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FUTURE EFFECTIVENESS OF PASSIVE HOUSE DESIGN STRATEGIES

EFECTIVIDAD A FUTURO DE LAS ESTRATEGIAS DE DISEÑO PASIVAS EN VIVIENDAS

EFICÁCIA FUTURA DE ESTRATÉGIAS DE PROJETO PASSIVO EM HABITAÇÃO

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RESUMEN

Las estrategias de diseño arquitectónico pasivo han sido una respuesta efectiva a la crisis energética del siglo XX. En climas templados, su integración resulta en comportamientos térmicos en los que se combinan el confort interior y la eficiencia energética. Sin embargo, los escenarios de cambio climático proyectados a futuro no ofrecerán los mismos rendimientos, resultando dichas estrategias menos efectivas. El objetivo de este trabajo es la cuantificación del cambio relativo en la efectividad de las estrategias de diseño pasivas en viviendas para clima árido templado-frío (Bwk), tomando como ejemplo la ciudad de Mendoza (Argentina). Respecto de las proyecciones de clima futuro para clima árido cálido (Bwh), utilizando el escenario RCP8.5 del CMIP5, equivalente al escenario SSP85 del CMIP6 del IPCC, los resultados muestran una disminución del 20% en la cantidad de horas en confort anual, con un incremento del 24% en la necesidad de estrategias pasivas de verano.

Palabras clave
cambio climático, arquitectura sustentable, viviendas unifamiliares

ABSTRACT

Passive architectural design strategies have been an effective response to the energy crisis of the 20th century. In temperate climates, their integration results in thermal behaviors that combine indoor comfort and energy efficiency. However, projected future climate change scenarios will not offer the same performances, resulting in such strategies being less effective. The objective of this work is to quantify the relative change in the effectiveness of passive design strategies in dwellings for arid temperate-cold climates (Bwk), taking the city of Mendoza (Argentina) as an example. Regarding future climate projections for warm arid climates (Bwh), using the CMIP5's RCP8.5 scenario, equivalent to the IPCC's CMIP6 SSP85 scenario, the results show a 20% decrease in the number of hours in annual comfort, with a 24% increase in the need for passive summer strategies.

Keywords
climate change, sustainable architecture, single-family houses.

RESUMO

As estratégias de projeto arquitetônico passivo têm sido uma resposta eficaz à crise energética do século XX. Em climas temperados, sua integração resulta em comportamentos térmicos que combinam conforto interno e eficiência energética. No entanto, os cenários de mudanças climáticas projetados para o futuro não oferecerão os mesmos desempenhos, tornando essas estratégias menos eficazes. O objetivo deste trabalho é quantificar a mudança relativa na eficácia das estratégias de projeto passivo em habitações para clima árido temperado-frio (Bwk), tomando como exemplo a cidade de Mendoza (Argentina). Com relação às projeções climáticas futuras para o clima árido quente (Bwh), usando o cenário CMIP5 RCP8.5, equivalente ao cenário CMIP6 SSP85 do IPCC, os resultados mostram uma redução de 20% no número de horas de conforto anual, com um aumento de 24% na necessidade de estratégias passivas de verão.

Palavras-chave
mudanças climáticas, arquitetura sustentável, habitações unifamiliares.

INTRODUCTION

Argentina has seen unfavorable climate changes since the second half of the last century, which, according to climate model projections, could intensify this century (Agosta et al., 2015) (Flores-Larsen et al., 2019). As a result of these changes, heat waves have become commonplace throughout the region.

An intense heat wave began in mid-December 2013, the longest and most intense recorded until 2021, which lasted until almost mid-January and geographically covered the center of Argentina, including Buenos Aires, Córdoba, and Mendoza, with maximum temperatures above 40 °C and minimum temperatures above 24 °C.

Electricity distribution collapsed in many sectors of the Buenos Aires metropolitan area; the result of record consumption due to the intensive use of air conditioning equipment. More recently, between December 2022 and February 2023, 10 heat waves were recorded in Argentina, 3 of which were particularly intense and prolonged. Figure 1 presents the records of said temperature anomalies.

Climate change is having and will have major impacts on buildings' energy consumption and the design of future buildings should consider this. The building sector, including the residential and commercial sectors, is responsible for between 30% and 40% of the world's total energy demand and emits one-third of the world's GHG emissions (Bhamare et al., 2019). Likewise, energy use and related emissions are expected to double, or even triple, by mid-century due to several key trends, especially as population living standards rise. In this context, buildings represent a critical part of a low-emission future and, at the same time, a global challenge for integration with sustainable development (Barea, 2022; Flores-Larsen et al., 2019; Flores-Larsen et al., 2021; Ganem et al., 2021; Rubio et al., 2015; Ruiz et al., 2022; Sánchez et al., 2017).

It is important to point out that the severity of the weather has a great influence on building design. Therefore, a thorough review of current architectural designs and the adoption of new strategies adapted to climate change are required. The potential for energy savings in both new and existing buildings ranges from 50% to 90% (Chalmers, 2015).

According to Lacaze et al. (2021), said saving potential depends on the strategy implemented in the building. These authors prepared an energy consumption estimate and identified the most favorable alternatives for consumption savings, GHG emissions, and their associated costs. Figure 2 shows the estimated savings by implementing efficient materials, certified equipment, and smart devices for Argentina.

Elias (2017) and Brager and de Dear (1998) have suggested that predictions about future climate conditions in different cities should be known to design buildings and optimize their thermal comfort

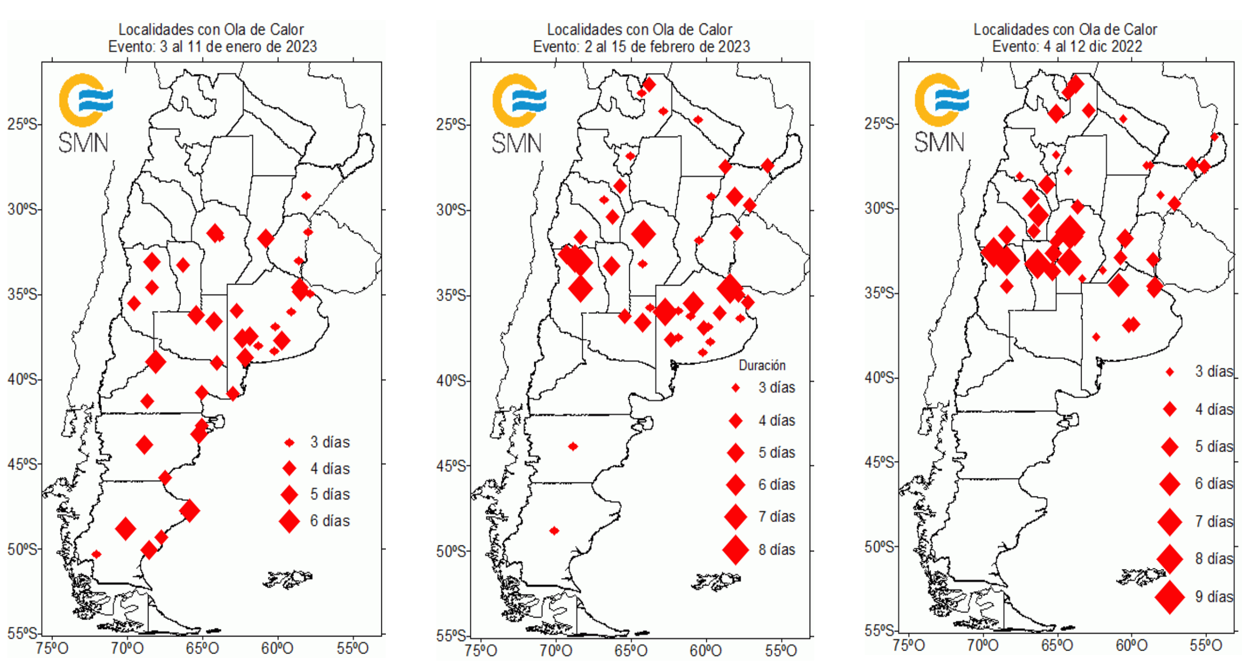

Figure 1. Heat waves recorded in Argentina during the 2022-2023 summer period. From left to right: a) December 4th to 12th, 2022; b) January 3rd to 11th, 2023, and c) February 2nd to 15th, 2023. Source: Argentine National Meteorological Service. (2022, 2023a, and 2023b)

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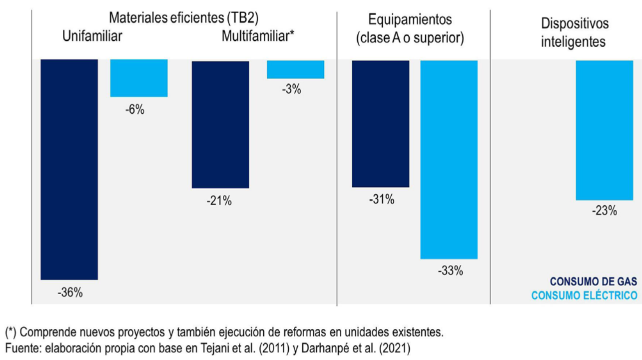

Figure 2. Savings percentage estimate by model and intervention strategy. Source: Lacaze et al., 2022.

in the coming years, without burdening the ecosystem with further environmental degradation. In this way, any changes can be anticipated and their effects counteracted through energy efficiency, better design, and, ultimately, energy savings (Li et al., 2012).

In Argentina, the Center for Marine and Atmospheric Research (CIMA, in Spanish) prepared a report on climate trends (second half of the 20th century) and a projection of the future climate (21st century) as part of the reference studies for the third National Report to the United Nations Framework Convention on Climate Change (3CN Cima, 2022). The study focuses on the observed and projected trends of surface temperature and precipitation and on some of the extreme indices that can cause relevant impacts.

Considering what has been said, the main goal of this work is to quantify the relative change in the effectiveness of passive design strategies in housing, in a temperate-cold arid climate (Bwk), using the city of Mendoza (Argentina) as a case study.

This will make it possible to identify the design measures that will gain or lose importance due to global warming and the correlation between the effectiveness of the passive systems analyzed. The results of the analysis will be directly applicable to building designers. Likewise, this work tries to contribute to the development of methodologies to prepare climate change files for dynamic building simulation.

METHODOLOGY

Initially, the bioclimatic potential of the temperate continental climate of Argentina (Mendoza, -33° 9′ LS, 69° 15′ LO) was analyzed using the BcChart tool (Košir, 2018).

The analysis of the bioclimatic potential correlates the essential climatic characteristics, such as air temperature, relative humidity, and solar radiation, with the ability to achieve comfort for the building's occupants through passive solar systems. This study allows representing, through passive potential, the climatic adaptation of buildings for

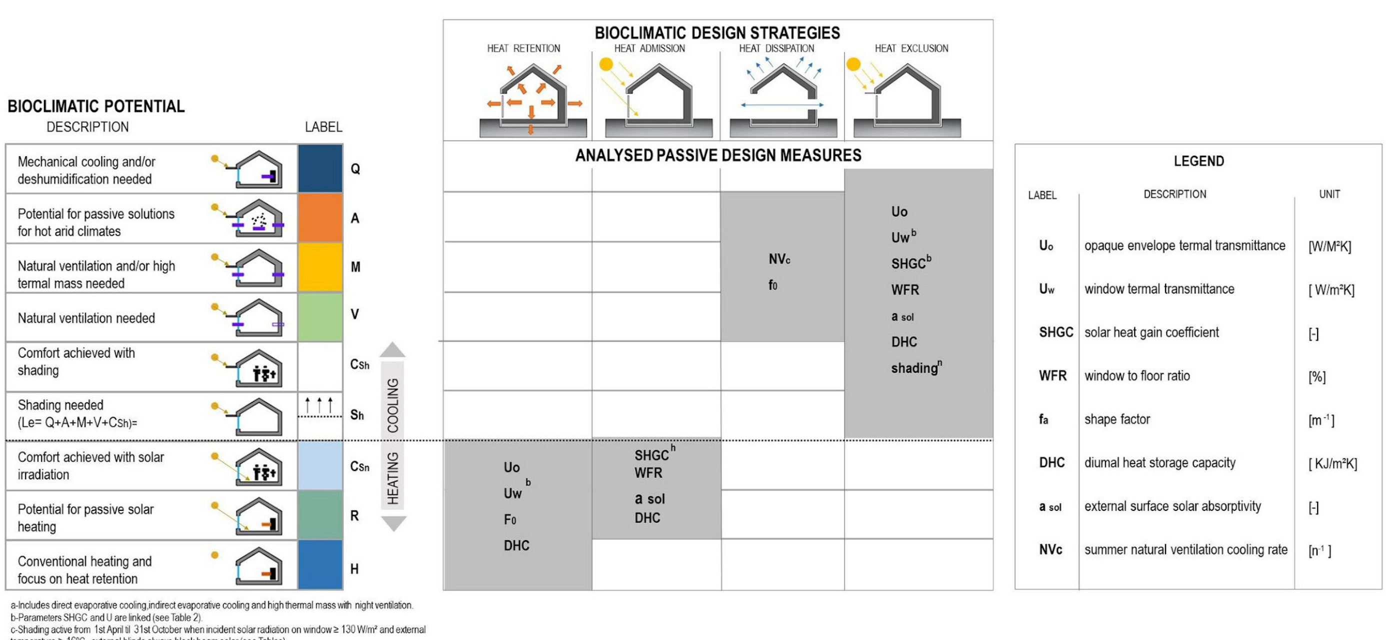

Figure 3. Bioclimatic potential measures calculated by BcChart as well as the passive design measures analyzed. Source: Košir et al., 2017; Košir, 2019.

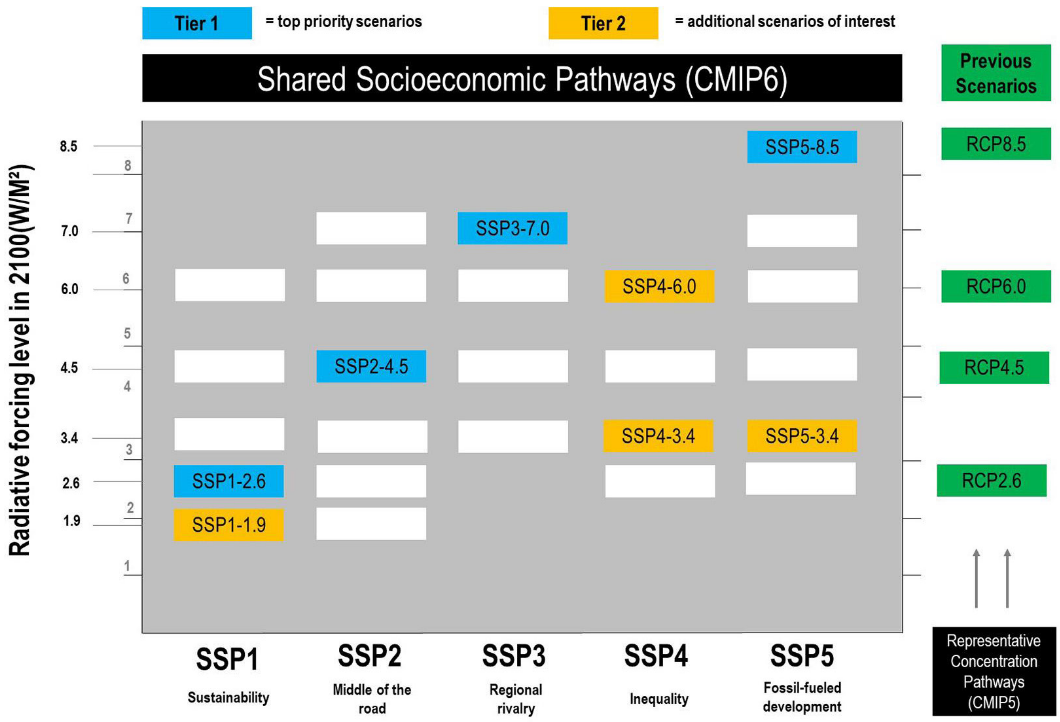

Figure 4. Shared socio-economic pathways and 2100's radiative forcing combinations used in MIP Scenario. Source: O'Neill et al., 2016.

the studied climate. The calculations are based on Olgyay's bioclimatic graph theory (1963), using air temperature, relative humidity (RH), and global solar radiation. The comfort zone is defined as between 21 °C and 27 °C with an RH between 20% and 80 %.

The combinations of the climatic variables will determine whether certain passive solutions can be used to achieve thermal comfort, or whether active systems (mechanical cooling, conventional heating) will be needed.

Figure 3 presents the definitions of each bioclimatic potential determined by BcChart. The relationship between the bioclimatic potential and the passive design measures analyzed is indicated whenever a certain design measure can be used to facilitate a better passive thermal response of a building and, consequently, greater energy efficiency.

Subsequently, how the bioclimatic potential of the studied climate would be changed towards 2100 was analyzed. The choice of that specific year responds to the following hypotheses: First of all, it is important to clarify that, although the average life cycle of a building is approximately 50 years, some buildings are designed and built to last longer. On the other hand, it is expected that, by that time, the effects of climate change will be more evident and may have a significant impact on the behavior and energy efficiency of buildings.

For this, future climate scenario data from the IPCC were used. The IPCC's Fifth Assessment Report has defined four new emission scenarios, the so-called Representative Concentration Pathways (RCP), which take into account the effects of 20th-century policies on climate change mitigation.

The total radiative forcing (RF) predicted for 2100 ranges from 2.6 to 8.5 W/m^2. The four RCPs comprise a scenario where mitigation efforts lead to a very low level of forcing (RCP 2.6), two stabilization scenarios (RCP 4.5 and RCP 6.0), and one scenario (RCP 8.5) with a very high level of GHG (greenhouse gas) emissions.

It is important to mention that, until the middle of the 21st century, the differences in the results between the RCPs are very small, as the climate system responds relatively slowly to changes in GHG concentration. Therefore, the RCP 8.5 scenario has been taken for subsequent analyses, as it provides a much faster warming and more pronounced changes in important indicators such as river flow, temperature, and precipitation.

The IPCC's sixth assessment report (AR6) has been fed with the development of a new set of scenarios, called SSP, which is formed through the Coupled Model Intercomparison Project 6 (CMIP6) of the World Climate Research Program (WCRP), which updates the CMIP5's RCP. The new scenarios represent different socio-economic developments, as well as different pathways of greenhouse gas concentration in the atmosphere (Falco et al., 2019; López-Franca et al., 2016).

Figure 4 shows a matrix representing all possible combinations of SSP and radiative forcing (RCP), which are color-coded to show the priority of each scenario. The level 1 or top priority scenarios are SSP1-2.6, SSP2-4.5, SSP3-7.0, and SSP5-8.5 (in blue). Three of the four Level 1 scenarios are updated versions of previous CMIP5 CPR scenarios (RCP2.6, RCP4.5, and RCP8.5) to facilitate the comparison between CMIP5 and CMIP6 projections. The Level 2 scenarios are SSP1-1.9, SSP4-6.0, SSP4-3.4, and SSP5-3.4 (in orange). All other combinations of radiative forcing and SSP are not feasible or are not designated as a priority by ScenarioMIP (O'Neill et al., 2016). As observed in Figure 4, the RCP8.5 scenario of the CMIP5, which is the one that has been used in this work, is equivalent to an SSP85 scenario of the CMIP6, with a priority of 1.

The methodology used to generate the future hourly data is known as *morphing* (Jentsch et al., 2008), which is a method that uses both a real-time weather file and predictions of average future monthly data of the variable of interest. Using mathematical "displacement" and "stretching" transformations based on the present and future monthly averages of the variables, a present weather file is transformed into a future weather file. The nature of the transformations ensures that the relationship between the meteorological variables is maintained in the future meteorological file. From this article, the current hourly data were those of the Typical Meteorological Year (TMYx) based on the averages of the 2007-2020 period.

For future predictions, the ACCESS 1-3[1], RCP8.5, r1i1p1 model was adjusted (with a grid of 1.875 by 1.25 degrees; or 68.7km by 111.1 km), with CRU TS4.05 reanalysis observational data, to corroborate the goodness of fit in the area of study. Data were taken from 1901 to 2021.

It is important to note that the ACCESS 1-3 model has been used in other studies to simulate the climate in regions of continental temperate climates similar to the case study (Bi et al., 2020; Lorenz et al., 2014; Stone et al., 2016; Ziehn et al., 2020).

To quantify the agreement between the reanalysis data and the future model (annual average data), the following widely used calculated statistical indicators were used: d (Equation 1), MAE (Equation 2), RMSE (Equation 3), and BIAS (Equation 4):

$$d = 1 - \frac{\sum_{i=1}^{n} (obs_i - sim_i)^2}{\sum_{i=1}^{n} \left(|sim_i - \underline{obs}| + |obs_i - \underline{obs}|\right)^2} \quad \text{(Equation 1)}$$

$$MAE = \frac{1}{n}\sum_{i=1}^{n} |sim_i - obs_i| \quad \text{(Equation 2)}$$

$$RMSE = \sqrt{\frac{1}{n}\sum_{i=1}^{n} (sim_i - obs_i)^2} \quad \text{(Equation 3)}$$

$$BIAS = \frac{1}{n}\sum_{i=1}^{n} (sim_i - obs_i) \quad \text{(Equation 4)}$$

Where:
d = Concordance or Willmott index
MAE = Mean absolute error
RMSE = Mean square error.
BIAS = Mean error
simi = Future model data
obsi = Measured reanalysis data
obs = Mean measured reanalysis data
n = Sample size

Then, anomalies were analyzed for 50-year periods up to 2100, and future EPWs were put together. The data were downloaded from the Climate Explorer site of the KNMI (Koninklijk Nederlands Meteorologisch Instituut), for Mendoza, Argentina.

It should be mentioned that, as a limitation of the study and also for this work, the terrestrial temperature variable was taken every 3hs (from the ACCESS 1-3 RCP8.5 model, or *r1i1p1*). Subsequently, they were interpolated to obtain hourly data. The other climatic variables were extracted from the original TMYx. Energy Plus' Weather converter software was used to set up the future EPW.

RESULTS AND DISCUSSION

The results of the study are presented in two sections. The first part presents the bioclimatic analysis of the studied locality (Mendoza) with the current climate, TMY. The influence of climate change on bioclimatic strategies is shown below.

1 ACCESS 1-3 is a global climate model developed by the CSIRO Research Center in Australia and the Joint Research Center of the European Commission. It is used in climate change studies and future climate projections, as it can simulate changes in surface temperatures, precipitation, wind, cloud cover, sea level, and other climatic factors.

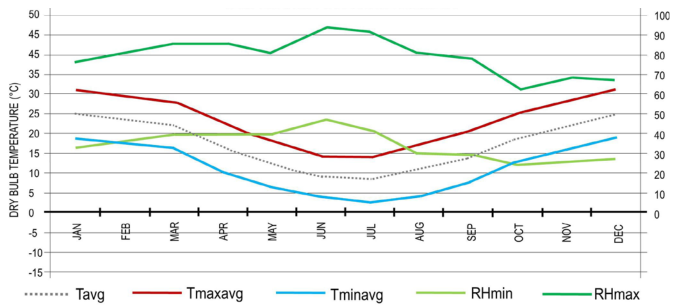

Figure 5. Relative humidity and temperatures of Mendoza. Source: Prepared by the authors using the BcChart software.

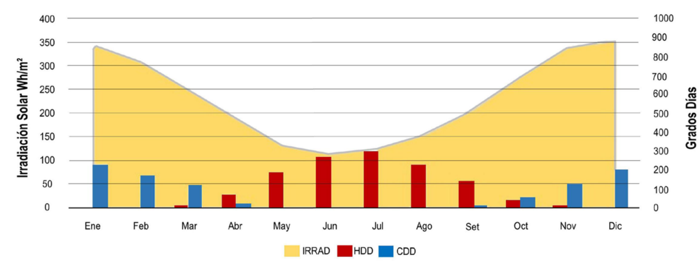

Figure 6. HDD and CDD function of solar irradiance. Source: Preparation by the authors.

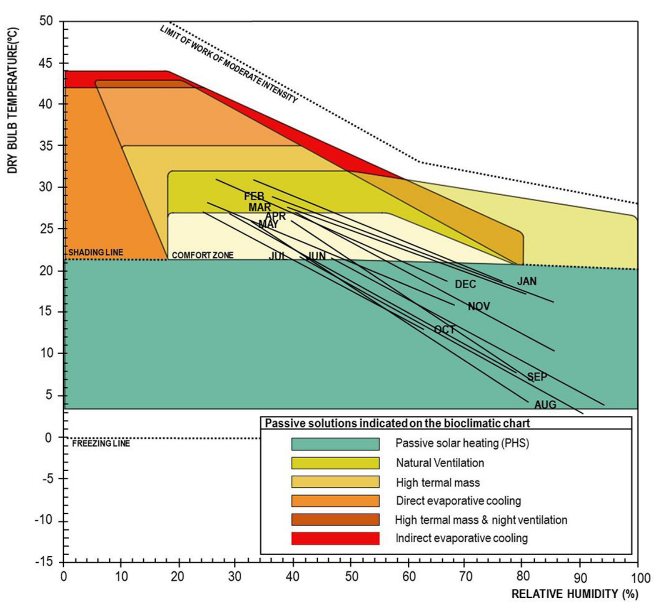

Figure 7. Givoni's chart as modified by Košir et al. (2017), with current data for Mendoza, Argentina. Source: Preparation by the authors using BcChart software.

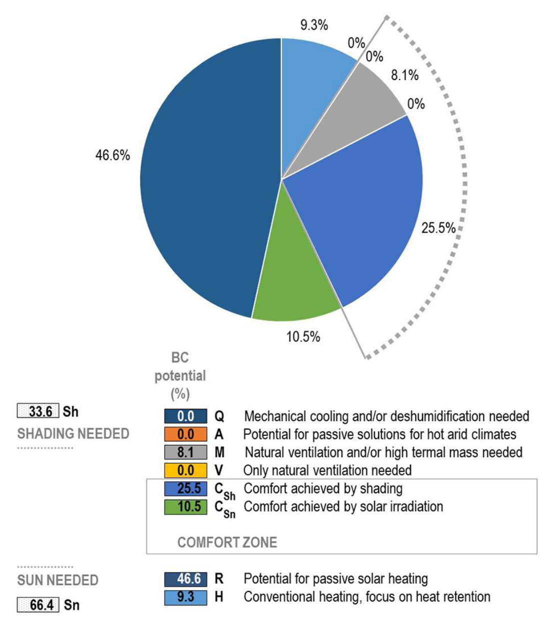

Figure 8. Bioclimatic potential with the current climate. Source: Preparation by the authors using the BcChart software.

BIOCLIMATIC POTENTIAL WITH CURRENT CLIMATE

Mendoza has a cold temperate continental desert climate with significant daily and annual variations. According to the Koeppen classification (Kottek et al., 2006), it has a Bwk climate. The letter "B" defines a dry climate, the letter "w" refers to annual rainfall below 250 mm, and the letter "k" is related to annual average temperatures below 18°C. Therefore, the Bwk nomenclature refers to an arid-temperate-cold climate. Figure 5 shows the monthly maximum, minimum, and average temperatures, along with the monthly minimum and maximum relative humidity. The average annual temperature is 17.2 °C, with the monthly average temperature of January (summer) being 24.8 °C., and for July (winter), the monthly average temperature is 8.2 °C.

The annual HDD (Heating Degree-Days, base 18.3) is 1231 HDD, while the CDD (Cooling degree-days, base 18.3) is 911 CDD (Figure 6). This shows the monthly need for heating and cooling.

The bioclimatic potential can be a practical starting point to define climate-appropriate building design strategies. Figures 7 and 8 show the possible bioclimatic solutions with the current climate data. Figure 7, which follows Olgyay's graph (1963), shows the monthly data on passive strategies. The tool's authors add the influence of the average and maximum daily solar irradiance received, which modifies the original graph (Košir & Pajek, 2017).

Most of the data are on the passive solar heating strategy and, to a lesser extent for the intermediate

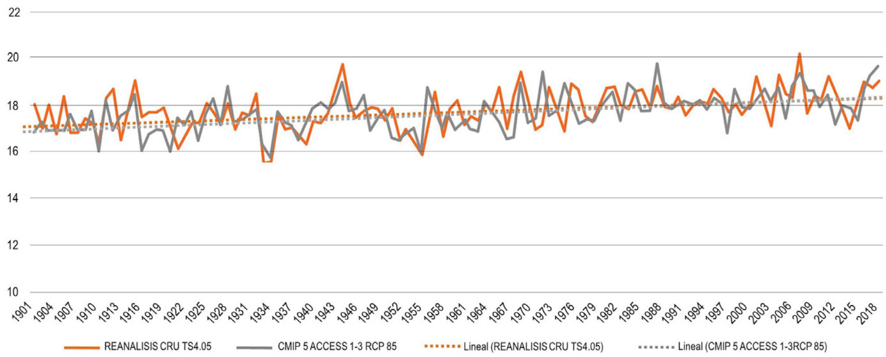

Figure 9. Comparison of annual mean temperatures from 1901 to 2020: CRU TS4.05 and the ACCESS 1-3 climate simulation model. Source: Preparation by the authors.

and summer months, natural ventilation combined with indoor thermal mass.

In Figure 8, it can be seen that the passive strategy requirements are divided into two groups: Shading Needed – Nh, and Sun Needed – Sn. The strategies to dissipate heat (SH) have a potential of 33.6% (8.1% of natural ventilation with thermal mass, and 25.5% by the use of shading). Note that the strategies for hot arid climates are at 0% because Mendoza is an arid-temperate-cold climate, where the combination of ventilation and shading suffice to achieve comfort through passive natural conditioning strategies. On the other hand, the strategies to collect solar radiation (Sn) have a potential of 66.4% (46.6% by passive solar heating, 9.3% by auxiliary heating, and 10.5% in comfort by the use of direct solar radiation).

INFLUENCE OF CLIMATE CHANGE ON PASSIVE HOUSING STRATEGIES

As anticipated in the methodology section, a CMIP5 model (ACCESS 1-3) was chosen to set up future EPW files and adjusted with the reanalysis data measured (CRU TS4.05). The period analyzed was from 1901 to 2020. Figure 9 shows the adjustment of the annual average temperatures of both models.

The results of the statistical indicators, as seen in Table 1, show acceptable errors according to the ASHRAE Guideline 14 (Clarke et al., 1993). The *BIAS* between the data results is 0.099°C. The mean absolute error *MAE*, discarding the outliers, turns out to be 0.68°C on average. When analyzing the coefficient of concordance *d*, this is 72%. Finally, the standard deviation of the residual values, *RMSE*, is 0.88°C.

Table 1. Statistical indicators of the fit between the CRU TS4.05 reanalysis data and the ACCESS 1-3 model for the RCP8.5 scenario. Source: Preparation by the authors.

INDICATORS	CRU TS4.05 vs ACCESS 1-3 RCP8.5
d	0.72
MAE (°C)	0.68
RMSE (°C)	0.88
BIAS (°C)	0.099

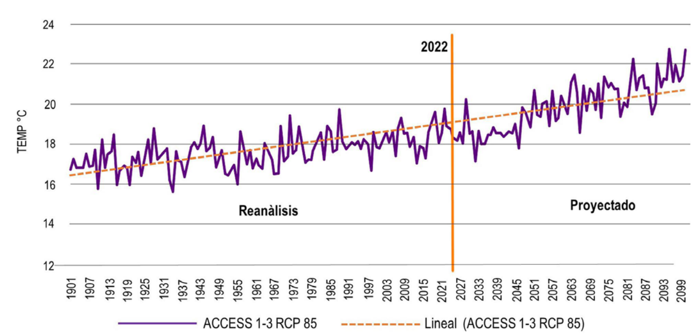

Figure 10. Average annual temperatures, RCP8.5. Source: Preparation by the authors.

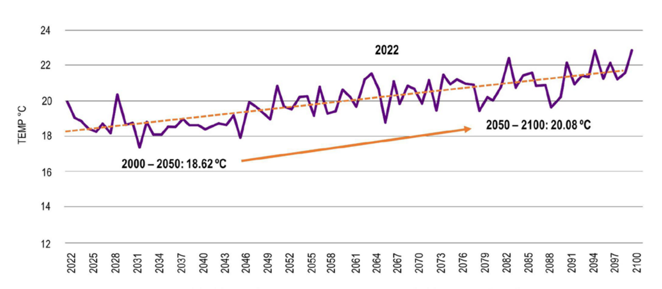

Figure 11. Average annual temperatures for the RCP8.5 scenario, future period, 2022-2100. Source: Preparation by the authors.

Table 2. Comparison of observed changes over 50-year periods. Source: Preparation by the authors.

	ACCESS 1-3	Difference to the base period 1900-1950
1900-1950	17.37	
1950-2000	17.77	0.40
2000-2050	18.62	0.85
2050-2100	20.80	2.18

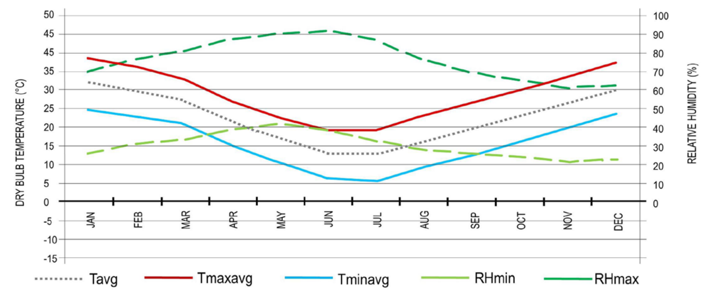

Figure 12. Temperatures and relative humidity in 2100 for Mendoza. Source: Preparation by the authors using the BcChart software.

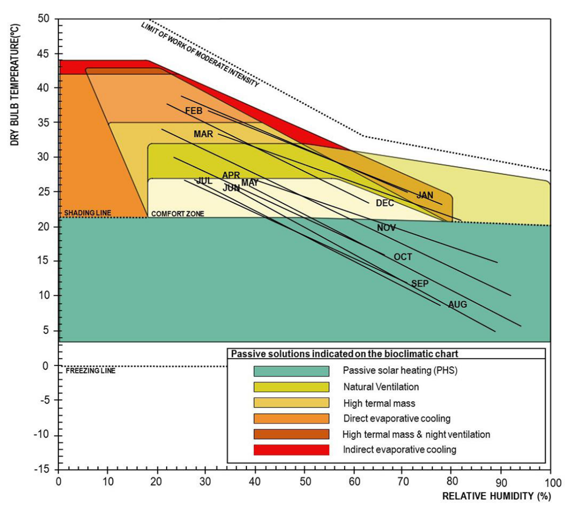

Figure 13. Temperatures and relative humidity in 2100. Source: Preparation by the authors using the BcChart software.

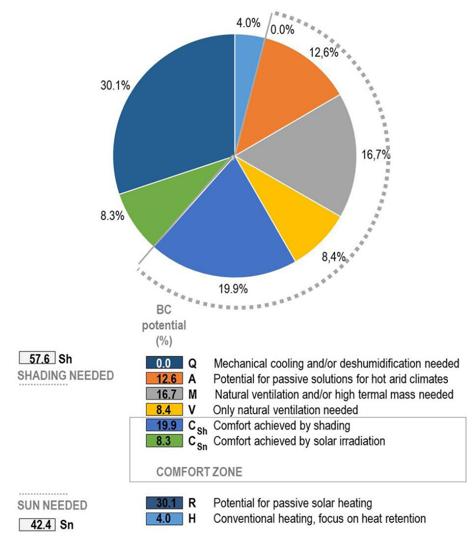

Figure 14. Future bioclimatic potential, 2100. Source: Preparation by the authors using the BcChart software.

Figure 10 shows the average annual temperatures of the calibrated model, from 1901 to 2100, for the RCP 8.5 scenario.

Figure 11 shows the data predicted for the future in the range between 2022-2100. Here, the temperature increase trend towards 2100 can be seen. If the anomalies in 50-year periods since 1900 are compared, the temperature towards 2100 could increase by around 2.18°C compared to the pre-industrial period for the climate studied, as can be seen in Table 2.

With the adjusted ACCESS1-3 model, the data were used to put together the *EPW* and to simulate the projected effect of climate change on the bioclimatic potential for Mendoza (Figure 12) in BcChart. The average annual temperature for 2100 is expected to be 22.50°C (5°C more than the current *TMY*), while for January of that year, the monthly average temperature is 31.88°C (7°C higher than the current one). It is expected that in July, the monthly average temperature will exceed the current one by 4.4°C (12.7°C).

The results of Figure 13 and Figure 14 clearly show that the bioclimatic potential is expected to shift towards the heat dissipation strategies.

Figure 14 shows that the Shading needed, *Sh*, is estimated at 57.6%, i.e., 24% more than the current climate. Within this percentage, there was a considerable increase (from 0% to 12.6%) in strategy A, which refers to a set of passive solutions for arid and hot climates, including direct and indirect evaporative cooling and the use of thermal mass with natural ventilation. The need to integrate passive strategies in the design for hot arid climates means that the average annual temperature is estimated to be above 18°C by 2100. The climate that today is classified as *Bwk* will become *Bwh*, i.e., hot arid climate, with precipitation below 250 mm, so the use of evaporative cooling is possible. The comfort zone, from using shading, is estimated to decrease from 25.5% to 19.9%.

For winter strategies, *Sn*, its potential is expected to decrease from 66.4% to 42.4%, which leads to a decrease in all the strategies inherent in the collection of solar radiation and thermal heat. The potential of passive heating will increase from 46.6% to 30.1% and auxiliary heating from 10.5% to 4%.

CONCLUSION

This paper addresses the impact of climate change on the effectiveness of passive strategies and the adaptation opportunities of buildings in different extreme future conditions, according to CMIP5's RCP8.5 scenario, equivalent to the SSP85 scenario of IPCC's CMIP6, in an arid-temperate-cold (Bwk) climate today, and in the future an arid-warm (Bwh) one, with important daily and annual variations.

This is a contribution to a relevant issue in passive and energy-efficient architecture: Would the current design still be energy-optimized in future emission scenarios?

Architectural design faces a double challenge: on one hand, buildings must work well today, achieving thermal comfort with close to zero consumption. On the other hand, they must be able to adapt to future climate scenarios, so it is very important to recognize the main trends and take into account the big picture.

The work contributes to the methodological development in the preparation of future climate files according to climate change projections (IPCC) for the dynamic simulation of buildings, with specific scope to the terrestrial temperature. A CMIP5 model is chosen (in this case, ACCESS 1-3 RCP8.5) to build future EPW files, and adjusted with measured reanalysis data (CRU TS4.05). The choice of this model is based on its high degree of fit and the availability of data for the region. Therefore, this work limits its results, discussions, and conclusions to the scenarios calculated with this model.

The dynamic simulation of buildings with the author's climate files, adjusted and validated for both the current and future situation, is consolidated as an indispensable tool to assess design decisions from a holistic perspective, which guarantees the proper operation of our buildings throughout their service life. The transfer of the results obtained to the building designers makes it possible to know which passive strategies will gain or lose importance due to climate warming and the relative magnitude of this change.

For the case presented in Mendoza (Argentina), annual average temperatures could increase by 5°C by 2100, with increases of 7°C in the summer monthly averages, and 4.4°C in the winter monthly averages. The results show a 20% decrease in the number of hours spent in comfort with a 24% increase in the need for passive summer strategies.

Regarding the latter, currently, the main passive strategies recommended are shading or radiation protection and natural ventilation, together with the incorporation of thermal mass in the envelope. To cope with future climate change scenarios, these strategies will need to incorporate direct and indirect evaporative cooling. This is because the current temperate climate will become a warm climate with average annual temperatures above 18°C and, due to the low relative humidity, these will have a high degree of effectiveness. If the arid territory where water scarcity is a constant is added to this situation, the research related to the correct design of passive strategies in housing becomes increasingly important.

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BIBLIOGRAPHIC REFERENCES

Agosta, E., Araneo, D., Camilloni, I., Carril, A., Doyle, M., Frumento, O., Nuñez, M., Ortiz de Zárate, M., Penalba, O., Rusticucci, M., Saulo C., & Solman. S. (2015). Tendencias y Proyecciones: Centro de Investigaciones del Mar y la Atmósfera (CIMA). *En Tercera Comunicación Nacional sobre Cambio Climático*. Secretaría de Ambiente y Desarrollo Sustentable de la Nación.

Barea, G., Mercado, M. V., Filippín, C., Monteoliva, J. M., & Villalba, A. (2022). New paradigms in bioclimatic design toward climatic change in arid environments. *Energy and Buildings*, *266*, 112100. DOI: https://doi.org/10.1016/j.enbuild.2022.112100

Base de Datos Climáticos. (2022). *3ra Comunicación Nacional de la República Argentina a la Convención Marco de las Naciones Unidas sobre Cambio Climático (3CN CIMA)*. Recuperado de: http://3cn.cima.fcen.uba.ar/

Bhamare, D. K., Rathod, M. K., & Banerjee, J. (2019). Passive cooling techniques for building and their applicability in different climatic zones—The state of art. *Energy and Buildings*, *198*, 467–490. DOI: https://doi.org/10.1016/j.enbuild.2019.06.023

Bi, D., Dix, M., Marsland, S., O'Farrell, S., Sullivan, A., Bodman, R., Law, R., Harman, I., Srbinovsky, J., Rashid, H. A., Dobrohotoff, P., Mackallah, C., Yan, H., Hirst, A., Savita, A., Dias, F. B., Woodhouse, M., Fiedler, R., & Heerdegen, A. (2020). Configuration and spin-up of ACCESS-CM2, the new generation Australian Community Climate and Earth System Simulator Coupled Model. *Journal of Southern Hemisphere Earth System Science*, *70*(1), 225–251. DOI: https://doi.org/10.1071/es19040

Brager, G. S., & de Dear, R. J. (1998). Thermal adaptation in the built environment: a literature review. *Energy and Buildings*, *27*(1), 83–96. DOI: https://doi.org/10.1016/s0378-7788(97)00053-4

Chalmers, P. (2015). Cambio climático: Implicaciones para los Edificios. Hallazgos claves del Quinto informe de evaluación del IPCC [Revisión del Quinto Informe de Evaluación del Grupo Intergubernamental de Expertos sobre el Cambio Climático]. *University of Cambridge*.

Clarke, J., Strachan, P., & Pernot, C. E. E. (1993). Approach to the calibration of building energy simulation models. En: ASHRAE Transactions 99, 13.

Coronato, T., Carril, A. F., Zaninelli, P. G., Giles, J., Ruscica, R., Falco, M., Sörensson, A. A., Fita, L., Li, L. Z. X., & Menéndez, C. G. (2020). The impact of soil moisture–atmosphere coupling on daily maximum surface temperatures in Southeastern South America. *Climate Dynamics, 55*, 2543-2556. DOI: https://doi.org/10.1007/s00382-020-05399-9

Elias, S. A. (2017). Editor's Note. En: *Reference Module in Earth Systems and Environmental Sciences. Encyclopedia of the Anthropocene, 1*, 227–231. DOI: https://doi.org/10.1016/B978-0-12-809665-9.05958-9

Falco, M., Carril, A. F., Menéndez, C. G., Zaninelli, P. G., & Li, L. Z. X. (2019). Assessment of CORDEX simulations over South America: added value on seasonal climatology and resolution considerations. *Climate Dynamics*, 52, 4771–4786. DOI: https://doi.org/10.1007/s00382-018-4412-z

Flores-Larsen, S., Filippín, C., & Barea, G. (2019). Impact of climate change on energy use and bioclimatic design of residential buildings in the 21st century in Argentina. *Energy and Buildings*, 184, 216–229. DOI: https://doi.org/10.1016/j.enbuild.2018.12.015

Flores-Larsen, S., & Filippín, C. (2021). Energy efficiency, thermal resilience, and health during extreme heat events in low-income housing in Argentina. *Energy and Buildings*, 231, 110576. DOI: https://doi.org/10.1016/j.enbuild.2020.110576

Ganem, C., & Barea, G. (2021). A methodology for assessing the impact of climate change on building energy consumption. En: *Urban Microclimate Modelling for Comfort and Energy Studies*. Editorial Springer. ISBN 978-3-030-65420-7

Jentsch, M. F., Bahaj, A. S., & James, P. A. B. (2008). Climate change future proofing of buildings—Generation and assessment of building simulation weather files. *Energy and Buildings*, 40(12), 2148–2168. DOI: https://doi.org/10.1016/j.enbuild.2008.06.005

Košir, M., & Pajek, L. (2017). BcChart v2.0 – A Tool for Bioclimatic Potential Evaluation. *Proceedings of SWC2017/SHC2017*.

Košir, M. (2018). BcChart v2.1. *University of Ljubljana*, Faculty of Civil and Geodetic Engineering.

Košir, M. (2019). Climate Change and Its Implications for Bioclimatic Design. En: *Climate Adaptability of Buildings* , 197–236. Springer International Publishing.

Kottek, M., Grieser, J., Beck, C., Rudolf, B., & Rubel, F. (2006). World Map of the Köppen-Geiger climate classification updated. *Meteorologische Zeitschrift*, 15(3), 259–263. DOI: https://doi.org/10.1127/0941-2948/2006/0130

Lacaze, Zampelli, Estayno, y Braude (2021). Tecnologías para la eficiencia energética residencial y la reducción de emisiones de gases de efecto invernadero. Criterios de política pública para su priorización y marco de propuestas para su desarrollo y adopción en el contexto argentino. *Documentos de Trabajo del CCE N° 14*. Consejo para el Cambio Estructural - Ministerio de Desarrollo Productivo de la Nación.

Li, D. H. W., Yang, L., & Lam, J. C. (2012). Impact of climate change on energy use in the built environment in different climate zones – A review. *Energy*, 42(1), 103–112. DOI: https://doi.org/10.1016/j.energy.2012.03.044

López-Franca, N., Zaninelli, P. G., Carril, A. F., Menéndez, C. G., & Sánchez, E. (2016). Changes in temperature extremes for 21st century scenarios over South America derived from a multi-model ensemble of regional climate models. *Climate Research*, 68(2–3), 151–167. DOI: https://doi.org/10.3354/cr01393

Lorenz, R., Pitman, A. J., Donat, M. G., Hirsch, A. L., Kala, J., Kowalczyk, E. A., Law, R. M., & Srbinovsky, J. (2014). Representation of climate extreme indices in the ACCESS1.3b coupled atmosphere–land surface model. *Geoscientific Model Development*, 7(2), 545–567. DOI: https://doi.org/10.5194/gmd-7-545-2014

Naciones Unidas (ONU), *Acuerdo de París de la Convención Marco de las Naciones Unidas sobre el Cambio Climático* (UNFCCC), 12 Diciembre 2015.

O'Neill, B. C., Tebaldi, C., van Vuuren, D. P., Eyring, V., Friedlingstein, P., Hurtt, G., Knutti, R., Kriegler, E., Lamarque, J.-F., Lowe, J., Meehl, G. A., Moss, R., Riahi, K., & Sanderson, B. M. (2016). The Scenario Model Intercomparison Project (ScenarioMIP) for CMIP6. *Geoscientific Model Development*, 9(9), 3461–3482. DOI: https://doi.org/10.5194/gmd-9-3461-2016

Olgyay, V. (1963). Design with Climate: Bioclimatic Approach to Architectural Regionalism. Princeton University Press.

Rubio-Bellido, C., Pulido-Arcas, J. A., & Ureta-Gragera, M. (2015). Aplicabilidad de estrategias genéricas de diseño pasivo en edificaciones bajo la influencia del cambio climático en Concepción y Santiago, Chile. *Revista Hábitat Sustentable*, *5*(2), 33–41. Recuperado de: https://revistas.ubiobio.cl/index.php/RHS/article/view/2106

Ruíz-González, M. A., & Mack-Vergara, Y. L. (2022). Indicadores de resiliencia y sostenibilidad para la vivienda urbana panameña frente al cambio climático. *Revista Hábitat Sustentable*, 12(2), 08–25. DOI: https://doi.org/10.22320/07190700.2022.12.02.01

Sánchez-García, D., Rubio-Bellido, C., Marrero Meléndez, M., Guevara-García, F. J., & Canivell, J. (2017). El control adaptativo en instalaciones existentes y su potencial en el contexto del cambio climático. *Revista Hábitat Sustentable*, 7(2), 06–17. DOI: https://doi.org/10.22320/07190700.2017.07.02.01

Servicio Meteorológico Nacional Argentino. (2022). *Informe especial n°3 por ola de calor / altas temperaturas temporada 2022-2023.*

Servicio Meteorológico Nacional Argentino. (2023a). *Informe especial n°5 por ola de calor / altas temperaturas temporada 2022-2023.*

Servicio Meteorológico Nacional Argentino. (2023b). *Informe especial n°8 por ola de calor / altas temperaturas temporada 2022-2023.*

Stone, K. A., Morgenstern, O., Karoly, D. J., Klekociuk, A. R., French, W. J., Abraham, N. L., & Schofield, R. (2016). Evaluation of the ACCESS – chemistry–climate model for the Southern Hemisphere. *Atmospheric Chemistry and Physics*, 16(4), 2401–2415. DOI: https://doi.org/10.5194/acp-16-2401-2016

V., R. (2020). Una apuesta por la renovación urbana. *Ediciones EL PAÍS S.L.* [29 septiembre]. Recuperado de: https://elpais.com/economia/2020-09-29/una-apuesta-por-la-renovacion-urbana.html

Ziehn, T., Chamberlain, M. A., Law, R. M., Lenton, A., Bodman, R. W., Dix, M., Stevens, L., Wang, Y.-P., & Srbinovsky, J. (2020). The Australian Earth System Model: ACCESS-ESM1.5. *Journal of Southern Hemisphere Earth System Science*, 70(1), 193–214. DOI: https://doi.org/10.1071/es19035