Green Energy and Technology

Laura Marín-Restrepo
Alexis Pérez-Fargallo
María Beatriz Piderit-Moreno
Maureen Trebilcock-Kelly
Paulina Wegertseder-Martínez *Editors*

Removing Barriers to Environmental Comfort in the Global South

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Editors
Laura Marín-Restrepo
Architecture et Climat, Louvain research institute for Landscape, Architecture, Built environment (LAB)
Université catholique de Louvain
Louvain-la-Neuve, Belgium

Alexis Pérez-Fargallo
Department of Building Science
Faculty of Architecture
Construction and Design
Universidad del Bío-Bío
Concepción, Chile

María Beatriz Piderit-Moreno
Department Design and Theory of Architecture
Faculty of Architecture
Construction, and Design
Universidad del Bío-Bío
Concepción, Chile

Maureen Trebilcock-Kelly
Department Design and Theory of Architecture
Faculty of Architecture
Construction, and Design
Universidad del Bío-Bío
Concepción, Chile

Paulina Wegertseder-Martínez
Department Design and Theory of Architecture
Faculty of Architecture
Construction, and Design
Universidad del Bío-Bío
Concepción, Chile

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To Mercedes, Hernán, Cristian, Bernando, and Sebastian

Foreword

What a pleasure it is today, to write the foreword for a book like this, given the immensity of the questions we are all facing.

This book talks about environmental comfort and focuses, in particular, on vulnerable populations. It gives the floor to different experts from the Global South, with the validated results of their research, providing its structure.

Today, to discuss environmental comfort, in the broadest sense, is to consider all the contexts in which a project is developed: climatic, hydric, vegetation, societal, economic, technological, etc. More specifically, both inside buildings and in outdoor public spaces, it is to study and interconnect several objective-measurable physiological phenomena (air temperature, air movement and speed, relative humidity, the activity of the individual and their clothing, air quality, daylighting and sound) and a series of subjective psycho-sensory phenomena (the atmosphere of a garden, the presence of water, the architectural quality, the acoustic protection from external noises, the colors of the environment, the smell of the vegetation, the cleanliness, and the company of the people…).

On the other hand, this work of reference is imperiously engrained within the sustainable development framework, placing humankind at the heart of this concern.

By definition, sustainable architecture is ethically engraved in its environments (contexts), it benefits from their advantages, it protects itself from their disadvantages, it helps them benefit from what it generates, and, ultimately, it protects them from its own troubles.

Thus, new architecture can be born: the location is judiciously chosen, the planning is perfectly defined (mixed functions, mixed populations, and public meeting spaces), the energy design is optimal (summer-winter), the water issue is considered in its entirety (economy, rainwater, natural water cycle), the materials are chosen, respecting the environment and health, the design is thought out, taking into account the waste from the construction site and the end of the building's life.

Thus, this book is a guide for the entire construction sector and helps to respond to ever more pressing issues such as climate change, energy needs, and the comfort needs of occupants.

I would like to thank all the authors for the quality of this book.

October 2022

André De Herde
Professor Emeritus
Université catholique de Louvain
Director Emeritus
Architecture and Climate
Research Group
Louvain-la-Neuve, Belgium

Preface

The concept of environmental comfort is complex. It can be observed from different areas and is dynamic, evolving throughout history as it addresses social, technological, economic, and cultural evolution. Cultural, social, and economic factors, among others, are fundamental to understanding comfort holistically.

In recent years, environmental comfort has made relevant advances through research and the development of standards and policies at the international level. However, in the specific case of the Global South, where the countries with the highest levels of income inequality are concentrated, environmental comfort has its own characteristics and challenges that prevent a clear understanding from the established vision of the Global North.

As researchers linked to environmental comfort, we have found that in the Global South, there are regional barriers that entail approaching environmental comfort from other prisms, with angles tied to social, economic, and cultural realities and even industrial, technological, and constructive development.

However, as researchers in the Global South, we often tend to look at the Global North and believe that there are not many references outside the north, even though the diversity of aspects we have in common –climatic, geographical, social, etc.– confront us with common challenges.

It is precisely from this line that the idea of this book arises, at a latitude of 36°49'41"S and longitude of 73°3'5"W, where the group of editors of this book forms the "Environmental Comfort and Energy Poverty" research group and actively participates in the teaching of the Masters in Sustainable Habitat and Energy Efficiency and the Doctorate in Architecture at the University of Bío-Bío, with students and graduates from a variety of Latin American and Caribbean countries.

After several generations of graduates, we have found that the progress made is often undervalued or even worse, unknown by peers and/or actors of the built environment in our own countries. This is even though, in recent decades, efforts have been made by countries, political leaders, and researchers in the southern hemisphere to begin addressing these issues from our reality.

This is why we find it pertinent to collect part of this progress and make it available to a diverse public, not necessarily experts but those interested in finding ways to

improve the quality of people's lives without harming the environment. Therefore, the goal of this book is twofold. First, it seeks to broadly contribute to the development of the concept of environmental comfort, to visualize how from the Global South, progress has been made in understanding the concept from a culturally rooted vision.

Secondly, the book seeks to reach engineers, architects, and researchers from developing countries interested in environmental comfort and its influence on energy consumption, energy poverty, and other related factors, as well as decision-makers and public policy developers associated with the indoor comfort of buildings, making the knowledge generated and applied to this side of the world available.

How to Approach This Book

Our approach in this book has been an attempt to address the main barriers to environmental comfort in the Global South, collecting concepts, theories, arguments, strategies, and tools in a way that leaves them open for discussion, criticism, and understanding.

Environmental comfort is a broad concept still in development, and of which we do not fully know the barriers and how to overcome them. Hence, the concepts and ideas presented in this book are not the definitive answer but rather a first step to recognizing other realities that have their own characteristics and that, therefore, require new reflections. Where possible, we have tried to include the main barriers that are important to address to improve environmental comfort in buildings in the Global South as well as references to many original sources and key thinkers. A careful reading of these ideas may take some time, and we invite you to look at the sources we cite to reflect yet further. We also hope you will identify common aspects and references in countries with similar realities.

Finally, we would like to encourage you to think critically about the barriers, concepts, and ideas presented in this book to reach your own vision using your own social and cultural reality. As we have already indicated, this book is not a definitive text where solutions to all existing problems on environmental comfort are proposed, but rather it should be read as part of the evolutionary process of comfort in buildings in the Global South.

Concepción, Chile
October 2022

Laura Marín-Restrepo
Alexis Pérez-Fargallo
María Beatriz Piderit-Moreno
Maureen Trebilcock-Kelly
Paulina Wegertseder-Martínez

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We would like to thank the Vice-Rector for Research and Postgraduate Studies of Universidad del Bío-Bío, for financing the "Confort Ambiental y Pobreza Energética" (Environmental Comfort and Energy Poverty) research group (GC/C 19450), which was behind the development of this book, and the Ibero-American Program on Science and Technology for Development (CYTED), for financing the "Ibero-American Network of Energy Poverty, and Environmental Well-being" (RIPEBA Thematic Network 722RT0135), through which we have intensified cooperation with other researchers and centers in the Global South.

Laura Marín-Restrepo, while assembling and writing this book, left the Global South, and has been working as a postdoctoral researcher since October 2021 in the Architecture et Climat group, Louvain research institute for Landscape, Architecture, Built environment (LAB) at the Université Catholique de Louvain. Her research is Funded by the Belgian National Fund for Scientific Research (F.R.S.–FNRS).

We also feel it is necessary to thank all the organizations, institutions, centers, and postgraduate training programs that support research on a daily basis, by financing projects, providing technical support, and with advanced human capital training to improve the environmental comfort of buildings in the Global South. In this vein, special thanks go to the graduates of the Masters in Sustainable Habitat and Energy Efficiency and the Ph.D. program in Architecture and Urbanism at Universidad del Bio-Bío, for their contributions from different countries throughout Latin America and the Caribbean.

Finally, this book has only been possible thanks to the extraordinary efforts of the authors, who have shown, from their different countries and continents, an exceptional commitment to improving the comfort of buildings from science, contributing to "Removing Barriers to Environmental Comfort in the Global South." We are extremely grateful to everyone, and we hope this book meets their expectations.

Special thanks are given to Kevin Wright and Paz Sepúlveda for their support in reviewing the English version of the book and the edition of its texts; to Francisca Jiménez Reyes, for her help revising the format and bibliography; and to Sebastian Giraldi, for his valuable and generous collaboration in formatting and editing the manuscript.

Contents

Contributors

Hanan Al-Khatri Department of Civil and Architectural Engineering, College of Engineering, Sultan Qaboos University, Muscat, Sultanate of Oman

Jose Ali Porras-Salazar School of Architecture, University of Costa Rica, San Pedro de Montes de Oca, Costa Rica

Laura Andrade Sepúlveda EMAT Lab, School of Architecture, Architecture Faculty, Universidad Nacional de Colombia, Medellín, Colombia

Lucas Arango-Díaz Facultad de Artes Integradas, Universidad de San Buenaventura, Medellín, Colombia

John Arango-Flórez EMAT Lab, School of Architecture, Architecture Faculty, Universidad Nacional de Colombia, Medellín, Colombia

Bruno Damián Arballo FAUD, Universidad Nacional de San Juan. CONICET, San Juan, Argentina

Gabriela Magali Arrieta National Council for Scientific and Technical Research (CONICET), Buenos Aires, Argentina

Shady Attia Sustainable Building Design Lab, Department UEE, Faculty of Applied Sciences, Université de Liège, Liège, Belgium

Ariel Bobadilla-Moreno Center for Research in Construction Technologies (CITEC), University of Bío-Bío, Concepción, Chile

Daniela Borja Zuluaga Faculty of Architecture and Engineering, Institución Universitaria Colegio Mayor de Antioquia, Medellín, Colombia

Ivan Julio Apolonio Callejas Federal University of Mato Grosso, Cuiabá, Brazil

Carolina Cano Arroyave EMAT Lab, School of Architecture, Architecture Faculty, Universidad Nacional de Colombia, Medellín, Colombia

Elizabeth Castro Burbano EMAT Lab, School of Architecture, Architecture Faculty, Universidad Nacional de Colombia, Medellín, Colombia

Francisco Castro Department Design and Theory of Architecture, Faculty of Architecture, Construction, and Design, Universidad del Bío-Bío, Concepción, Chile

Daniel Chuk Instituto de Investigaciones Mineras, FI, Universidad Nacional de San Juan, San Juan, Argentina

Silvia de Schiller Research Centre Habitat and Energy, Faculty of Architecture, Design and Urbanism, University of Buenos Aires, Buenos Aires, Argentina

Muriel Diaz Department of Architectural Design and Theory, Faculty of Architecture, Construction and Design, Universidad del Bío-Bío, Concepción, Chile;
Sustainable Building Design Lab, Department UEE, Faculty of Applied Sciences, Université de Liège, Liège, Belgium

Renata Diniz Department of Civil Construction, Postgraduate Program in Civil Engineering, Universidade Tecnológica Federal do Paraná (PPGEC/UTFPR), Curitiba, Brazil

Luciane Cleonice Durante Federal University of Mato Grosso, Cuiabá, Brazil

Evyatar Erell Department of Man in the Desert, Ben-Gurion University of the Negev, Beersheba, Israel

John Martin Evans Research Centre Habitat and Energy, Faculty of Architecture, Design and Urbanism, University of Buenos Aires, Buenos Aires, Argentina

Leandro Fernandes Department of Graphical Expression, Universidade Federal do Paraná, Curitiba, Brazil

Jan-Frederik Flor Faculty of Architecture and Ekistics, Universiti Malaysia Kelantan, Bachok, Malaysia

Raphaela Walger da Fonseca Department of Architecture and Urbanism/CTC, Federal University of Santa Catarina, Florianopolis, Brazil

Suelem Schier de França Department of Architecture and Urbanism/CTC, Federal University of Santa Catarina, Florianopolis, Brazil

Ana Galarza Department of Architecture, Universidad de Piura, Piura, Peru

Ader García-Cardona EMAT Lab, School of Architecture, Architecture Faculty, Universidad Nacional de Colombia, Medellín, Colombia;
Integrated Arts Faculty, Universidad de San Buenaventura, Bello, Colombia

María José García Vallejo Integrated Arts Faculty, Universidad de San Buenaventura, Medellín, Colombia

Muhammad Luthfi Ghassan Architecture Consultant, Banda Aceh, Indonesia

Alex Gonzalez-Caceres Department of Architecture and Civil Engineering, Chalmers University of Technology, Göteborg, Sweden

Mahendra Gooroochurn Mechanical and Production Engineering Department, Faculty of Engineering, Universityof Mauritius, Reduit, Moka, Mauritius

Emeli Lalesca Aparecida da Guarda Federal University of Mato Grosso, Cuiabá, Brazil

Oscar Guillen Civil Engineering Program, Universidad de Piura, Piura, Peru

Giancarlo Gutiérrez Acoustics Consultant, Medellín, Colombia

Juan G. Gutiérrez Universidad de San Buenaventura, Cali, Colombia

Yury Hernández-Duque Integrated Arts Faculty, Universidad de San Buenaventura, Medellín, Colombia

Elisabeth Herreño-Téllez Integrated Arts Faculty, Universidad de San Buenaventura, Medellín, Colombia

Constanza Ipinza School of Architecture, University of Santiago de Chile, Santiago, Chile;
Department Design and Theory of Architecture, Faculty of Architecture, Construction, and Design, Universidad del Bío-Bío, Concepción, Chile

Luisa María Jaimes Nova EMAT Lab, School of Architecture, Architecture Faculty, Universidad Nacional de Colombia, Medellín, Colombia

Benjamin Jones Department of Architecture and Built Environment, University of Nottingham, Nottingham, UK

Ethieny Rossato Kramer Department of Architecture and Urbanism/CTC, Federal University of Santa Catarina, Florianopolis, Brazil

Eduardo Krüger Department of Civil Construction, Postgraduate Program in Civil Engineering, Universidade Tecnológica Federal do Paraná (PPGEC/UTFPR), Curitiba, Brazil

Ernesto Kuchen FAUD, Universidad Nacional de San Juan. CONICET, San Juan, Argentina

Arturo Raúl Maristany Center for Acoustic and Lighting Research (CIAL), Universidad Nacional de Córdoba, Faculty of Architecture, Urbanism and Design, Córdoba, Argentina

Laura Marín-Restrepo Architecture et Climat, Louvain Research Institute for Landscape, Architecture, Built Environment, Université catholique de Louvain, Louvain-la-Neuve, Belgium

Constanza Molina School of Civil Construction, Pontificia Universidad Católica de Chile, Santiago, Chile

Estefanía Montes-Villalva Department of Building Science, Faculty of Architecture, Construction, and Design, Universidad del Bío-Bío, Concepción, Chile

Olga Lucia Montoya Universidad de San Buenaventura, Cali, Colombia

Giobertti Morantes Department of Architecture and Built Environment, University of Nottingham, Nottingham, UK

Abdul Munir Architecture Department, Universitas Syiah Kuala, Banda Aceh, Indonesia

Jorge Muñoz-Fierro Center for Research in Construction Technologies (CITEC), University of Bío-Bío, Concepción, Chile

Moises Obando Robles School of Architecture, University of Costa Rica, San Pedro de Montes de Oca, Costa Rica

David Orozco Gallo EMAT Lab, School of Architecture, Architecture Faculty, Universidad Nacional de Colombia, Medellín, Colombia

Cristina Ospina Montoya EMAT Lab, School of Architecture, Architecture Faculty, Universidad Nacional de Colombia, Medellín, Colombia

Cecilia Palarino-Vico Department Design and Theory of Architecture, Faculty of Architecture, Construction, and Design, Universidad del Bío-Bío, Concepción, Chile

Lucia Pereira-Ruchansky Institute of Technologies, Faculty of Architecture, Design and Urbanism, University of the Republic, Montevideo, Uruguay

Fernando Oscar Ruttkay Pereira Department of Architecture and Urbanism/CTC, Federal University of Santa Catarina, Florianopolis, Brazil

María Beatriz Piderit-Moreno Department Design and Theory of Architecture, Faculty of Architecture, Construction, and Design, Universidad del Bío-Bío, Concepción, Chile

Jose Ali Porras-Salazar School of Architecture, University of Costa Rica, San Pedro de Montes de Oca, Costa Rica

Jesús Pulido-Arcas Center for Research and Development of Higher Education, The University of Tokyo, Tokyo, Japan

Alexis Pérez-Fargallo Department of Building Science, Faculty of Architecture, Construction, and Design, Universidad del Bío-Bío, Concepción, Chile

Raúl Ramírez-Vielma Department of Psychology, Universidad de Concepción, Concepción, Chile

Laura Rendón Gaviria Faculty of Architecture and Engineering, Institución Universitaria Colegio Mayor de Antioquia, Medellín, Colombia

David Resano Department of Architecture, Universidad de Piura, Piura Campus, Peru

Rodolfo Rodríguez Department of Basic Sciences, Universidad de Piura, Piura, Peru

Natalia Saavedra Universidad de San Buenaventura, Cali, Colombia

Jorge Hernán Salazar Trujillo EMAT Research Group, School of Architecture, Universidad Nacional de Colombia, Medellín, Colombia

Laina Hilma Sari Architecture Department, Universitas Syiah Kuala, Banda Aceh, Indonesia

Jaime Soto-Muñoz Department Design and Theory of Architecture, Faculty of Architecture, Construction, and Design, Universidad del Bío-Bío, Concepción, Chile

Maureen Trebilcock-Kelly Department Design and Theory of Architecture, Faculty of Architecture, Construction, and Design, Universidad del Bío-Bío, Concepción, Chile

Álvaro Vargas Olmos EMAT Lab, School of Architecture, Architecture Faculty, Universidad Nacional de Colombia, Medellín, Colombia

María Isabel Vivanco-Villavicencio Universidad Técnica Particular de Loja, Loja, Ecuador

Paulina Wegertseder-Martínez Department Design and Theory of Architecture, Faculty of Architecture, Construction, and Design, Universidad del Bío-Bío, Concepción, Chile

Manuela Yepes Ocampo Faculty of Architecture and Engineering, Institución Universitaria Colegio Mayor de Antioquia, Medellín, Colombia

What Are the Barriers to Environmental Comfort in the Global South?

Alexis Pérez-Fargallo and Laura Marín-Restrepo

Abstract Environmental comfort in buildings is a dynamic concept involving architectural, physical, environmental, as well as sociocultural, economic, geographic, and other variables. Today, the Brandt Line is still valid for establishing geographical differences in developments for sustainability, energy efficiency, renewable energy use, climate, altitude, emissions, and access to energy, and for identifying the barriers to environmental comfort. The current gaps in most Global South cases start from historical inequalities, along with geographical, topographical, cultural, and climatic singularities. There have been many and very varied barriers found. However, it is possible to highlight the ones the authors consider are the most important. The concepts related to environmental comfort and sustainable development goals and objectives have mainly been developed in the Global North, meaning for the Global South their definitions require not just conceptual adjustments but also new means of assessment and measurement. As a starting point, the actions and measures being implemented must include local efforts and advances, their available resources and capacities, and, in particular, each country's technological, economic, and social context. The chapters included in this book contribute in this sense.

Keywords Environmental comfort · Developing countries · Building sector · Architecture · SDG

A. Pérez-Fargallo
Department of Construction Science, Faculty of Architecture, Construction, and Design, Universidad del Bío-Bío, Concepción, Chile
e-mail: aperezf@ubiobio.cl

L. Marín-Restrepo (✉)
Architecture et Climat, Louvain Research Institute for Landscape, Architecture, Built Environment, Université catholique de Louvain, Louvain-la-Neuve, Belgium
e-mail: laura.marinrestrepo@uclouvain.be

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1 Introduction

Environmental comfort is relatively novel as an area of study. Its beginnings are linked to the Modern Movement and the introduction of air-conditioning systems within architecture. In 1902, when Willis Carrier invented air-conditioning in New York, looking to keep constant humidity, companies became interested in this invention to reduce problems of high humidity rates in their industrial processes. However, they were not initially interested in making temperatures more tolerable for their workers [1]. However, in 1906, Carrier began to exploit the potential of his invention for spaces with high occupation and little or no ventilation, such as theaters, even though it was not until 1920 that the general public experienced air-conditioning for the first time. From that moment, air-conditioning became an industry, and the first scientific research on thermal comfort was made. In 1923, Houghton and Yaglou [2] worked with the concept of climatic comfort in their study, "Determining lines of equal comfort", forming part of what today is known as American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE). In 1956, Carrier launched a window air-conditioning unit, and this type of installation reached homes, even affecting the demographics of the US, with the population in the hottest parts of the country, from Florida to California, rising from 28 to 40%, the so-called "North to South" effect. This influence continues today in cities like Dubai and Singapore. In the 1960s, Victor Olgyay [3] and Baruch Givoni [4] laid down the theoretical and scientific guidelines for human comfort within bioclimatic architecture. It is because of all this that "comfort" has been traditionally associated with thermal comfort.

However, the definition of comfort is complex and varies greatly depending on the area addressing it, be this engineering, architecture, psychology, sociology, or anthropology. This complexity grows further when the social, cultural, political, economic, climatic, and technological realities behind the definitions are radically distinct or start from different levels [5]. Nevertheless, as a starting point for this book, environmental comfort is considered the psycho-physical well-being of people in an environment related to the sensorial perceptions of an individual. It is determined then by factors linked to the environment, such as temperature, humidity, sound, and light [6]. Therefore, environmental comfort typically incorporates four parameters: thermal comfort, indoor air quality (IAQ), acoustic comfort, and visual comfort.

Currently, the main challenges facing the construction sector, such as energy consumption, energy poverty, and climate change, among others, are all linked, in one way or another, to the concept of environmental comfort [7], which is closely tied to the geographic location [8, 9]. For example, in 2018, it was shown that the United States and China represented 54% of the 1932 Terawatts per hour used by residential and commercial air-conditioning devices, which is the equivalent of the annual electricity consumption of Africa. However, Africa is the region of the world that is most exposed to the effects of climate change, even though its inhabitants are the ones who have contributed least to it, as they mainly find themselves in energy poverty, linked to access to energy, and therefore, find it impossible not just to reach a suitable environmental comfort, but to cover their basic energy needs [10].

Unfortunately, this is just one of the examples of the great contrasts between the Global North and the Global South regarding environmental comfort.

2 Global South

The "North-South" terminology arose from an allegoric application of categories to name patterns of wealth, privilege, and development into broad regions, initially driven by the Italian Marxist, Antonio Gramsci, in his essay "The Southern Question" about the differences between the north and south of Italy. Starting from here, the North-South concept began to be included in the international political lexicon, and in the 1980s, the Brandt Line was developed as a means to show how the world was geographically divided between the relatively wealthy and much poorer nations [11].

In this sense, the term, "Global South", refers to zones with a relevant background of colonialism, neo-imperialism, and differential economic and social changes through which major inequalities remain in the living levels, life expectancy, and access to resources [12]. In general, the Global South refers to regions outside Europe and North America, most with low incomes or substantial economic and social inequalities, which are mainly located in the tropics and the Southern Hemisphere, with the exception of Australia and New Zealand. However, this classification is questionable, as countries like Chile, Uruguay, and Costa Rica have a per capita GDP above the international average, while countries like Ukraine are now found among the set of poorer countries [13]. Even so, the evidence suggests that the Brandt Line is largely intact, as the states of the Global South are just as unsatisfied as they were four decades ago, while differentiated growth rates are remodeling world politics without eroding the North-South divide [14].

Although this division was made from a political point of view, it has been seen that, climatically, there are also relevant differences between north and south, finding, in general, countries with the highest level of horizontal solar radiation in the Global South (see Fig. 1), along with those with the highest temperatures (see Fig. 2), or most of those with the highest altitude cities (see Fig. 3). In this sense, it is important to highlight that more than 120 million people live above 2500 m, with all the countries with over a million inhabitants living at this altitude, in the Global South, with 7 of them in Latin America and the Caribbean [15]. Altitude is an additional factor that needs to be considered in the Global South.

These climatic differences have been fundamental for understanding architecture and its means of adapting to the climate. Examples of this are the Wind Towers or windcatchers in Iran, the house-courtyard of Arabian architecture for regions with a warm-dry climate, vernacular buildings built with heavy earthen walls in adobe or bahareque in tropical climates, intermediate zones that protect against the sun but use the wind for cooling, and architecture with solar protection elements or ventilated facades. This way of adapting architecture, generally to warm climates, unlike the Global North countries, which have less radiation and lower temperatures, is a differentiating aspect that must be considered further. However, in general, the

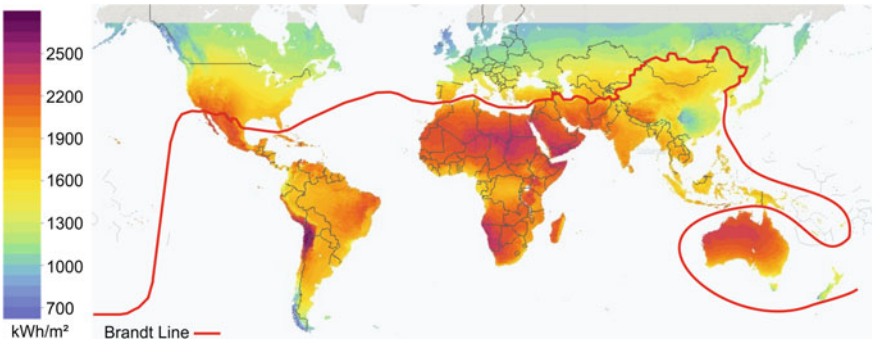

Fig. 1 Global horizontal irradiation (kW h m^2). Own preparation using [16]

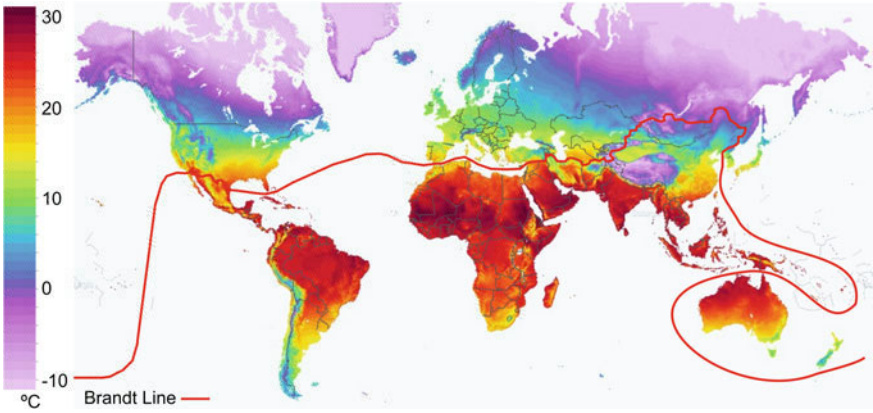

Fig. 2 Air Temperature at 2 m above ground level (°C). Own preparation using [16]

standards developed in recent decades, the energy rating processes, and the sustainability certifications are linked to cold climates and countries with a high economic level.

During the 1973 oil crisis, fears emerged in countries associated with the reduction of energy sources and energy dependence. To face this situation, they would launch incentive programs to reduce energy consumption, with energy efficiency standards later emerging. However, they were all developed in Global North countries. There were also advances in the Global South, such as the programs linked to energy efficiency in Mexico, which began in the 1980s. But it would not be until 2006 that Mexico would begin the Standardization and Labeling Program within the Energy Efficiency Project, and in 2008, issue the Law for Sustainable Energy Use. This shows that between the first experiences in energy efficiency standardization issues in the Global South and Global North, there is a time lag of approximately 30 years.

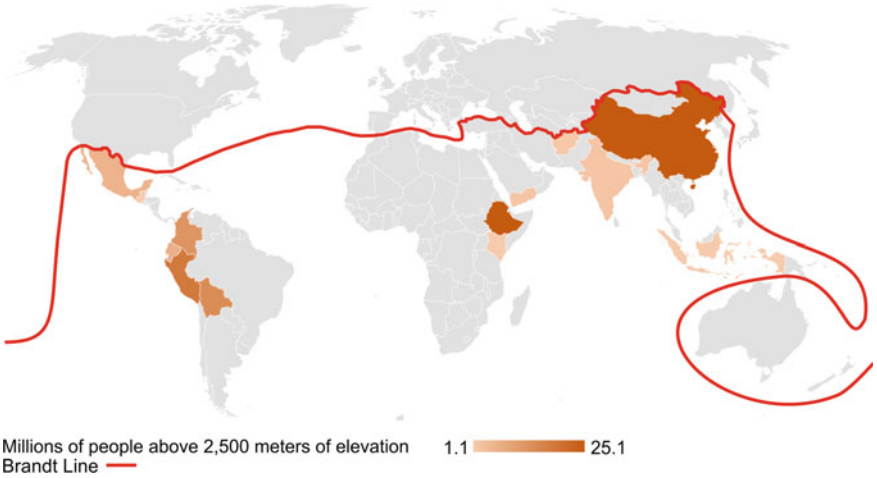

Fig. 3 Countries where more than a million inhabitants live above 2500 m. Own preparation using [15]

In the last two decades, noticeably many countries from the Global South have fostered policies and regulations on access to energy, energy efficiency, and renewable energies, as can be seen in the Regulatory Indicators for Sustainable Energy (RISE) scores of Fig. 4. The RISE scores provide a snapshot of the policies and regulations of a country in the energy sector, organized by the three pillars of sustainable energy: access to energy, energy efficiency, and renewable energy. It can be seen that despite the efforts and the progress there has been, there are still important gaps in the South, mainly in Africa and the Caribbean, with the energy efficiency indicator having the largest difference. This is addressed in greater detail in Chap. 29.

Access to quality energy, the production of renewable energy, energy efficiency, and international cooperation to facilitate access to energy-related research and technologies, promoting investment in clean technologies and energy infrastructure, expanding infrastructure, and improving technology to provide modern and sustainable energy services for everyone in developing countries, are the goals of the United Nations' Sustainable Development Goal N° 7 "Affordable and Clean Energy", and are a priority for Global South countries, linked to improving people's environmental comfort conditions. On the other hand, the goals described by the International Energy Agency [19] establish that, for 2050, more than 85% of buildings are zero-carbon ready, more than 90% of heavy industrial production is low emissions, and almost 70% of electricity generation globally is from solar PV and wind. In the same report, it indicates that

> For many rich countries, achieving net-zero emissions will be more difficult and costly without international cooperation. For many developing countries, the pathway to net zero without international assistance is not clear [19, p. 25].

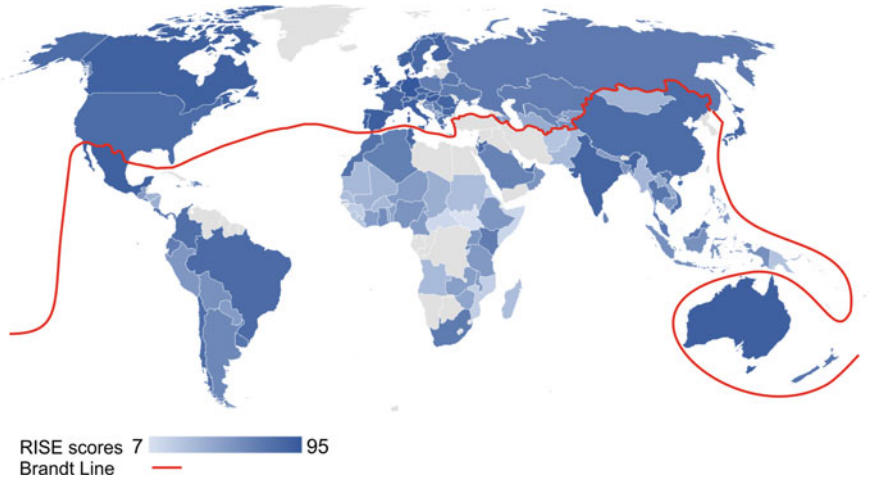

Fig. 4 Regulatory Indicator for Sustainable Energy (RISE) by countries. Own preparation using [17]

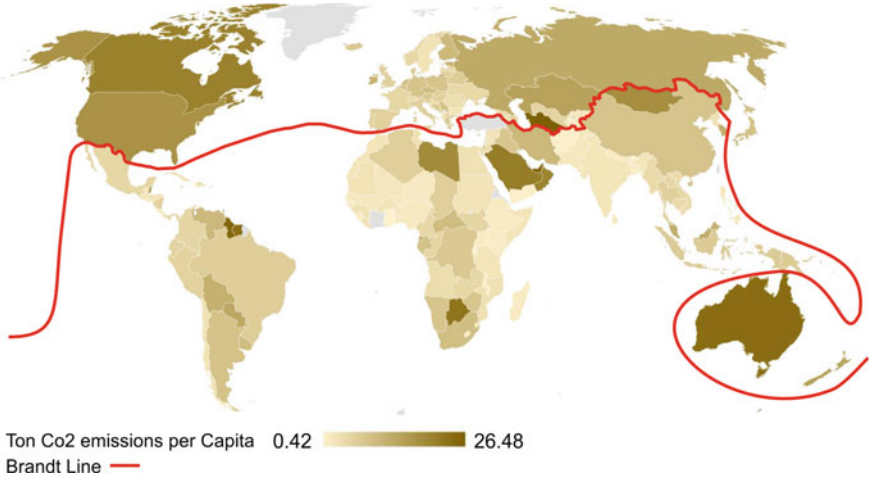

Fig. 5 CO_2 emissions per Capita 2019 (Ton/per Capita). Own preparation using [18]

However, the goals do not consider that in the Global South, there are already many countries whose CO_2 per capita emissions are very close to zero (see Fig. 5), showing a very different reality to most northern countries and, in general, this is not because of high energy efficiency, but rather an issue of access. It must be kept in mind that, in 2020, there were still 773 million people without electricity [20]. Furthermore, we do not know how many people live under conditions of low or zero environmental comfort on not having access to suitable air-conditioning systems, or simply not being able to use them due to energy poverty. Because of all this, the

objectives and/or goals marked out by the Global North are very difficult to reach without external financing or developing low-cost technologies for the Global South.

On the other hand, the Global South's socioeconomic context also implies different climate adaptations and responses to the "need" for comfort. Facing a lack of economic resources, extreme weather conditions in many cases, and the impossibility of hi-tech solutions, there is a better adaptation to the environment, namely personal actions that require little or no energy prevail in those places where they cannot afford or do not have access to it. To a certain extent, there are other priorities in the Global South.

As such, it is fundamental that the actions and measures being implemented, whatever their nature may be, must have as their starting point the local advances and efforts, the available resources and skills, and, especially, the technological, economic, and social context of each country.

3 Barriers to Environmental Comfort in the Global South

The beginnings of environmental comfort are relatively recent, linked to the introduction of air-conditioning systems in buildings in the Global North, and related to the main challenges of today for the construction sector. The definition of the concept is complex and varies depending on the social, cultural, political, economic, climatic, and technological variables. However, the methods, tools, and standards generally used in the Global South come from the Global North. In addition, there are common barriers related to geopolitical, economic, development, geographical, cultural, and social aspects, among others, that transcend the concept of environmental comfort but undoubtedly also affect it in many cases.

Although the Brandt Line is over 40 years old, considering the developments in sustainability, energy efficiency, renewable energy use, and other aspects related to environmental comfort, its territorial demarcation seems to be valid in most countries for these issues, also tying in with climatic, altitude, emissions, and access to energy aspects.

Currently, in the Global South's Indicators for Sustainable Energy, a relevant gap compared to the North is seen, which also suggests that for many countries of the South, it is impossible to reach the Sustainable Development Goals or the Net-Zero goals by 2050. The current gaps in most Global South cases start from geopolitical, economic, technological, and social-historical inequalities. The result is the barriers linked to environmental comfort, such as problems accessing energy, the use of contaminating energy sources, limited use of air-conditioning systems, a lack of energy infrastructure, low technological levels, high demand for housing, low standard self-builds, low labor quality, a lack of information on the building stock (thermal properties, use profiles, etc.), a lack of training for professionals on matters related to environmental comfort and energy efficiency, a lack of resources for development, high indoor and outdoor contamination, urban re-densification processes, and a major impact of climate change on the region.

Climate, socioeconomic conditions, and access to energy have a relevant impact on how environmental comfort and the Heating or Eating effect are faced in certain areas of the extreme Global South. This has meant that passive architecture and especially bioclimatic strategies associated with the thermal aspect and user comfort have been taken to the extreme in many cases, identifying important limitations when facing climate change and, on the other hand, being less developed on issues related to acoustic and visual comfort. On the other hand, the lack of environmental comfort regulatory requirements, or the importing of comfort requirements outlined for other climates and other construction, social, and economic realities, has also been seen as an important barrier in the Global South, given that these generate major performance gaps.

Climate change has and will continue to have a very relevant impact on the Southern Hemisphere, entailing, in many cases, a reduction of environmental comfort conditions, and in others, an increase in energy consumption caused by the widespread penetration of HVAC systems. Likewise, it has been seen that researchers have a particular interest in researching and developing low-cost tools and measures that do not increase users' energy dependence or that are easy to use for designers. However, in some cases, a disconnect in the design of the user, the architecture, and the climate has been described, as well as the designers' lack of knowledge of environmental comfort. It has even been discovered that the application of sustainability certifications in buildings does not imply that users have a better perception of environmental comfort.

Many Global South countries are building and modernizing their regulatory framework to improve environmental comfort in buildings. However, these processes, as their starting point, are using the Global North's developments of the last four decades, without fully addressing the technological, economic, and social context of each country, for different reasons. It is fundamental that the programs, laws, requirements, and procedures focused on demanding environmental and energy performance, are socially and economically acceptable in the current and future local reality.

On the other hand, the implementation of regulations on environmental comfort has barriers associated with the investment, the lack of awareness campaigns, a lack of agreements between parties, legislative progress, and the creation of verification and control processes, aspects that need greater political commitment and international support, mainly from the Global North. In addition, the new regulations are closely conditioned by housing shortages, and, therefore, define low demands for environmental comfort, to reduce public investments. In other cases, they focus on reducing demand and not improving environmental comfort through passive systems, thus fostering user energy dependence. In this vein, there are also barriers regarding investment in education and research, focusing attention on other priorities. Finally, there is a lack of connection between researchers and practitioners, between and within countries.

Ultimately, it must be emphasized that there are more and greater barriers in the Global South to improving environmental comfort in buildings than in most Global North countries. The concepts have been developed in the Global North, which means

that their definitions often do not face the realities of the Global South, entailing not just adjustments for the concepts but also new ways to evaluate and measure them. The chapters in this book contribute in this sense.

4 An Overview of the Content

This book has been structured considering the four parameters of environmental comfort: Thermal comfort, Indoor air quality, Visual comfort, and Acoustic comfort and its relationship with energy use and energy efficiency, seeking to address different barriers to environmental comfort.

Although the isolated study of comfort is a gap in itself, this structure shows the different angles of the topic, where clearly efforts have focused on the thermal aspect, perhaps fairly, because of its historical background and the specific climate challenges that countries are facing in the Global South.

Weather conditions and their variability in the Global South, and even within countries themselves, finding large countries with a great diversity of conditions, with deserts, coasts, mountains, forests, jungles, paramos, etc., and where often climate change is having a greater impact than in the Global North, is a relevant gap. Thus, the first two parts are dedicated to thermal comfort.

In Part I, with contributions from Costa Rica, Peru, Ecuador, Indonesia, Israel, and Chile, there is research on different building typologies, such as homes, schools, and offices. They assess the thermal environment and its perception in tropical, desert, Meso-Andean, and other climates. Part II has research from Argentina, Colombia, Mauritius, and Oman, on passive systems and resources for architectural and bioclimatic design, and studies of adaptive thermal comfort as a tool.

In Part I, Porras-Salazar et al., in Chap. 2, address vernacular architecture in Costa Rica, assessing the thermal performance of adobe and bahareque buildings to determine whether the thermal mass is effective in maintaining indoor temperatures within acceptable limits in the tropical climate zone. In contrast, Resano et al., in Chap. 3, focus on Peru, where despite being on the tropical strip, a large part of the population lives 3000 m or more above sea level in the Andes and is exposed to intense, cold climatic conditions. This study monitored the thermal performance of a typical Meso-Andean rural dwelling and proposed bioclimatic strategies for a context of resource scarcity. Meanwhile, Vivanco and Trebilcock, in Chap. 4, explore the thermal performance of educational buildings in different typical Andean tropical climates, including the Coastal Lowlands, the Andean Highlands, and the Amazon Rainforest in Ecuador, a context where thermal performance depends solely on the architectural design and occupant behavior.

However, in the Global South, there are many cases where air-conditioning systems are being incorporated into buildings to improve thermal comfort by eliminating the principles of tropical or vernacular architecture in contemporary buildings, as shown by Hilma et al. in Chap. 5. They focus on the current challenges of using air movement to improve thermal perception in Indonesia's warm-humid climate. Since,