PLEA STGO 2022

November 22 - 25, 2022

WILL CITIES SURVIVE?

The future of sustainable buildings and urbanism in the age of emergency.

BOOK OF PROCEEDINGS VOL 1 ONLINE SESSIONS

PLEA STGO 2022

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PLEA STGO 2022: WILL CITIES SURVIVE?

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ORGANISED BY

Passive and Low Energy Architecture (PLEA)
plea-arch.org

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ABOUT

PLEA Association is an organization engaged in a worldwide discourse on sustainable architecture and urban design through annual international conferences, workshops and publications. It has created a community of several thousand professionals, academics and students from over 40 countries. Participation in PLEA activities is open to all whose work deals with architecture and the built environment, who share our objectives and who attend PLEA events.

PLEA stands for "Passive and Low Energy Architecture", a commitment to the development, documentation and diffusion of the principles of bioclimatic design and the application of natural and innovative techniques for sustainable architecture and urban design.

PLEA serves as an open, international, interdisciplinary forum to promote high quality research, practice and education in environmentally sustainable design.

PLEA is an autonomous, non-profit association of individuals sharing the art, science, planning and design of the built environment.

PLEA pursues its objectives through international conferences and workshops; expert group meetings and consultancies; scientific and technical publications; and architectural competitions and exhibitions.

Since 1982 PLEA has been organizing highly ranked conferences that attract both academia and practicing architects. Past Conferences have taken place in the United States, Europe, South America, Asia, Africa and Australia.

After almost a decade the PLEA conference is coming back to South America, Santiago (Chile), to be organized by the Pontifical Catholic University of Chile (PUC). Inevitably, the theme of PLEA 2022 is inspired by the current pandemic which has put the whole world on alert and makes us rethink our built environment in terms of health and safety. Whereas due to its current social unrest and significant social divide Santiago and South America in general provides a great ground to talk about inequalities and revisit social movements, that spanned around the globe from Lebanon, France to Chile and other countries just before the pandemic hit.

The aim of the PLEA 2022 is to question the whole idea of a city, the way we inhabit and use them generating the definitive inflection point that a sustainable city requires.

GOAL AND THEME

For decades, the climate crisis has been demanding our action and commitment. Numerous efforts to reach an international consensus via climate summits, such as COP25, and Paris Agreement have not had any expected results yet. However, even though the COVID-19 pandemic has intensified the sense of urgency, many talks about climate change were put on hold during 2020, when the new virus put the world on alert.

In no time it has become a global issue and provoked various reactions from political leaders around the world—from absolute denial to the harshest restrictions—adjusting and learning in the process by trial and error.

This process has not been easy as COVID-19 highlighted critical deficiencies in our built environment and urban design. Even though infections battered affluent areas too, the pandemic hit the hardest when the virus reached sectors with high rates of poverty. Dense neighborhoods and overcrowded buildings could facilitate the rapid spread of infections due to the difficulty of generating social distancing and the application of extensive quarantines.

Yet, various changes have been adopted rapidly. Hygiene protocols, wearing masks, social distancing and other strategies has become part of our ordinary life. On top of that, the use of public spaces, streets, parks, homes and all buildings had to be adjusted to control the spread of the virus transforming our habits and conception of them. Numerous studies showed great variations in the use of transportation during the pandemic too. But the questions are: are those changes here to stay? What does the future hold for our built environments?

Some even go as far as to question: Will cities survive? While many intellectuals and academics call for the end of cities (at least as we know them), some stakeholders urge to return to normality, or so-called status quo.

Is this the last opportunity to effectively build a healthy, livable and equitable city? It is clear that cities can no longer be conceived as before and it is time to question the way we inhabit and use them. What are the standards, mechanisms and criteria to define a sustainable city and building? Do they respond to the problems and deficiencies in the age of emergency? History shows us how cities reacted to and changed after health crises similar to COVID-19; this is the time to question everything around us and strive for environmentally sustainable and socially just cities.

The aim of PLEA 2022 is to be a relevant part of the discussion and bring about proposals to the developing and developed world. It is a great chance to talk about the changes that affected cities around the globe since the start of the pandemic and bring the scientific knowledge generated in this short time to the discussion.

Social inequality should also be a part of the debate as both health and climate emergencies may further increase the injustice and, at the same time, the inequality may make such crises worse. Latin America, as the most unequal region, and Chilean case might serve as a great example of such issues and could become a source of inspiration to find the definitive inflection point that a truly sustainable city requires.

WELCOME TO SANTIAGO DE CHILE

Dynamic and cosmopolitan Santiago is a vital and versatile city. Home to many events showcasing the very best of Chilean culture, it also hosts superb international festivals of sound, flavor and color. The Chilean capital breathes new life into all its visitors!

The city's diversity shines through in its many contrasting neighborhoods. Set out to explore the city streets and you'll discover beautiful and original art galleries, design shops and handicraft markets, as well as a great selection of restaurants, bars and cafes. Night owls can enjoy a taste of lively Latino nightlife in hip Bellavista!

Visit downtown Santiago to get a real feel for the city. Learn more about the country in its many fine museums, or wander around the famous Central Market – a gourmet's delight.

Fans of the great outdoors can head for the hills that surround the city and marvel at panoramic views of Santiago with the magnificent Andes as a backdrop. Take the opportunity to grab a picnic and visit one of the city´s many parks.

In Chile there are places that have not seen a drop of rain in decades, while there are others where the rain brings out the green in the millenial forests.

This diversity captivates and surprises its visitors. Because, as a consequence of its geography, Chile has all the climates of the planet and the four seasons are well differentiated. The warmest season is between October and April and the coldest, from May to September.
The temperature in Chile drops down as you travel south. In the north, the heat of the day remains during the day while the nights are quite cold. The central area has more of a Mediterranean climate and the south has lower temperatures and recurring rainfall throughout the year.

The conference will be held at the Centro de Extensión de la Pontificia Universidad Católica de Chile, located at Avenida Libertador Bernardo O'Higgins 390, Santiago, Metropolitan Region. Universidad Católica subway station, Line 1

The Center is located in the center of the city of Santiago, with excellent connectivity to the rest of the city and the most characteristic neighborhoods of the capital, either through the Metro network (Line 1) or other means of public transport such as Transantiago (Santiago's public bus network).

To make your hotel reservations, we recommend looking in the Providencia or Las Condes districts, close to Metro Line 1. We also have some suggestions for accommodation close to the conference venue.

WILL CITIES SURVIVE?: TRACKS

PLEA STGO 2022

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1. Sustainable Urban Development
– Regenerative Design for Healthy and Resilient Cities
– Sustainable Communities, Culture and Society
– Low Carbon Neutral Neighbourhoods, Districts and Cities
– Urban Climate and Outdoor Comfort
– Green Infrastructure
– Urban Design and Adaptation to Climate Change

2. Sustainable Architectural Design
– Resources and Passive Strategies
– Regenerative Design
– Energy Efficient Buildings
– Net-zero Energy and Carbon-neutrality in New and Existing Buildings
– Vernacular and Heritage Retrofit
– Building Design and Adaptation to Climate Change

3. Architecture for Health and Well-being
– Comfort, IAQ & Delight
– Thermal Comfort in Extreme Climates
– IAQ and Health in Times of Covid-19
– Comfort in Public Spaces

4. Sustainable Buildings and Technology
– Renewable Energy Technologies
– Energy Efficient Heating and Cooling Systems
– Low Embodied Carbon Materials
– Circular Economy
– Nature-based Material Solutions
– Water Resource Management and Efficiency

5. Analysis and Methods
– Simulation and Design Tools
– Building Performance Evaluation
– Surveying and Monitoring Methods
– User-building Interaction and Post-occupancy Evaluation

6. Education and Training
– Architectural Training for Sustainability & Research
– Professional Development
– Sustainable Initiatives and Environmental Activism
– Methods and Educational Practices
– Strategies and Tools

7. Challenges for Developing countries
– Energy poverty
– The Informal City
– Climate Change Adaptation
– Affordable Construction and Architecture Strategies
– Urban Planning and Urban Design Policies for Sustainable Development
– Housing and urban Vulnerability

CRISTINA DORADOR

Keynote speaker
CHILE

Between July 2022 and July 2022 she served as a member of Chile's constitutional convention. She is currently back to teaching at the Universidad de Antofagasta.

Chilean scientist, doctor and politician who conducts research in microbiology, microbial ecology, limnology and geomicrobiology. She is also an associate professor in the Department of Biotechnology of the Faculty of Marine Sciences and Natural Resources at the University of Antofagasta. From July 2021 to July 2022 she served as a member of the Constitutional Convention representing District No. 3, which represents the Antofagasta Region.

Her achievements include the coordination in Chile of the Extreme Environments Network for the study of ecosystems in the geographic extremes of Chile and having developed biotechnological tools to value the unique properties of some altiplanic

microbial communities such as resistance to ultraviolet radiation to elaborate cosmetic creams, joining the field of cosmetic Biotechnology. She has also led application projects such as the development of textile material using the photoprotective properties of altiplanic bacteria.

She was a member of the transition council of the National Commission for Scientific and Technological Research in 2019 that gave rise to the National Agency for Research and Development of Chile, and has been recognized nationally and internationally as one of the most relevant researchers in Chile.

ADRIANA ALLEN

Keynote Speaker
ARGENTINA

Professor of Urban Sustainability and Development Planning at The Bartlett Development Planning Unit (DPU), University College London and President of Habitat International Coalition (HIC).

Adriana has over 30 years of international experience in research, graduate teaching, advocacy and consulting in over 25 countries in the global South, she has specialized in the fields of development planning, socio-environmental justice and feminist political ecology.

She is currently President of Habitat International Coalition (HIC), as well as a regular advisor to UN agencies, positions from which she is actively engaged in promoting urban justice through advocacy and policy evidence, social learning and fostering international collaboration both within UCL and globally.Through the lens of risk, water and sanitation, land and housing, food and health, her work examines the interface between everyday city-making practices and planned interventions and their capacity to generate transformative social and environmental relations.

Adopting a feminist political ecology perspective, her work combines qualitative, digital/mapping, and visual research methods to decolonize urban planning practices and elucidate the "cracks" in which transformative planning can be reinvented, nurtured, and pursued. Her work focuses on three interrelated themes: urban justice, everyday city-making, and transformative planning.
Over the years, she has worked at the interface between insurgent practices and planned interventions and their capacity to generate socio-environmentally just cities.

This work stems from her engagement with the analysis of governance approaches to address structural deficits at the interface between "policy-driven" and "needs-driven" approaches and emerging improvements at scale – in water and sanitation, as well as in other areas such as food security, land, housing and health. Since 2008, she has explored the intersection of urbanization and climate change, with a particular focus on the generation and distribution of risks, vulnerabilities and capacities for action in southern cities. A third strand of her research focuses on urban planning as a field of networked governance and pedagogical strategies to decolonize planning education and shape pathways for urban equality.

ANACLAUDIA ROSSBACH

Keynote speaker
BRAZIL

Economist with a track record of more than 20 years working on the issues of slums, social housing and urban policy.

She is currently Director for Latin America and the Caribbean at the Lincoln Land Institute of Policy. She also serves as a member of the editorial board of Vivienda magazine of INFONAVIT – México. And previously she worked as a consultant on housing and urban development issues for the IDB (Inter-American Development Bank).

She worked in the Prefecture of São Paulo, supporting the Brazilian Ministry of Cities in the design and implementation of the Brazilian housing policy. She founded and served on the board of directors of the NGO INTERAÇÃO, which supported the development of high-impact projects in communities in the state of São Paulo and Recife.

As a senior consultant to the World Bank, she provided technical assistance for the development and implementation of Brazilian housing policy and slum upgrading for 10 years, including two major programs: the "PAC Favelas" slum upgrading and the "Minha Casa, Minha Vida" housing subsidy.

She acted as a senior specialist in social housing for the World Bank and other research and project organizations in Brazil and several countries around the world such as the Philippines, China, India, South Africa and Mozambique, among others.

She was Regional Manager for Latin America and the Caribbean for the Cities of Alliance Global Informality Program where the exchange of experiences and knowledge through different networks was consolidated and structured.

The main achievements in Latin America are the Urban Housing Practitioners Hub (UHPH), which brings together practitioners and networks working in the field of social housing. In the global south, multi-sectoral and disciplinary communities of practice on the theme of slum upgrading in the global south with emphasis on the countries: Mexico, Guatemala, El Salvador, Paraguay, Brazil, South Africa and India.

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GIANCARLO MAZZANTI

Keynote Speaker
ARGENTINA

Born in Barranquilla, a port city in northern Colombia, Giancarlo Mazzanti is an architect graduated from Pontificia Universidad Javeriana with postgraduate studies in industrial design and architecture in Florence, Italy.

He has been a visiting professor at several Colombian universities, as well as at world-renowned academic institutions such as Harvard, Columbia and Princeton, and is the first Colombian architect to have his works in the permanent collection of the Museum of Modern Art in New York (MoMA) and the Centre Pompidou in Paris.

Giancarlo has more than 30 years of professional experience and his studio, El Equipo Mazzanti has gained notoriety due to its design philosophy based on modules and systems, which generate flexible elements capable of growing and adapting over time, seeking an architecture that is closer to the idea of strategy than to a finite and closed composition. The idea of architecture as an operation was born from exploring the different forms of material and spatial organization, considering concepts such as repetition, the indeterminate, the unfinished, instability, arrangement and patterns.

Equipo Mazzanti also stands out for its research on play and its link to the world of architecture. It is precisely this interest in the play-architecture relationship that has led it to seek new collaborations with professionals from different areas of knowledge, finding new opportunities for cooperation and developing projects and exhibitions that have been presented throughout the world under the We play You play brand.

Social values are at the core of Mazzanti's architecture, who seeks to realize projects that give value to social transformations and build communities. He has dedicated his professional life to improving the quality of life through environmental design and to the idea of social equality.

His work has become a reflection of the current social changes occurring in Latin America and Colombia, demonstrating that good architecture manages to build new identities for cities, towns and inhabitants, transcending reputations of crime and poverty.

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Innovative design solutions for the school of the future

The case Study of the secondary school Cino da Pistoia in Italy

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ABSTRACT: The EU recognizes the need for near-complete decarbonization of the building sector, defining energy performance requirements to encounter longer-term climate neutrality goals by 2050. To facilitate this transition, it is necessary to identify suitable passive strategies, innovative design solutions, and building integrated renewable energy systems specifically studied concerning climate conditions. The paper presents a simulation-based optimization process to evaluate design solutions' effectiveness on energy performances and indoor comfort for building the new school building "Cino da Pistoia" in Italy. The applied methodology helps enhance nZEBs design and facilitate decision-making in early building design phases. In addition, a comprehensive study on occupants' indoor comfort is presented with specific reference to thermo-hygrometric comfort and lighting comfort. The results have demonstrated that it is possible to reduce the global energy demand of the building and to improve the level of perceived comfort through the adoption of high efficiency building envelope technological systems and passive strategies.
KEYWORDS: Net zero energy building, Simulation-based optimization, Indoor Comfort, Daylighting analysis, School building.

1. INTRODUCTION

The sustainable design of public buildings through innovative technological solutions and the integration of renewable energies is one of the priority objectives of European policies (2010/31 / EU) and the new Next Generation Europe Economic Development Plan. Furthermore, the 2030 Climate Target Plan proposed by European Commission sets an intermediate target for reducing GHG to at least 55% below 1990 levels.

In Italy, these objectives were implemented by the D.M. 11/10/2017 on Minimum Environmental Criteria (CAM). Moreover, they have become the subject of numerous funding policies of the PNRR [1], which plan to improve, by 2026, the energy performance of public buildings through deep renovation or demolition interventions and reconstruction.

Moreover, in Europe, educational buildings are a significant part of public property and represent a critical issue because of their age and maintenance needs. Therefore, many schools need sustainable retrofitting interventions to improve buildings' performance in terms of energy consumption and deliver economic, environmental, and social benefits to the whole community [2].

The sustainable targets set by international regulations and the transition to Positive Energy Buildings (PEB) led in recent years to develop numerous research aimed at creating sustainable, efficient, and safe school buildings and even more at developing strategies intervention based on the use of BIM and BEM tools, which allow managing the design process by predicting the impact of integrated technological and functional solutions [3-4].

This paper shows the design proposal for the new secondary school "Cino da Pistoia" developed by the Municipality of Pistoia with the contribution of ABITA Interuniversity Research at the University of Florence. In particular, the analysis and dynamic simulations will be shown to study the building envelope solutions and the indoor comfort inside the classrooms.

The main aim of the research work was to demonstrate how to achieve the nZEB targets and the improvement of energy building performances, as well as aesthetic, architectural, and functional quality objectives to set the characteristics of future schools. Furthermore, the analysis procedures and verification methodology developed for verifying the sustainability of the design process could be replicated for other types of buildings.

2. THE CASE STUDY

The school building Cino da Pistoia is located in Pistoia, a city in the Tuscany region in Italy. It is part of an existing school complex including the primary school "G. Galilei", a gymnasium and a school canteen. The regeneration interventions consist of building demolition and reconstruction of a new school made up of two-story buildings (buildings 1 and 2) connected by a solar greenhouse (building 3). Buildings 1 and 2 host classrooms and laboratories, while building three has the function of the entrance to the common areas and to the vertical connections that allow access to the different floors.

The new school was designed according to the CAMs Italian law [5], implementing design solutions for the building envelope and plant systems that meet the minimum requirements for building energy efficiency. Therefore, attention was paid to the environmental impact generated by the building throughout its life cycle and to the indoor environmental quality (IEQ), health, and global comfort of occupants.

Figure 1: Render of the new secondary school "Cino da Pistoia", south façade.

Figure 2: Plant of the ground floor: A) classrooms; B) toilets; D) Corridors; I) Green house; T) Technical room

As a result, the new building was realized with a light steel frame structure to reduce its environmental impact and guarantee reversibility at the end-of-life cycle. Furthermore, according to the national legislation and EU directives, the school "Cino da Pistoia" was designed to achieve high sustainability and energy efficiency standards, reaching nZEB targets. For this reason, the classrooms and laboratories were exposed to the southeast to take advantage of solar gains in winter during the teaching activity's hours.

Similar passive strategies were applied to the bioclimatic greenhouse, which shows the same classrooms' exposure to solar radiation during the morning, to reduce the building energy needed for heating during winter. The shading devices outside the glass façade and the operable windows integrated into this transparent volume guaranted to decrease the overheating phenomena in the summer months.

Moreover, the high thermal performance of the transparent and opaque envelope of the other two buildings and floor thermal mass allowed to reduce energy consumption, related costs, and greenhouse gas emissions.

In detail, the opaque building envelope was made using a lightweight aluminium ventilated facade insulated with mineral wood panels (U value = 0.17 W/m2K), while the windows were designed with thermal break frames and low-emissivity double glazing and fitted with external shading (U value=1.20 W/m2K). The ground floor was built with sub ventilation system (U value=0.12 W/m2K), and the rooftop was constructed using a corrugated slab system insulated with EPS panels (U value=0.23 W/m2K).

The heating and cooling were provided from a radiant floor integrated with a mechanical air exchange system and heat exchanger. In addition, a PV plant of 25 watt-peak was integrated on the roof to produce renewable energy that will be possible to use for the electricity need of the school building.

Table 1: Thermal performances of building envelope components.

Building Envelope	Thermal Transmittance [W/m²K]	Indoor Thermal capacity [kJ/m²K]	Periodic Thermal Transmittance [W/m²K]
Wall	0.17	49.57	0.02
Windows	1.20	-	-
Floor	0.12	63.64	0.00
Rooftop	0.23	65.83	0.01

3. RESEARCH METHODOLOGY

The present study defines and analyzes the main sustainable design strategies adopted for the new construction intervention to assess the energy performance of the new school building through Building Energy Modelling (BEM) and dynamic simulation analysis.

Figure 3: Building simulation model

Two relevant aspects were investigated using simulation tools to support the designer's decision-making in comparing the performance of different design scenarios. First, a thermal performance assessment of the building envelope was carried out to choose the better façade solutions that meet the current national standards and improve indoor thermal comfort. Furthermore, a daylighting analysis focused on design optimization of the classrooms to improve their indoor daylighting quality.

3.1 Building dynamic simulation

The Italian legislation (Italian Ministerial Decree 26/06/2015) specifies a series of mandatory energy requirements for public buildings to reach nearly zero-energy buildings targets, concerning the minimum performance that the building must guarantee considering both energy performances of envelope solutions and energy needs related to technological plants such as heating, cooling, hot water, ventilation, and lighting, integrated with renewable energy sources.

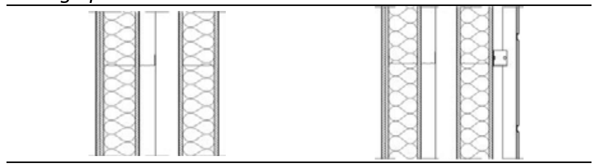
Accordingly, in the first phase of the design process the simulation methods was finalized to compare the results between the real building and the reference building (defined as a target building), which has the same location, function, size, and minimum values for thermal performances and technical systems efficiencies. This comparison between the two building models allowed to define the degree of sustainability of the design options (Tab. 2).

Table 2: Energy performances parameters for heating and cooling, hot water, mechanical ventilation and lighting.

Real building	Reference building	Verification
H'_T 0.37 W/m²K	$H'_{T,lim}$ 0.80 W/m²K	verified
$A_{sol,est}/A_{sup,utile}$: 0.03	$(A_{sol,est}/A_{sup,utile})_{lim}$: 0.04	verified
$EP_{H,nd}$: 50.69 kWh/m²	$EP_{H,nd,lim}$: 57.50 kWh/m²	verified
$EP_{C,nd}$: 15.20 kWh/m²	$EP_{C,nd,lim}$: 17.77 kWh/m²	verified
$EP_{gl,tot}$: 65.05 kWh/m²	$EP_{gl,tot,lim}$: 161.69 kWh/m²	verified
η_H: 2.22	$\eta_{H,lim}$: 1.34	verified
η_W: 0.63	$\eta_{W,lim}$: 0.53	verified
η_C: 1.64	$\eta_{C,lim}$: 1.26	verified

At the same time, a building simulation energy model for dynamic analysis was developed using the Energy Plus software to study the energy performances of two opaque envelope solutions (Tab.3): 1) a traditional pre-assembled dry facade with thermal cladding and outdoor plaster (P1: plaster); 2) a ventilated façade with an external aluminium surface (P2 ventilated facade). The objective was to compare their energy performance to choose the one that performs most efficiently throughout the year.

Table 3: Characteristics of the two opaque envelope solutions analysed with the dynamic simulation in the design phase



P1: Traditional pre-assembled dry facade with thermal cladding and outdoor plaster.	P2: Ventilated façade with an external aluminium surface
Thickness: 32.5 cm	Thickness: 38.5
U value: 0.20 W/mqK	U value: 0.17 W/mqK

In particular, the environmental conditions considered acceptable for indoor thermal comfort and those representing local discomfort were investigated, analysing the internal heat gains related to the occupancy profile of indoor spaces and users' activities.

The study was carried out according to ISO 7730:2005 methods for predicting the general thermal sensation and degree of discomfort of people exposed to moderate thermal environments through PMV (Predicted Mean Vote) and PPD (Predicted Percentage of Dissatisfied) indexes. Therefore, the Clothing Insulation Index (Clo) and the heat loss of the Metabolic Flow (Met) were defined considering different year periods. For better accuracy, the Met threshold for sedentary behaviour in children has been increased from 1.5 to 2.0 Mets depending on age-specific definition of sedentary behaviour in children aged 11 - 14 years (in fact people of this age group have a higher metabolic rate than adults).

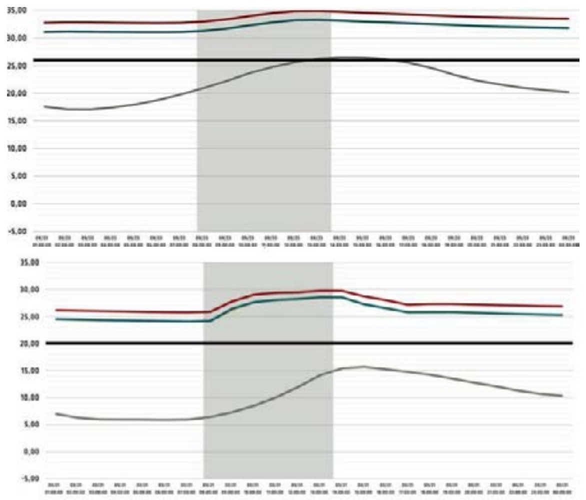


Figure 4: Comparison pre-assembled dry facade (plaster) and aluminium ventilated façade (ventilated facade): a) Indoor air mean temperature profile 21st March (upper); 23rd September (lower).

For sedentary such as school activities, the UNI EN ISO 7730 standard suggests a value equal to 1.2 meths, while the experimental data collected showed average values for subjects of that age group equal to about 2.2 Met [6].

The simulation was carried out without cooling, and the mechanical ventilation system made it possible to highlight an improvement in the perceived comfort values, limiting internal overheating in the final part of the heating period and, in general, in the spring and autumn season.

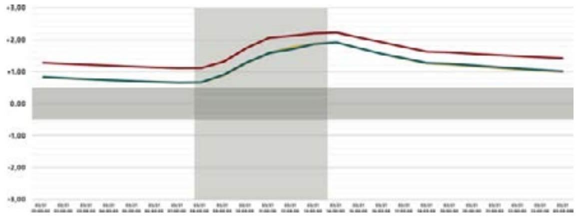


Figure 5: Comparison between outdoor plaster and ventilated facade (21st March): b) PMV index.

The average values recorded on the simulated dates of March 21 and September 23 allow us to observe a positive variation of the average internal temperatures between 1°C and 2 °C (Fig. 4), and a PMV index closer to the condition of thermal neutrality with a reduction of 0,5 compared to plaster solution. Regarding the PMV index, on the 21 March, the value related to the ventilated solution is closer to the condition of thermal neutrality with a reduction of 0,5 compared to plaster solution (Fig. 5).

3.2 Daylighting analysis

The daylighting of a school building must provide adequate light levels in the classrooms and on their work plane during the daytime, mainly from natural light. In detail, for the classrooms of a school building, depending on their exposure and building orientation, the following parameters influencing daylighting performance were analysed:

- Daylight Factor (DF) [%]
- Illuminance [lux]
- Luminance [cd/m2]

Accordingly, the daylighting analysis was conducted to evaluate the impact of passive design strategies for the classrooms of the new school "Cino da Pistoia" to achieve adequate daylight conditions and daylighting requirements in line with Italian and international regulations.

Concerning the mean value of Daylight Factor (mDF), which is expressed as a percentage of the amount of daylight available inside a room (on a work plane) compared to the amount of unobstructed daylight available outside under overcast sky conditions, the minimum threshold value set by the Italian regulations is DF≥3%.

Furthermore, for the Illuminance parameter, which refers to the amount of light received on the classrooms interior surfaces, typically expressed in lux (lm/m2), daylighting simulations were performed throughout the year with different sky conditions, comparing results with the minimum requirements for school spaces provided by EN 12464-1:2011, to estimate the energy needs from the artificial lighting system.

The daylighting parameters were predicted through a simulation tool for a qualitative evaluation of visual comfort and glare in the interior of each classroom. Finally, the total amount of daylight entering a classroom was linked to the total glazing area of windows.

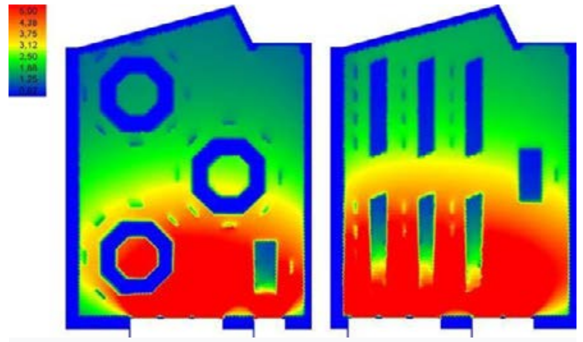


Figure 6: Mean Daylight factor (mDF) calculation for a classroom of the ground floor (left) and of the first floor (right).

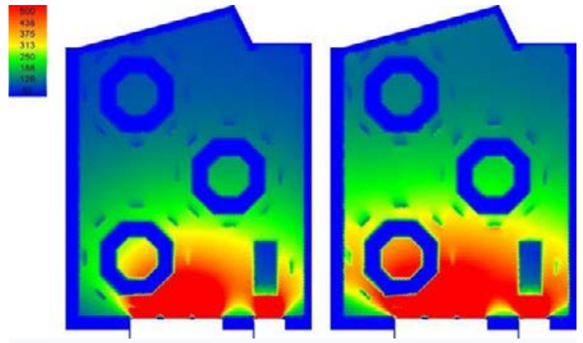


Figure 7: Illuminance calculation considering overcast sky (left) and clear sky condition (right) for a classroom of the ground floor.

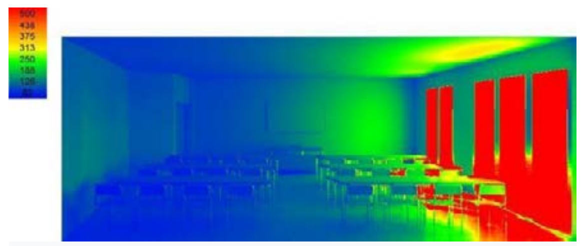


Figure 8: Luminance calculation of a selected classroom of the ground floor.

The simulation results showed a difference in daylighting performances between the classrooms on the ground floor and those on the first floor. In detail, the classroom on the ground floor had a mean Daylight Factor of less than 3% (mDF = 2,8%), for the smaller glazing to floor area ratio than the other classrooms.

Furthermore, even in some classrooms on the first floor, the calculated mean Daylight Factor (DF) was very close to this minimum requirement but not sufficient to reach a good daylighting indoor quality. The DF was highly non-uniform and not well distributed over the work plane area (Fig. 6 and Fig. 7), with very high values near the window and low values at the back, a typical condition that can cause visual discomfort and luminous glare. Also, results from the Luminance calculation (Fig. 8) give further evidence of the poor daylighting quality of indoor spaces.

As shown in Table 4, the illuminance calculations were performed with different sky conditions, and the results show a mean value of 180 lux for the classroom on the ground floor and 240 lux for that on the first floor, both below the minimum target of 300 lux.

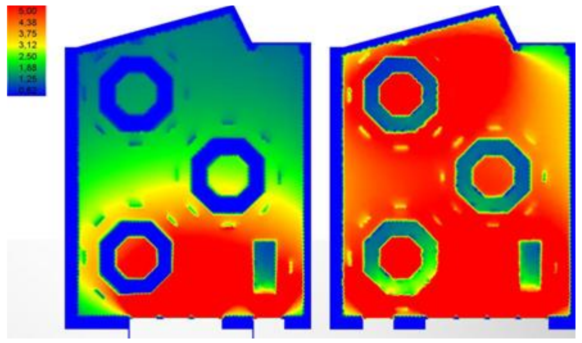
The glazing to floor area ratio was increased to provide useful DF levels over the entire work plane and to improve the indoor daylighting quality in the classrooms on the ground floor. Also, the design solution of the solar shading device was optimized based on data derived from the sun path analysis throughout the year. It adopted a horizontal reflective screen that prevents excessive light from direct sun radiation and, at the same time, allows a homogeneous distribution of natural light within the interior space.

Table 4: Simulation results comparison of daylight parameters before and after intervention.

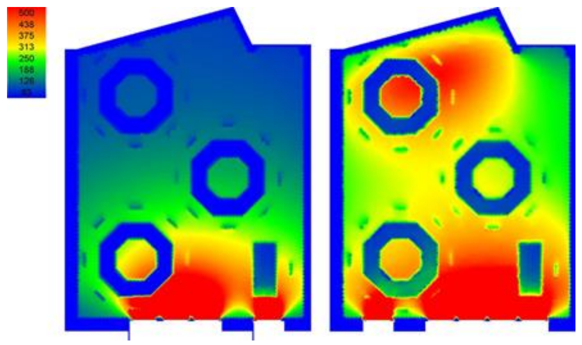
	Before	After
mean Daylight factor (mDF)		
Ground floor	2,8%	5,0%
First floor	3,7%	5,0%
mean Illuminance (I)		
Overcast sky		
Ground floor	180 lux	320 lux
First floor	240 lux	450 lux
Clear sky		
Ground floor	310 lux	450 lux
First floor	400 lux	450 lux

In addition, to ensure the light source from multiple directions and to mitigate the daylight glare effect, a different glazing surface was opened facing the hallway to obtain a better uniformity of light in the classrooms. As a result of these interventions, simulations of daylight parameters report an improvement in daylight parameters (Tab. 4).

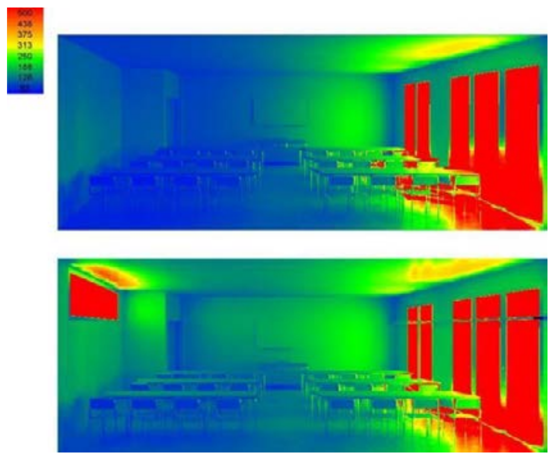
Furthermore, even in overcast conditions, the average Illumination values were significantly increased above 300 lux in all the simulated scenarios, reducing the energy needed for the artificial lighting of the school.



a) Mean Daylight factor



b) Illuminance



c) Luminance

Figure 9: Comparison of daylighting simulations results before and after the changing of the widows' size for a classroom of the ground floor: Daylighting simulations results

The simulation-based optimization process for daylighting analysis of the new building made it possible to obtain an important improvement both in the lighting comfort of users and in reducing glare effects.

Figure 9 illustrates the effect of design solutions compared after and before the intervention for a classroom of the ground floor: the results show a better uniformity of daylight in the classrooms and greater daylight levels in the interior spaces, achieving the minimum requirements for all the parameters.

4. CONCLUSION

This paper presents the new design project of a school building in Pistoia, developed using a simulation-based optimization method to evaluate the design solution's effectiveness on energy performance and the indoor comfort of users throughout the design process.

The analysis and dynamic simulations to study the highly insulated building envelope show the benefits of integrating a ventilated façade compared with a multilayer dry facade. About energy efficiency, the energy performance index for cooling the school building is equal to 15.20 kWh/m2, achieving the target nZEB.

With regards to thermal comfort, the ventilated façade can reduce the average indoor temperatures between 1°C and 2°C, depending on the season, improving the PMV index (closer to the condition of thermal neutrality) with a reduction of 0,5°C compared to plaster solution.

Furthermore, the in-depth daylighting quality of interior spaces in selected classrooms confirmed the effectiveness of all the design strategies concerning increasing the glazing to floor area ratio and integrating a new horizontal reflective screen for windows to prevent excessive light from direct sun radiation.

Finally, this study shows how simulation tools allow the designers to simultaneously assess the geometric-formal characteristics of a new building and its energy-environmental performances from the implementation phase to the use phase.

Besides, it is evident how, alongside the rapid evolution of indicators and legislation on the building's energy efficiency, new computer models for evaluating the design can assess the behaviors of the built environment and of the indoor comfort from the static to the dynamic situation [7].

In the future, the work will deepen the topic related to environmental assessment - in terms of LCA and LCC - of the implemented design solutions, with a particular focus on the façade technologies to analyze more in detail the vantage of using the ventilated envelope in cold climate area, as southern Europe. Moreover, after the realization, the building will be monitored to compare the simulated data of indoor comfort performances with the real data to improve the design simulation process with BEM tools.

REFERENCES

1. Piano Nazionale Di Ripresa E Resilienza, [Online], Available: https://www.governo.it/sites/governo.it/files/PNRR.pdf
2. Aldawoud A., Hosny F. E., Mdkhana R., (2020). Energy Retrofitting of School Buildings in UAE. *Energy Engineering*, 117(6): p. 381–395.
3. Loreti L., Valdiserri P., Garai M., (2016). Dynamic simulation on energy performance of a school. *Energy Procedia*, 101: p. 1026–1033.
4. D'Ambrosio V, Alborelli E., (2015). Progressive upgrade process for the energy retrofit of school buildings in Naples. *TECHNE*, 9: p. 256–266.
5. Ministry of Economic Development, DM 11 Gennaio 2017. Decreto Criteri Ambientali Minimi – CAM, [Online], Available: https://www.gazzettaufficiale.it/eli/id/2017/04/03/17A02375/sg
6. Saint Maurice P. F., Kim Y., Welk G. J., Gaesser G. A., (2016). Kids are not little adults: what MET threshold captures sedentary behavior in children? *European Journal of Applied Physiology*, Vol. 116 No. 1: p. 29–38.
7. Gallo P, Romano R., (2020). New cognitive models in the pre-design phase of complex envelope systems. In: Lauria M., Mussinelli E., Tucci F., *Producing Project*, Santarcangelo di Romagna: Maggioli Editore, pp. 452-458.

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Will Cities Survive?

Energy modeling of the residential building stock

Climate change impact and adaptability of the existing housing stock in Santiago de Chile

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ABSTRACT: Energy modeling of the existing building stock as a decision-making tool for governments is necessary for drafting national roadmaps to the carbon neutrality of the built heritage. A set of 297 building energy models is stochastically generated using architectural archetypes and national information. The energy models are created and simulated in batch mode using R and EnergyPlus, and tested using the weather files of the Metropolitan region of Chile under seven scenarios; the historical climate and six climatology modeling scenarios by 2050. After predicting the thermal behaviour of the simulated models, hours of discomfort and space heating energy use are analyzed, comparing the results under the historical climate against the six projected climates. Results show that the hours of discomfort are strongly impacted by the number of building floors and moderately by the window-to-wall glazing ratio. Considering that the residential air conditioning in Chile is a new and fast-growing market, retrofit strategies in the Metropolitan region should consider the risk of overheating in dwellings under different climate change scenarios.
KEYWORDS: Thermal comfort, Representative concentration pathways, Energy performance,

1. INTRODUCTION

Almost all countries reaffirmed their commitment at COP21 to reduce greenhouse gas (GHG) emissions to keep global warming below 2 degrees Celsius by 2050 compared to pre-industrial times (1850-1900). According to the International Energy Agency (IAE), the building sector accounts for 8% of the global greenhouse gas emissions in 2020 (2,9 of 33,9 $GteCO_2$) (International Energy Agency, 2021). To achieve a carbon-neutral economy by 2050, the target is to reduce 1.2 Gt by 2030 and 0.3 Gt by 2050. In addition, countries must implement new energy efficiency measures in buildings that lower their energy needs and ensure acceptable comfort inside by using renewable sources.

Although several countries have introduced thermal standards to increase their energy performance (Laustsen, 2008), numerous studies have highlighted the disparity between calculated and measured performance (Burman et al., 2014; Kelly et al., 2012). Furthermore, governments require decision-making tools to detect current energy consumption aspects and unintended consequences of new codes and policies on future energy use, GHG emissions, and population well-being.

Building energy modeling (BEM) is a valuable tool to estimate buildings' current and future energy use. Moazami et al. (Moazami et al., 2019) used 16 ASHRAE commercial building prototypes to study the energy use variation compared to historical data, considering typical and more extreme climate change scenarios in Geneva. The authors highlight the relevance of studies on the impacts of climate change on the built environment at national scales to involve architects and building engineers. Ultimately, various researchers are publishing their work at city scale, such as Nik and Sasic in Stockholm (Nik & Sasic Kalagasidis, 2013), or at national scale, like Olonsheck et al. in Germany (Olonscheck et al., 2011) and Gürsel and Meral in Turkey (Dino & Meral Akgül, 2019).

Regarding Chile, Rubio-Bellido et al. optimized office buildings' form factor and window-to-wall ratio for nine different Chilean climate zones (Rubio-Bellido et al., 2016). Verichev et al. simulated a house prototype in the southern macro zone of Chile (Verichev et al., 2020). The authors highlight the high variability of spaced heating shifts due to climate diversity. Finally, Rouault et al. (Rouault et al., 2019) studied the impact of climate change on space heating and cooling needs of houses in Chile using the simplified hourly calculation method from the international standard ISO 13790. The authors emphasize the critical situation of the Metropolitan Region (RM), the most populated area of Chile, about the potential increase of space cooling needs. However, the study only focuses on a unique archetypal house in each city, and so limiting the conclusion.

To account for the variability of input parameters in the housing stock, this study proposes an estimation of the impact of climate change on the energy use and thermal behavior of the residential building stock of Chile's most heavily populated region on a horizon to 2050. For that purpose, the current building stock is modeled in EnergyPlus, based on the previously defined geometric Chilean archetypes (Molina et al., 2020) and under six different climate change scenarios.

2. METHODOLOGICAL APPROACH

This work's methodological approach consists of generating a set of building energy models (BEM) that can be considered representative of the RM housing building stock. The input data are randomly generated using the Latin hypercube sampling (LHS), which ensure a multidimensional distribution, and uses national surveys (In-Data, 2019; Ministerio de Vivienda y Urbanismo, n.d.), datasets currently available, and the literature (Molina et al., 2020, 2021). The generated BEM models are then simulated in Energy Plus using different weather files of historical climate and projected climates of Santiago de Chile.

2.1 Inputs data

Molina et al. (Molina et al., 2020) defined 496 archetypes representing the Chilean residential stock and four thresholds of 2, 8, 29 90 archetypes, representing 13%, 35%, 70%, and 90%, respectively. These archetypes are based on the available data of the housing stock, and are defined by housing type (detached, mid-terrace, terrace), the construction period (before or after the current thermal regulation), the number of stories, the floor area, rooms, and the number of occupants. The set of 29 archetypes is selected for this study.

Table 1:
Input data of the energy model

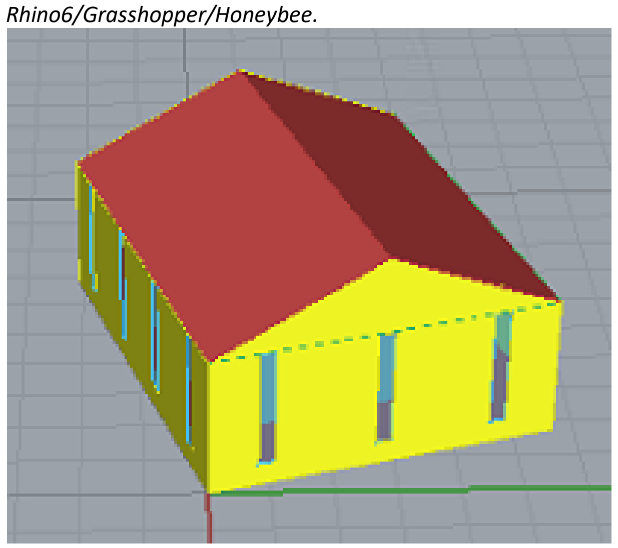
Input	Unit	Range
Permeability	ach	[0,001; 7]
Heating setpoint	°C	[18; 22]
Month of heating	-	[0; 12]
ΔU_{Wall}	W/m²K	[-0,15; 0,43]
ΔU_{Roof}	W/m²K	[-0,15; 0,27]
$U_{windows}$	W/m²K	[2,8; 5,8]
$\Delta U_{windows}$	W/m²K	[0,03; 0,08]
Lighting loads	kWh/m²year	[0,15; 38]
Appliance loads	W/m²	[1,2; 185]
DHW	W/m²	[1,3; 194]
Kitchen	W/m²	[0,39; 69]
Form factor	-	[1; 2]
Orientation	°	[0; 179]
Glazing ratio	%	[5; 32]
Thermal mass	kg/m²	[10; 100]

297 sets of input data, including the archetypes' ID, are stochastically generated, including other design parameters (see Table 1) and using the Latin hypercube sampling method to respect input data distribution.

2.2 Building Energy Modeling (BEM)

The Software Rhino6 (*Rhino - Rhinoceros 3D*, n.d.) with the plugins Grasshopper and Honeybee (*Ladybug Tools | Honeybee*, n.d.) are used to generate the BEM models (see Figure 1) and export in .idf file format compatible with the simulation software EnergyPlus (US Department of Energy, n.d.). The batch simulations are carried out using the statistical software *R-cran* and the *eplusr* package (Jia & Chong, 2021). The number of simulations is increased until a stopping criterion is met (here, the difference in the mean energy use is less than 0.5% between one sample and the previous).

Figure 1:
3D representation of the building energy model using Rhino6/Grasshopper/Honeybee.



2.3 Climatic data

The current climatic are export form Meteonorm v7.2(METEOTEST, n.d.) at .epw format. The temperature and precipitation estimations for 2045–2054 were possible using three climatology modeling scenarios: MIROC-ESM, IPSL-CM5A, and CCSM4 considering two different representative concentration pathways: 4,5 (RCP4,5) and 8,5 (RCP8,5) W/m².

2.4. Data analyses

The results of the BEMs thermal behavior using the historical climate are visually compared to monitoring data from the national housing monitoring network (RENAM in Spanish); see Section 3.1. The Chilean Ministry of Housing program, RENAM, collects and anonymously broadcasts hourly indoor environment quality indicators from 294 houses in five cities (Antofagasta, Valparaiso, Santiago, Temuco, and Coyhaique).

To evaluate the summer comfort, the adaptive thermal comfort is defined by the European standard EN 16798-1 (European Committee for Standardization, 2019). The following equation defines the comfort zone of temperature for existing buildings (category B):

$$T_{conf} = (0{,}33\, T_{rm} + 18{,}8) \pm 3°C \qquad (1)$$

With

$$T_{rm} = \begin{pmatrix} T_{ed-1} + 0.8\, T_{ed-2} + 0.6 T_{ed-3} \\ +0.5\, T_{ed-4} + 0.4 T_{ed-5} \\ +0.3 T_{ed-6} + 0.2 T_{ed-7} \end{pmatrix} /3.8 \qquad (2)$$

Where T_{rm} is the running mean outdoor temperature and $T_{ed\text{-}i}$ (i vary from 1 to 7), $T_{ed\text{-}i}$ are the daily mean of outdoor temperature from the previous seven days.

Hours of discomfort (HoD) are calculated as the sum of hours exceeding the upper limit of comfort in occupied hours (this is, 24 h/day and 8766 h/year); see section 3.2. For two-story houses with two thermal zones, the highest indoor temperature of the two zones is considered for the comfort calculation.

Finally, the evolution of space heating in kWh/m^2 and hours of discomfort in six projected climates are compared to the historical climate, and the relationship between these two indicators and the inputs are analysed using the Pearson's correlation coefficients.

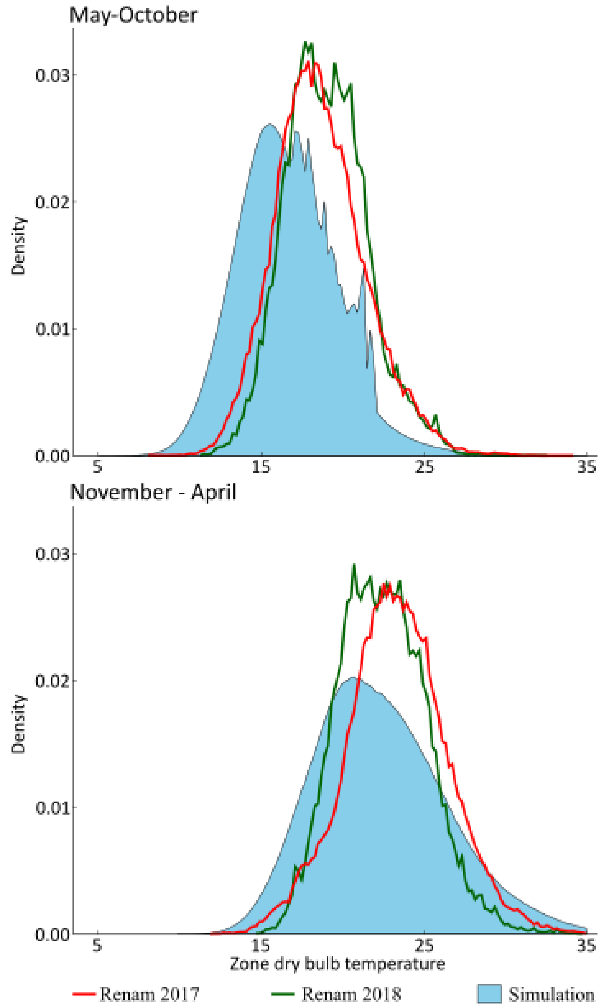
3. RESULT AND DISCUSSION

3.1 Thermal behaviour in historical climate

Figure 2 compares the air temperature between the simulation in the historical climate and the temperature inside 142 dwellings in the RM from the national monitoring network (RENAM) during 2017 and 2018.

Although some discrepancies can be identified, the simulation can be considered consistent with the measured data. For example, the distribution of simulated temperature shows a slight offset compared to measured temperature, probably due to an underestimation of the heating hours by the survey respondents.

Figure 2:
Comparison of indoor air temperature between simulation results (in light blue) and measured temperature by RENAM in 2017 (in red) and 2018 (in green). The top and bottom graphs show the heating and cooling season, respectively.



3.2 Projected summer comfort

Table 2 shows that at least 25 % (Q1) houses have no HoD in all scenarios. On the other hand, HoD exceeds 5% of occupied hours (438 hours) in more than 75 % (Q3) of houses HoD in all CC scenarios except IPSL 8.5; considering that the EN 15251 standard establishes the 5 % deviation as an acceptable limit (McNeil et al., 2008).

Figure 4 presents the Pearson correlation coefficients for space heating EUI and the HoD, and some of the input parameters. The results show a *strong* and *moderate* correlation between the HoD and the number of stories and glazing ratio, respectively. On the other hand, the space heating EUI and internal mass have a moderate correlation.

Figure 4 depicts the HoD according to energy use intensity (EUI) of space heating from each BEM model in historical climate and future scenarios. Each climate scenario result is linked to each to the historical climate result. Regarding historical results, two-story houses (triangle markers) generally have higher discomfort hours than one-story houses (circle markers).

Furthermore, space heating in *CC* case scenarios decreases and HoD increases except for IPSL 8.5, in which HoD decreases in some cases. Figure 4 presents the Pearson correlation coefficients for space heating EUI and the HoD, and some of the input parameters. The results show a *strong* and *moderate* correlation between the HoD and the number of stories and glazing ratio, respectively. On the other hand, the space heating EUI and internal mass have a moderate correlation.

Figure 4 shows that many houses without HoD in historical climate stay with no HoD for the *CC* scenarios. Furthermore, the HoD in two-story houses are >500 h; the historical scenario appears to be more sensitive in terms of HoD increase.

Table 2:
Summary statistisc of the total HoD [h] per house for the different simulation scenarios.

Scenario	Min	Q1	Med	Q3	Max
Current	0	0	23	434	2247
ccsm45	0	0	17	509	2342
ccsm85	0	0	19	520	2432
ipsl45	0	0	18	517	2422
ipsl85	0	0	13	454	2250
miroc45	0	0	17	519	2398
miroc85	0	0	17	520	2425

Figure 3:
Hours of discomfort vs. heating EUI of each model in historical and future climates

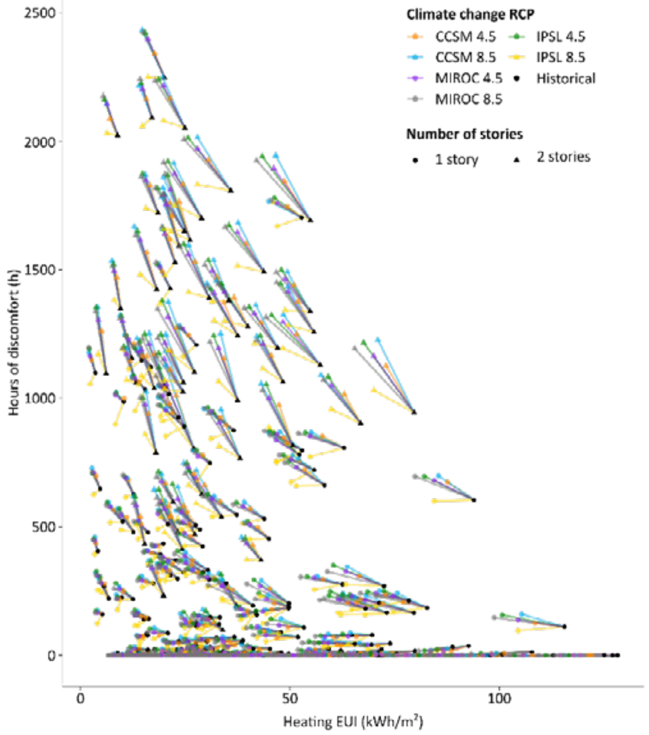


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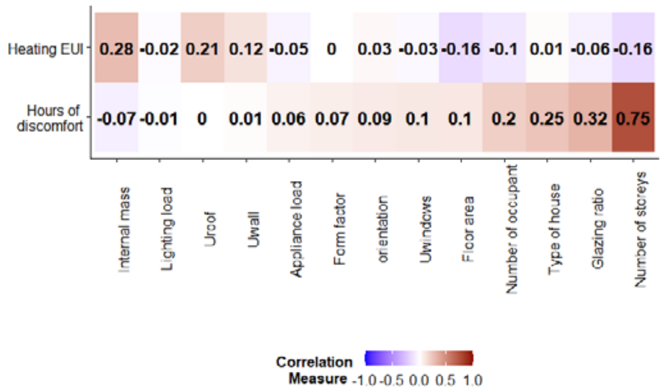
Figure 4:
Pearson correlation coefficients of Heating EUI and hours of discomfort according to some of the input data.



4. DISCUSSION

As presented in Figure 4 presents the Pearson correlation coefficients for space heating EUI and the HoD, and some of the input parameters. The results show a *strong* and *moderate* correlation between the HoD and the number of stories and glazing ratio, respectively. On the other hand, the space heating EUI and internal mass have a moderate correlation.

Figure 4, HoD is strongly impacted by the number of floors, mainly because the reference indoor temperature is higher in two-story houses. The second floor generally has the highest temperature because it does not benefit from the thermal inertia of an uninsulated ground contact floor, contrary to the first floor. Window-to-wall glazing ratio is the second significant input affecting the HoD, showing the importance of controlling solar heat gains to reduce the HoD. Surprisingly, the orientation has a low significance, probably due to the architectural symmetry of BEM models.

Regarding space heating, the significance of internal mass might be explained by the intermittency of space heating reported in the 2018 national energy survey. An 80% of the respondents living in the Metropolitan region declared using space heating for 6 hours a day or less. For the same reason, the impact of some parameters might be underestimated, such as the heat transfer coefficients of the roof and walls.

The residential air conditioning in Chile is a new and growing market. Indeed, the national energy surveys (Corporation de Desarrollo Tecnológico, 2010; In-Data, 2019) indicate that air cooling in RM increased from 1% in 2009 to 4.5% in 2018. Furthermore, according to the bottom-up model by (McNeil et al., 2008), the market saturation in Chile is estimated to be 35% of the stock - considering a GDP per Capita (PPP) of US$ 24,750 (The World Data Bank, n.d.), a household size of 3.1 members (Instituto Nacional de Estadísticas de Chile (INE)., 2018) and 319°C.days of cooling degree days, with a base of 18°C (CDD_{18}) in historical climate. Furthermore, the market saturation might increase to 60 % approximately by 2050 considering a prospect of GDP per capita at 31,500 USD (OECD, n.d.), a household size of 2.85 members (estimated through a linear regression between the household size and the logarithmic base 10 of GDP per capita) and CDD_{18} between 480 and 550°C.days.

Given that projection and the simulation results, the existing residential building stock needs to be adapted to prevent RM households from aquiring air conditioners. Although air conditioning devices might help reduce the carbon footprint of space heating due to better energy efficiency, they would add an extra energy consumption for space cooling, with the associated impact on the electrical grid and the carbon footprint associated with the operational and fugitive emissions. Considering that the glazing ratio is the second most influential parameter of HoD, the control of solar heat gains through exterior solar protection like overhangs, external shadings, and vegetation should be encouraged.

Current national energy policies are focused on increasing the energy performance of new buildings and subsidizing the retrofit of low-income dwellings such as wall and roof insulation, replacement of windows or renewables installation. Although these subsidies aim to eradicate energy poverty, an estimated 15.5% of the Chilean population (Villalobos et al., 2021), the national retrofit strategy should also consider the risk of overheating under future climates. Therefore, subsidies must include technical support for the benefiting families to ensure that the retrofit solution is tailored to their energy performance and comfort requirements.

5. CONCLUSION

A BEM method based on archetypes and stochastic input parameters is proposed to simulate the thermal behavior of a housing stock in the Metropolitan region of Chile under historical and projected climates. Preliminary results show a similar indoor temperature distribution as measured temperature by the RENAM program. The building stock is then simulated under different projected climates using six climate change scenarios based on three climates models with two representative concentration pathways. The main findings of the present study are the following:

- It is possible to generate a set of BEM models which improves the representation of the heterogeneity of a building stock using archetypes, and national datasets and surveys
- As expected, hours of discomfort will increase by 2050 and more especially in two-story houses with low energy use intensity of space heating
- Window-to-wall glazing ratio appears as the second more influent parameter in the hours of discomfort, highlighting the need for solar gain control through solar protection in retrofit strategies

Future work should deepen the presented analysis, including multifamily buildings and the operational carbon footprint of space heating and cooling systems. Finally, different scenarios of the existing building-stock adaptation to climate change should be studied.

REFERENCES

1. Burman, E., Mumovic, D., & Kimpian, J. (2014). Towards measurement and verification of energy performance under the framework of the European directive for energy performance of buildings. Energy, 77, 153–163. https://doi.org/10.1016/J.ENERGY.2014.05.102
2. Corporation de Desarrollo Tecnológico. (2010). Estudio de Usos Finales y Curva de Oferta de Conservación de la Energía en el Sector Residencial de Chile.
3. Dino, I. G., & Meral Akgül, C. (2019). Impact of climate change on the existing residential building stock in Turkey: An analysis on energy use, greenhouse gas emissions and occupant comfort. Renewable Energy, 141, 828–846. https://doi.org/10.1016/J.RENENE.2019.03.150
4. European Committee for Standardization. (2019). EN 16798-1:2019. Energy performance of buildings - Ventilation for buildings - Part 1: Indoor environmental input parameters for design and assessment of energy performance of buildings addressing indoor air quality, thermal environment, lighting and acoustics
5. In-Data. (2019). Informe final de usos de la energía de los hogares Chile 2018.
6. Instituto nacional de estadísticas de Chile (INE). (2018). Síntesis de Resultados CENSO 2017. https://www.censo2017.cl/descargas/home/sintesis-de-resultados-censo2017.pdf
7. International Energy Agency. (2021). Net Zero by 2050 A Roadmap for the. www.iea.org/t&c/
8. Jia, H., & Chong, A. (2021). eplusr: A framework for integrating building energy simulation and data-driven analytics. Energy and Buildings, 237, 110757. https://doi.org/10.1016/J.ENBUILD.2021.110757
9. Kelly, S., Crawford-Brown, D., & Pollitt, M. G. (2012). Building performance evaluation and certification in the UK: Is SAP fit for purpose? In Renewable and Sustainable Energy Reviews (Vol. 16, Issue 9, pp. 6861–6878). Pergamon. https://doi.org/10.1016/j.rser.2012.07.018
10. Ladybug Tools | Honeybee. (n.d.). Retrieved September 16, 2021, from https://www.ladybug.tools/honeybee.html
11. Laustsen, J. (2008). Energy Efficiency Requirements in Building Codes , Energy Efficiency Policies for New Buildings. Buildings, March, 1–85. http://www.iea.org/g8/2008/Building_Codes.pdf
12. McNeil, M. A., Letschert, V. E., McNeil, M. A., & Letschert, V. E. (2008). Future Air Conditioning Energy Consumption in Developing Countries and what can be done about it: The Potential of Efficiency in the Residential Sector Publication Date. Lawrence Berkeley National Laboratory. https://escholarship.org/uc/item/64f9r6wr
13. METEOTEST. (n.d.). Meteonorm. Retrieved October 10, 2013, from http://meteonorm.com/
14. Ministerio de Vivienda y Urbanismo. (n.d.). Red de Monitoreo de Viviendas. Retrieved January 15, 2022, from https://renam.cl/
15. Moazami, A., Nik, V. M., Carlucci, S., & Geving, S. (2019). Impacts of future weather data typology on building energy performance – Investigating long-term patterns of climate change and extreme weather conditions. Applied Energy, 238, 696–720. https://doi.org/10.1016/J.APENERGY.2019.01.085
16. Molina, C., Jones, B., Hall, I. P., & Sherman, M. H. (2021). CHAARM: A model to predict uncertainties in indoor pollutant concentrations, ventilation and infiltration rates, and associated energy demand in Chilean houses. Energy and Buildings, 230. https://doi.org/10.1016/J.ENBUILD.2020.110539
17. Molina, C., Kent, M., Hall, I., & Jones, B. (2020). A data analysis of the Chilean housing stock and the development of modelling archetypes. Energy and Buildings, 206, 109568. https://doi.org/10.1016/j.enbuild.2019.109568
18. Nik, V. M., & Sasic Kalagasidis, A. (2013). Impact study of the climate change on the energy performance of the building stock in Stockholm considering four climate uncertainties. Building and Environment, 60, 291–304. https://doi.org/10.1016/J.BUILDENV.2012.11.005
19. OECD. (n.d.). Domestic product - GDP long-term forecast. Retrieved January 18, 2022, from https://data.oecd.org/gdp/gdp-long-term-forecast.htm
20. Olonscheck, M., Holsten, A., & Kropp, J. P. (2011). Heating and cooling energy demand and related emissions of the German residential building stock under climate change. Energy Policy, 39(9), 4795–4806. https://doi.org/10.1016/j.enpol.2011.06.041
21. Rhino - Rhinoceros 3D. (n.d.). Retrieved September 16, 2021, from https://www.rhino3d.com/es/
22. Rouault, F., Ossio, F., González-Levín, P., & Meza, F. (2019). Impact of Climate Change on the Energy Needs of Houses in Chile. Sustainability 2019, Vol. 11, Page 7068, 11(24), 7068. https://doi.org/10.3390/SU11247068
23. Rubio-Bellido, C., Pérez-Fargallo, A., & Pulido-Arcas, J. A. (2016). Optimization of annual energy demand in office buildings under the influence of climate change in Chile. Energy, 114, 569–585. https://doi.org/10.1016/J.ENERGY.2016.08.021
24. The World Data Bank. (n.d.). GDP per capita, PPP (current international $) - Chile | Data. Retrieved January 18, 2022, from https://data.worldbank.org/indicator/NY.GDP.PCAP.PP.CD?locations=CL
25. US Department of Energy. (n.d.). Building Technologies Office: EnergyPlus Energy Simulation Software. Retrieved September 28, 2013, from http://apps1.eere.energy.gov/buildings/energyplus/
26. Verichev, K., Zamorano, M., & Carpio, M. (2020). Effects of climate change on variations in climatic zones and heating energy consumption of residential buildings in the southern Chile. Energy and Buildings, 215, 109874. https://doi.org/10.1016/J.ENBUILD.2020.109874
27. Villalobos, C., Chávez, C., & Uribe, A. (2021). Energy poverty measures and the identification of the energy poor: A comparison between the utilitarian and capability-based approaches in Chile. Energy Policy, 152, 112146. https://doi.org/10.1016/J.ENPOL.2021.112146

PLEA STGO 2022

November 22 - 25, 2022

SUSTAINABLE URBAN DEVELOPMENT

DAY 01
08:30 — 10:00

CHAIR
SEBASTIÁN LACLABERE

PAPERS
1548 / 1542 / 1504 / 1251 / 1536 / 1682

1ST PARALLEL SESSION / ONLINE

WILL CITIES SURVIVE?