in Boston, Boston Society of Architects, 2013).

The European Ecological Pact proposes that Europe achieve climate neutrality by 2050, but this economic transformation will require joint commitments. To this end, the document provides guidance to assist Stakeholders in this transition. Among them: the European Climate Law (2021); reduce net emissions by at least 55% by 2030; create financial mechanisms such as the New European Bauhaus: new shares and financing, to subsidize this transition.

Another major challenge is to get the engagement of most countries that have not yet submitted the renewal of their Nationally Determined Contributions (NDC) required to meet the targets set out in the Paris Agreement. Particularly for buildings, which are a key sector that needs specific mitigation policies despite a high contribution to global CO2 emissions. Of those who have submitted NDCs, 136 countries mention buildings, 53 countries mention the energy efficiency of buildings, and only 38 refer specifically to the energy codes of buildings.

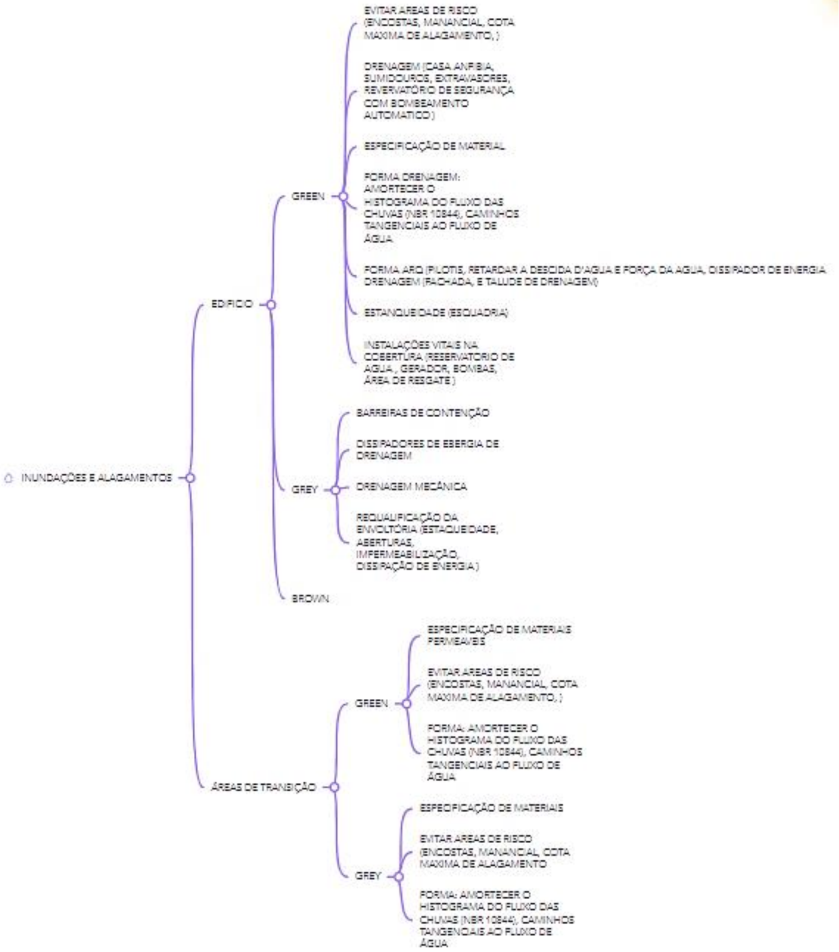
A promising market and integration between buildings with variable renewable systems and technologies, this integration is able to promote the flexibility of operational standards in response to the needs of the electricity grid. Researchers have identified two particularly promising ways to reduce emissions. The first involves energy-saving renovations and upgrades to walls, windows, roofs and insulation that make up the building's wrap. The second focuses on intelligent software that is capable of optimizing energy consumption based on artificial intelligence, in heating, cooling, lighting and ventilation systems of the building.

Another point that should be on the agenda of governance and the lack of supply of energy due to the increase in demand, since the trend of demand is to increase and the population is concentrated in the urban centers, and certain that the unavailability of water resources is a real threat, for consumption and principally to supply the reservoirs for the generation of energy. That is why it is necessary to plan the energy security of urban centers. In case of rationing or total power shortage, most of the systems that make up a city are unavailable. And without energy, it ends up causing chain problems in the systems of mobility, public safety, communication, treatment of effluents, medical attention, among others.

4.3 Critical events in buildings: hydrological, weather and safety

4.3.1 Floods

Picture 61: Structure of the Mental Map used to categorize good practice repertoire related to floods



Source: The Author, 2021.

Floods and floods will occur with greater frequency and intensity, to mitigate this impact it is necessary to work out all the urban morphology to have resilience to it. It is necessary for the government to draw up a risk map identifying the most vulnerable areas. Monitor and implement occupation-free area, referred to in Brazil as occupation rate and permeability index, so that these effects are minimized.

In transition areas, the specification of permeable materials should be prioritized, avoiding areas of risk such as: hillsides, springs and the maximum flood quotas of a given region. Another viable strategy for dampening the rainfall flow histogram (ABNT NBR 10.844) is to create architectural elements that collaborate with this effect, making them beacons and guiding the water flows to tangential paths.

On the scale of the built environment, the protection barriers can be designed on the scale of the built environment itself, i.e. on the scale of the built building, with the aim of protecting buildings from flooding in the midst of natural disasters (storms, gale, rapidly melting snow, etc.).

It is the role of the architect to propose resilience solutions for buildings, which may be temporary or permanent in nature.

Here it is also possible to avoid areas of risks, to design drainage compatible with the size of the enterprise, to use sinks, extravasators, safety reservoirs with automatic pumping in case of intense meteorological events. Making it possible to store this rainwater for a certain time during the disaster (Amphibious House). It is also of paramount importance to ensure the tightness of the sealing systems that make up the building, such as window frames, vertical and horizontal seals.

The morphology of the building can also be an impacting element to slow the descent of water down the facades. Creating elements that function as small barriers in the building envelope can reduce the force of falling water. It also recommends renting vital building facilities that impact directly on its operation, such as generators, water reservoir, engine room, among others, in sheltered areas and preferably on the roof of the building.

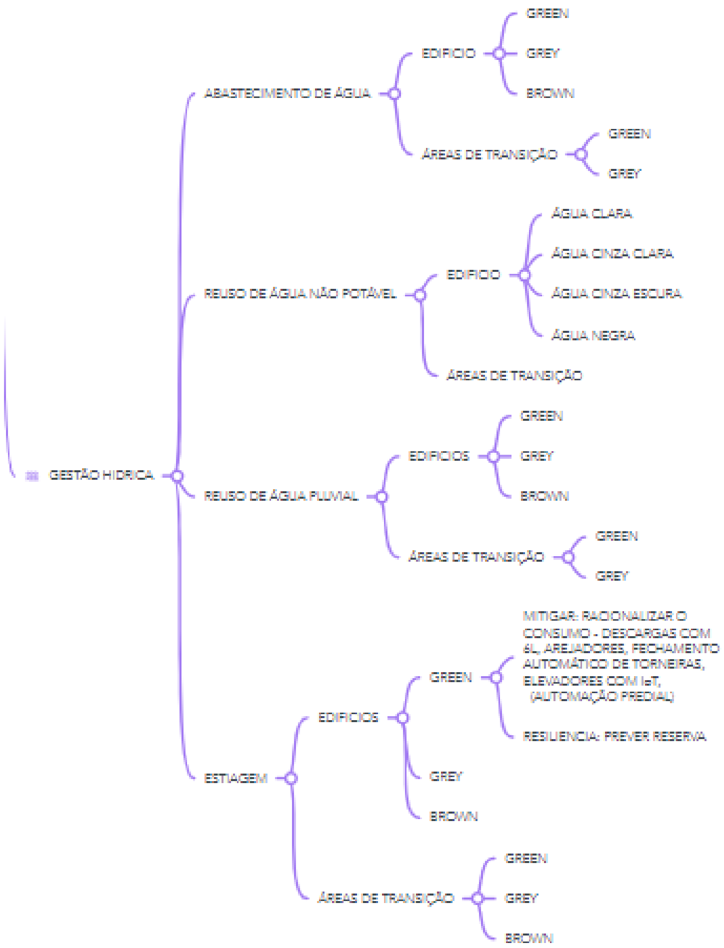
Also in the occurrence of strong storms, the poorly packaged and inadequately destined waste is spread out and carried to the drainage systems, contributing to the obstruction of the galleries and canals and generating more flooding. This is a national problem, since only 58.5% of the total volume of waste collected in the country is properly disposed of in landfills (IPCC, 2017, p.13).

4.3.2 Water management in buildings

Changes in rainfall regimes may influence the quantity and quality of water resources available for the supply of cities, since these are responsible for the consumption of 22% of the total water flow captured in Brazil. It is the highest demand after irrigation, equivalent to 55% of the total captured." (IPCC, 2017, P. 12)

Water use efficiency is based on the application of: river basin recovery; water storage and conservation techniques; water reuse; desalination; rainwater use and non-drinking water reuse. As well as reassessing and modifying the surface and underground sources of water abstraction and transfer. And it increases storage systems, and the infrastructure of the facility.

Picture 62: Structure of the Mental Map used to categorize good practice repertoire related to water management



Source: The author, (2021).

The rational use of water is a strategy to promote resilience to urban space and the built environment. Besides it, one can cite the use of rainwater, the reuse of non-drinking waters, which are clear waters, light gray waters, dark gray waters and black water; besides prioritizing the installation of components that save water.

4.3.2.1 Reuse of non-potable water

Seeking to optimize the use of available water resources, disregarding the demand for drinking water in urban centers, mainly in centers with high density or with scarce water resources. Among the practices currently adopted to promote the conservation, harnessing and reuse of water are a fundamental attempt of action to mitigate the scarcity of this resource. Current technologies related to this theme have proved to be efficient in saving drinking water, improving the water management of supply and demand of a city.

First, the Hydral Balance and the study of technical economic viability, according to ABNT NBR 16782 (2019)[126] this study is important to support the decision-making on the feasibility of the

[126] ABNT NBR 16782: 2019 - Water conservation in buildings - Requirements, procedures and guidelines.

os system deployment. According to ABNT NBR 16782 (2019) The water balance of a building is drawn up from the characterization of the systems of water consumption (demand) and of the generation of effluents (supply) of the various consumer activities.

"Building systems for the collection of effluents from light[127] water systems, light[128] gray, dark[129], black[130] and sewage[131] should comply with ABNT NBR 8160", according to ABNT NBR 16783 (2019). THE ABNT NBR 8160 (1997) is a Brazilian standard that establishes design and implementation guidelines for sewage building systems - Design and installation.

Still according to NBR 16783 (2019), a set of general requirements, design and quality parameters for non-drinking water, which must be met and achieved in order to be able to deploy a reuse system. The building system of non-potable water shall be independent of the building system of potable water. With architectural designs and complemetarers of the treatment system of these effluents and the building hydraulic system of non-potable and potable water satisfying the specific legislation.

Table 25: Quality parameters for non-potable water use.

Parameters	Limits
pH	6.0 to 9.0
Escherichia coli (Bacterium)	≤ 200 MPN/100 ml * Result of most probable number (MPN) analysis
Turbidity	≤ 5 UT * Turbidity Unit
DBO_5 * Oxygen Biochemical Demand (DBO)	≤ 20 mg O2/L * milligrams of O_2 per liter.
CRL *Free residual chlorine (CRL)	05 mg/L minimum - 5,0 mg/L maximum Recommended: 0.5 mg/L - Not more than 2.0 mg/L
Total dissolved solids (SDT) or electrical conductivity[132]	≤ 2000 mg/L or *milligrams per liter. ≤ 3200 µS/cm *microsiemens per centimeter
Total organic carbon (TOC)[133]	< 4 mg/L *milligrams per liter.

Source: (ABNT, 2019, p. 6)

After proper storage and treatment of effluents in accordance with the requirements of the standard, non-drinking water from buildings may be used for the following domestic activities and purposes, which are:

- Discharge of toilets and urinals, independent of the drive system;
- washing of patios, patios, garages and outdoor areas;
- vehicle washing;

[127] Clear water: effluent generated from cooling systems, vapor and condensate system, distillation system and other equipment.
[128] Light gray water: water served from showers, baths, wash basins, tanks and washing machines.
[129] Dark gray water: served water from a kitchen sink and dishwasher considered in isolation or added to light gray water.
[130] Black water: Water from the toilet and urinal.
[131] Sewage: all water served from the building's hydro-sanitary appliances.
[132] Conductivity values are correlated with total dissolved solids. Another option is to perform the analysis of the total dissolved solids.
[133] Only for water of lowering of water table.

- landscape[134] irrigation;
- Ornamental use (fountains, fountains and lakes);
- Water cooling systems;
- Roof cooling;

Preparation of the manual for use, operation and maintenance according to ABNT NBR 14037. With relevant information about the system and its components, ranging from the description of the models and components of the equipment, materials and accessories, to the procedures for starting, shutting down and guidelines for the operation of the system in emergency and safety situations, besides the characterized maintenance routines necessary to guarantee a good performance of the installation.

4.3.2.2 Prolonged droughts

The impacts of climate change are being investigated, and the most vulnerable are water crises. Since 1970, climate and water risks have been responsible for 50% of all disasters and 45% of all reported deaths. The report of the United Nations Convention to Combat Drought warns of worrying trends relating to the duration and intensity of droughts in recent decades, devastating biodiversity.

The whole sequence of the occurrence of drought originate from maladjustments or from the meteorological deficiency, but when they occur they generate even greater impacts that originate from these deficiencies. The environmental crises resulting from prolonged droughts turn fertile soils into powder and produce devastating impacts on agriculture, increasing food and nutritional insecurity.

EARTH DEGRADATION AND DESERTIFICATION

Deterioration is caused by delays in the loss of the physical, chemical and biological properties of the soil, which in the long term causes the loss of vegetation and is further intensified by the process of soil erosion caused by wind or water (UNCCD, 1994). But also as a result of man-induced actions that exploit the land, causing its utility, biodiversity, soil fertility and general health to diminish. And when this process of deterioration intensifies, the process of desertification of the soil begins

Desertification means land degradation in arid, semi-arid and sub-humid dry areas resulting from various factors, including climatic variations and human activities" (UNCCD, 1994); combating desertification includes activities that are part of their integrated development and sustainable: (a) preventing and/or reducing land degradation; (b) rehabilitation of partially degraded land; (c) recovery of desertified land; (UNCCD, 1994)

[134] Landscape irrigation: is the practice of irrigation with non-drinking water, parks, gardens, sports and leisure fields, or green areas of any kind, not being included for agricultural and/or forestry purposes (ABNT, 2019, p. 4).

To combat this problem the United Nations has drawn up a plan to counteract land degradation through the principles of Land degradation restructuring (LDN)[135]. The Program sets Earth Degradation Neutrality (LDN TSP) targets to help countries make the LDN concept a reality by 2030.

These goals are organized into four building blocks of the LDN's Goal-Setting Program:

Building Block 1 - Leveraging LDN: Facilitating engagement of decision makers and stakeholders involved in land management and the LDN's goal setting process. The definition of LDN goals is not an autonomous process - it offers opportunities for coordination between ministries and sectors involved in land management. Taking advantage of the LDN puts it at the forefront of national agendas and establishes the necessary institutional and technical environments, facilitating the engagement of stakeholders. The main output is the national LDN goal-setting leverage plan, which identifies opportunities and synergies at the country level with national, regional and global LDN-related processes.

Building Block 2 - LDN Assessment: Strengthening countries' capacities to make informed decisions about what actions to take, assessing the current state of the land and the drivers of land degradation and tracking progress using the best available data.

Evaluating the LDN establishes its baseline scenario in line with the ODS process, including drivers and land degradation trends. The baseline assesses the current status and condition of the natural capital and terrestrial ecosystem services. In September 2017, COP13 Decisions 2 and 3 invited countries to develop baselines for land degradation and identify time-bound quantifiable voluntary targets linked to national SDG agendas.

The LDN monitoring and reporting system, anchored in COP11 decision 22, identifies three subtran indicators of land degradation:

The documents ‘ODS Good Practice Guidance Indicator 15.3.1’ and ‘LDN Methodological Note’ describe the LDN methodology for assessing land degradation. They were updated with the guidance document for the 2018 UNCCD reports.

Tends in the covering of the earth

Trends in land productivity, and

Trends in above and below ground carbon stocks

Building Block 3 - Definition of LDN targets and associated measures: Support countries to define the ambitions of countries to combat land degradation by defining LDN targets and measures. The LDN's goals set a country's ambitions in terms of combating land degradation, and the LDN's measures comprise a series of interventions to prevent, reduce or reverse land degradation.

Building Block 4: Reaching LDN: Reaching the LDN involves identifying opportunities for transformative projects and programs (TPPs) and promoting the integration of the LDN into

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[135] Land degradation neutrality | Knowledge Hub (unccd.int)

national development plans. Deliveries involve integrating the LDN into selected national policies and commitments and identifying funding opportunities to support the implementation of the TPP LDN. These building blocks take into account lessons learned from the LDN's 2014-15 Target Definition Pilot Project, which featured 14 pioneering countries.

DEGRADATION CLASS

Forest fire scar: is characterized by the presence of areas hit by fire, and may or may not have tree vegetation.

Degradation: is characterized by loss of forest canopy and consequent exposure of soil, where there is vegetation usually arboreal individuals in early stages and initial intermediate of succession.

TIMBER FARMING CLASSES

Selective cut type 1: is considered a conventional exploration, where individuals of commercial interest are removed without prior planning, denoted by the disordered form of roads and branches in the interior of the forest and with the presence of storage yards with irregular dimensions and arranged in a random manner.

Selective cut type 2: is considered an exploration based on a management plan, in which one perceives the previous planning evidenced by the regular pattern between the roads and storage yards in the interior of the forest.

DEFORESTATION

The platform developed by INPE, called TerraBrasilis, a digital tool designed for organization, access and use through a web portal of the geographical data produced by its environmental monitoring programs to monitor deforestation in the Amazonia Legal region and in the Brazilian Cerrado. And it aims to attend mainly to the Amazon Program, but the concept and the software packages produced can be adapted and customized to attend to other projects that produce geographical data and that intend that these can be accessed in the environment of the internet. Three types of deforestation:

Deforestation: is the total removal of forest cover, regardless of the use destined for the deforested area. The process of deforestation can occur by shallow cutting, when the forest cover is abruptly removed in a single intervention, or it can be the result of recursive degradation events that lead to the complete collapse of the forest structure of the vegetation.

Deforestation with vegetation: these are areas in which there is evidence of deforestation, but the deforested area finds signs of a vegetal cover. These are cases in which there is a time lag between the occurrence of shallow cutting and its detection, caused by the covering of clouds between one event and another, or the final result of recursive degradation.

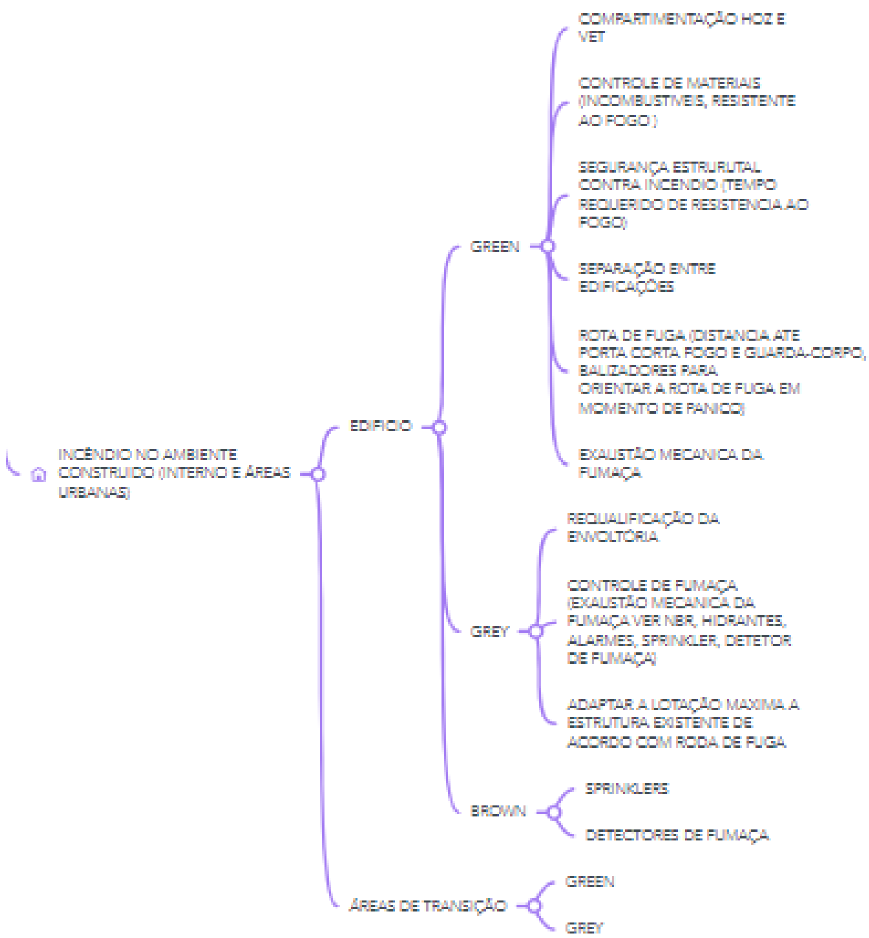
Mining: deforestation caused by mineral extraction activity. Traditional mining activities predominate in this class.

These plans should lead to the use of sustainable practices, such as precision farming, organic farming, agroecology and agroforestry, as well as to stricter animal welfare standards. By shifting the focus from compliance to performance, measures such as green schemes should reward farmers who improve environmental and climate performance, including in terms of management and storage of carbon in the soil, and nutrient management in order to improve water quality and reduce emissions. (COMMISSION, European, 2019, p. 14)

4.3.3 Fire spread

Mental map of the types of interventions to mitigate the spread of fire in the built environment built separate by the scale of the construction and transition areas, relating each intervention to the object.

Picture 63Subject: Structure of the Mental Map used to categorize good practice repertoire related to fire propagation



Source: The Author, (2021)

The concept of fire and fire is universally known and widely disseminated in the bibliography of different areas of knowledge, with their respective degree of deepening. The ABNT NBR 13860:1997 (p.6) defines fire as the "combustion process characterized by the emission of heat and light", in turn, combustion is defined by the same standard as the "exothermic reaction of a fuel with an oxidizer, usually accompanied by flames or embers or the emission of smoke" (op. cit., p. 4). The fire defines the situation in which the fire has taken proportions out of control (ONO, 2010) and tends to develop fully as long as there is fuel and oxygen available to feed the flame.

The cause of a fire may be internal or external to the building, depending on the origin of the fire. The external cause can occur both by direct contact of the flames generated outside the building with the combustible materials present internally, and by induction at the ignition temperature as a function of the heat absorbed by irradiation or convection. The outbreak of a fire occurs in successive stages.

The first moment is the ignition of a combustible material in the presence of the air, generating a flame or hot flame. In favorable conditions, the fire tends to develop freely, by means of a chain reaction, releasing hot gases that accumulate near the upper portion of the environment. The movement of the heated gases and the energy irradiated by the flames rapidly heat all the surfaces and the surrounding elements. The continuous increase in temperature can result in widespread combustion, a phenomenon known as *flashover* or deflagration.

In indoor environments, oxygen is consumed rapidly during the fire. Oxygen deficiency implies the incomplete burning of the fuel material, which brings about a reduction in temperature, but with an increase in the production of carbon monoxide [CO] and soot. However, a new generalized combustion cycle can occur if a gap is suddenly opened allowing the intake of oxygen-rich external air. This phenomenon is called a *backdraft*.

Case studies and laboratory tests indicate that the period of three to five minutes after the initial ignition is sufficient for the outbreak to occur in small environments. During the development phase, the ambient temperature can reach values above 1,100°C (SEITO *In*: *Ibid*., 2008, p. 46). The temperature can be estimated, with a certain precision, by means of the tonality of the flame (VENEZIA, 2004) during the fire or on the basis of the melting point of the metals melted by the flames, in surveys after the incident.

CBMRN IT NO 01/2018

Height is a guiding parameter in defining the minimum fire safety measures to be provided for a given project, along with usage. The following table, drawn up from the Technical Instruction No. 01/2018 of the CBMRN for the occupation and use group "Professional Services", shows that the higher the height, the more measures become obligatory.

Picture 64: Fire Safety Measures for Group D buildings: Area over 750m² or height over 12 meters

Grupo de ocupação e uso:	GRUPO D – SERVIÇOS PROFISSIONAIS					
Medidas de Segurança Contra Incêndio	Classificação quanto à altura (em metros)					
	Térrea (um pavimento)	Baixa ($H \leq 6$)	Baixa-Média Altura ($6 < H \leq 12$)	Média Altura ($12 < H \leq 23$)	Mediamente Alta ($23 < H \leq 30$)	Alta ($H > 30$)
Acesso de Viatura na Edificação	x	x	x	x	x	x
Segurança Estrutural contra Incêndio	x	x	x	x	x	x
Compartimentação Horizontal (áreas)	x	x	x	x	x	x
Compartimentação Vertical	-	-	-	x	x	x
Controle de Materiais de Acabamento	x	x	x	x	x	x
Saídas de Emergência	x	x	x	x	x	x
Plano de Emergência	-	-	-	-	-	x
Brigada de Incêndio	x	x	x	x	x	x
Iluminação de Emergência	x	x	x	x	x	x
Detecção de Incêndio	-	-	-	-	-	x
Alarme de Incêndio	x	x	x	x	x	x
Sinalização de Emergência	x	x	x	x	x	x
Extintores	x	x	x	x	x	x
Hidrantes e Mangotinhos	x	x	x	x	x	x
Chuveiros Automáticos	-	-	-	-	-	x
Controle de Fumaça	-	-	-	-	-	x

Fonte: Instrução Técnica Nº 01/2018, p. 13 (adaptado).

FIRE SAFETY - CIS

Fire safety - SCI is the set of measures to mitigate the risk of fire occurring and, in the event of a disaster, to minimize the consequences. The occurrence of fires is low when compared with other incidents that society is daily susceptible to. Even in a burned-out building, the risk of death is small, as it presupposes the successive failure or absence of various prevention and protection systems. According to Silva, "European research shows that the risk of death in fires is 30 times less than the risk of death in the transport system" (SILVA, 2014). In spite of the low risk of incidence and deaths, the protection of life must be understood as an essential prerogative in the architectural sense. In this way, the SCI needs to assert itself as a guideline independent of those contained in the needs program listed by the client.

The subtraction of human lives is certainly the worst kind of loss from a fire. In addition, the economic losses should be considered as the total or partial destruction of the property or of the building itself burned. The loss of raw materials, goods, equipment and furniture, as well as the cost of building reconstruction, represents a significant loss for a company, which could lead to its immediate bankruptcy or in the following years. In the case of a residence, the fire may mean the destruction of the largest investment made by the family. Of the three types of loss cited, the economic one is the only one that can be partially offset by means of the insurance policy. This explains why the first SCI codes, drawn up by insurance companies, were exclusively concerned with heritage conservation.

Social losses correspond to the indirect effects caused by a fire, such as: unemployment generated by the closure of a company whose headquarters suffered an accident, or the temporary or permanent suspension of activities carried out in a burned-out building. Social damage is also evident in the case of historic buildings or buildings housing elements of high historical or artistic value of society, such as museums, antiquaries, theaters, libraries or the like. Environmental contamination, generated by fire or by the products used in combat, also falls into this category. Finally, the feeling of insecurity caused by a fire is a social setback that is usually sustained in the memory of local citizens.

Berto (1991) proposes a set of eight functional requirements, called the 'comprehensive fire safety system', to be met by safe buildings: (1) to make the fire principle more difficult to occur; (2) to make the fire more general; (3) to facilitate the initial extinguishing of the fire; (4) to limit the spread of the fire; (5) to facilitate the safe escape of the occupants; (6) to make it more difficult to spread to adjacent buildings; (7) to prevent structural collapse; (8) to facilitate combat and rescue operations. According to the author, these requirements guide the design of projects aimed at the SCI and must be pursued "during all the stages developed in the productive process and use of the building" (op. cit., p. 11). The complexity of the theme therefore removes the SCI from isolated solutions adopted at any moment of the development of the architectural project.

Finally, it is worth highlighting that the effectiveness of the level of security foreseen in the project is strongly linked to the behavior of the users. When they are unaware of the risk of dangerous procedures that could cause a fire, safety measures are seriously compromised. The author of this work is an advocate of Del Carlo's opinion (In: SEITO [coord.], et. al., 2008) when he states that the education of the population is an indispensable tool in the dissemination of the SCI in society:

> *"The ideal is to implement education programs at all levels of courses, from preschool to third degree, so that everyone can know the fire risks of their activities and what attitudes should be taken in cases of fires" (DEL CARLO. In: SEITO [coord.], et. al., 2008, p. 15-16).*

FIRE SAFETY AND ARCHITECTURAL DESIGN

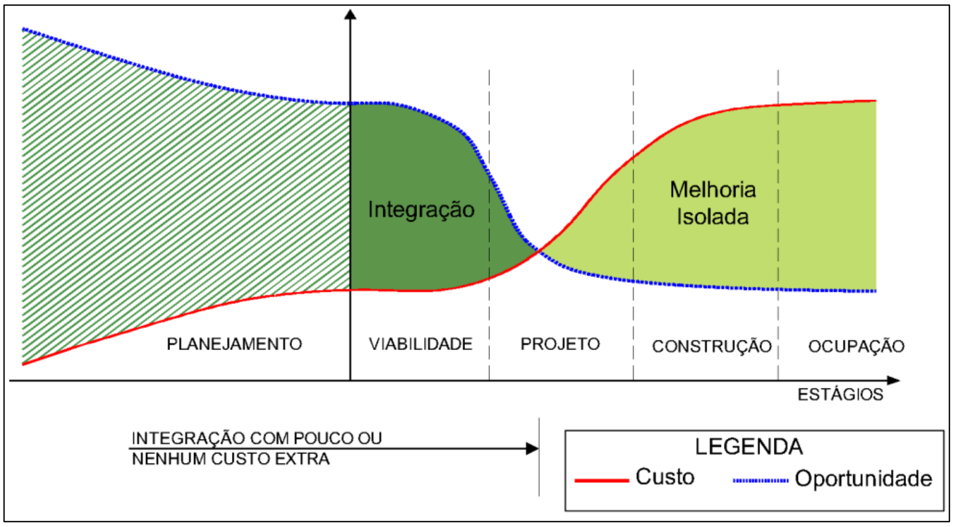
Architectural design can be understood as the product of successive decisions taken throughout a development process that aims to meet a given program of needs. In other words, "Designing is looking for solutions that are consistent with the exposure conditions of the enterprise and the demands of its customers, users and society" (AsBEA, 2012, p. 13). In this context, it is understandable that the sooner the designer assimilates the problems presented, the greater are the chances of adopting effective and economically viable solutions.

SCI is internationally regarded as a science and therefore an area of research, development and teaching (DEL CARLO In: SEITO [coord.] et al., 2008). In Brazil, it is still little covered in the academic curriculum, despite being considered as one of the basic requirements for building performance (ONO, 2011). According to Negrisolo (2011):

> *"All architects trained up to the mid-70s were not trained and therefore did not have the sensitivity and knowledge to point out that fire safety far exceeded this simple addition of fire hydrants and fire extinguishers to the building" (NEGRISOLO, 2011, p.10).*

SCIE should be considered, mainly, in the initial stages of the project, since it is at this stage that various problems verified in the occupation phase can be solved. This view is shared by Mitidieri, who stated that: "a large part of the building's fire safety is resolved at the design stage. Many guidelines are also, at this stage, directed to the general solution of the problem" (MITIDIERI In: SEITO [coord.] et al., 2008, p. 56). The initial stages of the project process stand out by offering a greater range of alternatives and, consequently, greater possibilities for control on the part of the author of the project. Figure 2.4, developed by the BRE Group (2015), illustrates the inverse relationship between 'integration opportunity' and the 'cost' of design decisions throughout the process of design, construction and occupation of buildings. It is clear that anticipating problems is a technically and financially advantageous strategy.

Picture 65: Relationship between integration opportunity and cost of design decisions over the life cycle of a building



Source: BRE (2015), adapted.

In the current context, the issue of fire safety is already linked, even, to the sustainability of buildings. Against this backdrop, differentiated and innovative project solutions need to be encouraged in the light of social, cultural, technological and economic development. Among the three aspects of the security theme contemplated by AsBEA (2012), the SCI is the one that is dealt with with the greatest emphasis by the normalizing bodies on the national scenario.

There is an interest in addressing the performance aspects of building systems and materials, as well as building facilities. Performance can be understood as the appropriate behavior, in use or in operation, of the elements throughout their life cycle, meeting the needs of the users through exposure conditions to which they will be subject. CIS measures are classified into prevention and protection measures, which in turn may be active or passive.

Preventive measures aim to reduce the probability of a fire starting and protective measures seek to protect the life, property and integrity of the building in case the fire occurs. The effectiveness of the SCIE measures is strongly influenced by architectural solutions and should present the expected design performance during a fire situation, otherwise they will not fulfill their prevention or protection function (ONO, 2010). "The concern to prevent a fire should begin at the design stage of the building architecture project" (GOMES, 1998, p. 2).

The passive protection measures are those incorporated into the construction of the building, which possess, maintain and exercise their characteristics permanently in the day to day, acting discreetly in a situation of fire. Its aim is to hinder the growth and spread of the fire; facilitating the escape of users and the entry of those responsible for fighting and rescuing victims. Passive measurements tend to be more efficient and of lower cost when incorporated into construction from the first stages of the design process.

The definition of the architectural party must incorporate the measures of prevention and protection, since practically all the elements of SCI have repercussions on the formal composition of the building. Passive protection measures, directly related to the architectural design, are:

a) Horizontal and vertical subdivision: responsible for preventing the propagation of fire into other environments on the same or subsequent floors.;
b) the fire resistance of the construction system and of the finishing materials: measures relating to structural safety and to the speed of fire propagation respectively;
c) the design and signaling of escape routes: traffic routes, both horizontal and vertical, must facilitate the safe and rapid evacuation of buildings in panic situations;
d) free access for combat and rescue teams: allow the fire brigade's car to approach any part of the building;
e) control of the built-in and occasional fire load: quantify the amount of combustible material inside buildings and the amount and variety of toxic gases that can be released during combustion;
f) The retreat between neighboring buildings: avoid the spread of fire between different buildings.

Fire incidents throughout history have shown that proper design of traffic routes and compartmentalization are crucial to safeguarding human life. The architectural design responds directly to both aspects, because it is this that determines the dimensions of the traffic routes and the area of the environments. According to Ono (2011), passive measures play an important role in ensuring the fire safety of buildings, and the effectiveness of these measures is heavily influenced by architectural decisions, especially those involving elements intrinsic to the project. Design solutions must be monitored during the construction and occupancy phase to ensure that they are being properly implemented, operationalized and maintained.

The financial aspect is undeniably preponderant in the draft decisions. It is therefore necessary to strike a balance between the cost and the likely benefits, since excessive spending does not always necessarily result in significant improvements in the conditions of SCIEs. On this subject, Berto (1991) makes the following exposition:

> *"Fire prevention and protection measures should be selected and combined not only with the aim of establishing proper*

> *risk-taking, but also with the aim of achieving an adequate balance between costs and benefits and the preservation of the perfect functionality of the building" (BERTO, 1991, p. 25).*

VAULTING

The containment of the fire, preferably in its initial state, in the smallest possible space is, in principle, the best strategy to limit its growth and propagation to the other rooms of the building (VASCONCELOS, 2008). Compartmentation is a passive protection measure that is critical to fire safety and consists of dividing the building into cells that are resistant to fire propagation. Fire containment restricts the free movement of smoke and gases within the building, facilitating the safe abandonment of occupants and contributing to fire-fighting operations. Unlike fire load control, compartmentalization is a measure of great control by the architect.

In Brazil, the definition of compartmentalization can be obtained in normative instruments. ABNT NBR 13860:1997 distinguishes between horizontal and vertical compartmentalization, where the former is defined by the "subdivision of pavement into two or more autonomous units, carried out by means of fire-resistant walls and doors, with the aim of making it difficult to propagate fire and facilitating the removal of persons and goods" (op. cit., p. 4). The second is defined as the "set of fire protection measures intended to prevent the propagation of fire, smoke or gases from one deck to another, internally or externally" (op. cit., p. 4). In turn, ABNT NBR 14432:2001 defines a compartment as "a building or part thereof, comprising one or more rooms, spaces or decks, constructed to prevent the spread of fire from within its boundaries, including the spread between adjacent buildings, where applicable" (op. cit., p. 2). It is therefore understood that the definitions brought by the Brazilian norms have a generic character, since they expose the need for implantation, but do not present values per se.

The compartmentalization is obtained by means of fire-resistant construction elements. The concept of fire-resistant, or 'fire-retardant', applies to those materials that retain the characteristics of integrity, stability, tightness and thermal insulation for a predetermined period when submitted to standardized temperature elevation. Its function is to prevent the free spread of fire and smoke, confining the fire in its original environment, allowing the eviction of the building and facilitating combat and rescue operations.

ABNT NBR 14432:2001 presents the concepts of tightness and insulation: the first refers to "the ability of a construction element to prevent cracks or openings through which hot flames and gases capable of igniting a cotton lead can pass" (op. cit., p. 3). Insulation, in turn, is the "ability of a construction element to prevent the occurrence, on the face that is not exposed to fire, of temperature increments greater than 140 °C in the mean of the measuring points or greater than 180 °C at any measuring point" (op. cit., p. 3). The fire wall, besides meeting the mentioned requirements, needs to be built from floor to ceiling and be strongly linked to the structure of the building by means of reinforced elements. Where the roof is composed of combustible elements, the fire wall shall extend at least one meter above the ceiling of the roof.

The absence of horizontal or vertical compartmentalization elements turns the whole building into a single compartment in the event of a fire. The compartment certification is therefore obtained by checking the presence of the safety elements and their specific 'Required Fire

Resistance Time’. The regulations do not include intermediate levels of compartmentalization, since the absence of one of the items described above is already sufficient to characterize the environment as non-compartmentalized.

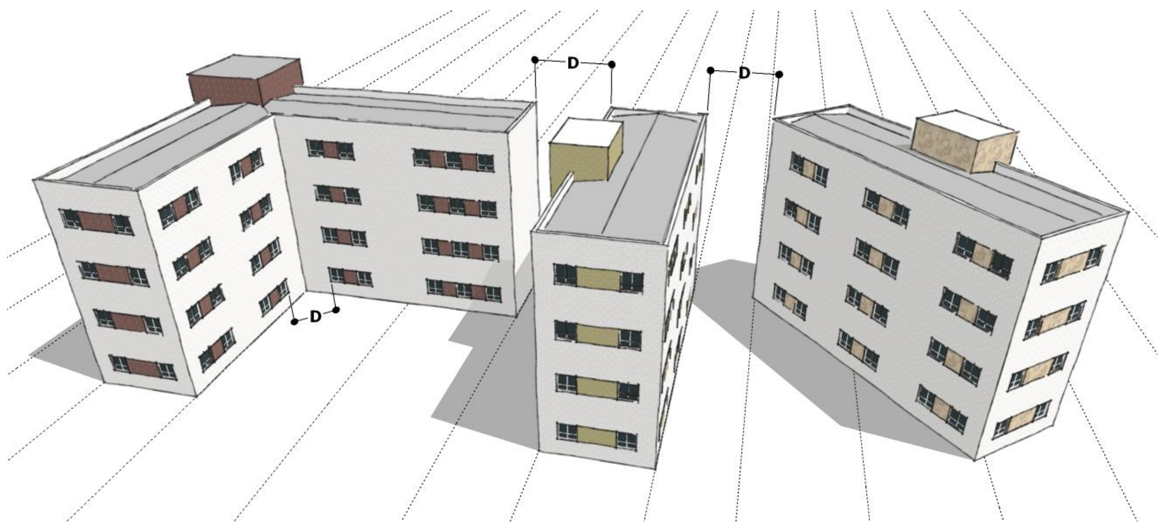
Horizontal compartmentalization consists of confining the fire in its original environment, without reaching the surrounding spaces of the same deck. Vertical compartmentation aims to isolate each floor from the others, so as to confine the fire to its original pavement. Both forms of compartmentalization can be further subclassified as internal or external, in reference to the confinement occurring inside the building or on the facade, respectively.

The external compartmentalization is strongly influenced by the aesthetic-functional elements that make up the envelope. Buildings that make use of non-traditional construction systems represent an inexhaustible source of study, like Law (2011) which, by studying the SCI in glazed facades and thermally isolated for the European climate, concluded that rock wool shows superior performance than expanded polyurethane in insulating thermal bridges.

Technical Instruction No. 09 - IT 09/ 2011 (CBPMESP, 2011) presents in a very didactic way the minimum or recommended values for the design of the compartment to be adopted in the architectural design. Briefly, IT 09/ 2011 recommends:

a) For external horizontal subdivision: the openings on the same facade, but on opposite sides of the subdivision wall, shall be separated horizontally from each other by a two-meter-long stretch of wall, duly consolidated to the subdivision wall and having the same fire resistance. This distance may be replaced by an extension, external to the building, of the subdivision wall with a length of at least 90 centimeters. In the case of orthogonal, parallel or uncoinciding facades (**Picture 59Erro! Fonte de referência não encontrada.**), the minimum distance between the vents of enclosed environments is given by the **Table 26Erro! Fonte de referência não encontrada.**.

Picture 66: Minimum distance (D) between openings of compartmentalized environments: on orthogonal, parallel and non-coinciding facades.



Source: IT 09/ 2011 (CBPMESP, 2011), adapted.

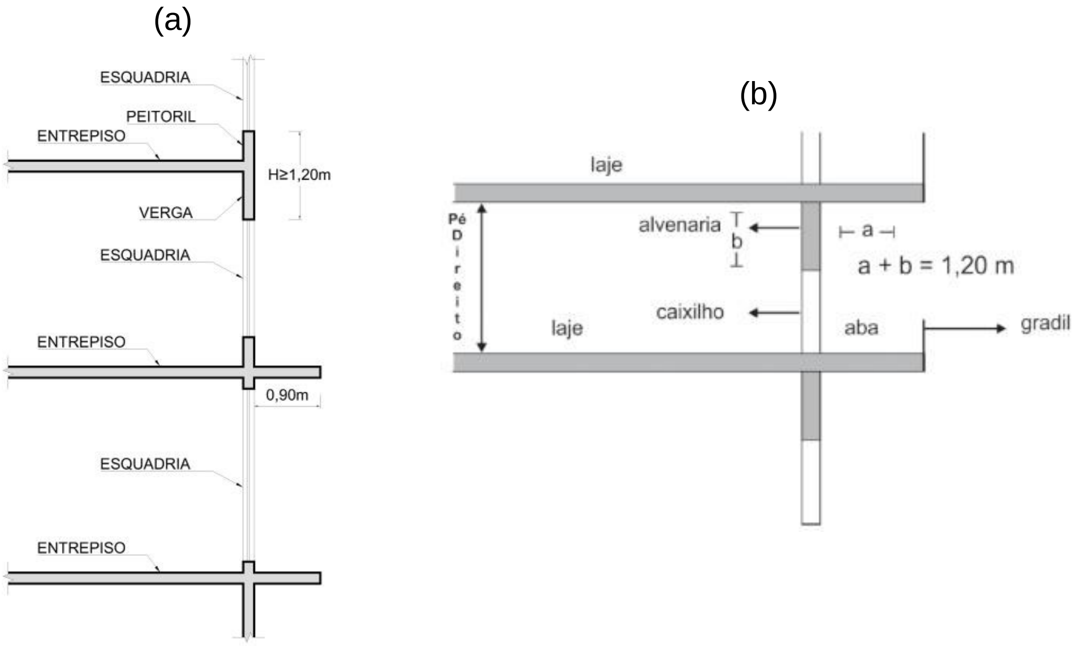
Table 26: Minimum distance between vents of enclosed environments

Percentage of opening of all facade (%)	Subdivision distance 'D' (m)
Up to 20	4
From 21 to 30	5
From 31 to 40	6
From 41 to 50	7
From 51 to 60	8
From 61 to 70	9
Above 70	10

Source: IT 09/ 2011 (CBPMESP, 2011).

b) For external vertical subdivision: is obtained by means of elements which make it difficult for the fire to pass between successive deck openings. The minimum distance between the top of the lower deck opening and the base of the upper deck opening shall not be less than 1,20 m. This value may be disregarded if the interlayer slab is projected to be 0,90 m or greater (**Picture 67Erro! Fonte de referência não encontrada.**(a). If a mixed system of vertical and horizontal flaps is chosen, the sum shall be at least 1,20 m (**Picture 67**(b). Special attention should be given to glass facades, which should be sealed by fire seals in the cracks.

Picture 67: Dimensioning of the external vertical compartmentalization elements



Source: IT 09/ 2011 (CBPMESP, 2011).

c) For internal horizontal compartmentalization: this is the result of the adoption of fire walls and, where necessary, of other elements of the same category, such as doors, seals and records. The TRRF is always more than 30 minutes, and can reach 180 minutes in specific cases, as prescribed in IT 08/ 2010 (CBPMESP, 2010). The maximum compartmentalization area varies according to the use and height of the building and are duly described in IT 09/ 2011, Annex B (CBPMESP, 2011). Generally speaking, the maximum area of compartmentalization tends to be smaller in tall buildings, with a large number of occupants and in uses that present a greater risk of fire. The revision of IT 09/ 2011, made available for public consultation in 2015, proposes the value of 2000.00 m² as a maximum compartmentalization area for school buildings with a height of more than 23.0 m, a category that until then was free of parameters in this aspect. Finally, IT 09/ 2011 classifies classrooms, among other special cases, as autonomous units, for which "the dividing walls between autonomous units and between units and common areas, (...) must possess minimum requirements for fire resistance, as prescribed in IT 08/ 2010" (CBPMESP, 2011, p. 5).

d) As for the internal vertical compartmentalization: it is represented mainly by the fire gap. However, when this element needs to be discontinued for the passage of the building systems, the use of seals, registers and fire dampers is necessary to ensure the containment of the fire on the original deck. The protection of shafts and stairway or lift boxes deserves attention, since they are spaces naturally devoid of horizontal barriers and therefore can allow the free spread of fire along several consecutive floors.

Besides the traditional classification, other authors present complementary understandings to the concept of compartmentalization. Malhotra (1993, apud COSTA; ONO and SILVA, 2005) proposes a classification of compartmentalization into two types, which he termed "essential" and "control". The first is to establish specific permanently isolated areas, capable of preventing the fire from spreading to adjacent areas. This category includes escape routes, *shafts*, enclosed stairs, ventilation ducts and ceilings. The control compartmentalization, in turn, deals with limiting the fire in order to reduce the risks of the users and facilitate the actions of fighting the fire. The author also suggests adding compartments of different sizes when heritage protection is relevant. However, it does not mention the criteria of the subdivisions, recommending that the designer consult the insurers for this purpose.

VAULTING SYSTEM FAILURES

Failures in compartmentalization systems can be grouped into three categories: early, random or due to material degradation. Early failures arise mainly from lack of maintenance or operational vices such as misuse or poor conservation of fire doors. Random failures are usually attributed to execution errors or even design failures not yet recognized by the test and calculation methods. Finally, the failures resulting from the material degradation are related to the non-functioning of electronic and mechanical equipment due to the natural or occasional deterioration of internal mechanisms.

Attention should be paid to the non-visible spaces of the building, where the fire can propagate to adjacent environments without being perceived by the occupants or even by the active detection systems. False ceilings and floors, *shafts*, ducts and pipes and expansion joints fall into this category. If the hidden cracks and passages represent points of fragility, the crates and the openings are, of course, the most vulnerable parts of a compartmentalization system. Therefore, the protection of these elements requires specific care in view of the evacuation and access functions of the fire fighting team naturally associated with the window frames. As for the sizing, Costa, Ono e Silva (2005) suggest that the area occupied by the vents is limited to 25% of the surface of the vedo, so as not to jeopardize the efficiency of the compartmentalization. If the presence of translucent elements in these openings is indispensable or mandatory, special high temperature resistant glass shall be used that minimizes radiant heat transmission.

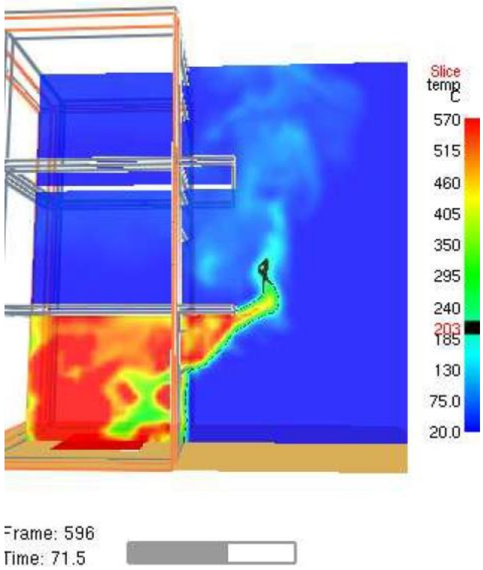
The prediction of the damage effects of a fire can be obtained by means of computer simulation. Computer fire simulation is a strand of CFD in which fluid flow is strongly induced by the high temperature difference. The designer can make use of simulations to determine the type of subdivision most effective from the point of view of the SCI (Figures 3.1 and 3.2) and the correct positioning of the emergency staircase according to the shape of the building, as well as to indicate the most suitable materials according to the fire resistance and smoke propagation. (ALVES; CAMPOS and BRAGA, 2008). However, Braga and Landim make the following caveat:

> *"Obviously, the simulation does not bring in itself all the answers about the incident, since it is just another tool, but its use by the investigator, together with his knowledge in fire protection engineering and the scientific method of fire investigation, makes it possible to obtain well consolidated results" (BRAGA e LANDIM In: SEITO [coord.] et al, 2008, p. 342).*

Picture 68: Laboratory test of the external vertical subdivision.

Source: Rodrigues (2009).

Picture 69: Reproduction of the SDF test, based on the data collected in the experiment



Source: Rodrigues (2009).

CONSIDERATIONS

The fire is one of the most serious incidents that can happen in a building, since, besides the material damage, it is also strongly associated with the loss of human lives (ROSA, 2010).

Building fire safety [SCIE] is a relatively new field of study in Brazil, and the architectural approach to the subject is even more recent.

The compartmentalization is a passive protection measure of total control on the part of the architect, which can be defined right at the first stages of the project process. By restricting flames and their by-products within the original environment, compartmentalization effectively contributes both to the safe evacuation of occupants from the rest of the building, and to fire-fighting operations (ABNT NBR 14432: 2000).

The typical compartmentalization assessment is done by checking the characteristic elements and their dimensions. The current certification follows a binary distinction, of the type: 'exists' or 'does not exist', the absence of a single element being enough for the building to be classified as not compartmentalized. In this way, little attention is paid to the performance of the elements not foreseen in the standards. Corroborating the thinking of Ono (2011), which highlights the worldwide tendency to follow recommendations based on performance, it becomes justifiable to assess the efficiency of elements ignored by traditional prescriptive codes in the current context.

Computer simulation tools, adequately adjusted and with an acceptable degree of uncertainty, favor both the understanding of fire behavior and the creation, revision and improvement of SCI technical standards. In the international scenario, fire simulation is already used as a tool for assessing the projectional decisions of high-standard buildings or historic heritage sites. The goal is to evaluate the performance of projects when submitted to performance-based standards, considering that most empirical prescriptive standards prove inadequate for high-complexity projects. According to Gouveia e Souza (2008),

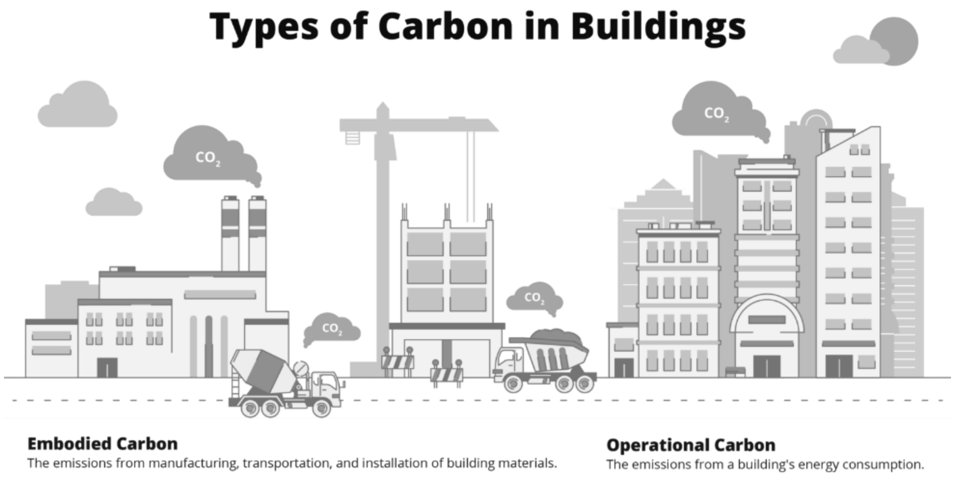
> *"... the use of the performance-based system is recommended in more complex programs, such as historic buildings, as it makes the innovation of security strategies a constraining factor in the design process" (GOUVEIA e SOUZA, 2008, p. 3).*

The simulation allows for a more reliable risk assessment, making the projects economically viable and adapted to the peculiarities of the enterprise, without ceasing to take into account the aspects of safety. In Brazil, the use of fire simulators in the development of architectural projects and fire prevention is still very restricted (SCHEER and BARANOSKI, 2007). Although the software makes possible the resolution of the extensive calculations involved in a situation of fire, the use demands from the users a prior knowledge of the behavior of the fire and of the physico-chemical characteristics of the materials used in civil construction. Therefore, the application of fire simulation in the national scenario concentrates on the reconstruction and investigation of previous fires and is still strongly linked to the academic environment

4.4 Greenhouse gas emissions

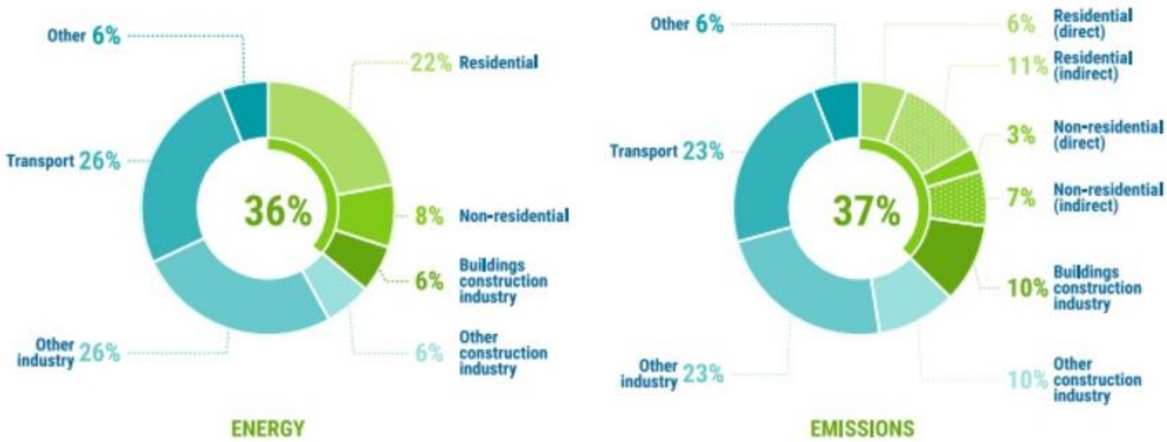
According to the most recent IPCC report, Climate Change 2022: Mitigation of Climate Change (WGIII-AR6), anthropogenic total net emissions of GHGs continued to increase during the period 2010-2019, as did cumulated net emissions of CO2 since 1850. In 2019, the highest growth in absolute emissions occurred in CO2 emissions from fossils. Buildings and the construction sector are one of the main contributors of GHG demand and emission. According to IEA Statistics, in the year 2019 the energy consumption of residential buildings, represent 36% of the final global energy demand and almost 40% of the global emissions related to energy and the construction process that employs up to 12% of the workforce in many countries.

Embedded carbon is the carbon dioxide (CO2) emissions associated with materials and construction processes over the entire life cycle of a building or infrastructure. It includes any CO2 created during the manufacture of building materials (extraction of materials, transportation to the manufacturer, manufacturing), the transport of those materials to the workplace, and the construction practices used. Simply put, embedded carbon is the carbon footprint of a construction project or infrastructure before it becomes operational. It also refers to the CO2 produced by maintaining the building and eventually demolishing it, transporting the waste and recycling it. Embedded carbon is distinct from operating carbon - carbon that comes from energy, heat, lighting, etc. Thanks to advances in reducing operating carbon, recent data from the World Green Building Council indicate that embedded carbon is becoming an important seal to be combated within the sector's carbon footprint portion.



The Global Alliance for Buildings and Construction (GlobalABC) in its latest report published by the United Nations Environment Program (UNEP) in 2021, showed that construction accounted for 36% of energy consumption, 37% of energy-related carbon emissions and 50% of natural resource consumption. And unfortunately, the future projection is that these indices will increase by 100 percent by 2060.

Picture 70: Building and construction's share of global final energy and energy-related CO2 emissions, 2020.



Source: (Global Alliance for Buildings and Construction, 2021).

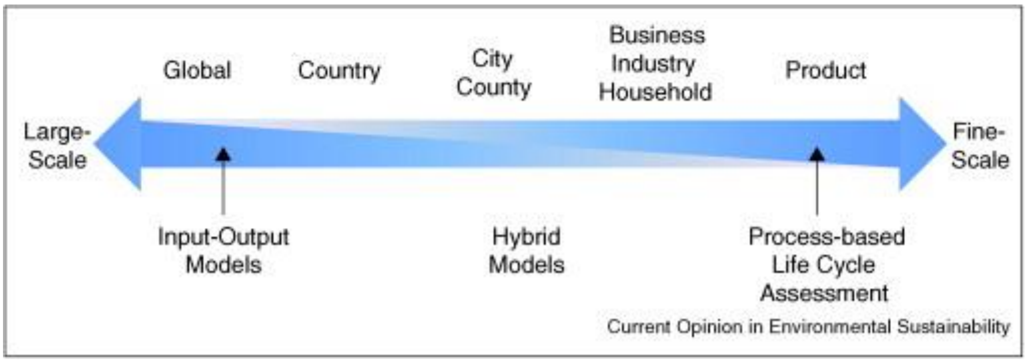
According to the *Global Alliance for Buildings and Construction*, half of the buildings that will exist in 2060 have not yet been built, this expansion of the global housing stock could directly impact the efforts needed to limit warming under the Paris Agreement. To achieve this goal of carbon neutrality by 2050, **all new buildings and 20% of the existing housing stock would need to r=be carbon-free by 2030**. This alone is a huge challenge for the industry, requiring a lot of investment in technology, training and financing (IEA, 2021). The International Energy Agency (IEA) estimates that direct CO2 emissions from buildings need to fall by 50% by 2030, while indirect emissions from the construction sector need to fall by 60%. This represents 6.25% per year for direct emissions from buildings and 7.5% per year for the construction sector. This means that the energy consumed per square meter in 2030 should be 45% less than in 2020 (IEA, 2021).

Of the 192 countries that are signatories to the Paris Agreement, 151 have submitted their *Nationally determined contributions* (NDCs) with their long-term goals, of these 136 countries mention the word "buildings" in their plans, but of these, only 53 countries mention the energy efficiency of buildings, and only 38 countries specifically address energy codes of buildings (UNFCCC, 2020). To accelerate this process, high governments need to update and elaborate regulations related to the performance of buildings, specifying higher performance thresholds capable of reducing both the built-in carbon footprint of buildings, and the operating carbon. Adopting mandatory codes based on adequate performance for both new developments and existing building stock upgrades. Many of the countries that will undergo this intense process of urban expansion in the next few years do not have mandatory basic codes and guidelines related to this climate problem.

Investments should be made in new technologies focused on the production of sustainable and possible to be recycled materials, construction systems that avoid waste and waste production, best practice in the building design process, following bioclimatic guidelines, passive strategies that promote thermal comfort, light and air quality, and specification of performance-based materials. According to the *Global Alliance for Buildings and Construction,* by strengthening these codes every 3 to 5 years, zero emission code and net zero energy can quickly become the norm. The need for funding to promote the renovation of old and low-performance buildings also needs priority attention, the speed with which we renovate buildings needs to increase, reaching 2% by 2025 and

3% by 2040 in developed countries and 1.5% and 2% in developing countries (Global Alliance for Buildings and Construction, 2020).

The concept of carbon footprint, which is widespread today due to the problems of climate change and its effects, is not a new concept and it is possible to have applications on several scales (large-scale of the fine-scale).



The origin of the carbon market came from the Kyoto Protocol (parties specified in Annex B of the Protocol) and the clean development mechanism (CDM) - established in Article 17 of the Kyoto Protocol. Drives:

- assigned amount units (AAUs);
- removal unit (MRU)
- emission reduction unit (ERU)
- certified emission reduction (CER)

An important step towards reducing GHG emissions, proposed in 2015 by the COP21 of the Paris Agreement, and resumed the discussion of the carbon market at the COP26. During the COP26 held in Glasgow in 2021, as a result of the Glasgow Climate Pact, during the conference the rules were presented on how this new carbon market would work for each market mechanism presented in the Kyoto Protocol, which provides for three units that can be traded each equal to 1tCO2, are as follows:

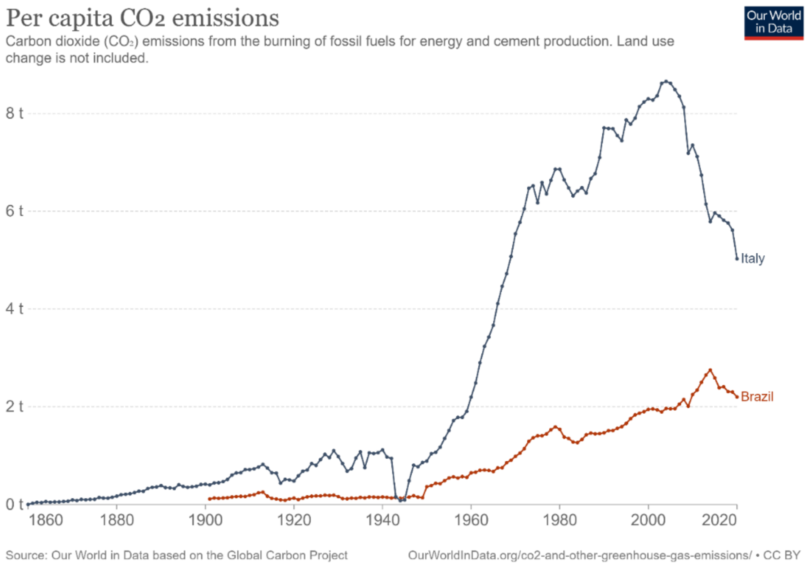
- removal unit (RMU);
- emission removal unit (ERU);
- emission reduction certificate (CER). According to the UNFCCC, the European Union's emissions trading scheme is the largest in operation today.

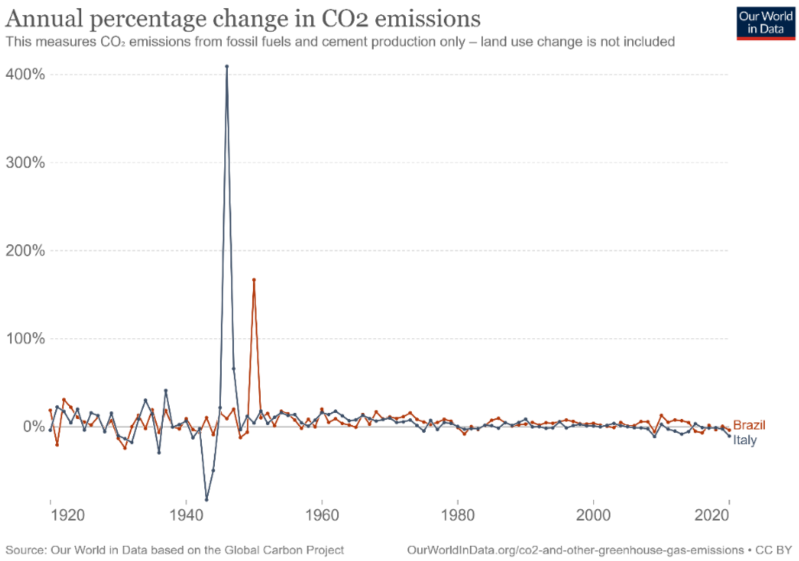
Recommendations for carbon reductions and offsets:

- Carbon offsets are an important initial step
- Choose comprehensive carbon calculators
- Define significant limits of liability
- Put efficiency first
- Get 100% truly new renewable energy
- Voluntary market has developed many credible compensation projects
- Compensation projects that avoid emissions are better for the long term
- carbon sequestration in plants and soils may be vulnerable, but it has additional benefits

- tropical reforestation and avoided deforestation are efficient and economical land strategies
- Choose offset projects with strict standards
- Integrate expenses for compensation into the cost of activities
- Carbon inventory
- Point to zero net carbon emissions

COMPARISON BRAZIL ITALIA





Peak in Italy occurred in 1946	**Peak in Brazil occurred in 1950**
1946	1950
Itália 409.35%	Brasil 166.86%
Brasil 9.34%	Itália 4.17%

IN BRAZIL

Second (IPCC, 2013, pp. 149-151), Can Geoengineering Counter Climate Change and what Side Effects may occur?

Geoengineering is defined as a broad set of methods and technologies that purposely change the climate system to alleviate the impacts of climate change. Generally, two distinct categories of geoengineering methods are considered: Solar Radiation Management (SRM, assessed in Section 7.7) aims to compensate for warming caused by anthropogenic greenhouse gases by making the planet more reflective, while Carbon Dioxide Removal (CSR, assessed in Section 6.5) aims to reduce atmospheric CO2 concentration. The two categories operate on different physical principles and on different time scales. The models suggest that if the GRS methods were achievable, they would be effective in countering rising temperatures and would be less, but still effective in combating some other climate change. GRS would not counteract all the effects of climate change and all the proposed geoengineering methods also entail risks and side effects. The

additional consequences cannot yet be anticipated, as the level of scientific knowledge about SRM and DRC is low. There are also many issues (political, ethical and practical) involving geoengineering that fall outside the scope of this report.

Carbon Dioxide Removal Methods DRC methods aim to remove CO2 from the atmosphere through deliberate modification of carbon cycle processes or through industrial (e.g. chemical) approaches. Carbon taken from the atmosphere would then be stored on land, in the ocean or in geological reservoirs. Some DRC methods rely on biological processes such as large-scale afforestation/reforestation, carbon capture in soils through biochar, bioenergy with carbon capture and storage (BCAC), and ocean fertilization. Others would depend on geological processes, such as wear and tear

accelerated silicate and carbonate rocks - on land or in the ocean (see FAQ.7.3, Figure 1). CO2 removed from the atmosphere would then be stored in organic form in earth reservoirs or in inorganic form in oceanic and geological reservoirs, where it would have to be stored for at least hundreds of years for the DRC to be effective.

GRS methods would reduce the radiative forcing of CO2 as they are effective in removing CO2 from the atmosphere and keeping removed carbon away from the atmosphere. Some methods would also reduce ocean acidification (see FAQ 3.2), but other methods involving ocean storage may, however, increase ocean acidification if carbon is sequestered as dissolved CO2. A major uncertainty related to the effectiveness of the GRS methods is storage capacity and carbon storage. The removal and permanent storage of carbon by the DRC would decrease climate warming in the long term. However, non-permanent storage strategies would allow CO2 to return to the atmosphere where it would once again contribute to warming. Intentional removal of CO2 by DRC methods will be partially offset by the response of oceanic and terrestrial carbon reservoirs if atmospheric CO2 concentration is reduced. This is because some oceanic and terrestrial reservoirs of carbon will emit to the atmosphere anthropogenic CO2 that was previously stored. To fully compensate for past anthropogenic CO2 emissions, DRC techniques would have to remove not only the CO2 that had accumulated in the atmosphere since the pre-industrial era, but also the anthropogenic carbon previously absorbed by the terrestrial biosphere and the ocean.

DRC's methods of higher biological and chemical wear cannot be extended indefinitely and are necessarily limited by various physical or environmental constraints, such as competitive demand for land. Assuming a maximum DRC capture rate of 200 PgC per century from a combination of DRC methods, it would take about a century and a half to remove CO2 emitted in the last 50 years, making it difficult - even for a set

adequate of additive DRC methods - quickly mitigate climate change. Direct air capture methods could, in principle, operate much more quickly but may be limited by large-scale implementation, including energy use and environmental restrictions.

The DRC may also have adverse climatic and environmental effects. For example, better productivity of vegetation can increase emissions of N2O, which is a more powerful greenhouse gas than CO2. A large-scale increase in vegetation cover, for example through afforestation or energy crops, could alter surface features such as surface reflectivity and turbulent flows. Some modeling studies have shown that forestation in the seasonally snow-covered boreal regions can in fact accelerate global warming, while forestation in the tropics can be more effective in slowing global warming. Ocean-based DRC methods that rely on biological production (e.g. ocean fertilization) would have numerous side effects on ocean ecosystems, ocean acidity and could produce CO2-free greenhouse gas emissions.

Methods of Solar Radiation Management

The global average temperature of the planet's surface is strongly influenced by the amount of sunlight absorbed by the Earth's atmosphere and surface, which heats the planet, and by the existence of the greenhouse effect, the process by which greenhouse gases and clouds affect the way energy is eventually radiated back into space. An increase in the greenhouse effect causes the surface temperature to rise until a new equilibrium is found. If less incoming sunlight is absorbed because the planet has become more reflective or if energy can be emitted more effectively into space because the greenhouse effect has been reduced, the global average surface temperature will be reduced.

The suggested geoengineering methods for managing the Earth's energy input and output streams are based on this fundamental physical principle. Most of these methods propose reducing the sunlight that hits Earth or increasing the reflectivity of the planet, making the atmosphere, clouds, or surface brighter (see FAQ 7.3, Figure 1). Another technique proposes to suppress the high clouds called cirros, since these clouds have a strong greenhouse effect. Basic physics tells us that if any of these methods changes the energy flow as expected, the planet will cool down. However, the picture is complicated due to the many complex physical processes that govern the interactions between energy flow, atmospheric circulation, climate and the resulting changes.

While the global average surface temperature will respond to a change in the amount of sunlight reaching the surface or a change in the greenhouse effect, the temperature at a given location and time is influenced by several other factors and the amount of cooling due to GRS will generally not equal the amount of warming caused by the greenhouse gases. For example, GRS will change heating speeds only during the day, but increasing greenhouse gases can change temperatures during the day and at night. This inaccurate compensation can influence the day cycle of the surface temperature, even if the average surface temperature is not changed. As another example, calculation models suggest that a uniform decrease in sunlight reaching the surface could compensate for the CO2-induced global average warming, but some regions will cool more than others. The models suggest that if anthropogenic warming of the greenhouse effect were fully offset by stratospheric aerosols, the polar regions would be left with a small residual warming, while the tropical regions would become a little colder than in the pre-industrial era.

Theoretically, GRS could quickly counteract anthropogenic climate change by cooling the Earth to pre-industrial levels within a decade or two. This is known through climate models but also through climate records of large volcanic eruptions. The well-observed eruption of Mount Pinatubo in 1991 caused a temporary increase in stratospheric aerosols and a rapid decrease in surface temperature of about 0.5°C. The climate is composed of many factors beyond the surface temperature. Consequences for other climate features such as precipitation, soil moisture, river flow, accumulated snow and sea ice and ecosystems may also be important. Both the models and the theory show that compensating an increase in the greenhouse effect with GRS to stabilize the surface temperature would slightly reduce the global average precipitation (see FAQ 7.3, Figure 2 for an idealized model result) and there could also be regional changes. Such inaccurate compensation in regional and global climate patterns makes it unlikely that GRS will produce a future climate that is "equal" to what we experience today or have experienced in the past. However, available climate models indicate that a climate resulting from geoengineering studies with SRG and high levels of atmospheric CO2 would generally be closer to the climate of the 20th century than a future climate with high concentrations of CO2 and no SRG.

GRS techniques are likely to have other side effects. For example, theory, observation and models suggest that stratospheric sulfate aerosols originating in volcanic eruptions and natural emissions deplete stratospheric ozone, especially when chlorine emissions from chlorofluorocarbons reside in the atmosphere. Stratospheric aerosols introduced for GRS are expected to have the same effect. Depletion of the ozone layer would increase the amount of ultraviolet light that would reach the surface, damaging terrestrial and marine ecosystems. Stratospheric aerosols would also increase the ratio of direct or diffuse sunlight reaching the surface, which generally increases plant productivity. There have also been some concerns that GRS with sulfate aerosols increases acid rain, but model studies suggest that acid rain is probably not a major concern since the rate of GRS acid rain production from sulfate aerosol would be much lower than the values currently produced by pollution sources. GRS will also not address ocean acidification associated with increased CO2 concentrations and its impacts on the terrestrial ecosystem.

Without conventional mitigation efforts or potential GRS methods, the high CO2 concentrations of anthropogenic emissions will persist in the atmosphere for more than 1,000 years and GRS would have to be maintained as long as CO2 concentrations are high. Stopping GRS while CO2 concentrations are still high would lead to very rapid warming for a decade or two (see FAQ7.3, Figure 2), severely pressuring human and ecosystem adaptation.

If GRS were to be used to avoid some of the consequences of increased CO2 concentrations, the risks, side effects and deficiencies would clearly increase as the scale of GRS increased. Approaches to using a limited amount of GRS have been proposed, together with aggressive strategies to reduce CO2 concentrations to help avoid transitions between climatic thresholds or reversal points that would otherwise be inevitable; the assessment of such approaches would require a very careful risk-benefit analysis going far beyond this Report.

THE EMBEDDED CARBON

Coalition #BuildingToCOP26 has called for worldwide building emissions to be halved by 2030, and for net zero lifecycle emissions to be achieved for all buildings by 2050.

EN 14040/44 — Life cycle assessment

EN 14064 — Responsibility and certification for greenhouse gases

EN 14064 is composed of three parts:

Part 1 - specifies requirements for the design and development of inventories of organizations or GHG agencies

Part 2 - detailed requirements for quantification, monitoring and reporting on emission reductions and improvements in the reduction of GHG projects, and

Part 3 - provides the requirements and guidelines for conducting the validation and verification of GHG information (and applies to certification bodies)

PAS 2050: CARBON FOOTPRINT

PAS 2050 is a preliminary document for EM 14067. Give your organization a competitive advantage by implementing PAS 2050 with SGS and it will be easier to adopt EM 14067 when it launches.

Le norme per la promozione della sostenibilità nelle opere definiscono, a livello di struttura, a livello di edificio, a livello di prodotto finale, che:

Nível de estrutura*	**EN 15643-1: 2010** Sustentabilidade das obras - Avaliação da sustentabilidade dos edifícios - Quadro geral		
	EN 15643-2: 2011 Sustentabilidade das obras - Avaliação de edifícios - Estrutura para avaliação do desempenho ambiental	**EN 15643-3: 2012** Sustentabilidade das obras - Avaliação de edifícios - Quadro para avaliação do desempenho social	**EN 15643-4: 2012** Sustentabilidade das obras - Avaliação de edifícios - Estrutura para avaliação do desempenho econômico
	EN 15643-5: 2017: Sustentabilidade de obras - Avaliação da sustentabilidade de edifícios e obras de engenharia civil - Parte 5: Quadro sobre princípios e requisitos específicos para obras de engenharia civil		
Nível do edifício**	**EN 15978: 2011** Sustentabilidade das obras - Avaliação do desempenho ambiental dos edifícios - Método de cálculo	**EN 16309: 2014** Sustentabilidade das obras - Avaliação do desempenho social dos edifícios - Métodos	**EN 16627: 2015** Sustentabilidade das obras - Avaliação do desempenho econômico dos edifícios - Métodos de cálculo
	CEN / TR 17005: 2017 Sustentabilidade das obras - Categorias e indicadores adicionais de impacto ambiental - Informações e possibilidades		
Nível do produto***	**EN 15804: 2012 + A1: 2013** Sustentabilidade das obras - Declarações ambientais de produtos - Regras fundamentais para a categoria de produtos de construção		Nota: no momento, as informações técnicas relacionadas a alguns aspectos do desempenho social e econômico estão inclusos nas previsões da EN 15804 para fazer parte do EPBD
	CEN / TR 16970: 2017 Sustentabilidade das obras - Orientação para a implementação da EN 15804		
	EN 15942: 2011 Sustentabilidade das obras - Declarações ambientais de produtos - Formato de comunicação *business-to-business*		
	CEN / TR 15941: 2010 Sustentabilidade das obras - Declarações ambientais de produtos - Metodologia para seleção e uso de dados genéricos		

Table 27 Tabella riassuntiva dei problemi di mitigazione dei gas a effetto serra e delle sabi soluzioni:

Problematic	Solutions	Advantages
Under-occupation of residences	High compactness index	Energy Efficiency Embedded Carbon
Sealing	Specify Thermally Capable Ranks	Thermal Comfort Energy efficiency
Reduction of area in horizontal and vertical planes, reduction of labor costs,	Rosso Compacity Index (1978)	Thermal Comfort Energy efficiency Sealing Constructive method

4.5 Urban Mobility

Transport is responsible for about a quarter of the EU's greenhouse gas emissions. All modes of transport therefore need to contribute to the decarbonization of the mobility system. This requires a system-based approach. Low and zero emission vehicles with highly efficient alternative powertrains in all modes is the first pin of this approach. As with renewable energy in the previous decade, the automotive industry is already investing heavily in the emergence of zero and low emission vehicle technologies, such as electric vehicles. A combination of decarbonized, decentralized and digitized energy, more efficient and sustainable batteries, highly efficient electric powertrains, connectivity and autonomous driving offer prospects for decarbonizing road transport with strong global benefits, including clean air, reduced noise, accident-free traffic, generating major health benefits for citizens and the European economy. Electrification of short sea shipping and inland waterways is also an option, where the power/weight ratio makes it feasible.

Based on current knowledge and technology, electrification by renewables alone will not be the only silver bullet for all modes of transport. The batteries have so far a low energy density, and for the time being their high weight makes the technology poorly suited for aviation and long-distance transportation. Also for trucks and long-distance buses, it is currently unclear whether the batteries will achieve the required cost and performance level, although there are prospects for electrifying with overhead contact line lines. The railway remains the most energy-efficient solution for transporting loads over medium and long distances. Therefore, rail freight should become more competitive compared to road transport, eliminating operational and technical barriers between national networks and fostering innovation and efficiency across the board. Until we see the emergence of new technologies that will make it possible to electrify more modes than today, alternative fuels will be important. In addition, hydrogen-based technologies (such as electric vehicles and fuel cell-based vessels) can become competitive in the medium and long term. Liquefied natural gas with high mixtures of bioethane can also be a short-term alternative to long-distance distance. Aviation should see a shift to advanced biofuels and carbon-free e-fuels, with hybridization and other improvements in aeronautical technology having a role in improving efficiency. In long-distance transport and heavy vehicles, not only biofuels and biofuels, but also electronic fuels can play a role provided that they are carbon-free throughout their production chain. Electronic fuels can be used in conventional vehicle engines, relying on existing refueling infrastructure. Other significant steps in research and development are needed in the production of decarbonized fuels, as well as vehicle technologies such as fuel cell batteries and hydrogen gas engines.

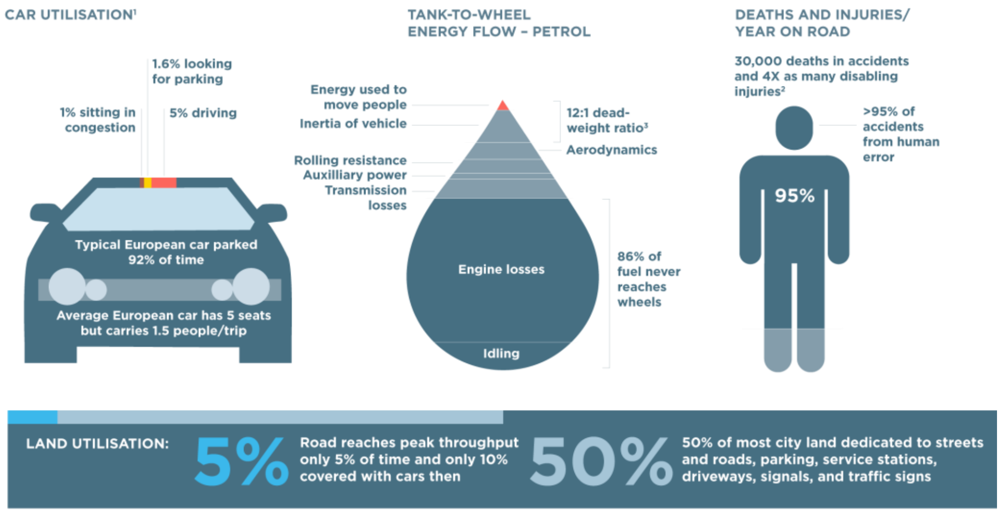
Secondly, a more efficient organization of the entire mobility system based on digitization, data sharing and interoperable standards is of utmost importance to make mobility cleaner. This will allow for increasingly automated intelligent traffic management and mobility in all modes, reducing congestion and increasing occupancy rates. Regional infrastructure and spatial planning must be improved to realize the full benefits of increasing the use of public transportation.

Urban areas and smart cities will be the first centers of innovation in mobility, especially because of the predominance of short distance travel and air quality considerations. With 75% of our population living in urban areas, urban planning, safe bike paths and trails, clean local public transportation, introduction of new delivery technologies such as drones, and mobility as a service, including the advent of car and bicycle sharing services, will change mobility. Combined with the transition to carbon-free transport technologies, reducing air pollution, noise and accidents, this will result in major improvements in the quality of urban life.

Behavioral changes on the part of individuals and companies should sustain this evolution. For long-distance travel, developments in digital technologies and video conferencing may well mean that for certain purposes, such as business travel, preferences will change and demand for travel may be reduced compared to what is expected today. Well-informed travelers and carriers will make a better decision, especially when all modes of transport are put on an equal footing, including in regulatory and fiscal terms. Internalizing the external costs of transport is a prerequisite for making the most efficient choices in terms of technology and mode of transport.

The transition to net-zero by 2050 also requires the necessary infrastructure, i.e. completion of the trans-European core network (TEN-T) by 2030 and the comprehensive network by 2050. Future investments need to focus on less polluting modes, promote synergies between transport, digital and electricity networks to enable innovations such as vehicle-to-network services, and include intelligent features such as the European Railway Traffic Management System (ERTM). This would, for example, allow high-speed train connections to become a real alternative to aviation for short- and medium-distance passenger travel within the EU.

1. Europe must remain the champion of multilateralism. Given the intrinsically global nature of the shipping and aviation sectors, the EU needs to work with global partners to encourage further efforts and build on the progress that has recently been achieved in the International Maritime Organization (ICO) and the International Civil Aviation Organization (ICAO) to have them guaranteed, as an essential first step towards decarbonization of these sectors. However, further efforts will be needed (COMMISSION, European, 2018).



1 Based on car parked number for France and productive vs. unproductive driving time in US. 2 For every death on Europe's roads there are an estimated four permanently disabling injuries. 3 Based on average car weight of 1.4 tonnes and average occupation of 1.5 passengers of 75 kg.
Source: EU Commission mobility and transport, accident statistics; www.fueleconomy.gov; EEA car occupancy rates data; S. Heck and M. Rogers, *Resource revolution: How to capture the biggest business opportunity in a century,* 2014; Centre d'études sur les réseaux, les transports, l'urbanisme et les constructions publiques.

Most cities already have multiple transport options for users - shared cars, buses, trams, trains and shared bikes etc. However, the promise of multimodal mobility is to see these services working together to offer a complete user solution. This would likely take the form of an application that would identify the best mode(s) of transport. These services are already in operation in cities like Helsinki.

Encourage remanufacturing, which is about restoring an engine part that has been recovered from an old car, to a condition that is as close as possible to its original state and features. Production of remanufactured automotive parts began in 1949 in Choisy-le-Roi, and since then the factory has constantly diversified its production to include injector pumps, gearboxes, injectors and turbochargers.

The remanufacturing operation relies on a reverse logistics ecosystem of partner companies (see infographic) that collects the old parts, disassembles and verifies compliance, reassembles and then sells them as genuine and guaranteed parts within Renault's sales network.

The parts are 40% cheaper than the new parts, but pass the same quality control test as the new parts. Since 2012, the volume of engine parts that have received a second life through remanufacturing is quite significant.

Another point is to encourage active mobility, such as walking and cycling. They fit the vision of a circular economy because they are low-impact, low-cost, and have many associated economic and health benefits.

5 CONCLUSION

Measuring the scientific quality of a publication or magazine based only on statistical metrics, such as using the h index or the impact factor of a given journal or periodical, is not necessarily the most effective method. Since evaluating only this criterion within the overall context, it showed that the final sample represents a small part within the overall sample. One should consider the peculiarities of each area, or even the experience over the years of the researchers, as well as the relevance of the magazine and its reviewers. The method adopted was suitable for dealing with the large amount of data that the Scopus platform has available, being an important tool for reviewing the state of the art.

With regard to the qualitative analysis of the information contained in each publication, the work proved to be painstaking and repetitive, besides the need for prior and adequate technical knowledge. Thus, the important role that the IPCC plays in conjunction with its researchers and proofreaders and that they develop reports and all scientific production about each conference held and the publication of content on this theme.

Systematization and subsequent bibliometric analysis of a given collection is a very efficient tool for quantitatively evaluating the production produced in a given cut-off, but with the need for basic knowledge about programming language. The analysis was effective in identifying research nuclei that stand out in certain areas of knowledge, pioneering researchers in certain themes and research centers and universities of relevance. Another interesting result that the bibliometric analysis was capable of identifying were the thematic evolution over the years, and the tendency of the theme addressed.

The research carried out emphasized the important role of the academic community and of scientific research, which, in conjunction with the public and private power, guides the development of new technologies capable of solving current problems and of giving guidance in the formulation of guidelines capable of raising common well-being. As well as the public authorities and the funding mechanisms, they make it possible to review or develop new public environmental policies with a focus on climate change. Through the research carried out, it was found that through the development of these policies promotes the development of research and innovation.

To analyze the climatic context in which the objects of study (municipality of Natal/Brazil and Bologna/Italia) used the Climate Consultant software, software that uses annual observed climate data of EPW format that are made available in an open way for local climatic characterization. It would be interesting to develop software similar to Climateconsult, but using reanalysis data based on the same methodology used in the simulations of the socioeconomic scenarios used to make the climatic projections, with CPM6 models and the SSP scenarios made available by the IPCC.

From the point of view of climatic changes and their impacts on the built environment, there was difficulty in finding platforms that make available climatic data on a scale suitable for the urban context, and above all for the context of the built environment.

The projections made by the IPCC in the Fifth Assessment Report (AR5) indicate that the changes will occur even in different emission scenarios and that, if current levels are maintained, the forecast for the end of the century would be an increase of 2.6 to 4.8 degrees Celsius in the global average temperature, with an increase of 0.45 to 0.82 meters in sea level. The international scientific climate research community concluded that human activities are changing the Earth's climate in such a way as to increase the risks for cities. This conclusion is based on different types of evidence, including Earth's climate history, observations of changes in the recent climate history record, emerging new patterns of climate extremes, and global climate models (ROSENZWEIG et al., 2015). It is already recognized that cities are the main contributors to these emissions. Urban centers are responsible for the consumption of 70% of available energy and 40% of GHG emissions (ROSENZWEIG et al., 2011; ECF, 2014). Moreover, it is in the major urban centers that more than half of the world's population is concentrated.

The research found that we are inserted into an irreversible one, with impacts related to GHGS emissions and the effect of unprecedented global warming. Joint international action is needed so that the situation does not worsen. This suggests:

- the valuation of carbon through taxes, taxes, trade and regulation.
- development and innovation in low-carbon technologies.
- remove barriers and enable energy efficiency in all economic sectors.
- Reduce to the point of almost eliminating fossil fuel-based economic sectors;
- Reduce solid waste production (domestic, industrial, rubble, among others)
- Combating deforestation by strengthening forests and their biodiversity; by imposing fines, taxes, fees that deforestation causes damage to the environment;
- Developing the carbon market: to favor those who emit little and to increase non-polluting technological innovation;
- technological cooperation;

Effective responses to the adaptation of the existing infrastructure must be developed, this transition will depend on the international effort to create policies and measures at various scales: international, national and regional, supporting this transition and promoting transfer as well as funding.

The public authorities must highlight the sustainable socio-economic model by defining policies that favor energy efficiency and better use of natural resources in all urban activities, such as restrictive measures such as urban toll, minimum efficiency of vehicles, equipment and new constructions, support for the use of renewable energy, among others. Incentive measures are also welcome, such as: traffic priority for vehicles with full occupancy, tax reduction for homes and enterprises using renewable energy, for example. The success of these measures implies a change in the behavior of society and in the possible imbalance between the individual cost and the collective benefit. This means that for more efficient and cleaner technologies to be disseminated, it is necessary to have a mandatory public policy, as a requirement for minimum standards of efficiency, taxation, among other economic instruments.

Governance should support and develop the identification of vulnerabilities, plan their adaptation, and produce risk assessment and strategic management frameworks in the face of critical events, whether they are climate threats or opportunities arising from adaptability. Governance should from beginning to end, aim to contribute to processes to benefit diverse cities and plan responses to current extreme climate risks and future climate change. These responses include effective planning to safeguard all inhabitants from identified risks and in an equitable manner.

Circulation priority for vehicles with full occupancy, tax reduction for residences and enterprises using renewable energy, for example. Mandatory public policy, as a requirement of minimum standards of efficiency, taxation, among other economic instruments.
Creation of green spaces to improve drainage and reduce urban heat island effect. Protection of natural and artificial barriers. E.g. creation of dikes, marshy and humid areas as buffer to contain sea level rise etc.

Revision of laws and regulations related to building codes and regulations on the use of urban space. In order to require new constructions, and reform and retrofit, minimum requirements of resilience to climate change. For example, elevation of buildings so that areas under pilotis are flood-resistant (use of permeable floors), building protection works, restrict the expansion of buildings in coastal areas, prioritize constructions Eco-efficient constructions, which follow the principles of bioclimatology, with passive ventilation and built-in and operational energy efficiency of the building.

6 REFERENCES

ABNT. (1997). NBR 8160. *Sewage building systems - Design and installation*, pp. 1-74.

ABNT. (2005). NBR 15.220-3 Thermal performance in buildings. *Part 3: Brazilian bioclimatic zones and building guidelines for low-cost houses*. Retrieved from file:///C:/Users/Karilene%20Rochink/Downloads/NBR15220-3.pdf

ABNT. (2013). *NBR 15575Edificações habitacionais: desempenho.* Rio de Janeiro.

ABNT. (2019). NBR 16782. *Water conservation in buildings — Requirements, procedures and guidelines*, pp. 1-22.

ABNT. (2019). NBR 16783. *Use of alternative sources of on-potable water in buildings*, pp. 1-25.

Alves, E., & Vecchia, F. (2012). Influence of different surfaces on the temperature and energy flux: an experimental trial. *Ambiência, 8*, 101-111. doi:DOI:10.5777/ambiencia.2012.01.08

Aria, M. &. (2017). Bibliometrix: An R-tool for comprehensive science mapping analysis. *11(4),*.

BECK, H. e. (2018). Present and future Köppen-Geiger climate classification maps. *5:180214*. Sci. Data. doi:10.1038/sdata.2018.214

Berkeleyh Earth. (2020). Warming in Brazil. *2021 Temperature Report*. Retrieved from http://berkeleyearth.org/

Boehm, B. W. (1991). Software Risk Management: Principles and Practices. *IEEE Software, 8*, 32-41. doi: 10.1109/52.62930

Brasil. (2008). Estatuto das Cidades. (S. Federal, Ed.) *Lei n° 10.257 de 10 de Julho de 2011*, p. 102. Retrieved from https://www2.senado.leg.br/bdsf/bitstream/handle/id/70317/000070317.pdf

CAPES. (n.d.). (Coordenação de Aperfeiçoamento de Pessoal de Nível Superior) Retrieved Agust 07, 2020, from Plataforma Sucupira: https://sucupira.capes.gov.br/sucupira/public/consultas/coleta/veiculoPublicacaoQualis/listaConsultaGeralPeriodicos.jsf

Climate.gov. (2022). Climate Change: Atmospheric Carbon Dioxide. *Climate.gov*. Retrieved from https://www.climate.gov/news-features/understanding-climate/climate-change-atmospheric-carbon-dioxide

COMMISSION, European. (2005, february 9). Retrieved july 15, 2020, from Winning the Battle Against Global Climate Change : https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX%3A52005DC0035&from=RO

COMMISSION, European. (2018, Novembrer 28). *A Clean Planet for all.* Retrieved ottober 2020, from A European strategic long-term vision for a prosperous, modern, competitive and climate neutral economy: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52018DC0773&from=EN

COMMISSION, European. (2019, april 19). *COMMUNICATION FROM THE COMMISSION: The European Green Deal.* Retrieved april 16, 2020, from EUR-lex Access to European Union law: https://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1588580774040&uri=CELEX:52019DC0640

Comune di Bologna. (2020). Piano Urbanistico Generale. *Regolamento edilizio*. Bologna. Retrieved from http://sit.comune.bologna.it/alfresco/d/d/workspace/SpacesStore/4dbbe351-b42b-429f-b052-288455390fa5/RegolamentoEdilizio.pdf

Corbella, O., & Yannas, S. (2003). Em Busca de uma Arquitetura Sustentável para os Trópicos. (2.ed.), 305.

De Camprieu, R. D. (2007). 'Cultural'Differences in project risk perception: An empirical comparison of China and Canada. *Internacional Journal of Project Management*, 683-693. doi:10.1016/j.ijproman.2007.07.005

DECRETO DEL PRESIDENTE DELLA REPUBBLICA 26 agosto 1993, n. 412. (1993, gennaio 9). *Regolamento recante norme per la progettazione, l'installazione, l'esercizio e la manutenzione degli impianti termici degli edifici ai fini del contenimento dei consumi di energia, in attuazione dell'art. 4, comma 4, Ultimo aggiornamento all'atto pubblicato il 28/04/2022*. Italia. Retrieved from https://www.normattiva.it/uri-res/N2Ls?urn:nir:stato:legge:1993;412~%7B%7Dart2!vig=

ELSEVIER B.V. (n.d.). (Elsevier B.V) Retrieved july 27, 2020, from Scopus Preview: https://www.scopus.com/sources

ELSEVIER B.V. (n.d.). (Elsevier B.V) Retrieved July 27, 2020, from Science Direct: https://www.sciencedirect.com/

ELSEVIER B.V. (n.d.). (Elsevier B.V) Retrieved July 27, 2020, from Scopus: https://www.scopus.com/

Erell, E., Pearlmutter, D., & Williamson, T. (2011). Urban Microclimate: Designing the Spaces between Buildings. London: Earthscan.

European Commission. (2013). Guidelines on developing adaptation stratefies. Brussels, Belgium. Retrieved from https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52013SC0134&from=EN

European Union. (2010). Directive 2010/31/EU of the European Parliament and of the Council of 19 May 2010 on the energy performance of buildings. *Official Journal, 53*(L153), 13-35. Retrieved from https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2010:153:FULL:EN:PDF

Ferreira, L. S. (2019). Vegetação, temperatura de superfície e morfologia urbana: um retrato da região metropolitana de São Paulo. 195. São Paulo, Brasil: Repositório USP. doi:https://doi.org/10.11606/T.16.2019.tde-02102019-173844

FINK, A. (2005). *Conducting research literature reviews: From the Internet to paper (2nd ed.).* Thousand Oaks, CA: Sage.

Forster, P. e. (2007). Changes in Atmospheric Constituents and in Radiative Forcing. *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate*. (S. D. [Solomon, Compiler) Cambridge and New York, United Kingdom and USA: IPCC. Retrieved from https://www.ipcc.ch/site/assets/uploads/2018/02/ar4-wg1-chapter2-1.pdf

Friedlingstein, P., O'Sullivan, ,. M., Jones, ,. M., Andrew, ,. R., Hauck, ,. J., Olsen, ,. A., . . . Le Quéré, ,. C. (2020). Global Carbon Budget 2020. *Earth System Science Data, 12*(4), 72. doi:https://doi.org/10.5194/essd-12-3269-2020

Global Alliance for Buildings and Construction. (2021). *2021 Global Status Report for buildings and construction.* UNEP. Retrieved from https://globalabc.org/resources/publications/2021-global-status-report-buildings-and-construction

Grigg, D. (1965). The Logic Regional Systems. *Annals of the Association of American Geographers*, 465-491. doi:doi:10.1111/j.1467-8306.1965.tb00529.x

GUEDES, V. L. (2012, Agosto). A Bibliometria e a Gestão da Informação e do conhecimento científico e tecnológico: uma revisão da literatura. *PontoAcesso*, pp. 74-109.

HAWKINS, Ed e JONES, P.D. (2013). Notes and Correspondence On increasing global temperatures: 75 years after Callendar. *Quarterly Journal of the Royal Meteorological Society, 139*(DOI:10.1002/qj.2178).

Hersbach, H., Bell, B., Berrisford, P., Hirahara, S., Horányi, A., Muñoz-Sabater, J., . . . Jean-Noël, T. (2020). The ERA5 global reanalysis. *Quarterly Journal of the Royal Meteorological Society, 146*, 1999-2049. doi:https://doi.org/10.1002/qj.3803

Hersbach, H., Simmons, A., Berrisford , P., Dahlgren, P., Horányi, A., Muñoz-Sabater, J., . . . Thépaut, J.-N. (2021). The ERA5 global reanalysis: Preliminary extension to 1950. *Quarterly Journal of the Royal Meteorological Society*. doi:https://doi.org/10.1002/qj.4174

Hirsche, J. (2005, Sep 29). An index to quantify an individual's scientific research output. pp. 1-5. Retrieved from https://arxiv.org/pdf/physics/0508025.pdf

Huebner, G., Shipworth, D., Hamilton, I., Chalabi, Z., & Oreszczyn, T. (2015). Explaining domestic energy consumption – The comparative contribution of building factors, socio-demographics, behaviours and attitudes. *Applied Energy, 159*, 589-600. doi:https://doi.org/10.1016/j.apenergy.2015.09.028

Huebnere, G. M., Hamilton, I., Chalabi,D, shipworth, D, & Oreszczyn, T. (2015). xplaining domestic energy consumption – The comparative contribution of building factors, socio-demographics, behaviours and attitudes. *159*, pp. 589-600. Retrieved from https://www.sciencedirect.com/science/article/pii/S0306261915010983

IBGE. (2012). AItlas Geográfico Escolar Digital - Clima - Brasil. *Atlas geografico Escolar (versão Web)*, 1. Retrieved from https://geoftp.ibge.gov.br/produtos_educacionais/atlas_educacionais/atlas_geografico_escolar/mapas_do_brasil/mapas_nacionais/informacoes_ambientais/brasil_clima.pdf

IEA. (2020). Retrieved setembre 02, 2020, from The International Agency: https://www.iea.org/topics/buildings

IEA. (2021). *Tracking Buildings 2021.* Paris: IEA. Retrieved from https://www.iea.org/reports/tracking-buildings-2021

IPCC. (2012). Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation. *A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change*, 582. Cambridge and NY, UK and USA: Cambridge University Press. Retrieved from https://www.ipcc.ch/site/assets/uploads/2018/03/SREX_Full_Report-1.pdf

IPCC. (2013). Climate Change 2013: The Physical Science Basis. *Working Group I Report to the Fifth Assessment Report*, 151. Geneva, Switzerland: World Meteorological Organization (WMO). Retrieved from http://www.climatechange2013.org/images/report/WG1AR5_ALL_FINAL.pdf

IPCC. (2014). *Fifth Assessment Report (AR5): Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)].* Geneva, Switzerland: United Nations. Retrieved from Climate Change 2014: Synthesis Report: https://www.ipcc.ch/site/assets/uploads/2018/02/SYR_AR5_FINAL_full.pdf

IPCC. (2019). Special Report on the Ocean and Cryosphere in a Changing Climate. Retrieved from https://www.ipcc.ch/srocc/chapter/technical-summary/

IPCC. (2021). Climate Change 2021: The Physical Science Basis. *Working Group I contribution to the Sisth Assessment Report (AR6)*. Geneva, Switzerland: United Nations. Retrieved Setember 16, 2021, from https://www.ipcc.ch/report/ar6/wg1/downloads/report/IPCC_AR6_WGI_Full_Report_smaller.pdf

IPCC. (2021). *Climate Change 2021: The Physical Science Basis.* UNEP. Retrieved from https://www.ipcc.ch/report/ar6/wg1/downloads/report/IPCC_AR6_WGI_FullReport.pdf

IPCC. (2022). *Climate Change 2022: Impacts, Adaptation and Vulnerability.* UNEP. doi:doi:10.1017/9781009325844

IPCC. (2022). *Climate Change 2022: Mitigation of Climate Change.* UNEP. Retrieved from https://report.ipcc.ch/ar6wg3/pdf/IPCC_AR6_WGIII_SummaryForPolicymakers.pdf

IPCC. (2022). *Climate Change 2023: Mitigation of Climate Change.* UNEP. doi:https://www.ipcc.ch/report/ar6/wg3/downloads/report/IPCC_AR6_WGIII_Full_Report.pdf

Iturbide et.al, M. (2020). *An update of IPCC climate reference regions for subcontinental analysis of climate model data: definition and aggregated datasets.* Retrieved from permitiu aumentar o número de regiões para uma melhor representação de diferentes climas, resultando em um novo conjunto de 46 regiões de referência terrestres e 1https://essd.copernicus.org/articles/12/2959/2020/

KÖPPEN, W. (1936). Das Geographisca System der Klimate. 44. Berlin, Germany: Gebr, Borntraeger. Retrieved from http://koeppen-geiger.vu-wien.ac.at/pdf/Koppen_1936.pdf

KOTTEK, M. e. (2006). Retrieved outobre 2020, 07, from World Map of the Köppen-Geiger climate classification updated: http://koeppen-geiger.vu-wien.ac.at/pdf/Paper_2006.pdf

Kottek, M. G. (2006). *Climate Change and Infectious Diseases Group.* Retrieved from World Map of KöppenGeiger Climate Classification updated. Meteorol. Z., 15, 259-263pp: http://koeppen-geiger.vu-wien.ac.at/pdf/kottek_et_al_2006_A4.pdf

Kowalski, L. F. (2019). Influência do albedo de pavimentos no campo térmico de cânions urbanos: estudo de modelo em escala reduzida.

Kriticos, D. e. (2012). CliMond: global high-resolution historical and future scenario climate surfaces for bioclimatic modelling. *3*, 53-64. Methods in Ecology and Evolution. doi:doi: 10.1111/j.2041-210X.2011.00134.x

Lamberts, R., Dutra, L., & Perreira, L. (2014). Eficiência Energética na arquitetura. (3. ed.).

Lamberts, R., Ghisi, E., de Abreu, A., Carlo, J., Marinoski, D., Naranjo, A., & Duarte, V. (2016). Desempenho térmico de Edificações. 239.

Lin, Z., & Xu, H. (2016). A study of urban heat island intensity based on "local climate zones": A case study in Fuzhou, China. *2016 Fourth International Workshop on Earth Observation and Remote Sensing Applications*. Retrieved from https://www.researchgate.net/publication/308495792_A_study_of_Urban_heat_island_intensity_based_on_local_climate_zones_A_case_study_in_Fuzhou_China

Liu, B., Xie, Z., Qin, P., Liu, S., Li, R., Wang, L., . . . Shi, C. (2021). Increases in Anthropogenic Heat Release from Energy Consumption Lead to More Frequent Extreme Heat Events in Urban Cities. *Advances in Atmospheric Sciences, 38*, 430-445. Retrieved from https://link.springer.com/content/pdf/10.1007/s00376-020-0139-y.pdf

Lohmann, U., Sausen, R., Bengtsson, L., Cubasch, U., Perlwitz, J., & Roeckner, E. (1993). The Köppen climate classification as a diagnostic tool for general circulation models. *3*, 177-193. Clim. Res. Retrieved from https://www.int-res.com/articles/cr/3/c003p177.pdf

MILLER, A. A. (1931). Climatology. 304. London, UK: (Methuen and Co., Ltd.). doi:https://doi.org/10.1002/qj.49705824313

Nag A., K. D. (1999). Exposure limits of women in hot environment. *The Indian Journal of medical research, 110*, 138-144. Retrieved from https://pubmed.ncbi.nlm.nih.gov/10645102/

Nag, P. K. (1997). Human heat tolerance in simulated environment. *The Indian Journal of medical research, 105*, 223-234. Retrieved from https://pubmed.ncbi.nlm.nih.gov/9183079/

Nakicenovic, N., & Swart, R. (2000). *Special Report on Emissions Scenarios (SRES) – A Special Report of Working Group III of the Intergovernmental Panel on Climate Change.* IPCC. Retrieved from https://www.ipcc.ch/site/assets/uploads/2018/03/sres-en.pdf

National Research Council. (1979). *Carbon Dioxide and Climate: A Scientific Assessment.* Washington, DC: National Academy of Sciences. Retrieved from https://nap.nationalacademies.org/read/12181/chapter/1

NATIONS UNITED. (n.d.). *Glasgow Climate Pact.*

NATIONS, United. (2012). *United Nations Audiovisual Library of International Law.* Retrieved Agust 24, 2020, from https://legal.un.org/avl/pdf/ha/dunche/dunche_ph_e.pdf

NATIONS, United. (2015, October 21). Retrieved April 2020, from Transforming our world: the 2030 Agenda for Sustainable: https://www.un.org/ga/search/view_doc.asp?symbol=A/RES/70/1&Lang=E

NATIONS, United. (2015). *2030 Agenda for or sustainable development.* Retrieved from https://documents-dds-ny.un.org/doc/UNDOC/GEN/N15/291/89/PDF/N1529189.pdf?OpenElement

NATIONS, United. (2015, December 12). Conference of the Parties on its twenty-first session . *The Paris Agreement*. Paris, França: UNFCC. Retrieved from The Paris Agreement: https://unfccc.int/files/essential_background/convention/application/pdf/english_paris_agreement.pdf

NATIONS, United. (2018). *Global indicator framework for the Sustainable Development Goals and targets of the 2030 Agenda for Sustainable Development.* Retrieved from https://unstats.un.org/sdgs/indicators/Global%20Indicator%20Framework%20after%20refinement_Eng.pdf

NESBITT, K. (2006). *A Nova Agenda para a Arquitetura.* São Paulo: Cosac Naify.

NÓGREBA, R. (2010). Um pensamento crítico sobre classificações climáticas: de Köppen até Strahler. *03(01)*. Recife, Brasil: UFPE. Retrieved from https://periodicos.ufpe.br/revistas/rbgfe/article/viewFile/232646/26659

Oke, T. (1982). The energetic basis of the urban heat island. *Quarterly Journal of the Royal Meteor. Soc. , 108*, 1-24. Retrieved from http://www.patarnott.com/pdf/Oake1982_UHI.pdf

Oke, T. (2004). Initial Guidance to obtain representative meteorological observations at urban sites. *WMO/TD, Report nº 81*, 47. Retrieved from https://www.researchgate.net/publication/265347633_Initial_guidance_to_obtain_representative_meteorological_observations_at_urban_sites

OKOLI, C. (2015, November). A Guide to Conducting a Standalone Systematic Literature Review. *Communications of the Association for Information Systems*, pp. 879-910.

OKOLI, C. (2015, November). A Guide to Conducting a Standalone Systematic Literature Review. *Communications of the Association for Information Systems, 37*(https://aisel.aisnet.org/cais/vol37/iss1/43/), pp. 879-910.

Ong, B. (2003). Green plot ratio: an ecological measure for architecture and urban planning. *Landscape and Urban Planning, 63*, 197-211.

Peel, M., Finlayson, B., & McMahonT , T. (2007, Out). Updated world map of the Köppen-Geiger climate classification. *11*, 1633-1644. Hydrol. Earth Syst. Sci. doi:https://doi.org/10.5194/hess-11-1633-2007

Perreira, C. (2014). *Influencia da refletância e da emitância das susperfícies externas no desempenho térmico de edificações.* Tese de doutorado, Florianópolis.

Petticrew, M., & Roberts, H. (2006). Systematic Reviews in the Social Sciences: A PRACTICAL GUIDE.

Riahi, K., Vuuren, D., Kriegler, E., Edmonds, J., O'Neill, B., Fujimori, S., . . . Dellink, R. (2017). The Shared Socioeconomic Pathways and their energy, land use, and greenhouse gas emissions implications: An overview. *Global Environmental Change, 42*, 153-168. doi:https://doi.org/10.1016/j.gloenvcha.2016.05.009

Rochink, K. (2017). Requalificação de edifícios: anteprojeto arquitetônico do centro de convivência Djalma Marinha da UFRN com enfoque na eficiencia energética da envoltória. *Dissertação (Mestrado)*, 181. Retrieved from file:///C:/Users/Karilene%20Rochink/Downloads/RequalificacaoEdif%C3%ADciosAnteprojeto_Costa_2017%20(1).pdf

RORIZ, M. (2004). Software ZBBR.

RUBEL, F. a. (2010). *Climate Change and Infectious Diseases Group.* Retrieved from Observed and projected climate shifts 1901-2100 depicted by world maps of the K6oppen-Geiger climate classification: http://koeppen-geiger.vu-wien.ac.at/pdf/2026-2050_A1FI.pdf

RUBEL, F. a. (2010). Word Map of Köppen-Geiger Climate Classification: projected using IPCC A1FI Tyndall SC 2.03 - period 2076-2100. Retrieved from http://koeppen-geiger.vu-wien.ac.at/pdf/2076-2100_A1FI.pdf

Schurer, A., Mann, M., Hawkins, E., Tett, S., & Hegerl, G. (2017). Importance of the pre-industrial baseline for likelihood of exceeding Paris goals. *Nature Climate Change, 7*, 563-567. doi:https://doi.org/10.1038/nclimate3345

SOUZA, E. C. (2013). Impactos das mudanças climáticas sobre o bem-estar relacionado à saúde no Brasil.

Stern, N. (2006). *STERN REVIEW: The Economics of Climate Change.* UK.

Stewart, I., & Oke, T. (2012). Local Climate Zones for Urban Temperature Studies. *Bulletin of the American Meteorological Society, 93*, 1879-1900. doi:https://doi.org/10.1175/BAMS-D-11-00019.1

The World Bank. (2010). Retrieved from World Development Report 2010: Development and Climate Change: https://openknowledge.worldbank.org/handle/10986/4387

THORNTHWAITE, C. W. (1948). An Approach Toward a Rational Classification of Climate. Geographical Review. doi:https://doi.org/10.2307/210739

UNCCD. (1994). United Nations Convention to Combat Desertification. *In those Countries Experiencing serious drought and/or desertification particularly in Africa* . Retrieved from https://catalogue.unccd.int/936_UNCCD_Convention_ENG.pdf

UNEP. (2009, March). *United Nations Environment Programme.* Retrieved from Global Green New Deal: Policy Brief: https://wedocs.unep.org/bitstream/handle/20.500.11822/7903/A_Global_Green_New_Deal_Policy_Brief.pdf?sequence=3&amp%3BisAllowed=

UNFCCC. (2021). *Glasgow Climate pact.* Retrieved from https://unfccc.int/sites/default/files/resource/cop26_auv_2f_cover_decision.pdf

United Nations. (1945). *Charter of the United Nations: Statute of the international court of justice.* San Francisco: UN. Retrieved from https://treaties.un.org/doc/publication/ctc/uncharter.pdf

VOM BROCKE, J. e. (2009). *Reconstructing the Giant: On the Importance of Rigour in Documenting the Literature Search Process.* Verona/IT: Conference: 17th European Conference on Information Systems (ECIS).

Webber, M. E. (2016). Thirst for Power: Energy, Water and Human Survival. *International Journal of Environmental Studies, 73*(5), pp. 857-858. doi:DOI: 10.1080/00207233.2016.1199415

WMO World Meteorological Organization. (2020, November 23). WMO Greenhouse Gas Bulletin No.16. *The State of Greenhouse Gases in the Atmosphere Based on Global*. UNITED NATIONS. Retrieved from https://library.wmo.int/doc_num.php?explnum_id=10437

WorkSafeBC. (2008). OHS Guidelines Part 7: Noise, Vibration, Radiation and Temperature. Retrieved from https://www.worksafebc.com/en/law-policy/occupational-health-safety/searchable-ohs-regulation/ohs-guidelines/guidelines-part-07#SectionNumber:G7.27_1

Zanetti, V., de Sousa Junior, W., & de Freitas, D. (2016). A Climate Change Vulnerability Index and Case Study in a Brazilian Coastal City. *Sustainability, 8*, 811. doi: https://doi.org/10.3390/su8080811