Coping with Urban Climates

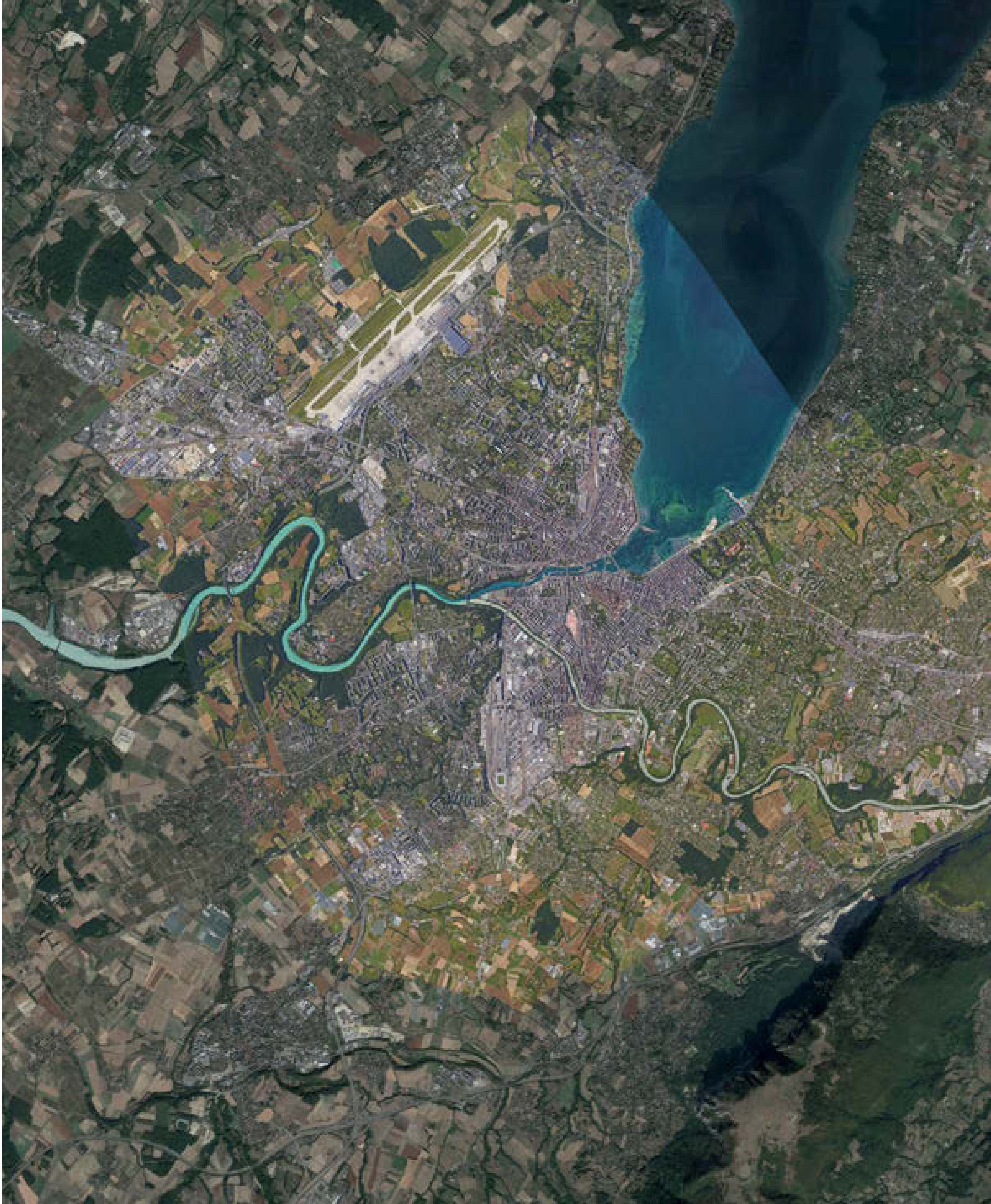
Comparative Perspectives on Architecture and Thermal Governance

Sascha Roesler,
Madlen Kobi,
Lorenzo Stieger (eds.)

KLIMA POLIS Vol. 2

Birkhäuser

Geneva, Switzerland



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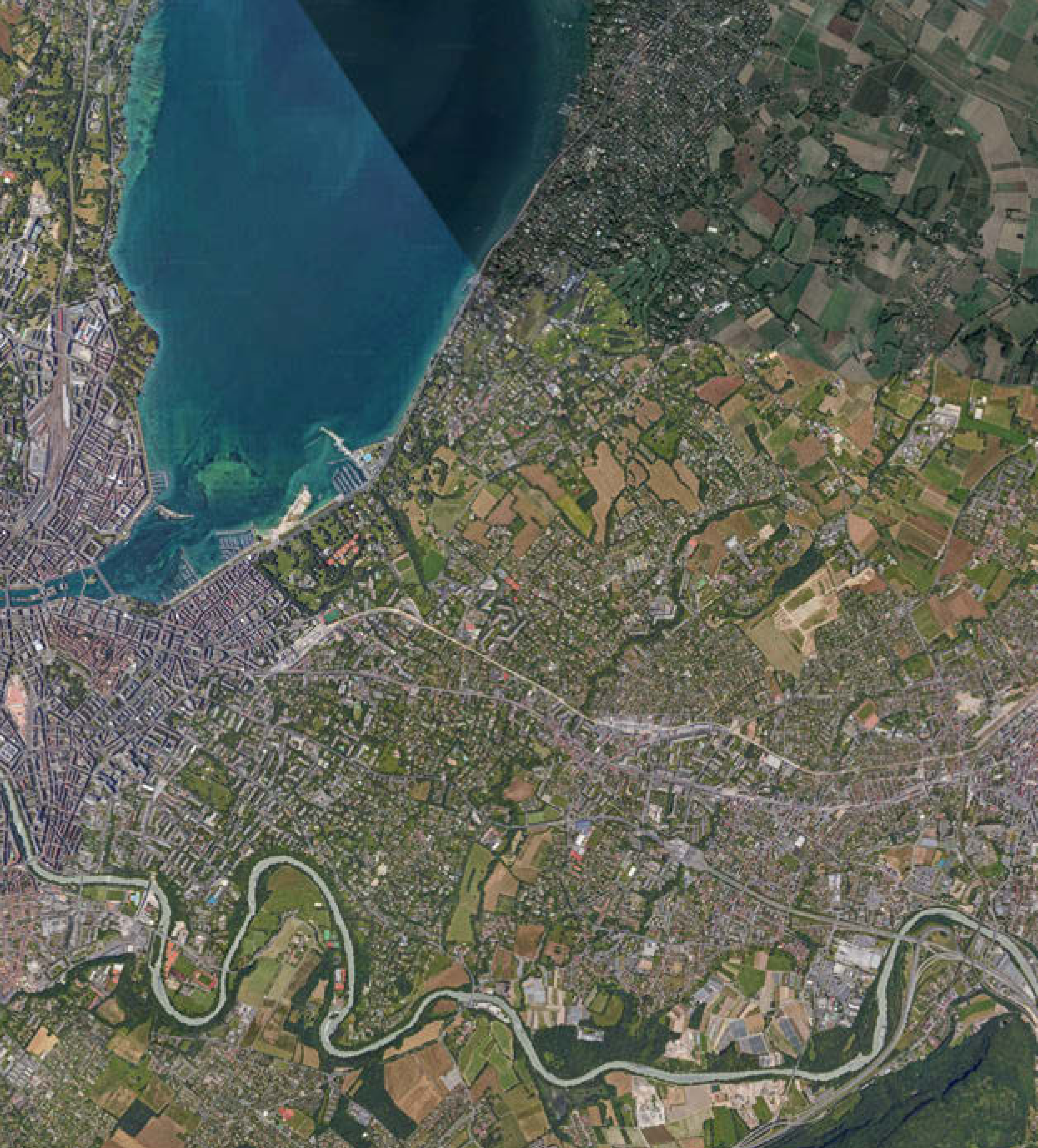

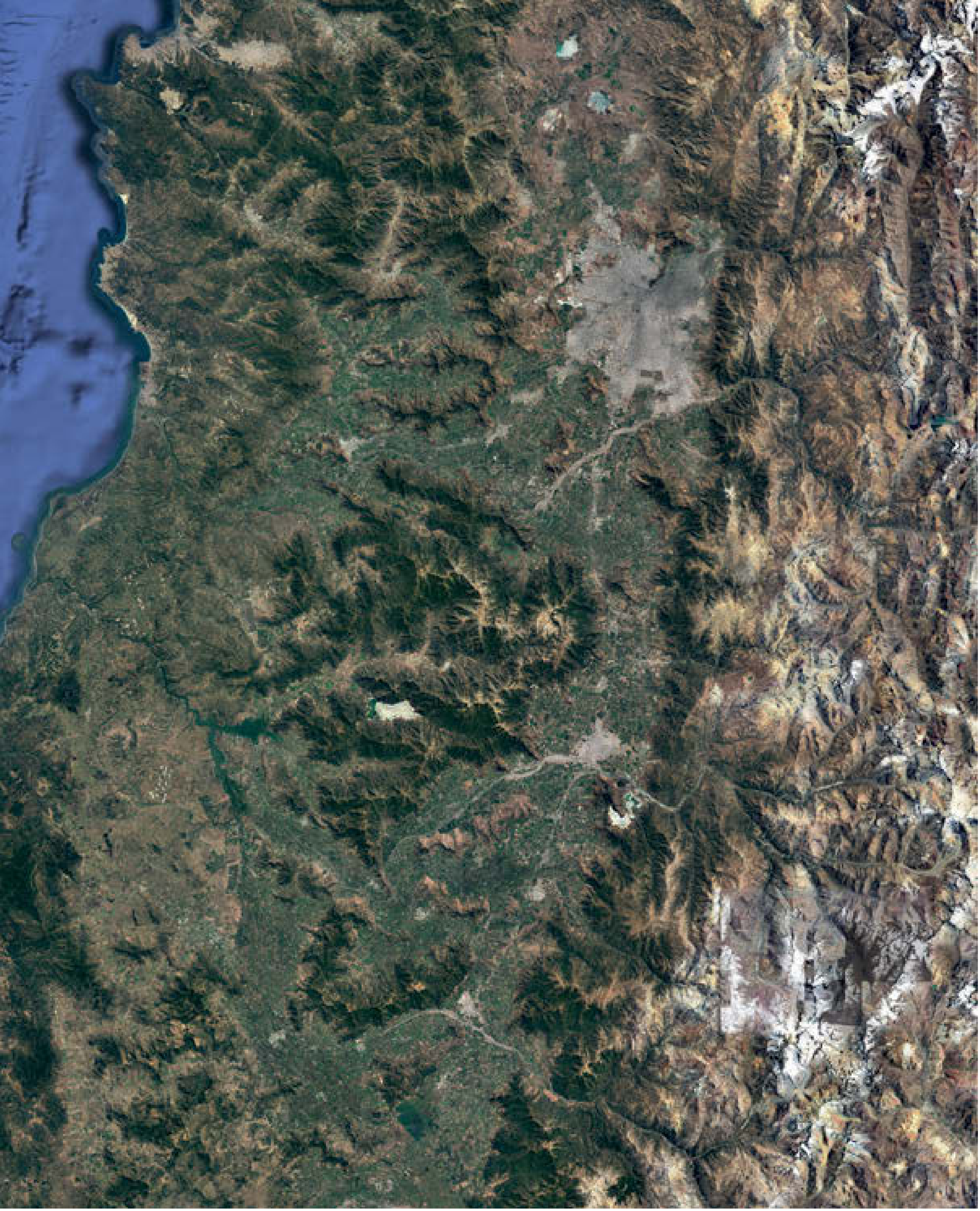

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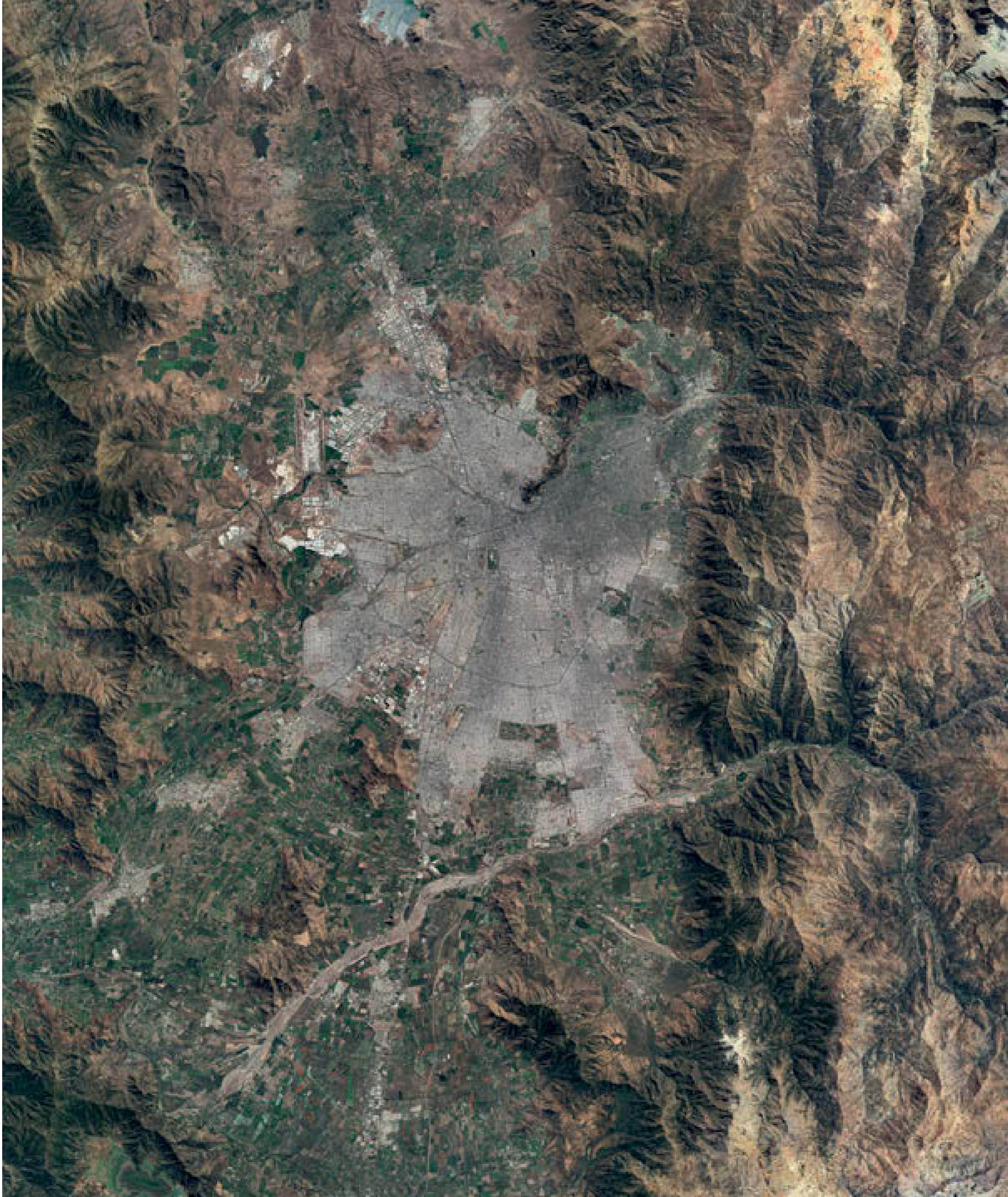

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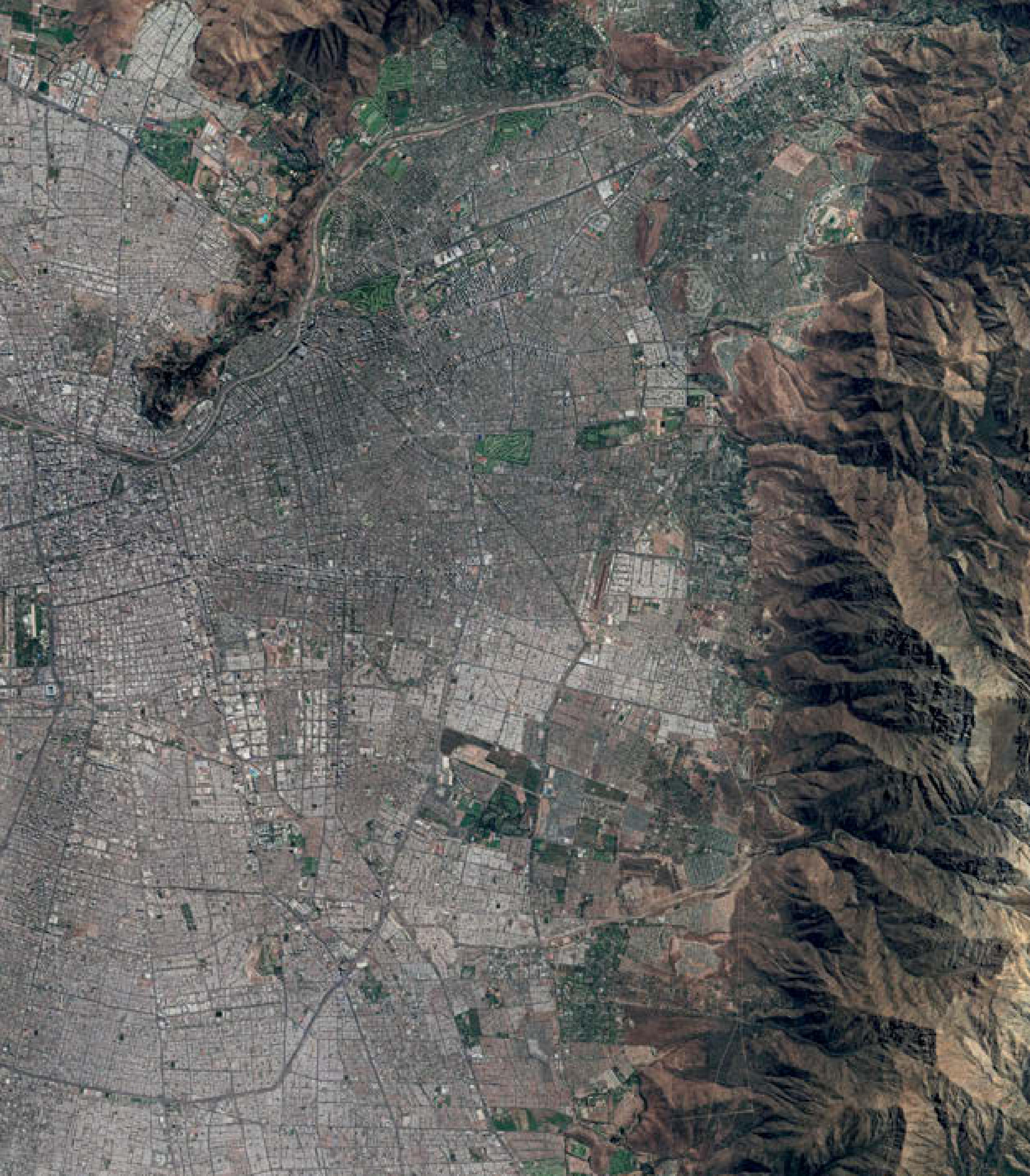

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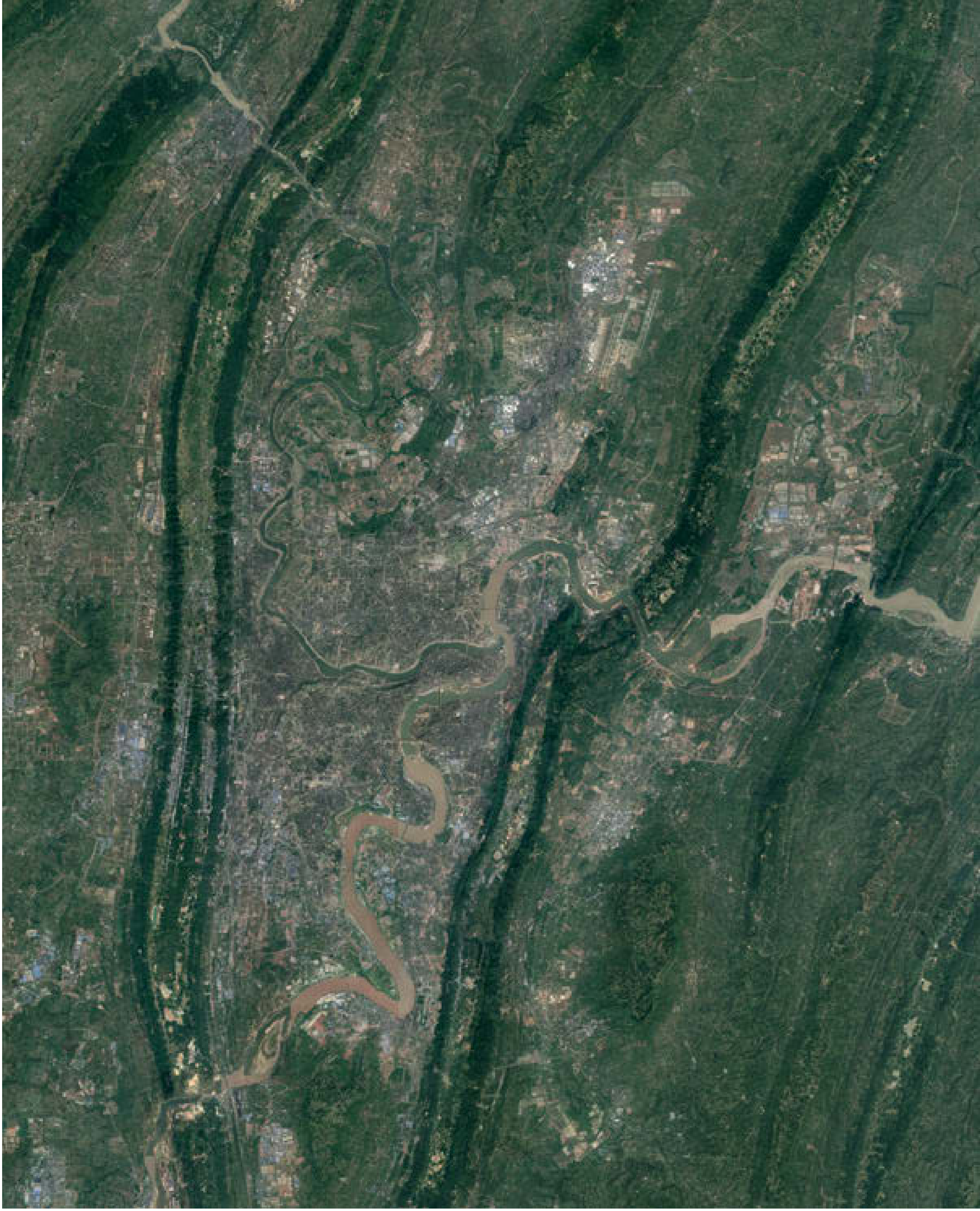

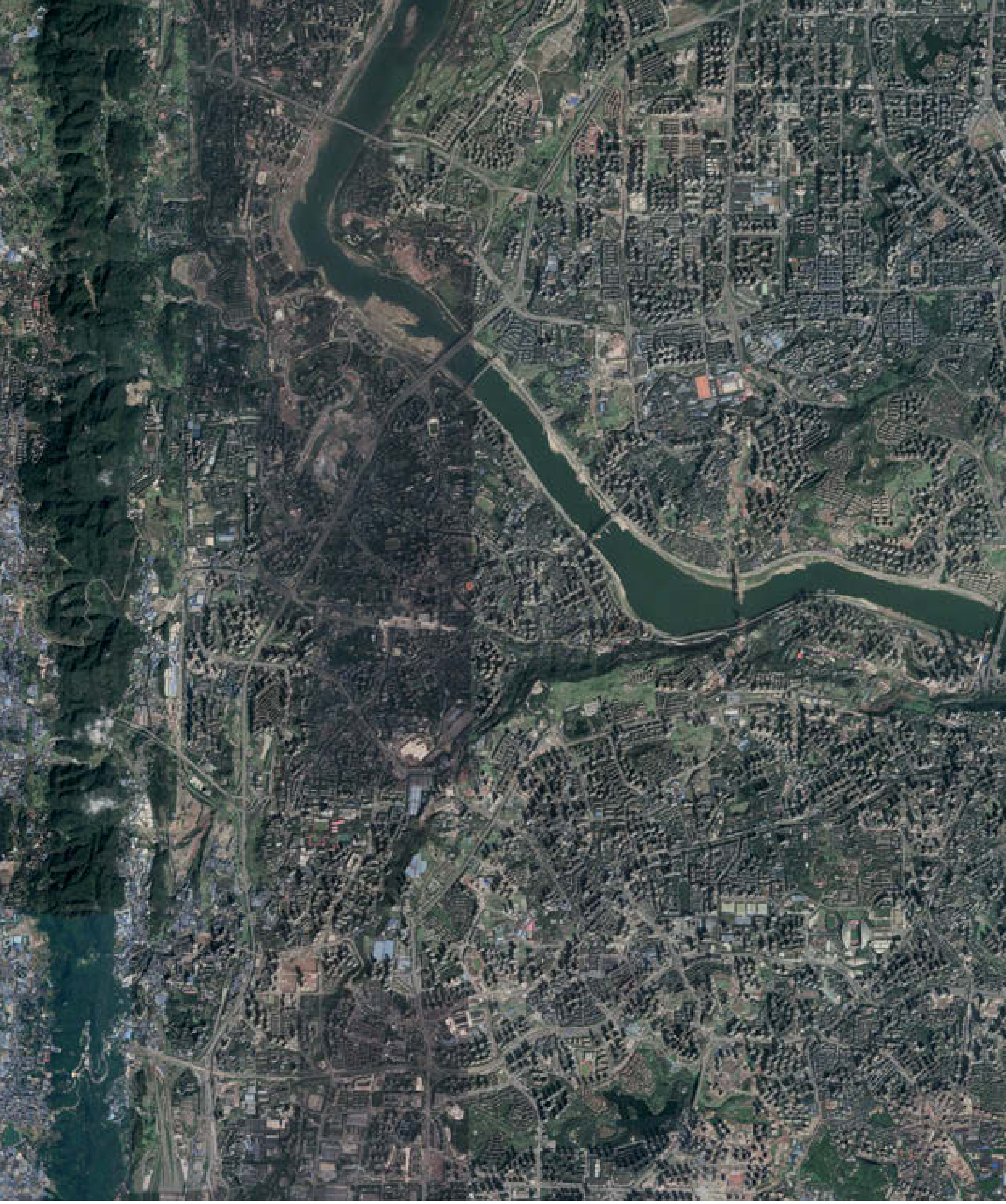

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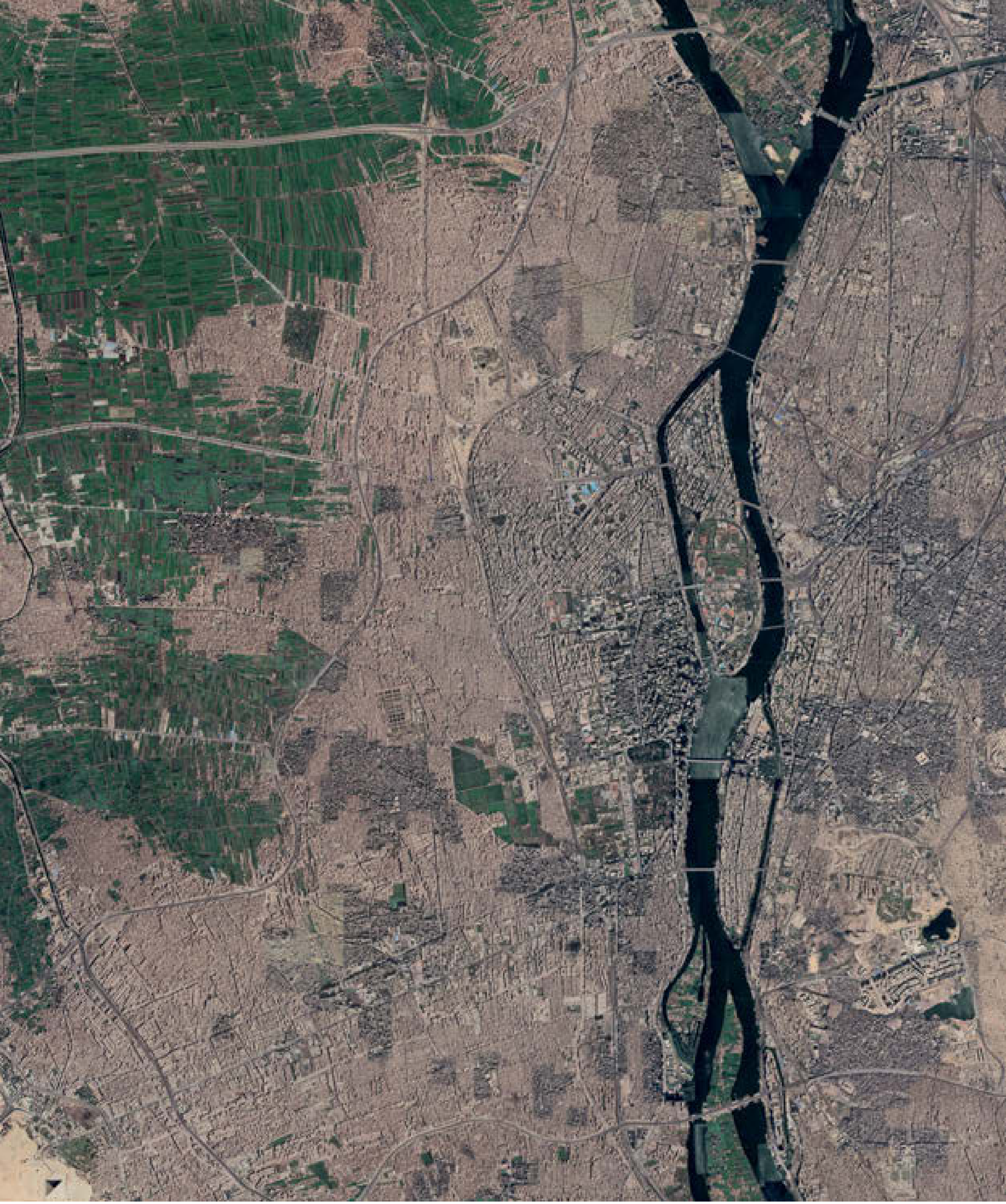

Cairo, Egypt

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Preface

It is not surprising that climate change and rising temperatures in cities have sparked a renewed public interest in concepts of urban climatology. However, the current debate on urban climate largely excludes the design issues that are so important. Currently it is science journalists, rather than architectural journalists that are setting the tone in the public sphere. So far, there is hardly any talk of architectural solutions in a more comprehensive sense, although the urban climate is in a fundamental way the product of the design—the form, arrangement and material—of urban buildings, and the cooling and heating requirements inside buildings depend to a large extent on the climatic conditions outside.

How can we translate insights of urban climatology into design? This methodological question was the starting point of a long-term research project. I initiated this project in 2013 at the Future Cities Laboratory of ETH in Singapore and it was continued in Switzerland as part of a six-year research grant on "Architecture and Urban Climates". The research was conducted at the Academy of Architecture in Mendrisio and at ETH Zurich in Switzerland thanks to generous funding by the Swiss National Science Foundation providing a grant of SFr. 2.2 million between 2015 and 2021.

Our conclusions have now taken the form of two major publications. These two books entitled *City, Climate, and Architecture* (Vol. 1) and *Coping with Urban Climates* (Vol. 2) launch a new international series entitled KLIMA POLIS, published by Birkhäuser.

The two first volumes of this series aim at rethinking climate control—a key concern of the discipline of architecture—through the lens of urban climate phenomena. They aim to stimulate new ways of thinking about the spatial order of cities by complying with the potentials of climate control at the scale of groups of buildings and their surrounding (urban microclimates). The two books clearly question whether the energy-source supply of urban architecture can still be taken as a private matter. Vol. 1 is an intellectual history, tracing the emergence of modern urban climatology and its adaptation by architecture and urban design. Vol. 2 is a cross-cultural study of four cities around the world, exploring the manifold relations between urban climates, architecture and society both within and beyond buildings. Each volume is self-contained, but they are complementary in their assessment of architecture and urban climates from a historical (Vol. 1) and a contemporary (Vol. 2) perspective.

What we present here is the outcome of intense exchange based on the interdisciplinary expertise and the international network of the members of our research group (Sascha Roesler, Madlen Kobi, Lorenzo Stieger, Dalila Ghodbane, and Lionel Epiney).

Sascha Roesler, March 2022

Coping with Urban Climates

An Introduction

Sascha Roesler

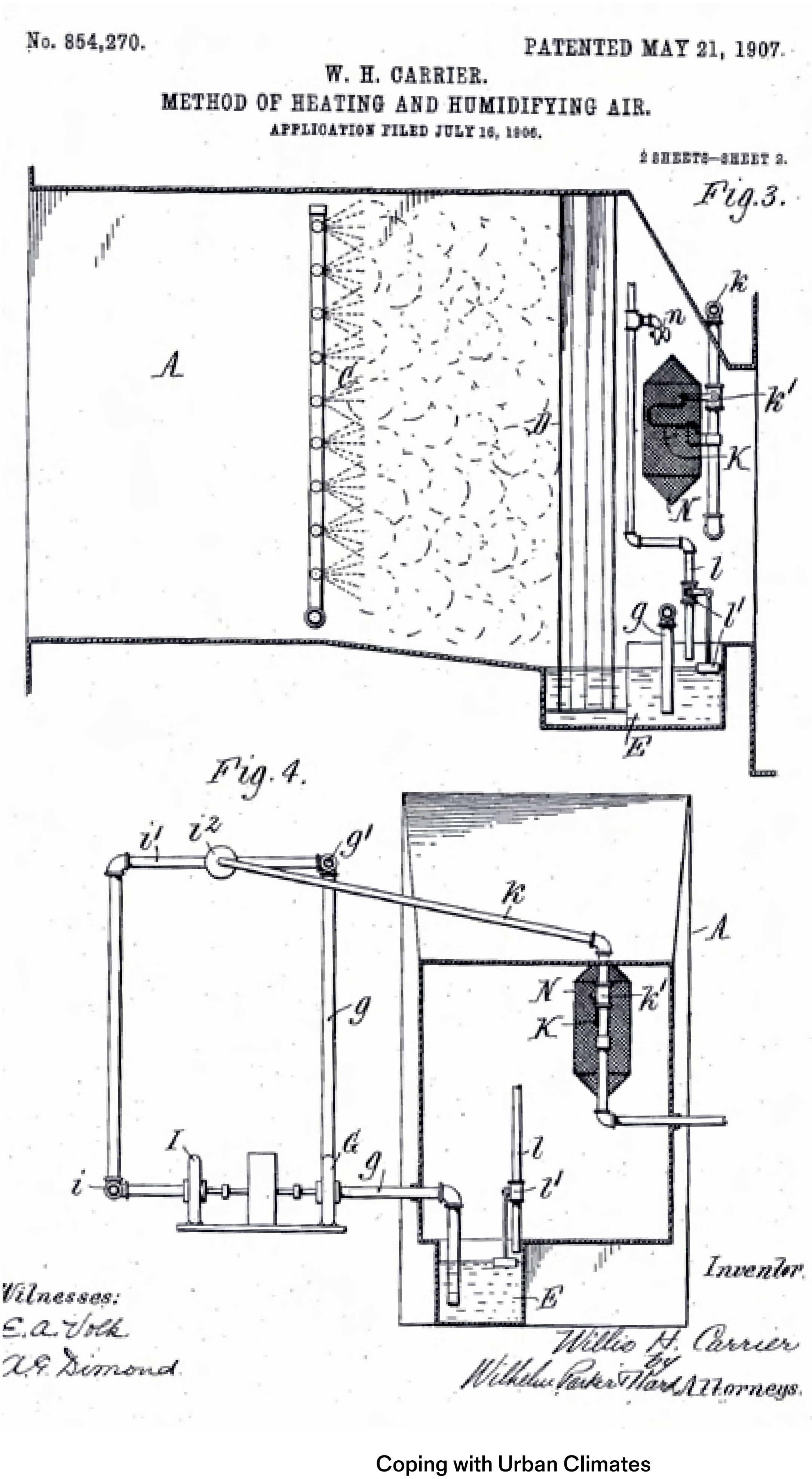
The notion of "man-made weather" refers to an expression coined by the supposed inventor of air conditioning for his novel discovery: American engineer Willis Carrier made use of the phrase for decades in order to promote his patented technology.[1] His 1906 patent *A Method for Heating and Humidifying Air*[2] represents a seminal treatise of the 20th century; its significance is comparable with Sigmund Freud's *The Interpretation of Dreams*, a book published in the same era.[3] Just as for Freud, the interpretation of dreams represented the key to the unconscious, air conditioning, for Carrier, was a key to the weather. In both cases, an unromantic attempt was made to bring what is in fact uncontrollable—the unconscious, the weather—under man's control. Carrier's phrase "man-made weather" connotes the hopes of both of the engineer and the rainmaker to add artificially created weather to something naturally given. Since Carrier's inventions, the artificial creation of weather has meant harnessing four interdependent parameters of an overall system: 1) controlling temperature, 2) controlling humidity, 3) controlling air circulation; and 4) purifying the air.

However, at least since the turn of the millennium, the notion of man-made weather has given rise to a second and "uncanny" meaning,[4] and one which grew out of the first: the building sector contributes substantially—via heating and cooling practices—to the global phenomenon of climate change. Or, in the words of environmental sociologist Elisabeth Shove: "The resources consumed in 'managing' the indoor environment are, ironically, one of the more significant causes of outdoor environmental change."[5] Increasingly, the climate is becoming a hybrid between *nature and culture* that can no longer be seen as a variable independent of mankind. This applies particularly to the climate of cities, which are increasingly affected by this "dialectic of division."[6] While controlling the indoor climate, emissions are caused that make the outdoors even more hostile. To date, although indoor and outdoor climates "are obviously linked to each other, their examination has proceeded along different paths and there has been remarkably little 'cross-over'" conceptually so far.[7]

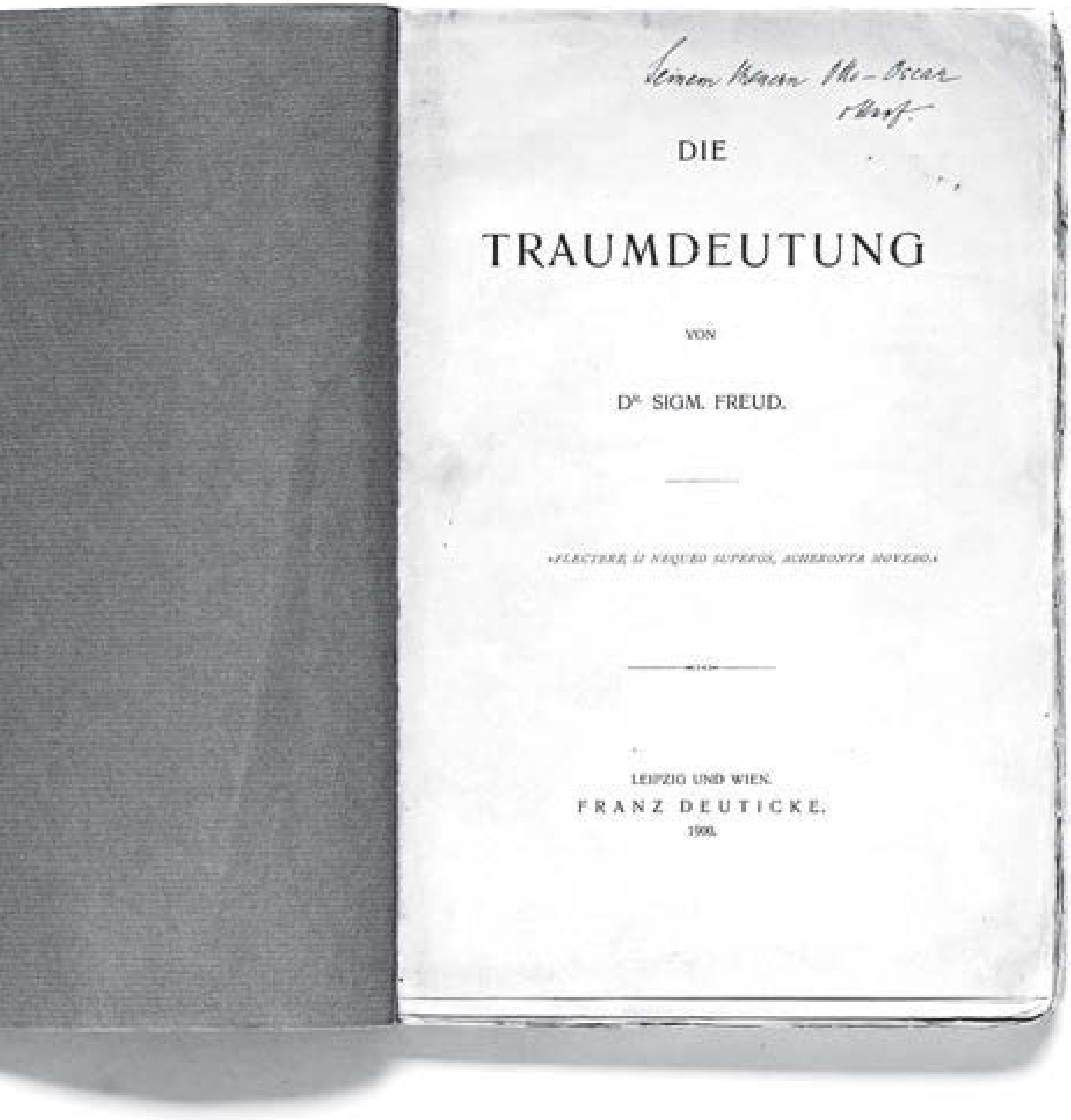
Climate Control = Climate Change

With some justification, one might say that architectural modernity ultimately brought the (interior) climate under its control. Controlling is a paradigm of building-services engineering that has increasingly dominated the way architecture is considered in relation to climate. The notion of control represents the center of gravity in today's climate discourses in architecture. The systems thinking from the sphere of machines has been transferred to the thermal manipulation of interiors.[8]

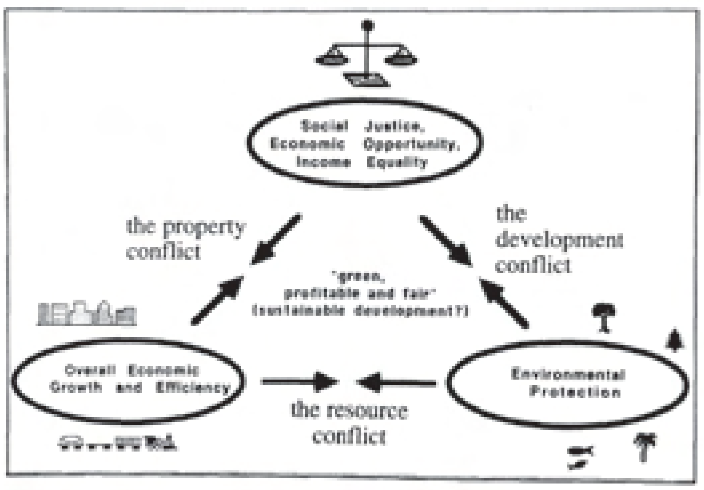
→ figs. 1, 2



1
Willis H. Carrier: Method of Heating and Humidifying Air (1906).



2
Sigmund Freud's *The Interpretation of Dreams* (1900).



3
Conflicting Goals of Planning, Scott Campbell (1996).

The English term, “control,” predetermined the metaphorical space of just how climatization and the relationship between climate and buildings was considered in the 20th century.[9] Beyond that, the actively “controlled” interior became the model for dealing with climate in general, affecting even the debates on global climate change. However, for the “man-made weather” of cities, which is the focus of this publication, a different form of metaphorical formation must be sought. The focus is no longer on “control” but instead on the mutual dependency of inside and outside, urban culture and nature, which must be rethought and redesigned. Nothing less than a new epistemology of mixing and influencing relationships is at stake.

The interior, dichotomously separated from the outside world, is the historical result of 20th-century building-technology innovations. The obsession to control the climate in both workplace and residential spaces has been accompanied by an increasing standardization of indoor temperature, from which a powerful global standard has now emerged. Meanwhile, 20–22°C and 50 percent relative humidity represent the formula for a thermal universalism that has gained global acceptance, and is equally valid in cities such as Geneva (Switzerland), Santiago (de Chile), Chongqing (People’s Republic of China) and Cairo (Egypt). In residential construction for the middle classes, a great thermal uniformity has been established worldwide at enormous energy cost; the former differentiation of cooler and warmer zones in the house has given way to a simple one-size-fits-all solution through air conditioning. Elisabeth Shove speaks of comfort as a “hegemonic model.”[10]

In this publication, we argue that the control paradigm’s demand for a homogeneous indoor climate has caused many other aspects of climate relevant to architecture to be neglected. The focus on the normative category of *comfort* has prevented greater consideration of the empirically endorsed diversity of *microclimates*.[11] To cite Bruno Latour, “the work of purification”[12] in the climate thinking in architecture correlates outdoor climate again and again (even against better knowledge) with nature, and the indoor climate with culture.[13] Yet, the majority of all inhabited structures remain excluded from this discourse, inasmuch as nature still governs the interiors of these buildings. Over and beyond the global standard of comfort, numerous other forms of climate, architecture and individuals’ interaction exist.[14] Architects and scholars today would do well to investigate more thoroughly this diversity outside of the cognizance of building-services engineering, incorporating the approaches of the social sciences. If the discipline of architecture is called upon to develop alternative climatic thinking, then it is with an awareness of where the global comfort standard has led us in the past hundred years.

As we wish to show in this publication, the notion of urban climate is the new paradigm for seeking fundamentally new approaches to climate in architecture. In the 21st century, cities are more than simply main contributors to climate change; they are also affected by climatic changes, with regard to air pollution and heat-island effects in particular. This shift demands new and specific answers from the planning and design disciplines. Climate change with ever warmer summers (and winters) is leading, for example in Geneva (Switzerland), to increased use of air conditioning during the summer months when, even as recently as two decades ago, such mechanical cooling was virtually nonexistent.

→ fig. 3

The Notion of "Thermal Governance"

Relying on a growth in scale, this publication scrutinizes and pioneers the new concept of "thermal governance." Just as the political tools that address global warming have so far been tied spatially to nations, thermal standards and climate control have, so far, been tied to the individual building. There is a need for "governance on other scales" and "scalar imagination,"[15] to which this publication aims to contribute with empirically derived insights. The relevant components of a thermal governance shall be identified by investigating architectural and technological, as well as legal and economic aspects. Exceeding the scale of the individual building, new forms of thermal thinking in architecture that weigh the impact of seasons, the public spaces and several buildings together have been examined. Urban climates have been investigated as part of larger energy landscapes—namely, as the result of the dynamics between the urban fabric, the thermal infrastructures and the anthropogenic ambient climate.

Contemporary urban societies are still short of concise, deliberately planned thermal governance that is effective for the thermal management of urban districts or even entire cities. Up until now, the provision of specific thermal conditions has been a private matter, one not subject to city-wide coordination. Yet, considering the politically launched transition from active to more passive, and from carbon-based to renewable energy-supply methods, this will change over the next few decades. Energy transition and climate adaptation are, in fact, one and the same process. In this publication, the basics of a synergetic understanding that brings together active and passive means of climate control, as well as thermal and energy-related issues of the city, will be developed. Numerous empirical examples underscore the fact that such synergies happen among individual residents when controlling their thermal environment, and are also achieved by citizen initiatives that strive for accessible and climatically pleasant public spaces in their respective neighborhoods.

The notion of thermal governance is interpreted in a way that is guided by insights from the social sciences, emphasizing the influence of cultural standardization ("hegemony"),[16] specific forms of politics ("governmentality")[17] and ideological reproduction ("apparatuses of the state").[18] We adapted these concepts to the manner in which individuals and groups control the climate of cities indoors and outdoors. In a Foucauldian interpretation, controlling the urban climate means connecting the weather with its political economy. In a hegemonic interpretation of predominant forms of climate control that is based on Gramsci and Althusser, the relationship between thermal regulations and thermal everyday practices is considered dynamic and full of tension. The thermal conditions of "urban environments"[19] are, on the one hand, empirically characterized as *energy balance* of all the contributing (palimpsestic) layers. On the other hand, thermal conditions are normatively shaped by thermal governance—namely, by the implementation of thermal regulations and standards. Thus, thermal regimes take on political and legal dimensions in the form of urban governance.

However, in our use of the term, thermal governance not only works as a top-down force through governments and institutions aiming to control urban climates. Thermal governance also includes the agency of

→ fig. 4

everyday “praxis.”[20] The adaptability of a building to changing climatic conditions includes not only architectural designs and constructions but also specific types of knowledge about how to activate the available potential of the house as built environment. Seasonally and diurnally varying behaviors unfold as climate-dependent proxemics between the occupants and their buildings and as movements of citizens’ bodies in the urban space. This goes along with an architectural culture of sojourn in specific outdoor spaces on a private–public continuum from terraces and balconies to courtyards, forecourts, squares and parks. Beyond people’s sojourning in different spaces, seasonal and diurnal transformations are also manifest in the adaptation of buildings and clothing. This brings into view temporary shading and opening measures taken, such as the use of doors and windows, and the use of different textiles and clothing that change inside and outside the house, depending on the time of the day and the season.[21] Accordingly, methodological approaches to the study of vernacular knowledge systems,[22] material culture research[23] and the anthropology of the body[24] play a central role when pioneering thermal governance. Relying on the agency of praxis reveals the culture-specific and time-bound logic of climatization. Particularly with regard to socio-economically poor citizens in cities of the Global South, our case studies outline that thermal governance manifests through behavior rather than technology, and through the practices of mobility, clothing and changing rooms rather than through meeting certain global standards.

Research Approach

While 20th-century architecture learned to *control* the climate of a building, the architecture of the 21st century needs to learn to *cope* with the climate of cities. They are “the new indoor environments” of today’s societies.[25] According to our understanding of the term, “thermal governance” replaces the 20th century’s notion of “climate control” by pioneering climatization on other scales, relying on a conscious integration of indoor and outdoor environmental conditions. The one-sided focus on either “well-tempered environments” (interiors) or “meteorology and urban design” (exteriors) shall be overcome, and the thermal dialectics between inside and outside elaborated instead. It is the critical goal of this publication to outline this new epistemological enclosure from the perspective of architecture.

Pursuant to the ideas of early modern urban climatology,[26] this publication aims at encompassing indoor and outdoor in one epistemological framework. For this purpose, we follow a theoretical and methodological account that unites the architectural, technological, legal, social and economic dimensions of coping with urban climates. The machinery for implementing such an enclosure is, indeed, “thermal governance.” This new deployment comprises various scales, from the room to the building to the district and the city. Most critically, we argue that in contemporary urban societies, climate management relies on three fundamental agencies: *thermal structures* (e.g. building envelopes, energy infrastructures), *thermal practices* (e.g. behavior, residents’ thermal material culture in apartments) and *thermal regimes* (e.g. regulations, codes).[27]

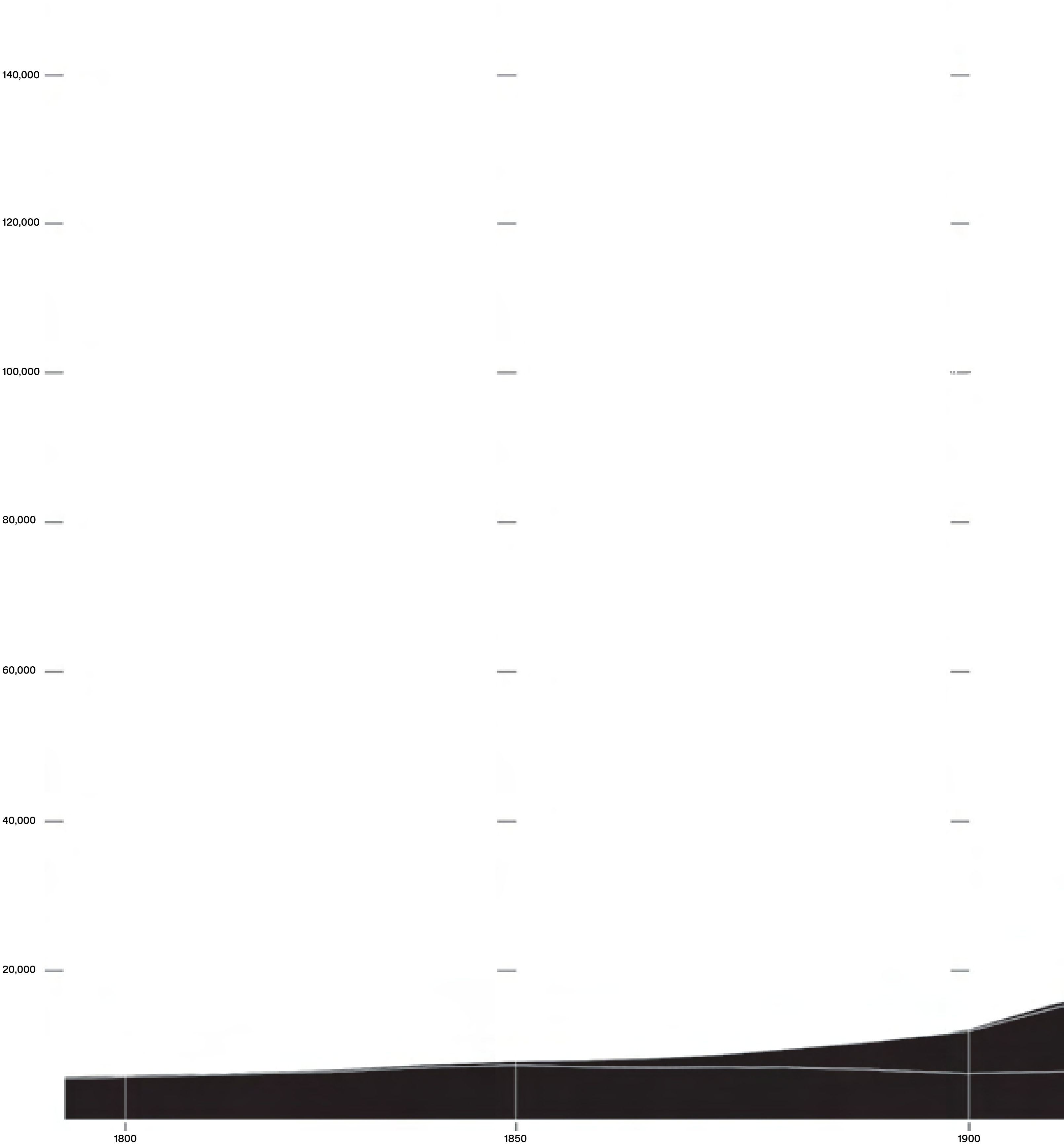
1. The first agency concerns physical *structures,* such as building envelopes and infrastructures of various scales. Until the mass proliferation of central heating and air conditioning, built structures always featured an inherent thermal dimension. Reyner Banham rightly speaks of "structure as prime controller of environment."[28] Thick walls in a hot-dry climate also serve as thermal reservoirs, absorbing the incident heat and keeping interiors cool. Only since the epistemological divergence of buildings into the separate entities of structure, on the one hand, and building services, on the other, have *structures* lost their foremost thermal significance, becoming pure load-bearing entities accompanied by non-load-bearing elements such as thermal, acoustic and other supplementary functions. Our approach conjoins structural and building-service-related technological elements in order to break with the epistemological separation.

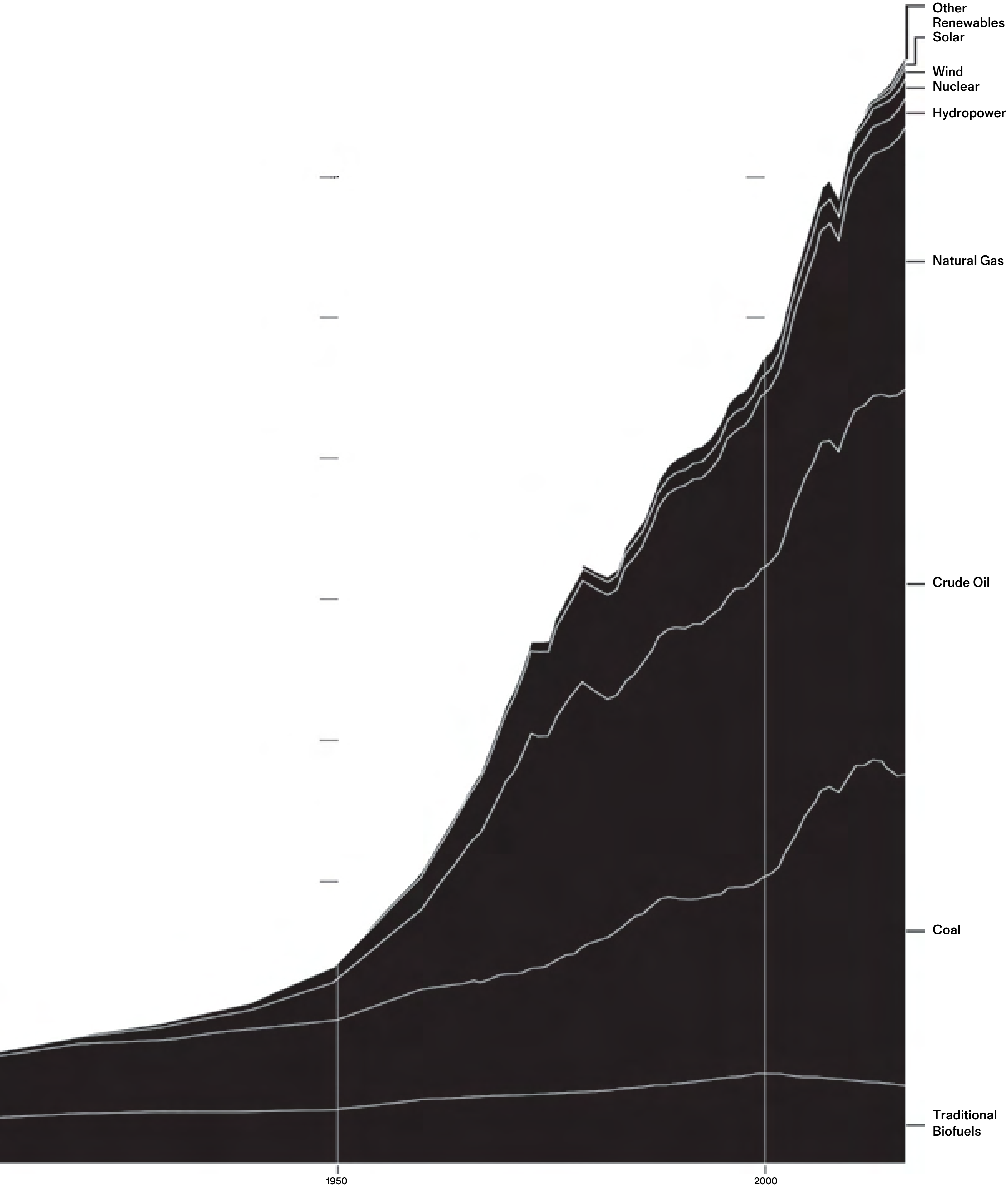
2. The second agency concerns human behavior that manifests in *practices.* An understanding of climatization, informed by popular construction around the world, relies on the constant and inevitable interplay between body and building, between corporeal and building technologies, between ways of life and ways of building. Thermally relevant activities that take place near and inside buildings are an integral part of any climatization culture in both rural and urban areas. Thermal practices include the way people inhabit their houses according to the season or the time of day, or how they vary their manner of dress relative to the changing outdoor temperature. Beyond clothing, it includes the material culture of thermally inhabiting a house, including the use of ventilation, curtains, electric devices or furniture that support the creation of comfortable spaces.[29] One might concur with architectural theorist James Fitch, who states that "our very concepts of warmth and coolness are relative and highly subjective."[30] Alongside their clients, architects have to learn to design buildings whose climatic strategies will be complemented by the thermal practices of their future inhabitants.

3. The third agency in climate management relates to issues of *thermal regimes.* This concept connotes the complex relationship societies form with their climates in different periods. No matter the climatic conditions, people all over the world have developed ways to deal with factors such as extreme heat, humidity or pollution. Architecture has become a fundamental way to control given environmental conditions. With increasing frequency, modern thermal regimes are superimposed upon naturally given environmental conditions. Thermal regimes include customary, written and governmentally imposed regulations and standards, as well as the social norms that guide everyday best practices of climate control. Regimes manifest differently across societies and include the interplay and tensions between thermal regulation and social norms.

In the context of comparative research on architecture and thermal governance, these agencies constitute our guiding research matrix, given that they have a decisive impact on the environmental conditions of cities. The three agencies cover the most critical dimensions of thermal governance, to be explored as the relationship between *microclimates and buildings* (structures), *microclimates and bodies* (practices) and *micro-*

4
Global primary energy consumption, 1800–2017, measured in Terawatt-hours (TWh) per year.




Other Renewables
Solar
Wind
Nuclear
Hydropower
Natural Gas
Crude Oil
Coal
Traditional Biofuels
1950
2000

climates and society (regimes). This major framework has to be further complemented by a more finely tuned list of criteria, including, amongst others, climatic aspects (seasons, climate zones, data etc.); legal aspects (existing laws, regulations, zoning, subsidies, etc.); economic aspects (deficient versus high-standards, high versus low taxes etc.); ownership (property, rented, self-built, etc.); and management aspects (central versus decentralized building services and maintenance, etc.).

	The Framework of Thermal Governance		
	Thermal Structures	*Thermal Regimes*	*Thermal Practices*
Agency	Things (Objects, Buildings, Materials)	Norms/Standards	People
Sphere of Influence	The space of the city	Political ecology of the city	The time of the city
Forms of Organization	Energy commons (natural forces in the city, spatial arrangement and quality of buildings, etc.) and energy infrastructures (heating networks, building services, etc.)	Connecting things and people, space and time, energy commons and energy infrastructure	Modes of behavior that are cyclically adjusted to the seasons and times of day: changing one's residence, clothing, body positions, etc.

Since the 1980s, there has been a tendency to normalize architecture via thermal standards and green labels.[31] The standardization of climatic conditions and the constraint for architects to apply these standards and labels have coined the building practice of the last four decades; they were part of a "global environmental protection regime."[32] David Eisenberg and Peter Yost speak of "the inherent but largely unrecognized relationship between sustainability and building codes, and efforts under way to change this relationship."[33] The inherent difficulty of the current standards lies in gaining "approvals for alternative designs, systems, and materials within the existing regulatory framework."[34] By directly dictating the solution path, "prescriptive" codes[35] may simplify procedures but they severely limit the range of solution paths, thus preventing innovations in the field of architecture and construction. "Performance codes," on the other hand, also come at a price: they impose far greater competence in estimating the solution path on the actors involved—architects, builders, administrators. Eisenberg and Yost criticize the resistance to implementing new approaches in the building sector: "It can be frustrating to have the knowledge and skills required for building green, yet lack the approval to do it."[36]

→ fig. 67

A contemporary notion of thermal governance must recognize this ecological legacy of thermal standards. However, the goal must be to create "adaptive standards"[37] that are open enough to innovative approaches in architecture and urban design. Thermal governance advocates for the inseparability of climate (control) and politics. It must be rethought by developing regulations on urban scales, transforming the very idea of conditioning and managing urban environments. To rethink climate control through the lens of city climate phenomena, this publication deals with the following main questions: 1) What are the conceptual and theoretical components and procedures of an urban thermal governance? How do they expand the limited scope of current thermal standards in architecture? 2) Who are the most relevant stakeholders for implementing and practicing thermal governance, both in formal institutions and in civil society? From a comparative perspective, what are the political preconditions for a successful urban thermal governance? 3) What comprises an architectural and urban-design practice that is committed to thermal governance? How can current architectural tools and practices be used to implement thermal governance and what are their limitations? In what ways can we generate the technical, legal and architectural knowledge that is necessary for an international best practice of thermal governance?

City Analysis: Four Empirical Case Studies

Empirically, this publication draws on data from four case-study cities, providing a global perspective on thermal governance: the complex urban territories of Geneva (Switzerland), Santiago (de Chile), Chongqing (People's Republic of China) and Cairo (Egypt). The four cases focus on selected aspects of contemporary urban climates, highlighting the agency of actors from architects and governments to standard-setting organizations and residents alike. Physical data, including meteorological and geographic information, is juxtaposed with ethnographic and historical information, thus providing an added value to conventional approaches to urban climates. This gives form to "an understanding of climate and weather not just as a natural but as a *social and cultural fact*, or, as Latour would have it, a 'hybrid' of both."[38]

During fieldwork in selected neighborhoods, conducting "microclimate ethnographies,"[39] the researchers gathered data related to the actual thermal practices on site. The particular focus on neighborhoods emphasizes the role of thermal governance for urban forms of climate control beyond the design of individual buildings. The different chapters engage with thermal governance by highlighting the role of, and interaction between, thermal regimes, thermal structures and thermal practices in the following ways:

Chapter One investigates the greater region of Geneva (Switzerland) with regard to questions of the energy landscape of the 21st century. In the mapping of various natural and infrastructural elements, Lorenzo Stieger shows how energy has been anchored historically in the local territory, and how it spatially affects the development of the city and its hinterland. The way in which energy is produced, distributed and consumed reflects territorial, social, political and historical specificities of the region. By focusing on water bodies as a common good of Geneva's urban environment, the chapter addresses the use and neglect of water as both an urban energy resource and a means of climate adaptation.

In Chapter Two, Lionel Epiney analyzes the interplay of thermal standards and social norms in Santiago (de Chile). Thermal standards such as LEED (Leadership in Energy and Environmental Design) have proliferated globally and are becoming increasingly important for the development of the "energy-efficient" city. The chapter scrutinizes indoor–outdoor climate relations by questioning the use of standards, inasmuch as these are mostly indifferent towards a building's surroundings. By including Santiago's modernist neighborhood constructions of the 1950s and 1960s, which paid more attention than their successors did to public outdoor spaces, and also the contemporary self-build, Epiney investigates the dynamics between thermal universalism and local thermal traditions.

Chapter Three focuses on the role that electrification and high-rise constructions play in urban climate control and the thermal practices of residents in Chongqing (People's Republic of China). Madlen Kobi outlines the ways in which newly emerging energy infrastructures have, since the 1980s, facilitated indoor heating and cooling in formerly unconditioned buildings where climate relief was hitherto found outdoors, in the shade of neighborhood greening. Scrutinizing the excessive cooling and heating practices that have exacerbated urban climate conditions, such as urban heat-island effects and air pollution, reveals the challenges that contemporary cities face around electricity provision, energy-transition policies and the offer of thermally pleasant spaces for their inhabitants.

In Chapter Four, Dalila Ghodbane takes the perspective of the domestic scale in Cairo (Egypt) to document how everyday life is continuously adapted to changing microclimatic conditions. Creating a comfortable indoor climate is a thermal project that encompasses architecture, everyday objects and time-specific practices. The material agency between indoors and outdoors and urban thermal navigation depends on gender, available economic resources, personal experience and social expectations, among other factors. The chapter points to the gap that exists between legitimized knowledge about climate, as represented in publications and architectural teaching, and the actual position of thermal concerns in people's everyday lives.

Comparative Framework

Based on the empirical study of four cities around the world, the theoretical and methodological foundations for a future thermal governance shall be elaborated. Each of the individually led studies offers rich empirical data on the complex interrelations between thermal regimes, thermal structures and thermal practices. All of the chapters focus on the role of the house and architecture more broadly in terms of thermal governance. The objective is to assess the different scales of urban thermal governance, depending on the respective cultural, political and economic contexts. The comparison in the publication's final part reveals that sustainable cities, as dependent on the conscious governance of microclimates and energy landscapes, create *nexuses* between regimes, structures and practices. Both visual translation and the processing of research data into maps have been integral to the research methodology. The visualization allows a comparison and juxtaposition of different climatic parameters, whether urban heat-island effects with the socio-economic composition of neighborhoods, green areas with residential density or topography with architectural structures.

By applying this research to dense urban contexts around the world, the traditional climatic field of analysis (focusing on single buildings) has been reconsidered and integrated into a reflection on the local social conditions. We understand buildings as part of an *urban political ecology,* one which requires a combination of climatic *and* social research approaches. Only the integration of a socio-political perspective can transcend the seeming universalism of global standards towards an analysis of specific urban ways of life. All too often, the notion of the Anthropocene overlooks the fact that climate change has very different effects depending on the region and the social class affected.[40] In agreement with Bruno Latour, we believe that political ecology is "not a reaction to a crisis of nature, but to a crisis of objectivity." Contrary to the notion of climate control, thermal governance aims, from the start, to address those "risky entanglements"[41] between nature and society that characterize climatization in cities today. The nature/culture dichotomy has become obsolete: even supposedly "natural" areas in the city, such as parks, gardens or waterways, are the products of truly man-made decisions and interventions.

"Globally, two-thirds of our energy is consumed in cities, making city authorities an important part of the solution," writes environmental physicist Catherine Bale.[42] Over and beyond architects and urban planners, policy makers and administrators recognize that a different kind of thermal management is needed: one that takes the mutual reactions between air-conditioning practices and anthropogenic urban climates into account. At issue is a new thermal governance that responds to contemporary environmental urban conditions. So far, the scale of the city has played only a marginal role in the thermal management of societies.[43] Psychoanalytically speaking, it is necessary to detach oneself from "the fixation"[44] on the (air-conditioned) interior and, instead, focus on the dialectic between indoor comfort and outdoor microclimates.

Far beyond advocating for using less energy and improving the material structure of buildings, this volume underlines the conviction that coping with urban climates happens on a multi-scalar spectrum of interventions. It encompasses urban landscapes and combines a thermal thinking of domestic and public spaces. The contributions underline the ways in which architects, citizens and policy makers create urban microclimates over and beyond the efforts of governments to curb emissions. This publication carves out the interdisciplinary dimensions of thermal governance and demonstrates pathways to make the concept applicable for cities and communities all over the globe. Ultimately, the organization and management of thermal governance rely on political guidelines. Today, climate change spurs us once again to address, and in greater depth than hitherto, the complex relationship between buildings and urban climates, in hopes of achieving a more sustainable way of dealing with climate change in cities. A better understanding of thermal governance as an instrument with which to face urban climate challenges will serve across the globe as a critical benchmark for the city of the 21th century.

→ fig. 3

Geneva (Switzerland)

Surface area Canton Geneva:	245,74 km²
Inhabitants Canton Geneva:	508,774
Altitude:	375 meters above sea level
Adjusted net national income per capita (World Bank): 2019:	65,600 USD (Switzerland)
Climate zone (according to Köppen):	(CfB) Marine west coast climate
Annual mean concentration of particulate matter of less than 2.5 microns of diameter (PM2.5): 2019:	11.6 μg/m³
Annual precipitation:	1864 mm
Average annual amount of rainy days:	109
Mean annual temperature:	10°C
Average temperature (warmest month):	19.3°C, July
Average temperature (coldest month):	0.9°C, January

Santiago de Chile

Surface area:	641 km²
Population in the Metropolitan Area:	6.5 million (2016)
Altitude:	570 meters above sea level
Adjusted net national income per capita (World Bank): 2019:	11,719 USD (Chile)
Climate zone (according to Köppen):	(BSk) Cold semi-arid climate
Annual mean concentration of particulate matter of less than 2.5 microns of diameter (PM2.5): 2019:	27.7 μg/m³ Moderate level
Annual precipitation:	517 mm
Average annual amount of rainy days:	39
Mean annual temperature:	10°C
Average temperature (warmest month):	15.7°C, July
Average temperature (coldest month):	22.2°C, January

Chongqing (People's Republic of China)

Chongqing Municipality 重庆市:	82,403 km²
Surface Area City 重庆主主城区:	28,657 km²
Inhabitants Chongqing Municipality:	30.2 million (2015)
Inhabitants City Area:	15.9 million (2020)
Altitude:	244 meters above the sea
Adjusted net national income per capita (World Bank): 2019:	8,394 USD (People's Republic of China)
Climate zone (according to Köppen):	(Cwa) Monsoon-influenced humid subtropical climate
Annual mean concentration of particulate matter of less than 2.5 microns of diameter (PM2.5): 2019:	37.1 µg/m³,
Annual precipitation:	1,287 mm
Average annual amount of rainy days:	152
Mean annual temperature:	18.3°C
Average temperature (warmest month):	28.3°C, July
Average temperature (coldest month):	7.9°C, January

Cairo (Egypt)

Surface area Greater Cairo Region:	1,709 km²
Altitude:	23 meters above sea level
Inhabitants Greater Cairo Region:	20.9 million (2020)
Inhabitants Cairo City Area:	7.7 million (2020)
Adjusted net national income per capita (World Bank): 2019:	2,615 USD (Egypt)
Climate zone (according to Köppen):	(BWh) Hot desert climate
Annual mean concentration of particulate matter of less than 2.5 microns of diameter (PM2.5):	1999–2016: 84 µg/m³
Annual precipitation:	18 mm
Average annual amount of rainy days:	14
Mean annual temperature:	22.1°C
Average temperature (warmest month):	29.2°C, July
Average temperature (coldest month):	13.4°C, January

Urban Climates

I

Geneva
Santiago de Chile
Chongqing
Cairo

Geneva (Switzerland): The Architecturalization of Water Ecologies

On the Integration of Energy Transition and Climate Adaptation

Lorenzo Stieger

In Geneva, water has been a central driver of urban development, providing people with food and energy for centuries, and being a key element for the identity of the city and the self-image of its inhabitants. In the 20th century, however, water was slowly replaced by other forms of energy, mainly carbon-based resources. This chapter acknowledges and deals with the presence of water in Geneva as a common good of the urban environment. The two case studies—the first one, historical; the second, empirical—address the use and the neglect of water, both as an urban energy resource and as a means of climate adaptation.

Just as elsewhere in Switzerland, the high standards of building practice in Geneva are driven by comfort thinking, which defines indoor conditions independently from the outdoor climate. With the building stock accounting for more than 30 percent of Geneva's total energy consumption, current undertakings for an energy transition in the Greater Region suggest that energy savings in heating and cooling practices are particularly important.[45] Geneva's climate is strongly dependent on the seasons, with climate change leading increasingly to a shift in thermal practice. Whereas in the past, the focus was mainly on heating, cooling becomes more urgent in the warmer summer months.[46] A new Mediterranean feeling experienced during those months has raised awareness among citizens of the need for a substantial shift in thermal practice. Cooling strategies at home, on public transport or on the larger scale of the urban environment are seen as increasingly necessary. The impact on the various strata of daily life is not only exemplified by city dwellers' increasing demand to mitigate climatic tendencies by finding appropriate means of cooling down. It has also sparked recent discussions among politicians on extending permits in Swiss cities for restaurants to serve customers later at night, when temperatures are more accommodating. The latest addition to the canton's strategies to relieve thermal stress is the city's public beach, which opened in 2020 on the left bank of the bay.[47]

1. Geneva's Urban Nature in Light of its Planning History

The urban history of Geneva demonstrates a gradual attempt to reconcile the city with nature. Advocating for an ecological urbanism *avant la lettre*, the concept of interlocking city and nature has been called for repeatedly in the planning history of the city region. At the time of the *Ancien Régime* (1589–1789), Geneva predominantly figured as a city squeezed into its ramparts "without a hinterland."[48] The demolition of the town's fortifications prior to 1880 not only initiated urban renewal but also gave impetus to economic and social modernization.[49] The dualism of town and country was particularly challenged by the advent of modern planning in Geneva. The relational setting between *city* and *nature* oscillated between aesthetic and functional aspects of the (urban) landscape, between the ornamental quality and productive capacities of green spaces. Within this polarity, an awareness that nature in the city would increasingly enhance the well-being of its inhabitants was to evolve.

1.1 Integrating Nature and the City

For the most part, the canton's larger, contiguous green spaces are located to the west of Geneva, while the city and agglomerations along the lake basin and towards the French town of Annemasse on the southern border are largely urbanized. Geneva's urban fabric is gradually shifting from compact and open buildings of medium height in its core to widely distributed low-rise buildings on its outer perimeters.[50] There are also several large industrial areas within the city's territory. This spatial distribution creates a strong temperature gradient of up to 10°C between the city and countryside, leading to the well-known phenomenon of the urban heat-island effect. There are temperature differences of up to 6°C between individual districts, and in certain areas the mercury does not drop below 25°C on so-called "tropical nights."[51]

→ figs. 5, 6, 7, 12

Green Spaces

Using nature as a means of organizing green spaces according to functional requirements, productive capacities and well-being is particularly evident in the planning of modern Geneva that was laid out at the beginning of the 20th century. In the publication on the first Swiss urban-planning exhibition, in 1928, the authors concluded that, apart from the already existing parks and promenades, Geneva had very little public land and lacked any immediate plans to expand urban green spaces.[52] In addition, there was a scarcity of forest land due to uncontrolled deforestation, while land reserves for greening were located mainly on large private properties. As a result, the "Bureau du plan d'extension" called for an inventory of the Greater Geneva area that would, at an early stage, identify or prevent urban-planning mistakes by coordinating the various influential activities of public and private actors.[53] The response paved the way for the regional and urban structure plans for the city, which led, in turn, to the documentation of planning requirements for Geneva and the regional scale in equal measure.[54]

The 1936 *Regional Plan for Geneva* exemplifies the effort to overcome the duality of city and countryside by intertwining nature and city. For the first time, this planning instrument stipulated the protection of green spaces, forests and agricultural land by specifying areas across the entire canton that should remain untouched by future construction activities. Based on the theories of the garden-city movement, the proposal can be understood as a synthesis of two urban-planning trends that combine the idea of a ring system with a radial system of green spaces.[55] By introducing green alleys and avenues on the scale of the city, the 1936 plan was to link the urban center with the hinterland, envisioning access that would allow all residents to experience the benefits of nature in their daily lives. Although the vision of "Geneva in the Park" was never actually realized, the approach of simultaneously infusing the city with "green fingers" and loosening it up to enhance the quality of life and ensure a favorable urban climate is still inherent in the planning of Geneva's territory today.

The Lake

The waters' whipping heights and the long icicles that form along the lakeside basin paths, on boat railings or on the bodies of parked vehicles are familiar spectacles to the Genevois during the winter months. This natural phenomenon of bizarre ice formations, caused by the tellingly dubbed "Geneva Bise" (a cold, persistent wind of the Alps) has its origins in the geomorphological configuration of the mountain ranges and the geographical location of the canton of Geneva at the southwestern tip of Switzerland. Nestled at the center of the Geneva basin, and at some 400 meters above sea level, the nation's second largest city is surrounded by mountains of the Jura range: *Le Crêt de la Neige*, the *Vuache* range, *Mont Salève* and *Les Voirons*. The pronounced glacial morphology forms a natural container, one that channels winds that, for the most part, blow from the northeast through the Swiss Plateau at wind speeds of up to 60 km/h, with gusts peaking at 100 km/h. In addition, both the local climatic and weather phenomena within the larger territory of Greater Geneva are influenced by the presence of the lake.

As a source both of natural beauty and fertile ground, Lake Geneva has been the driving force behind the development of the entire region. With an area of 580 square kilometers and a shoreline of over 200 kilometers, it is one of Western Europe's largest water bodies. With a maximum depth of 309 meters, the crescent-shaped freshwater body counts among the world's 50 largest lakes by volume.[56] Besides featuring extensive biodiversity, supporting fishing activities and serving as a reservoir of drinking water, the peri-alpine Lake Geneva has also always been renowned for its scenery.[57] From the 18th century on, aesthetic campaigns and the *Belle-Époque*-style Grand Hotels focused on the touristic exploitation of the picturesque landscape, with its idyllic scenery: the lovely lake, sunny slopes and Western Alps. The so-called "Grand Tour" undertaken by young British aristocrats put Geneva on the tourist map early on.[58] Through the writings of Jean-Jacques Rousseau, or the first ascent of Mont Blanc in 1786, the Alps played a central role in underscoring the relationship between mankind and nature, both in literature and in painting. Therapeutics developed at the end of the 18th century with the baths of the *Arve* and the *Eaux-Vives* also shaped the image of a healthy Geneva that lasted throughout the 19th century and helped promote tourist activity. From 1830 to 1900, the hotel business remained a strictly seasonal summer activity, but by the end of the century tourism had become increasingly international—and Geneva was soon considered "the gateway to the Alps" for the many winter sports activities.[59]

→ figs. 8, 9

5
The transition from closed to open perimeter-block development in the *Eaux-Vives* district.

6
The stone buildings of Geneva's old town, with its narrow streets and shady squares, follow the logic of the hill's topography.

7
A villa neighborhood in the *Le Lignon* district, characterized by its extensive green spaces with dense trees (1984).

1.2 Geneva's Energy Infrastructure

Between 1920 and 1939, the city developed at a rapid pace that drastically increased the need for energy and infrastructure. Geneva wanted to live up to its privileged role of a city with an international orientation,[60] which has continued to be an important driver for the multiple energy systems and networks—water supply, electricity, thermal comfort, mobility, communication or research—that, embedded in the urban environment, form Geneva's infrastructure landscape today. The many fountains proliferating in the city's neighborhoods bear witness to the far-reaching pipes of pumping stations along the rivers. As Switzerland has no coal resources, the goals of domestic water supply have always been linked to the need to convert water into energy to support industrial development. In the 1860s and 1870s, that need heralded the birth of urban, turbined and reticulated water.[61] In 1886, Geneva's first hydroelectric power station produced electricity, which, at the time, was mainly used for street lighting. The lack of alternative energy resources inevitably led to the promotion of hydropower and hydroelectricity, with early electrification of railways and cities from the 1890s onwards.[62]

The Carbon City

Apart from the use of local bodies of water as a natural energy resource, new forms of energy, such as fossil fuels and nuclear energy, shaped the modern appearance of Geneva in the 20th century. As many newly formed international organizations made their home in the city, exchange with the rest of the world became an essential part of the city's obligations and self-image. The idea that energy was abundant also influenced planning: the fact that Geneva was better and more efficiently organized was thanks to enormous investments in infrastructure. Such thinking ultimately favored the image of a Geneva "petrolscape," as envisioned in the 1966 master plan for the city. Geneva Airport, CERN, the International District, highways and transport hubs, industrial zones and energy networks all figure among the key urban figures of Geneva's enormous energy landscape, and link the local and global scales. The growing exchange of people, goods and services associated with transportation led to an increasing demand for fossil-fuel energy. Fuel combustion impairs the urban climate through air pollution and noise emissions. Their impacts are particularly prevalent in the city center due to traffic congestion, but also in the areas beneath flight paths.[63]

Urban expansion between 1939 and 1990, the postwar modern and post-modern periods, obeyed the paradigm of personal mobility, infrastructural connectivity, living comfort,[64] an abundance of space and cheap energy in the form of oil and nuclear power. This belief in unlimited resources was accompanied by severe traffic congestion and a housing crisis in the 1950s and 1960s, and was then followed by an explosion of satellite cities on Geneva's outskirts.[65] These grand ensembles, such as the iconic *Le Lignon*, were modern neighborhoods, each housing up to 18,000 inhabitants and featuring its own cultural, commercial and institutional facilities. Until the 1970s, these neighborhoods were testimonies to the postwar belief in unbridled growth and the primacy of infrastructure. Yet, having developed dynamically in the 1950s and 1960s, housing construction in the area subsequently seemed almost paralyzed for over 25 years. Indeed, since the economic crisis of the early 1970s, Geneva has been described as being shaped by an "era of stagnation and housing shortage."[66] Today, the city has one of the lowest housing-vacancy rates in the world.[67] It is only in recent years that new developments, known as *Grands Projets*, have been pushed throughout the city—resulting in twelve neighborhood projects, some of which are scheduled for completion by 2030.

The Post-Carbon City

Though water has long been eclipsed by carbon-based and nuclear energy sources, the potential of renewable energy sources such as water, wind and solar increasingly determines the conception of today's urban infrastructures. In Switzerland, the total energy consumed in 2019 was composed of 75.9 percent non-renewable and 24.1 percent renewable energy resources.[68] The former sources are composed, approximately, of carbon-based sources such as oil (42 percent) and natural gas (11 percent), as well as nuclear energy (22 percent).[69] Among the latter, hydropower dominates (61.4 percent), followed by wood (16.4 percent) and waste combustion (11 percent), with geothermal, solar and wind energy sharing low percentages. Household spending on energy (including fuels) in 2019 was 267 USD (US Dollars),[70] or some 2.6 percent of gross household income, which is considered low compared with other spending (e.g. medical care, etc.).[71]

Heating is the main factor (75 percent) in the overall energy demand of Swiss building stock, with three-quarters of households heated by carbon-based sources (oil, 50 percent; gas, 25 percent).[72] The average energy consumption for heating varies

→ figs. 10, 11

depending on the type (single-family house, apartment building) and energy efficiency of the building (e.g. old structure, renovated, energy-label standard), and it ranges for a four-person household in a detached house between 7,500 and 30,000 kWh per annum.[73] In the canton of Geneva, 30 percent of the electricity needs can be met by hydroelectric power, with 55 percent being provided by the Verbois dam alone.[74] According to estimates, the exploitation of energy commons in Greater Geneva could increase from a 14 percent share of renewable resources in primary energy in 2020 to a 40 percent share by 2050.[75] The residential and service sectors account for some 40 percent of the overall consumption. Reduction of the latter will require novel synergies between the (passive) architecture of buildings, infrastructure systems and the energy commons of the city region.

2. Geneva's Water Ecologies

The key and first step to understanding the extent of available natural energy resources is to make the processes in nature visible. Measuring, mapping and modelling are means to evaluate the various potentials of Geneva's energy commons. In aiming towards a future energy transition, the forces of nature in the urban environment are of critical importance: harnessing the potential of solar radiation; wind currents; and thermal potentials of soil and water, of weather conditions and seasonal changes, and also of the green spaces. By highlighting the narrative around water as an energy provider and its associated infrastructure, urban climatic phenomena in Geneva can be addressed at different scales, ranging from apartments to whole neighborhoods.

- ↘ For an urban-scale reading, an energy-specific analysis of Geneva's urban history was undertaken. Written and visual documents drawn from archival research in the estate of André Corboz provided valuable input.[76] The production of maps allowed a visualization of the different manifestations of energy that otherwise either remain hidden or can only be read indirectly in the spatial–structural formation of the city. Three thematic maps of Geneva's energy commons, energy infrastructures and water ecologies were also produced, incorporating insights into the city's history, energy systems and architectural practices.
- ↘ At the scale of the apartment, climatic studies with the help of qualitative and quantitative data were conducted. Research, both on the history of the site and on structural analysis of the building, was supplemented by ethnographic research using semi-structured interviews and protocols to capture homeowners' own thermal-related practices. Using an array of sensors, the microclimatic dynamics in the apartment were monitored remotely, and subsequently matched with data sets on the weather in Geneva and the protocol.

Covering the different scales that make up the urban climate exposes the relationships between the static manifestation of the built environment, the technological and legislative means and the dynamic response of the people who have to cope with the thermal conditions in Geneva in their daily lives. "Water remains vital and elusive; in its oscillation between different cultural and material realms, it underpins both the limits and the possibilities of modernity. Over the last decade the study of water has itself evolved, connecting with new fields, while the political and environmental dimensions to relations between water and society, including the impact of climate change, have become more pressing. By adopting an interdisciplinary and historically grounded approach we can begin to unravel some of the complexities behind landscape, infrastructure, and modernity."[77]

2.1 Water as Energy Source and Climatic Factor

Water-related infrastructures play a central role in regulating and controlling climate in the city of Geneva; they follow an ecological rationale[78] that revolves around water, both as a resource for energy production and as a passive contributor to the urban climate. Historically, the modernization of the infrastructure spurred a redesign of the riverbanks to provide better access to water. The constitution of Geneva's waterfront paralleled the emergence of the city itself, and has evolved in line with numerous transformations over the past centuries. As a natural energy resource, the lake and the converging rivers Rhône and Arve affected the various social and economic strata of urban life. During industrialization, harvesting the forces of nature meant being able both to transform the energetic potential of water in novel ways and facilitating the production of electricity as the highest form of energy.

→ figs. 14, 15, 143, 144, 145, 146, 147

8
1948 map of the *General Report of the Geneva Commission for Development Studies*, which proposes various green zones, linking them to form a network penetrating the built environment of the city.

9
The mapping of nature according to its distinguishing features enables the formation and claiming of sites within the territory: view of the countryside known as “La Fenêtre près Genève” in the 1830s with an indication of the residences of notable figures of the period.

10
Aerial view of CERN from 1959 with its synchrotron-proton ring infrastructure. Today, the research infrastructure is fed with energy level of 1.3 terawatt hours per year from a French nuclear power plant.

11
The international airport at Cointrin, near Geneva, in October 1950, against the background of the city, the lake and the Alps with Mont Blanc.

12
The intertwining of the city and nature as a means of urban climate control.

13
The sealed industrial area in contrast to *Pointe de la Jonction*, where the sediment-rich waters of the Arve mix with the Rhône.

The Rivers in the City

Looking at the rivers and the Lake of Geneva historically reveals a gradual shift from harvesting kinetic energy for economic reasons to using the diverse capacities of the lake to develop and direct the sociocultural identity of the city. Exploiting water as a resource for everyday life required various forms of energy infrastructures, which made bringing water and energy to the neighborhoods away from the riverbanks possible. The factories along the riverbanks on the *Rhône Island* and bridges thus consisted primarily of grinding or stamp mills for the processing of grains in food production or fulling mills for the textile industry—which, to a large extent, had been set up in and around already packed residential buildings. The textile industry—competing with watchmakers, jewelers, metalworkers, tobacconists and chocolatiers—not only led to an increasing demand for hydropower but also caused a number of conflicts between mill operators in the 18th century.[79]

In 1709, the hydroelectric installation that later gave its name to the *Pont de la Machine* (Machine Bridge) was put into operation, and was eventually given a prestigious building in 1840. From 1862 until 1868, Geneva built two plants that supplied enough pressurized water to provide sufficient motive power for the expanding watchmaking industry, while making water accessible on all floors of buildings. A rampant typhus epidemic in 1881 forced the city to stop supplying drinking water from the surface waters of the Rhône and to pump lake water up from a depth of 15 meters instead. Between 1886 and 1898, having been rebuilt, the hydroelectric installation became the first power station to supply the city of Geneva with electricity. It was finally replaced in 1892 by a new hydroelectric power station, the *Bâtiment des Forces Motrices*, which generated electricity and supplied drinking water. For its construction, part of the riverbed was drained so that an additional dam could be built. The dam served not only to supply water to the city's many fountains and light its streets but also to regulate the water level of the lake. The large factory building that housed the turbines was built in the Beaux-Art style, and decorated on the lake side with statues of Neptune, Ceres and Mercury. The operation of the *Services Industriels de Genève* (SIG, Industrial Services of Geneva) brought the city a satisfactory profit, one which covered one fifth of the city's budgetary expenditure between 1896 and 1931. Income from services alone would amount to the equivalent of 70 percent of all direct municipal taxes over this period, thus relieving taxpayers. For those who lived near the rivers, the infrastructure also provided important meeting places within the city for daily affairs and public events. A pressure-relief valve let out a fountain of water every evening, and this technical-aesthetic spectacle became increasingly popular with residents. In 1995, the dam *Barrage de Seujet* eventually replaced both the functions of the *Pont de la Machine* as a dam and the *Forces Motrices* as a hydraulic plant.

The water infrastructure was continuously replaced and expanded according to the city's energy needs. Over time, it formed an almost necklace-like infrastructure landscape that extended far beyond the city area along the rivers Rhône and Arve. In the 20th century, in addition to the modernization of existing structures to increase performance (e.g. the *Verbois dam* from 1942, replacing the former *Barrage des Chèvres* from 1896), environmental concerns related to water and energy production became increasingly relevant. These concerns found their technical equivalent in plants that would allow for water purification (e.g. *Usine du Prieuré*, 1948) or the production of biogas by filtering detritus from the water (*STEP d'Aïre* et *Porteous,* 1965). With the boost in performance, the architecture of energy along the rivers adapted to a modernist language of the time. The migration of production out of the city led to the freeing up of valuable space, which then became available for city dwellers' other needs. Today, many of Geneva's former power stations are used as cultural venues; various activities take place in this built heritage of industrialization. *Forces Motrices* hosts a theater hall, while the public infrastructure-service provider of the canton of Geneva (SIG) runs an event hall in the *Pont de La Machine*. Further, *Les Berges des Vessy*, a former hydro plant at the Arve, and the *Porteus*, both outside the city limits, now host a museum and a low-key outdoor cultural venue, respectively.

Iconic Infrastructure at the Waterfront

The synergy of natural forces with infrastructural technology was perhaps realized most successfully at the southernmost point of Lake Geneva in the form of magnificent lakeside promenades, which heralded the flourish of progress and prosperity in the city. The lake basin became the culmination of Geneva's modern identity in the 19th century, following projects championed both by politician James Fazy and engineer and army general Guillaume Henri Dufour to demolish the city walls and construct embankments. Here, the beauty of the landscape, the prestigious façades of hotels and commercial buildings, and the recreational spectacle of the lake all came together and found their expression in the iconic *Jet d'eau*, a

→ figs. 16, 17

140-meter-high fountain set out in the lake. The infrastructural transformation along the lake basin enabled an architectural and social rapprochement of the city with the water and all its beneficial aspects.

At the beginning of the 19th century, the cantonal engineer Henri Dufour cited aesthetic and hygienic arguments related to Geneva. He argued that the city's appearance was anything but satisfactory for those coming from the lake, given the randomness of the "unhealthy" and asymmetrical buildings. Being a founding member of the first real-estate company in Geneva, the *Société des Bergues*, Dufour proposed an initial project for a uniform design on the right bank of the Rhône in 1827. The *Quai des Bergues* was subsequently completed in 1838. Major transformations of the opposing quay, the *Grand Quai,* were made between 1829 and 1835, and included the beautification of the building façades, a new sewage system and an additional bridge between the quays. A standardized building type designed by Dufour became the blueprint for the quay development. In order to make room for the prestigious waterfront, many local industries, such as fishing and wood-trading facilities, had to relocate together with their workers—either up- or downstream—while the same period witnessed the social relocation of the bourgeoisie into the newly erected town houses. In 1835, the quays were extended on both sides of the river, while *Rousseau Island*, as pride of the city, marked the keystone in the midst of the renovated urban area.[80] The emptied water surface became the new and ideal center of Geneva. In various illustrations, it appeared together with the surrounding snow-capped mountains and that symbol of modernity: the steamboat, which became a local iconographic tradition.[81]

Since the waterway was the preferred means of transport for heavy goods, Geneva was an important geographic–economic hub at the southern tip of the lake. Between 1850 and 1860, better access to the banks of the Rhone and a new harbor were created because the existing commercial port was barely accessible at low tide. A competition organized by the Liberal government (Radicals) around James Fazy envisaged a "multifunctional infrastructure" that was eventually completed as the *General Port Project* in 1858.[82] Having adopted three main aspects of previous competition entries, the project was a synthesis of technical and aesthetic considerations that also addressed Geneva's seasonal climatic conditions. One was the concept of the roadstead: two jetties as aligned breakwaters to protect the anchorages offharbor from the notoriously recurring year-round "bise." Second, the project proposed the construction of a symmetrical arrangement of two quays on either side of the basin. And third, it included the promise of glamorous promenades (*La Rade*), as advertised by the supporters of the roadstead and the local newspapers, who argued that such an infrastructure would be advantageous for leisure and tourism. The transformation of the basin into a large harbor, allowing unobstructed views of the lake and delightful walks in the summer months, were aesthetic arguments that would serve the city well for years to come.

The *Jet d'eau,* a spectacle that delighted people when it was still functioning as a pressure valve of the *Forces Motrices*, was reconstructed in the basin in 1891 for the 600th anniversary of the Swiss Confederation. In view of the National Exhibition held in Geneva in 1896, the promenades along the lake and the lighthouse on the pier of *Les Pâquis* were developed; the roadstead was transformed into a space dedicated primarily to relaxation and leisure for the city's population and tourists. Anyone strolling under the shady plane trees along the quays could experience the juxtaposition of grand hotels, piers and marinas, and had superb views of the Alps. At the same time, the living conditions for most of the population in the adjacent neighborhoods remained hidden behind the glamourous façades of the international city.

Leisure and Thermal Culture in the Lake Basin

What fostered the profound connection between residents and the waterfront was a kind of multifunctional infrastructure that allowed residents to cope with the city's climate through recreational activities during the warmer summer months. The addition of public bathing facilities to Geneva's waterfront gave all the city's residents the chance to cool off in the lake basin, regardless of the neighborhood they lived in. Bathing as a thermal practice became a crowd-puller, bringing people from different social classes and cultural backgrounds together. A pleasant swim in Lake Geneva had a long tradition among the Genevans, as evidenced by the many street names that refer to the ancient presence of baths.[83] Similar to the wash boats, where women cleaned clothes as a daily necessity, floating baths on the Rhône at the turn of the 20th century reflected people's passion for water. The state, as the owner of the shoreline and the lake itself, guaranteed access to both at several spots outside the city. The construction of the prestigious quays, on the other hand, limited the direct access of inhabitants to the water through the terrace constructions and ripraps of stone rubble. An exception was the bath *Les Bains des Pâquis*, which opened on the mole of the *Les Pâquis* district in 1872 and became a

→ figs. 18, 19, 20, 21, 22

municipal public establishment in 1890. It offered special opening hours for women only, and free entry on Sundays and public holidays. Later, two sections separated male from female bathers. During heat waves, such as in 1932, and on hot summer days, the baths almost burst under the high demand, as it was the only official inner-city bathing place for Genevans.

Over the years, the venue underwent several structural changes. The *Association des Usagers des Bains des Pâquis* (Association of Users of the *Pâquis* Bath), founded in 1988, successfully averted the demolition of the venue. And today, in addition to its popularity in the summer, the baths host various cultural events throughout the year, offer massages and feature a sauna, which has become a welcome thermal sensation during the cold winter months. On one hand, the flatness of the lake means that the sun there shines low, which warms the bathers especially in winter; on the other hand, the bathing cabins protect against the cool Geneva breezes, which is why residents enjoy the spot even in the cooler seasons. As a neuralgic point of the lake basin, the baths have become something of an institution in the city: a welcome opening for the otherwise densely-populated neighborhood of *Les Pâquis*, which stretches behind the waterfront all the way to the main railway station. The association managing the baths strives to conserve and promote the space, "allowing socialization between individuals from different social classes,"[84] and, as such, the venue is often considered a place of tolerance, freedom and participation.

Both the importance of access to water as a means for the body to regulate thermal stress and the prevailing scarcity of cooling facilities in the city have become increasingly apparent with the changing climatic conditions and more frequent heat waves in Geneva. Growing demand from citizens has been met by the recent extension of the roadstead to include the *Plage des Eaux-vives*, a public beach on city territory that opened in summer 2020. The new nearby lido is a welcome addition to an existing lido in the municipality of *Cologny* that was established as early as 1932, both in the wake of hygienic developments and in light of the canton's concern for the physical and mental well-being of its population.[85] The *Genève-Plage* project, developed in conjunction with a marina, featured major infrastructural upgrades in the second half of the 20th century: an Olympic-sized swimming pool (1972), a new surf center (1987) and a water slide (2006), all accompanied by additional activities such as water skiing or gymnastics for adults.

The design of the newly built *Plage des Eaux-vives* is based on computer modelling of currents and wave dynamics. Developed as an embankment, and angled at 30° from the shoreline, it adds four beach sections with sand and gravel, green lawns for sunbathing, a restaurant with views of the city and a reed-filled water garden. The inaccessible biotope of the beach, which has become a natural habitat for native animals and plants, can be understood as a reconstruction of the shoreline condition that ceased to exist once the quay was constructed in the 18th and 19th centuries.[86] The different elements subsumed in the beach infrastructure combine ecological thinking and leisure activities with strong ties to the urban climate and individual thermoregulation, as well as being a place that emphasizes the identity of Geneva as a city of water. While such thermal locations illustrate the fact that climate mitigation is not understood by city dwellers as a technical and strategical endeavor, the locations are, nonetheless, embedded in the urban landscape through architectural structures and socio-cultural activities that enrich the repertoire of ways to cope with the urban climate.

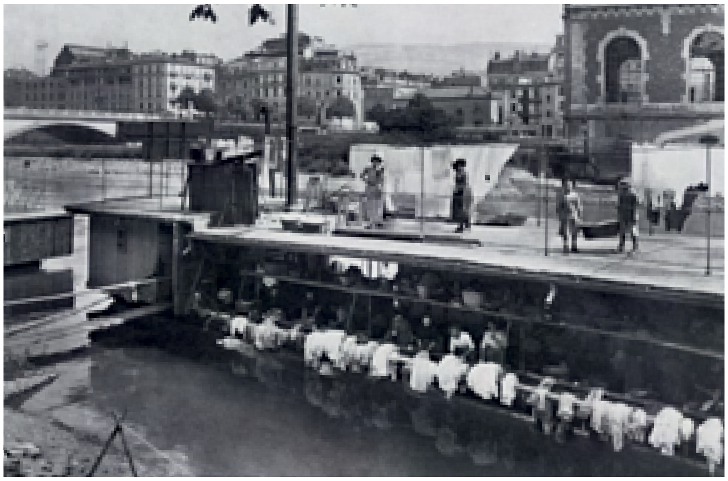
Integrated Thermal Infrastructures

When considering natural and technological potential for thermal regulation, the larger urban environment shows itself a promising benchmark for the climatic planning of neighborhoods. Using the thermal capacity of water to control the interiors of buildings, or help shape the microclimatic conditions in neighborhoods, would strengthen the interweaving of city and nature through various types of infrastructure. Similarly to the urban climate, lake water exhibits dynamic behavior and is subject to the conditions of its context. The average residence time of water originating from the Rhône glacier and exiting into the lake in the city of Geneva is 11.3 years. The average water level is 372.05 meters, with maximum fluctuations measured at 70 centimeters. Just like the seasonal changes throughout the year, the lake has its own weather—one influenced by the inflow from the watercourses and the climatic conditions, and which results in ever-changing temperatures and thermal fluxes in different places. Hence, climate-induced changes to the temperature, the water dynamic and the thermal stratification all disturb the functioning of the aquatic ecosystem.[87]

The project GeniLac, whose construction started in 2015, and is scheduled for completion in 2035, takes a further step in the influence that the different water ecologies have exerted on the urban space of Geneva and its inhabitants. The water infrastructure should

→ figs. 23, 24, 25, 26, 29, 30

14
The Rhône with simple embankments and a small mill around 1880.



15
A washing boat moored at the bottom of Saint-Jean's garden serves as a public place for daily laundry.

16
The *Quai du Seujet* with mills and workshops in 1860.

17
The hydro plant of Forces Motrices (as yet, without its turbine hall) releasing residual pressure every evening via a safety valve, hence being the main attraction in the city, c. 1886.

18
The Rhône estuary with the Pont du Mont Blanc (1862) and the paddle steamers *France* (1886) and still-operating *Rhône* (1927) in 1930.

19
Geneva's lake basin, showing the moles with *Les Bains des Pâquis* and the iconic *Jet d'eau* backed by prestigious façades and Mont Salève.


BANK
UOB
AMBASSADOR
HUBLOT
BAUME & MERCIER

20
The new quay with the Hotel des Bergues, built in 1830, on the right and the hydropower plant *Pont de la Machine* on the left.

help the city bring about the energy transition. Lake water is being used to create a city-wide thermal network for the energy-efficient thermal control of buildings. From a depth of 47 meters, water at a temperature of 7°C is piped into a pumping station in the *Le Vengeron* neighborhood, then passes through the heat exchangers (and heat pumps) installed in the buildings connected to the grid before finally being returned to the lake. After that, a secondary, internal circuit supplies the buildings with either cold or hot water depending on the seasonal cooling or heating requirements.

The return temperature to the lake is reciprocal, and must not deviate more than 1.5°C from the original temperature in order to maintain the lake's ecological balance.[88] The predecessor of GeniLac was the hydrothermal network Geneve-Lac-Nation, which already cooled several institutions of the *International Quarter* (UN, ICRC, UNHCR). According to the operator SIG, the expansion of the GeniLac energy network is expected to reduce CO_2 emissions by some 63,500 tonnes per year by reducing fossil-fuel consumption by 39 percent per person (in combination with geothermal energy).[89] Heating with water is hardly a new concept; it was already used in Zurich in the 1930s to heat the town hall, using the heat capacity of the River Limmat.[90] However, various examples that followed were never able to trigger a broader breakthrough in the technology. The deep waters of Switzerland actually offer favorable conditions for renewable heat production for cities, providing the coordination among the different actors works smoothly and the impact on ecosystems is minimized.[91] In Geneva, twelve projects connect different parts of the city, mostly as part of the *Grand Projets*, to the large heating network, which is ultimately fed with water from both the lake and the Rhône.[92] Similar to the energy infrastructure at CERN, the water network, with its 1.4-meter-diameter pipes, complements Geneva's water ecology, which exists primarily underground. Buildings in the city center could be connected to the system, laid mostly unnoticed under the streets of Geneva, by 2021 and the airport could follow by 2022. The future impact of the gigantic energy infrastructure on the lake's ecosystem and its potential for architecture and the urban space still awaits scrutiny.

The infrastructural landscape is part of an amalgamation of water-related ecologies, and also includes the water-protected areas and floodplains along the Rivers Arve and Rhône (e.g., *Sentier du Rhône*, *Chèvres Barrages, Verbois Barrage, Rhône-Verbois* nature reserve or Étangs d' Étrembières). Such blue corridors established along the water bodies should be understood as we do the green corridors of the 20th century. Their potential as cold-air generators affect the microclimate of their immediate surroundings.[93] The idea of fundamentally reconsidering water as a significant urban element offers new opportunities for contemporary architectural design practice and urban planning to explore issues of energy in relation to ecology, society and urban climate on a larger scale. The synergetic interplay of nature, technology and the urban environment converges in a novel form of *infrasystem*,[94] allowing the authority of architecture to be recalled in order to propose spatial solutions for coping with the urban climate. Like a new Infra-architecture (addressing technical architectural and social aspects), microclimatic conditions in the city could be manipulated and designed as specific (thermal) places.

2.2 Architectural Strategies of Thermal Adaptation

While Genevans valued water in its many manifestations as a habitat and source of energy in one place, one that was cultivated both socially and aesthetically as an integral part of the city, urban history elsewhere paints a picture that increasingly assigned water a subordinate role, with consequences for the city's climate. The current urban landscape of the *Praille-Acacias-Vernets* (PAV) area of Geneva, with its industrial character, is based historically on the presence of water as a natural source of energy and its successive harnessing by agriculture and, later, manufacturing plants. Developed in the second half of the 20th century into a major transportation hub on what were then the city's outskirts, the centrally-located area is today part of one of Geneva's most recent neighborhood-development projects, the so-called *Grand Projet PAV*. The 230-hectare site is home to some 1,650 businesses, a stadium, several shopping centers and some newly located banking facilities. Despite its industrial character and extensive system of railway tracks and road infrastructure, this vital neighborhood "does not represent a wasteland," which is why the expansion of the dense city in the wake of the *Grand Projet* "must take place in a process of progressive mutation"[95] and will eventually provide for an additional 12,000 flats and 6,000 workplaces.

In 2019, a young couple in the industrial area moved into the rooms of their new condominium, which they had purchased in PAV inside a former brewery building of the *Feldschlösschen* company. Over the course of a year, Cloé and Guillaume, who are both archi-

→ figs. 27, 28, 31, 35

tects, converted the space to meet their personal and professional needs. In the process, they developed an individual approach to controlling the indoor climate through targeted heating and cooling strategies. The climatic conditions of the industrial environment exert a significant influence on the decisions made in the interior.

I investigated the interplay between personal perception, conscious control of the indoor environment, and measurable parameters in a research project that collected and recorded data from several temperature sensors distributed throughout the studio flat. In the period between 2019 and 2021, a log of thermally relevant actions in the interior was kept alongside the measurements. In addition, semi-structured interviews complemented the quantitative information by including the residents' personal assessments. By comparing and analyzing the actions taken to adapt the internal structures (e.g. moving a folding wall or curtains) with the change in microclimatic disposition in the room, the overlapping of information revealed potential convergence and differences between such measures and personal perception.

From Floodplain to an Urban Heat Island

It is telling that the names of the areas that form the project perimeter of the *Grand Projet PAV* today refer to the natural environment that long provided for Geneva's inhabitants in the past. In Old French, "praille" was a reference to meadows; "acacias" to the robinia tree, which originated in America; while "vernets" signified alders, which grew along watercourses or in wetlands. Formed by an ancient loop of the Arve River, the site was a floodplain that was used by fishermen in the Neolithic period, partially meliorated in the Middle Ages, and has the Aire and Drize riverbeds as its borders. Already by 1388, the first hydraulic mill, in *Pesay*, had been erected to exploit the energy potential of the River Drize. It was followed soon after by a second mill, the *Moulin de Lancy*. In the 16th century, the amelioration of the open plain opened the way for agriculture with cattle breeding and market gardening. Both were strengthened with the Savoyan protection of Carouge until the early 1790s, and the town's integration into the canton of Geneva in 1816.[96]

The convergence of agriculture, the presence of water and the construction of the first railway infrastructures in the plain in 1846 led, not only to the establishment of the first modern milk-processing factory in 1838 (*Laiterie modèle*), but also, in 1873, to an entire industry based around the production of artificial ice. Subsequently, that stimulated the beer-producing activities of five Genevan breweries between 1888 and 1901. The first half of the 20th century was mainly driven by the industrial development of *Carouge*, and the major development projects in *La Praille* that were related to the railway sector. The meadows and market gardens, on the other hand, provided a particularly unspoiled terrain for building, which is why industrial plants were able to be established according to their own logic and infrastructural setups. This resulted in unique architectural expressions in many buildings. The geometry of the dominant north-south-oriented layout resulted from the major river-service projects that were envisioned in the 1930s but never realized. With the establishment of the industrial zone in 1960, the principle of zoning with the specialization of neighborhoods was introduced. It, in turn, gave rise to a specific urban morphology that obeyed the logic of the infrastructural connection of numerous enterprises to the railway and transport system.

The continuous transformation of the district's landscape into a place where buildings, infrastructures, and services were closely interlinked was carried out according to the objectives of market process optimization, but neglected the spatial allocation of natural elements. Today, the neighborhood is characterized by immensely sealed surfaces produced by many access roads, train tracks and building complexes that were all erected in the 1960s to establish the city's huge freight-transport hub. Unlike other neighborhood developments dedicated to housing, the area has little to no green space to offer.[97] In order to boost the development and attract more companies, the industrial zone was adapted to automobile traffic, and individual plots were allocated a (reduced) maximum size in order to achieve better land use.[98]

Considering Geneva's current urban climate, the PAV area is one of the hottest neighborhoods in the city during the summer months; it has very high surface radiation emitted by the asphalt, railway ballast and its many concrete buildings.[99] Surface temperatures may rise up to 10°C higher than in other parts of the city, depending on the urban design—namely, the intermixing of green spaces, building density, typology and the extent of traffic areas.[100] Due to its structural and material disposition, the industrial area today contributes significantly to the phenomenon of the urban heat island in the city of Geneva.[101] For this reason, the redevelopment of the PAV area envisages a number of measures to mitigate the negative effects of the urban climate as set out for Geneva, in general, in the Cantonal Climate Plan and specifically formulated in the *Plan Directeur de Quartier* PAV.[102]

→ figs. 32, 33, 34

21
General expansion plan for the city of Geneva on both banks of the Rhône from the year 1858.

22
Panorama showing people strolling along the Quai du Mont-Blanc promenade on a sunny summer day in the 1890s.

23
Crowded men’s section of *Les Bains des Pâquis* and many recreational activities at the lake in July 1932.

24
Genève-Plage and its “do your business in the lake” type of toilets, around 1932.

25
The mushroom-shaped showers embody the architectural identity of *Genève-Plage* in August 1933.

Most parts of the perimeter have been developed by deliberately combining working, living, sports and leisure activities in dedicated areas. In the surrounding area, the Office of Urban Planning, part of the *Cantonal Department of Territorial Planning*, envisages an increase in green spaces with a new central park and the restoration of the two small rivers, the Drize and the Aire. Both were canalized in the 1960s and buried under the industrial park at a depth of up to 20 meters; they are now to be brought back to the surface and re-naturalized. The reintegration of water into the neighborhood is intended to create identity and, through the creation of new cold-air-generation areas, could also result in more pleasant microclimatic conditions for the new housing estates.

Energy-related construction regulations for buildings and technical installations are defined in both the Swiss Energy Act[103] and the cantonal and municipal Planning and Building Acts.[104] If a building is newly constructed or renovated, a building energy certificate[105] must be provided, which states “how much energy a residential building requires for heating, hot water, lighting and other electrical consumers in standardized use.”[106] New buildings in Geneva must also meet the “2000-Watt Society” guidelines (energy consumption per person max. 17,520 kWh per annum) using, for example, energy labels, solar heat gains, non-fossil heating systems, etc.[107] The energy verification is an integral part of the ordinary building permit and considers aspects such as construction, insulation methods, and technical equipment,[108] which ultimately define the thermal conditions inside the building. The local architecture is therefore characterized by a strong thermal–structural separation between inside and outside. However, in the case of the couple’s new architect-studio apartment, the energy regulations do not apply because, legally, they are not applicable to internal construction in existing buildings.

Designing an Internal Thermal Landscape

While Guillaume was looking for a new location for his architectural practice, an opportunity emerged that is extremely rare in the city of Geneva. The firm was given the chance to take part in a bidding process for the purchase of a particular studio floor in the former *Feldschlösschen* brewery building in the middle of the *Carouge* industrial area. The building is located in the area designated “Transformation Zone 2” in the PAV’s master plan, where a mixture of commercial, service and residential uses is permitted. At the same time, and in contrast to the rest of the project area, no specific planning measures are anticipated by the city in this zone to increase its quality for future habitation. Instead, the landowners themselves are to decide whether, and how, to make changes to their properties in the near future, with the area undergoing a gradual transformation over time. Thus, the prevailing industrial character constituted by the material–cultural landscape of rail and road infrastructure, but also some of the thermal characteristics of the neighborhood, will be largely preserved.

In order to buy the studio in the course of the application procedure carried out by the landowners, the *Fondation pour les terrains industriels de Genève* (FTI), Guillaume and Cloé had to prove a close link between the profession exercised in the studio space and the possibility of using the space for living.[109] Eventually, the couple obtained the studio space in 2019 as leasehold for the next 50 years, and at a price considered rather moderate compared with the regular real-estate market in Geneva. Globally, Geneva counts as one of the most expensive cities and one with the lowest vacancy rates.

Occupying a duplex unit on the upper floors of the building, the two architects transformed the space over the course of one year—making substantial alterations to the existing structure. They extended a mezzanine, formerly used for storage, to gain enough floor space for a living area—one large enough to host a sleeping niche, a small bathroom with toilet, a work and living room, and a kitchen. Guillaume and Cloé had to install all the technical equipment required in the bathroom and kitchen themselves, while they covered the false floor with commercially available floor tiles commonly used in garden settings outdoors. A spiral staircase connects the private area with the roof, which is accessible via a sawtooth-shaped, fully glazed roof construction. A second staircase connects the upper floor via the kitchen to the common area on the lower floor. Another staircase, partially hidden, provides direct access to the private area from the shared hallway.

The ground floor features the common workstations, the photocopier, the library, the model-making area, the meeting table, a washing trough, the coffee kitchen and numerous plants—which decorate the high room like a winter garden, their organic forms contrasting with the raw industrial architecture. Guillaume not only runs his own architectural firm with two employees in the common area of the studio apartment, but, to finance his mortgage, also rents out three work desks to an engineer and a landscape architect. Due to such financial considerations, the couple decided to keep the studio apartment de-

→ fig. 148

tached from the heating regime of the building in order to avoid a high energy bill. All parties in the large, uninsulated building share—in proportion to their occupied floor space—the cost of the considerable heating bill. Neighbors in the building include offices, a wine trader, a bakery, a company selling concrete façades, a neobank start-up, a dance studio, a landscape architect, artists, and an art gallery, among others. With this atomized mix of functions among the building users, a more demanding sense of comfort must be met in the former factory. This has the effect that the entire building has one of the highest energy consumptions per square meter of floor space of all its neighbors.[110] For the 270-square-meter space, Guillaume says the cost of heating oil would have been about 3,300 USD per year and would have required the installation of new radiators, which he felt would be "too expensive and too un-ecological" overall.[111] Instead, an individual approach should combine greater efficiency with ecological considerations. The strategic addition of adaptable building elements and heating appliances not only enables the orchestration of the tense relationship between the private and public spheres in the duplex by blocking visual and acoustic nuisances; by installing two fireplaces fed with wood logs or pellets to heat the lower and upper floors separately, the thermal environment can be individually regulated and adapted to changing circumstances. Buying larger quantities of local wood from the wholesale *Landi* also cut the cost for heating by some 75 percent.[112]

Guillaume mentions that he has to take into account the thermal requirements for workspace environments stipulated by the *State Secretariat for Economic Affairs* (SECO) since he rents out parts of the office to different parties.[113] As required by existing norms and applicable law, a comfortable room temperature for office work has to be around 20.5°C and should not exceed 26.5°C.[114] Hence, the architects' priority lies in controlling the thermal conditions in the common area to meet such legal standards. The first floor is also the part of the studio space that is occupied most of the day, while the private area is mostly used by the couple in the evenings. Heating the upper part is of less urgent relevance to Guillaume as he tries to use the temperate air rising from the common area as far as possible.

Considering the control of the indoor climate a personal matter, the couple was willing to re-evaluate their perception of thermal comfort—not only in order to save energy and money but also to establish new everyday practices and routines. At the center of controlling the thermal dynamics between the two different spheres in different seasons is a large folding wall installed on the upper floor as a physical barrier to separate the private from the public areas. Being fully glazed, the adaptable structure allows for maintaining the visual connection between the different parts of the studio-apartment and was only perceived by the couple as a significant climatic influence after its installation.[115] By deliberately determining the openness of the foldable glass wall, the thermal flows can be orchestrated according to need.

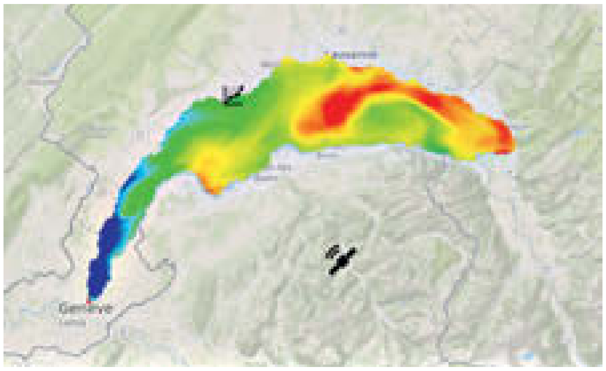
In Winter:
Place Making by Virtue of Niches

In the colder winter months, the working space is heated during the day by the fireplace on the ground floor. The wood pellets are combusted piece-by-piece to maintain a certain room temperature suitable for the desk work taking place nearby. Guillaume explains that in order to keep his employees comfortable, he starts heating the common area if the temperature drops below 20°C.[116] Two additional electric stoves are used sporadically when employees are too cold from working in a seated position for long periods, and the wood stove is insufficient. Cloé, being employed in an architecture office in the city of Basel, commutes in the early morning and the evening, so the private area remains mostly unused during the daytime. In the evenings, though, once work is finished and people have left the office, the doors are folded open like the aperture of a camera in order to allow the warm air to flow upwards and slowly raise the room temperature by up to 5°C in the private area. Should the thermal capacity be insufficient in establishing an agreeable environment, a second fireplace located right behind the folding door can also be used to heat up the upper floor.

This method of heating with wood is, of course, limited to the manual operation of the fireplaces. Especially at night, when the heat from the pellets or logs begins to fade, and no one is feeding the fireplace, the thermal oscillation within the studio apartment becomes most evident. As soon as the couple leaves their bed and stores the blankets that kept them warm overnight, they have to cope with cool temperatures. Guillaume notes that during very cold winter nights, the temperature in the living room can drop to as low as 12°C; the only remedy for them then is to get a hot shower and put on additional clothing to keep warm.[117]

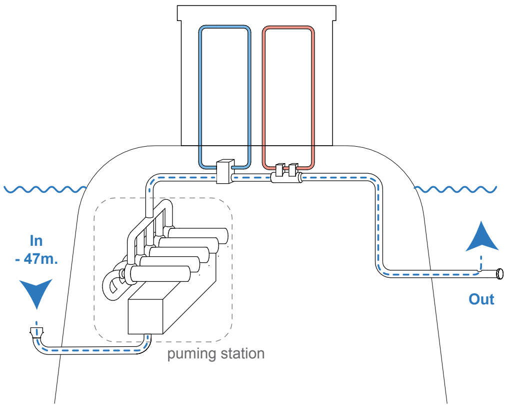
In the absence of technical automation, the couple has to control the thermal conditions by consciously deciding whether to fire up one or the other fireplace.

→ figs. 36, 37



26
Lake Geneva's weather highlights the annual temperature variations and distortions of the water at different depths.

27
Earth works in the lake and at the shore for the construction of the GeniLac pumping station in the *Le Vengeron* neighbourhood in Geneva, 2019.



28
GeniLac's Underground system of pipes and pumps to cool and heat buildings via heat pumps and exchangers with lake water.

29
View of the pebble beach of the city beach *Plage des Eaux-Vives* with view of the shore of the Lake Geneva basin.

30
The interaction of the city beach and the reed water garden of the wildlife biotope as part of Geneva's blue infrastructure.

If they are spending time alone in the studio apartment, the main focus is the thermal condition of the private area and kitchen. The architects also plan to insulate the shed roof opening, which is basically just a layer of tile and a concrete roof, to reduce the condensation that occurs and keep heat inside longer. This is because during very cold periods and due to the insufficient insulation, cold air may move down from the upper floor to the common area if the sliding door remains open. This sensory perception of thermal flows is supported by the recorded measurements, which show significant temperature drops in the common area as a result of opening the folding door.[118] While insulating the roof involves substantial interventions in the roof structure, as well as permission from the entire residential owner group in the building, a simpler and more straightforward solution to keeping the warmth in place is the installation of aluminum insulating curtains. Instead of defining separate spaces and uses, the curtains create distinct climatic micro-spaces or thermal niches within the otherwise open area.

When creating smaller thermal spaces, such as the bathroom or the sleeping niche, other thermal sources and materials may start to play a more important role than any stoves; the warm water from the shower helps heat an area for a certain period—as does the body itself, which continuously gives off heat to the environment during the night. Drawing the curtains means preserving energy in a specific place. It helps, in effect, to create a cascade of microclimates, which mediate between the absolute outside temperature and the indoor environment. The compartmentalization of the interior space through the use of adaptable structures is a key aspect of Guillaume's strategy in creating a thermal landscape that balances (financially driven) energy concerns with those of comfort.

In Summer: Softening the Inside-Outside Relationship

In controlling the thermal environment, the summer months hold challenges different from those faced in winter. While equipping offices with air conditioning seems to be increasingly popular in the industrial neighborhood, the acquisition of air-conditioning devices for Guillaume and Cloé is out of the question for "ideological reasons."[119] Guillaume adds that another argument against engineered "constant indoor temperature" is the loss of "sense of seasonal change" in the home, inasmuch as windows in air-conditioned rooms stay closed, creating a "problematic contrast" between inside and outside.[120] Therefore, the cooling of the apartment without the help of such technical devices relies on passive means. Since, due to its lack of insulation and its structural design, the structure of the brewery building has little thermal inertia to cool the studio spaces, cross-ventilation becomes the only available measure. In contrast to what a differentiated room layout achieves in the winter months, thermal comfort now requires fully opening the entire studio space. The door to the roof, the two skylights, the green sliding door, and the door to the outdoor terrace overlooking the railroad tracks and adjacent industrial complexes are all opened to facilitate air flow through the two-story space as much as possible.

In this state, the studio apartment presents itself as one continuous, largely permeable space that is subject to the laws of thermodynamics. Guillaume says that stagnant air in the studio space is even worse than high indoor temperature, which is why airflows should circulate as effortlessly as possible. In summer, the air in the lower floor is usually cooler, so opening the entire room allows the warm air to escape through the roof door. The chimney effect draws air from the backyard through the patio door in the common room, so the constant flow through the apartment is a welcome relief. The architect decides, day by day, whether cross-ventilation is the appropriate method to cool the apartment, or whether it is even advisable to close all doors at dawn to keep indoor temperatures low for as long as possible. Around noon, however, there is no way around opening the apartment, less to cool than to maintain a subtle airflow that the constantly changing reflections in the moving curtains show. That said, an increase in "tropical" nights with little cooling sometimes makes working in the studio a challenge for the team.

The internal flows are subject to the interplay between the layout of the apartment and the daily weather fluctuation, but also to the more persistent urban climatic condition. The "Geneva Bise" makes for a constant wind on the roof, which allows for cross-ventilation of the apartment in the industrial area even in the hottest times of the year. Air temperatures are then well above 32°C, with a physiognomic temperature equivalent (PET) of 46–48°C.[121] The "indicative daytime planning map" for the period 2020 to 2049, published by the canton, rates the "bioclimatic situation" of the industrial area as "unfavorable."[122] In August at midday, the sun-exposed terrace facing the tracks heats up to around 42°C.[123] It goes without saying that people avoid the outdoors during lunchtime, and gather instead around the meeting table among the work desks and green plants in the cooler indoor space. Although the indoor temperature in the

→ figs. 38, 39, 40

common area reaches 27.5°C, almost the maximum for workplace environments for heat days, it is 15°C cooler than outside.[124]

The industrial zone is not subject to the *Grand Projet*'s strategies to improve urban climatic conditions through interventions such as the new greening and reintroduction of open waterways. Instead, people must rely on personal practices to mitigate the effects of urban climates. Guillaume, who often crosses the streets and tracks of the industrial district to go to the weekly market in *Carouge*—whether for errands or for the odd jog—says that few people here go outside in the summer, and that during heat waves, the air almost "burns" and shimmers like a Fata Morgana in the desert.[125] The continuously sealed material landscape is responsible for the microclimatic conditions that, even today, affect the urban climate of the entire city. The only way to cool off is to visit the nearest river or lake, or plunge into the Rhône three kilometers away at *Pointe de la Junction*, which is Guillaume's favorite way to cool off.

31
The steady transformation from an alluvial plain into a transport-infrastructure hub for cargo handling, here seen in 1968.

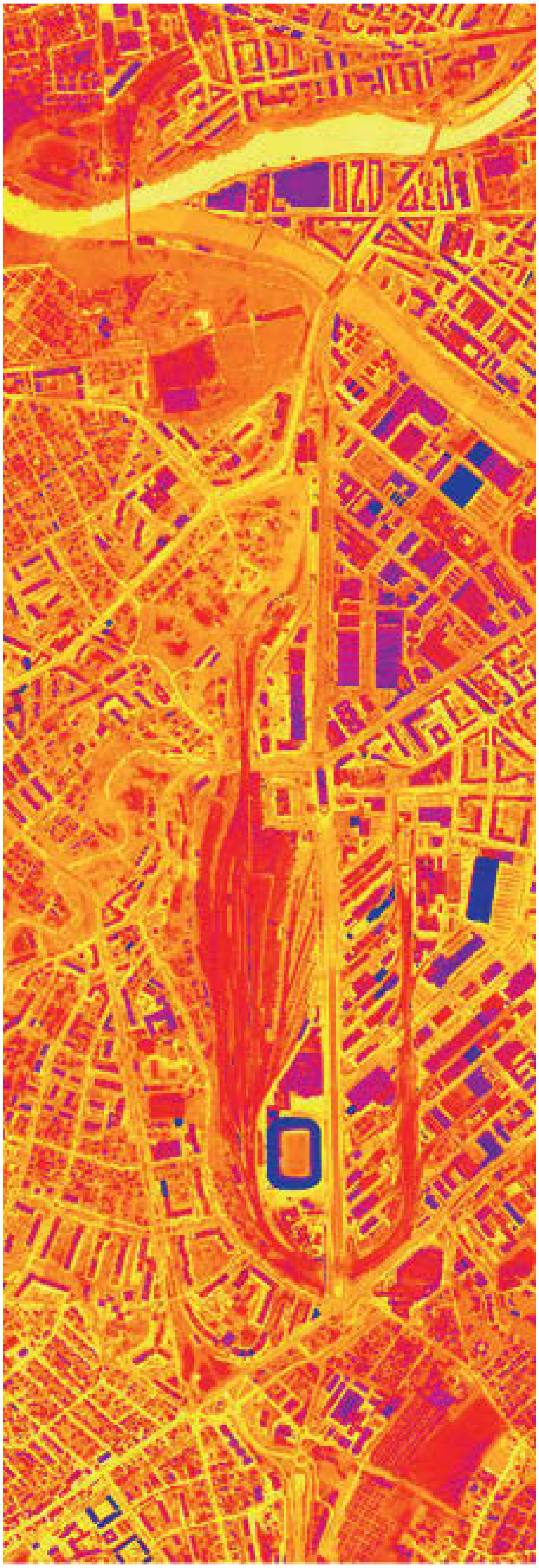
3. Infra-architecture: A Conceptual Approach Towards Thermal Design

This chapter has outlined how a natural resource, water, is closely intertwined with the urban history of Geneva and has been a transformative force in the city's energy landscape. Technological developments, both in the past and today, provide suitable means to use renewable energy resources with the corresponding energy infrastructure ever more efficiently. In Switzerland, given the geographical and morphological condition of the country, the potential of water has played a key role historically and led to a real push of energy production during industrialization. Recent advances in the development of large-scale heating networks that use water to heat and cool buildings promise to have a positive impact on reducing carbon emissions, and thus represent a concrete component of the energy transition. Technological solutions, however, still need to team up with measures that aim to reduce the energy consumption of urban activities across the board, the discipline of architecture being at the heart of contributing new strategies in the field of climate control and climate adaptation.[126]

Both case studies addressed forms of thermal permeability that are aimed at understanding the urban climate as constituted by a set of interdependent microclimates. At the scale of the dwelling, both the permeability of the building envelope, and the adaptive components inside, play a central role in shaping the thermal landscape, and how microclimatic niches can be appropriated daily by occupants in specific ways. The account of Geneva's waterfront ecology advocates new concepts of integrating natural elements in the city's fabric as thermal–infrastructural elements that have both architectural and social meaning. Henri Dufour argued at the time for an "aesthetic transparency of the city" through a structural opening of the urban fabric around the Lake Geneva basin. The case studies suggest a new "transparency of the urban climate" in the sense that we understand both the house and the city as a coherent thermal landscape, rather than as isolated entities.

Today, the experimental approach to thermal design requires both the willingness and the interest of users to acquire the necessary empirical values. Guillaume developed a sense of the environment at a young age, whether in the family home, in the Boy Scouts, or later, when he had his architectural practice in the same factory for four years without the idea of one day ever living there.[127] As such, he understands this way of living in the "Transformation Zone 2" as a self-imposed "pilot project," one for which "one would like to have a client" but which is "not legally feasible in Switzerland" under regular planning circumstances.[128] Structural adjustments and individual in-

→ fig. 13



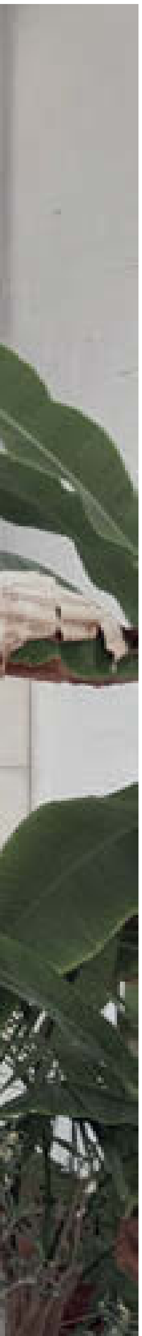
32
Map of thermal emissions (infrared thermography) of the district's environment characterized by impermeable tarmac, gravel and concrete.

33
View of the meadows in *La Praille* around 1900 with Mont Salève in the background.

34
Logos of companies located in the FIPA industrial zone in 1985.

35
The industrial building of the former *Feldschlösschen* brewery was converted to mixed use and now also has partly residential space.

36
The adaptable element of the folding door serves as architectural tool of thermal control. View of the kitchen area with its sky window.



37
The two fireplaces in the common and the private area are fired with wood bought at the local wholesale Landi store.

38
The insulation curtains—together with the adaptable green folding wall—permit the design of distinct thermal environments in an otherwise continuous indoor space.

39
Thermal diversity in the studio apartment thanks to curtains and a folding wall.

40
The common room with the fireplace, plants, and a meeting table is used for various occasions in both the summer and winter months.

terior control, as practiced by the two architects, allow for the creation of an incremental thermal landscape inside the building to mitigate the uncomfortable outside conditions of the PAV area. The promotion of intermediate zones become a solution to partially compensate for insufficient building insulation, the positive effect being that the awareness of external climatic conditions is in no way suppressed.

Behavioral adjustments also help reduce energy consumption by linking one's perception of comfort with economic considerations.[129] The avoidance of overly energy-intensive insulation materials, combined with thermal intermediate spaces and an awareness of nuances in indoor comfort, could represent a new architectural approach—one significant in countries where existing buildings are retrofitted rather than newly built.

As the examples of Geneva's waterfront and industrial district show, an "overlap [of] natural and human-built systems"[130] in cities, as referred to by Michael Hough, offers great opportunities for sharpening the imagination in regard to thermal spaces in architecture and urban planning, and for comprehending the urban climate as an anthropogenic construct that can be designed more deliberately and thoughtfully. Where urban planning—as highlighted in the PAV district—offers no solution, there should be scope at the structural level of a building to influence microclimatic conditions in an appropriate way. An "architecture of choice" allows diversification within the thermal landscape of interior spaces through adaptable structures and intermediate spaces that are responsive both to the environment and the user.[131] Promoting new forms of architecture that allows individuals to be actively involved in controlling the indoor environment can potentially help to increase a sense of responsibility, if not challenge normative notions of comfort.

The idea that the energy commons found in urban nature—and, in particular, that the case of Geneva water, with its thermal capacities—have an influence on the co-design of the urban microclimate should spur a reconsideration of the notion of energy infrastructures. As the mainspring of modernity, infrastructure should be thought of in such a way that, enriched by the ability to influence urban climatic aspects, it also carries urban-design and social significance. Therefore, in addition to technical efficiency, more attention should be paid to the qualitative integration of water infrastructures into the city. One way this has happened to date is by reintroducing water openly through the city, as suggested in the urban-climate literature.[132]

Another approach could be to deliberately use water as a thermal cycle, much like "GeniLac," to help influence the city's microclimatic landscape. Just how the interaction between technological systems and architecture could inform the thermal conditions in public spaces, say, still needs to be explored, both in climatological terms and from a design perspective. In this sense, the architecture of Geneva's waterfront, with its public baths and climatically comfortable places, offers insight into a broader vision of what "thermal infrastructure," beyond pipes and hydroelectric plants, could look like as an integral part of the cityscape. The idea of a thermal Infra-architecture, understood as a space-generating setup made up of natural elements and technical systems, could play a key role in the coping with, and controlling of, urban climate. Such Infra-architecture combines technical, aesthetic, ecological and social aspects, and may help create a favorable urban climate in the future.[133]

Neither house nor city should be understood in climatic terms as a closed container (inside–outside dualism or urban heat island), but rather as a coherent thermal landscape with a wide variety of localities yet to be identified for urban planning. While climate control at various levels means the active designing of the urban climate, the energy transition requires a reassessment of thermal practices in order to save energy. In this sense, coping with urban climate through climate adaptation on the one hand, and controlling microclimatic landscapes in cities through spatial means on the other, puts research-driven design practice by architects at the forefront of solution-finding. As the interplay of natural processes, infrastructural systems, and the constituents of the urban climate suggest, energy-conscious planning of the urban environment takes place at different levels. In this context, the thermal governance of the city becomes a multi-scale challenge for many different actors.

Santiago de Chile: The Standardization of Indoor–Outdoor Transitions

On the Dynamics between Public Spaces and Climate Control

Lionel Epiney

Thermal standards and regulations shape both the way cities are built and the way in which they are climatically experienced. Agencies such as the US-American LEED (Leadership in Energy and Environmental Design), the British BREEAM (Building Research Establishment Environmental Assessment Methodology), the French HQE (Haute Qualité Environmentale), the German Passivhaus or the Swiss Minergie offer certifiable solutions for thermal comfort in combination with the promise of sustainability in architecture, as well as for cities. However, by establishing building standards that regulate boundaries between interior and exterior, standardization can lead to homogeneous thermal indoor environments with little attention paid to the local specificities.

Based on data from Santiago de Chile, I will outline the variety of architectural, technical, socio-cultural and historical manifestations that deviate from the oft-perceived objective, rationally defined standards. The chosen case studies outline this questioning of an apparent universality of standards by pointing out local specificities of thermal comfort. I explore whether standards might represent a new form of norm, as they can substitute for informal practices or building traditions, and where formal ways might replace experience.

Methodologically, this chapter relies primarily on an analysis of thermal-related documents collected during thirteen months of fieldwork in Santiago de Chile in 2017 and 2018. The documents range from government-issued policies, plans, construction manuals and official guides on how to apply certain regulations, to public records in the form of newspaper articles and advertisements. The analysis of the documents is complemented by a set of qualitative interviews with architects, inhabitants, policy makers and academics who are concerned with climate control and standards. In addition, I assessed different neighborhoods and houses through ethnography and microclimatic walking in order to have a sensory experience of their thermal qualities, and also examined photographic material. Through this diversity of materials, I was able to assess how standards relate to political and economic transformations in the city as well as how they are being implemented in everyday practice.

1. Climate and Energy Transition in Santiago

The city of Santiago de Chile is built in something like a bowl, the "Santiago basin," that reduces airflow. Indeed, the two mountain ranges, the *Cordillera de la Costa* in the west and the *Cordillera de los Andes* in the east, block the winds going in and out of the city. This results in bad ventilation conditions and a superficial thermal inversion in the first tens of meters, thus affecting the capacity to remove pollutants from the basin—particularly during the city's cold period. However, the urban climate is also influenced and changed by the actions of the city's citizens, their mobility and settlement patterns. At the urban scale, it is evident, too, that the number of green spaces is significantly lower in the outskirts and poorer districts of the city—a circumstance that also affects these areas' temperatures, which tend to be higher given their large amounts of "asphalt-covered" ground.

1.1 Thermal Standards versus Social Norms

As regards thermal comfort, the norm is partly defined by technological innovations that control indoor temperature and humidity.[134] Since the mid-20th century, indoor climates in many parts of the world have been transformed by the use of efficient materials, products, and appliances such as air conditioning and central heating. Thanks to structural improvements in the building envelope, the indoor climate can be better regulated, which leads to new norms of comfort. However, thermal practices, those various strategies one uses to cope with climatic conditions, also depend on socio-cultural expectations as to what a comfortable house means. In addition to scrutinizing standards and their impact on built structure in Santiago, this chapter juxtaposes them with social norms. The norm represents what is commonly accepted as comfortable, with thermal standards either challenging or reinforcing norms. In addition, the norms associated with the creation of a favorable

→ figs. 41, 42, 43, 44

International Developments

1970:
Global Oil Crisis

1987:
Brundtland Report

Government in Chile

1965–70:
Frei Montalva

1970–73:
Salvador Allende

1973–90:
Augusto Pinochet

National Developments in Chile

1950:
population growth and lack of housing services

1953:
Establishment of CORVI (*Corporación de la Vivienda* / Housing Corporation)

1965:
Establishment of MINVO (*Ministerio de Vivienda y Urbanismo* / Ministry of Housing)

1977:
Norm 1079:
Aquitectura y construción, zonificación climática-habitacional y recomendaciones de diseño arquitectónico (INN/ISO)

1979:
Deregulation of land and rising real-estate prices

Building projects mentioned in the chapter

1953–65:
UV Providencia

1954–65:
UV Portales

1960–64:
Villa Olímpica

1960–70:
Bloques 1010/1020

1965–69:
Villa Frei

1980:
Vivienda Tipo C

1950s | 1960s | 1970s | 1980s

1990:
BREEAM

1993:
LEED

2006:
Establishment of BRE Global (Building Research Establishment)

1994–2000:
Eduardo Frei Ruiz-Tagle

2010–14:
Sebastián Piñera

1990–94:
Patricio Aylwin

2000–6:
Ricardo Lagos

2014–18:
Michelle Bachelet

2006–10:
Michelle Bachelet

2000–14:
National Thermal Regulation (First thermal regulation in Latin America)

2010:
Chile becomes member of the OECD (Organisation for Economic Co-operation and Development)

PDAs (*Planes de Descontaminación Atmosférica /* Atmospheric Decontamination Plans)

2014:
Code for Sustainable Homes in Chile (collaboration Chilean Ministry of Housing and BRE)

1997:
COPEVA
houses had to be wrapped in plastic to resist rainfall

2010:
LEED Street

2010–14:
Lo Barnechea

2010:
Transoceánica Building

2012:
Costanera Center

1990s | 2000s | 2010s

41
Overview of housing developments in Chile in the context of local and global events.

thermal environment can, indeed, differ from the objectives of a standard.

Actors

While the standard is aimed at performance, the norm describes users' practices and expectations. It is this gap between standardized solutions and nuanced practices that I will scrutinize. While the standards embedded in the regulations state the U-values for every building element, the implementation of the right elements is another issue. When analyzing the creation and use of a standard or a certification scheme, we must not only look at the standardizing institution but also at the entire building sector and the actors involved in it—for example, the building professionals' associations, the manufacturers, construction companies and homeowners. By analyzing how these actors import global standards in construction processes, I aim to outline "where systems and ideas originate, […] what messages they carry with them and […] how these are constructed and reconstructed through local processes of appropriation."[135]

My main hypothesis is that regulations and standards, rather than being fixed, are subject to interpretations over their many stages of existence. They are not " out there," waiting to be used, but are, instead, being constantly manipulated and changed by different actors who ascribe them value in their usage. Standards must not be categorized as merely technical–scientific artifacts, because they also depend on localized practices, the available products and materials, the builders' skills and design, as well as the building culture into which they are inserted. Indeed, in the case of technical specifications or recommendations, the rule cannot be separated from the way it is applied in a particular context. There are innumerable ways for architects to design and build with the same standard, no matter whether a mandatory or a voluntary standard. Standards are incorporated into the built environment by the architects and builders who rely on the laboratories and bureaucracies that issue those standards. Based on my empirical data, I argue that thermal standards are socio-cultural artifacts which must be investigated as such.

Santiago de Chile is an appropriate place to study the frictions between standards and norms given its climatic characteristics, the socio-economic stratification of housing, and the wide diffusion of international thermal standards such as LEED. Since the mid-1990s, Chile has experienced economic growth accompanied by rapid urbanization. Indeed, some 90 percent of the population in Chile lives in urban areas.[136] Almost 40 percent of the national population resides in Santiago. This urban population density results in a growing energy demand, in turn causing environmental threats such as the air pollution that is found in many other cities of the Global South. In addition to urban sprawl, housing policies of the second half of the 20th century shaped the variety of thermal environments we find in Santiago. From the 1960s onwards, state construction of residential buildings aimed to reduce the housing deficit as more and more people migrated to the capital (Santiago's population was 1,400,000 in 1952 and 2,860,000 in 1970).[137]

Policies

Housing policies differed widely during the democratic governments of Eduardo Frei Montalva (1964–70) and Salvador Allende (1970–73) and the subsequent dictatorship of Augusto Pinochet (1973–90).[138] Before the *coup d'état* in 1973, housing policies considered dwelling a right, with the understanding that the state acts as a provider of this right. The basic idea was that, through public projects, the state should offer access to a house for the majority of the population. Many of those projects were oriented towards modernist ideas of architecture, standardization and mass production. When Pinochet came into power, the production of houses was increasingly relegated to the private market.[139] Pinochet worked hand-in-hand with neoliberal economic policies, which had a large impact on long-term urban development. The deregulation of land in 1979, as well as rising real-estate prices, caused the relocation of many poor families to the peripheries of the city. From an economic point of view, Pinochet's housing policies are still considered successful.[140] Indeed, since the 1980s, the so-called "Chilean housing model" has even been taken as an example by other Latin American governments, including those in Colombia, Mexico and Costa Rica.[141]

At the beginning of the 1970s, state agencies linked to the field of housing design and production evaluated and assessed the environmental conditions of governmental housing projects from a qualitative perspective. These investigations focused on the thermal performance of buildings, including aspects such as heat losses and gains, thermal inertia, acoustic insulation, natural lighting, solar radiation and the durability of building materials.

Thermal quality slowly entered the debates, but these analytical research projects were abandoned abruptly in the mid-1970s. The dictatorship transformed the state into a mere demand-manager and subsidy-provider.[142] This led to a growing deterioration in residential quality, while building stock should, in fact, be considered a basic governmental non-renewable resource—a significant example of financial, physical and cultural capital.[143] Housing construction suffered a decrease in quality as regards environmental conditions in and around dwellings. While considered extreme, a case that raises awareness of the housing crisis at that time would be the "COPEVA" houses, a name that derived from the real-estate company that developed them and tried to lower costs by all possible means. In 1997, these houses, inhabited by the lower middle classes, had to be wrapped in plastic during rainstorms given their deficient construction and leaking exterior walls.

The Chilean model of housing policy, which is based on individual financing and neoliberal methods of development, played a part in practically eradicating slums. Yet, immigration led to an enormous urban sprawl and social segregation, with many families relocating to the urban peripheries.[144] When overlaying the locations where socio-economically weaker groups live with climatic data, we can see that people from the most vulnerable groups are the ones living in zones facing episodes of extreme heat, including urban heat-island effects. The urban climate is partly related to topography and the specificity of Santiago's layout.

1.2 Chile's National Thermal Regulation (RT)

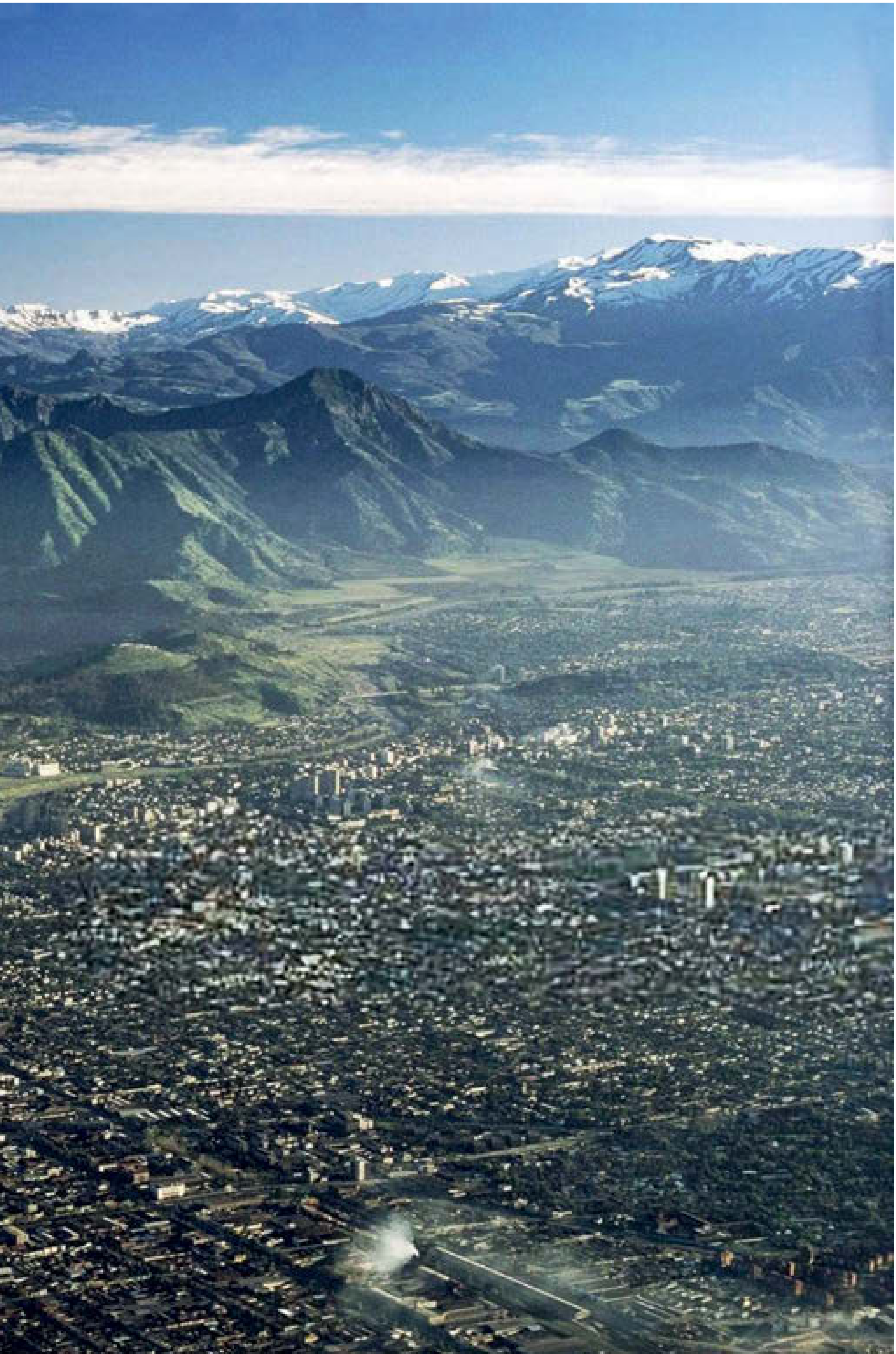
Chile stretches across 38 degrees of latitude from Patagonia in the south to the Atacama Desert in the north. According to the Köppen climate classification, the country hosts at least seven climate subtypes, with Santiago falling into the Mediterranean climate category with its dry summers and wet winters. Climatologists established the country's climatic zoning in the 1970s, serving as a starting point for the regulations of heating and cooling across the country. One of these experts underlined the fact that such zoning represented a great opportunity for developing passive means of climate control in the building sector for each region: "A single building would no longer be built the same way on the coast or in the mountain range, in the north or in the south, as it is today. The life cycle of the buildings would be extended, their maintenance costs reduced, savings would be made on expensive air conditioning, which is usually installed from the central area northwards, and also a considerable amount of fuel and heating devices in the center and in the south."[145] From an energy perspective, the beginning of the 1970s was an important period because petrol shortages thwarted exponential growth. The global oil crisis raised awareness of ecological concerns that were related to the impact of industrialized societies.[146] Thirty years later, in 2000, the climatic zoning became the foundation for the issuing of the RT (*Regulación Termica*, National Thermal Regulation).

"Furnaces" and "Ice Cubes"

Studies have shown that both air pollution in winter and the heat-island effect in summer, reach alarming figures.[147] Heating demand in the region of Central Chile, where Santiago is located, for example, is at its highest for four to five months (May to September) due to the cool nights. During the winter months, however, it is sometimes colder inside than outside because many apartment houses lack heating systems. Only some buildings (primarily office premises) have installed hot-water pipes that circulate through ceiling and floors, thus generating ambient heat. However, most buildings are constructed of reinforced concrete and have little or no insulation. Dwellings perform particularly badly as regards airtightness, resulting in major heat losses.[148] The main heating strategies used in this region are gas-burning stoves (kerosene, paraffin, liquid gas). Poorer households use wood, creating an even more precarious smog situation in those neighborhoods.[149] Carbon monoxide emissions are a major health concern with gas heaters. What is more, poor ventilation can cause the air quality inside the home to be worse than outside on the street.

In Santiago, growing energy consumption started to manifest itself in the increasing occurrence of smog. Throughout Chile, the primary cause of air pollution is a combination of wood-fired heating, lack of smog filters and poor insulation. On the one hand air pollution has severe health implications. On the other hand, it affects the economy, as the city more or less "shuts down" during alarming pollution peaks. Cities in southern Chile, such as Temuco or Osorno, which suffer from high air-pollution levels, have enacted strict regulations, such as atmospheric decontamination plans (PDA in Spanish). While that is a step forward, the PDA have still not been adopted on a national level, such that Santiago continues to suffer from air pollution on a regular basis. Moreover, similar to the RT, which considers only the cold winter situation, the

→ figs. 45, 46



42
Aerial view of Santiago de Chile, taken in October 1973 a few weeks after the *coup d'état*, when the sky was still clear (in contrast to nowadays) and the Moneda presidential palace was still smoking due to its bombing (in the bottom-right corner).

PDAs target the specific problem of particulate-matter pollution, but fail to consider the urban climate as a whole, complex phenomenon that is embedded in a political and economic context—clearly illustrating the shortcomings of the regulation to engage with climate control.

Most of the dwellings in Santiago are built either of brick masonry or concrete. Due to poor insulation, many of the homes and buildings are, in the common adage, “a furnace” in summer and “an ice cube” in winter. This is related to the harsh climatic situation of daily oscillation in Santiago—for example, of up to 18°C between day and night all year around. The temperature fluctuation is tempered by high energy consumption for cooling or heating. This problem was already identified in 1967 when Rodríguez wrote: “there are buildings that in the cold season spend huge sums in central heating, while in summer their temperatures reach the maximum outside.”[150] Rodríguez concluded that the main reasons for this situation lay in the building construction–namely, in the extensive use of glass; the replacement of wood by metal; the use of walls, partitions, ceilings and floors of thin materials; and the lack of legislation that specified and required acceptable minimum insulation.

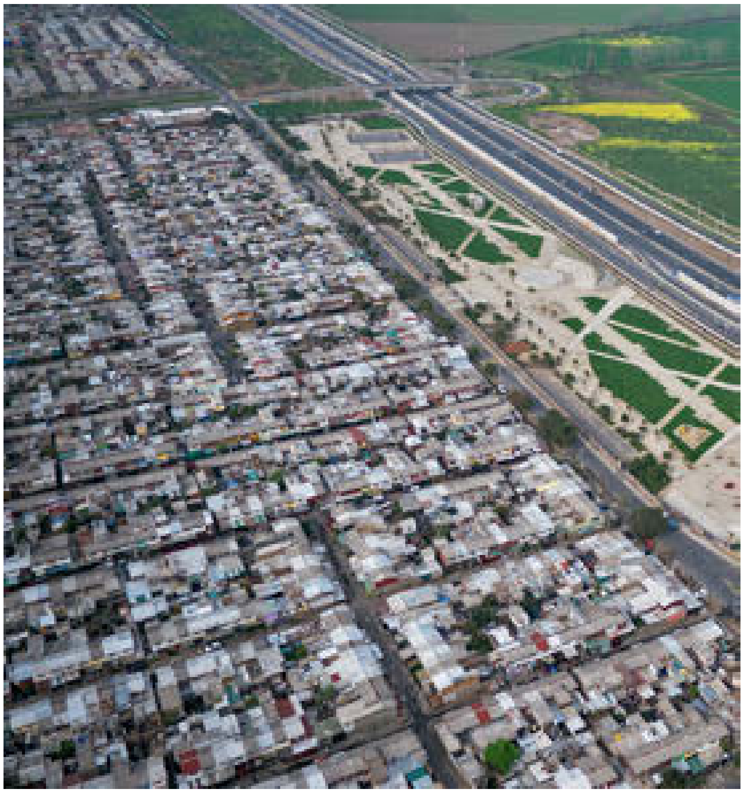
Thermal Regulation

After the country’s return to democracy in 1990, Santiago’s urban climate, the state of the art in construction, and the need to conserve energy drove the development of implementing a minimum level of insulation. In 2000, following the global trend for green building, Chile introduced the first thermal regulation in Latin America. This RT, conceived in three phases, was based on US-American standards issued by the ASHRAE (American Society of Heating, Refrigerating and Air-Conditioning Engineers). The first regulation, in 2000, prescribed roof insulation. The second, in 2007, was a reaction to the energy shortages in 2005 and regulated the insulation of walls, floors and windows for all new dwellings. In the third phase, beginning in 2014, a certification system for energy performance in housing was developed, but dropped shortly after its announcement.

The main objective for introducing regulations such as the RT is to guarantee efficiency through an assessment of the building’s performance and the control of the energy flux between its interior and exterior. Thermal standards are linked particularly to the improvement of the building envelope, inasmuch as each element’s heat-transfer value is specified. In Chile, the number of heat-degree days influences the strategy to attain minimum requirements. With the reduction of the building’s energy consumption as the goal, the focus goes primarily to avoiding heat losses while maximizing gains. While the RT aligns with contemporary standards for building insulation, 90 percent of buildings in Santiago were built prior to 2000. They were thus constructed before the legally binding regulation was implemented, and even those built later often fail to comply with the law due to a lack of control or resources. In actual fact, the regulatory thermal requirements are so low that they can be achieved without the use of any insulation materials, which calls their very relevance into question.

Energy efficiency in housing began to be considered again in the 2010s. This was partly because of external causes regarding the country’s energy security. Chile’s electricity system is highly dependent on imports: 78 percent of gas, in fact, is imported—mainly from Argentina. When, in 2004, Argentina stopped delivering gas owing to its economic crisis, Chile had to suddenly shift from gas to oil and started investing in liquid natural-gas import facilities from, for example, Indonesia. These transitions in the energy market led to a rise in electricity prices.[151] While they boosted the development of diesel- and coal-fueled power plants in Chile, they also placed energy saving at the center of preoccupations.[152] At a transnational scale, the OECD (Organisation for Economic Co-operation and Development) put pressure on Chile to improve its energy sustainability with a report issued in 2005. Indeed, after becoming a member of the OECD in 2010, Chile was forced to comply with the energy standards of other OECD countries.

So far, the regulation and standardization in Santiago’s building sector has only addressed some, but not all, relevant aspects: orientation or vegetation, for example. When the standard of the RT was defined in 2000, only ideal cases of orientation and location were analyzed. The RT is based on selected representative building types in order to calculate the standards’ performance indoors. Even collectively, these standards fail to encompass the reality of the urban fabric—nor do they include the neighborhood scale. Although the RT embeds some directives about public space, it seems that the design of urban spaces only comes after the house is constructed. Further, the RT primarily focuses on the winter months by specifying resistance values (U-values) for materials. Overheating during the summertime is barely addressed. This becomes problematic, as climate change predictions suggest that Santiago will become even hotter and drier in the coming decades.



43
La Pintana district: low-rise, high-density dwelling patterns in a poor district in the south of Santiago.

44
Las Condes district: dwelling patterns with lush green space in a high-income district in the northeast of Santiago.

45
COPEVA houses, wrapped in plastic during rainstorms given their deficient construction and leaking exterior walls.

46
COPEVA houses.

The RT hence underestimates summertime-effects and an update is long past due.

In general, standards of any kind are not neutral, but they emerge from the interaction and considerations of different actors. In this case, it is the assessment of the climatic situation by human actors that shapes the definition of the thermal standards. Relying on ideas of ANT (Actor-Network-Theory), the context is not something "out there" but rather that "actors—through the circulation of forms and standards—contextualize each other, not to do the work of 'situating' the actors in an a priori context."[153] As stated previously, standards are not mere technical artifacts but, instead, are socially constituted. Different economic, political, architectural, social and cultural forces shape standards. An ANT framework helps in assessing all the human and non-human forces and powers at play in the creation and implementation of thermal standards, which often appear as "black boxes"—difficult to dismantle and study. In the controversies that follow, the rational side is hardly the winner, while nontechnical aspects are dismissed or taken as abnormal divergences. Yet, all aspects are crucial in revealing the standards' widest possible outcomes without favoring one sphere or domain over another. Their whole architectural, political and socio-cultural implications are taken into consideration and revealed.

2. The Urban Environment through the Lens of Thermal Standards

The following three case studies deal with thermal standardization in Santiago in different ways—namely, as regards public spaces in collective housing (2.1), voluntary green labels in the business district (2.2) and microspatial self-building practices (2.3). The aim of this multifaceted approach is to learn about the diversity and malleability of apparently objective thermal standards. The main objective is to understand the role that thermal standards play in shaping the mutual reactions between forms of climate control, urban morphologies and the city climate. The actors involved in implementing standards in the urban built environment range from the architect to the inhabitant, from the construction worker to the Ministry of Housing, from the local brick manufacturer to the transnational label agency. They all have different ideas on how certain standards improve thermal conditions indoors and outdoors.

2.1 The Climate of Collective Housing: Green Public Spaces as Regulators of the Thermal Environment (1956–68)

The first modernist architecture in Chile appeared in public-housing projects in the 1930s and 1940s.[154] Under the lead of the *Caja de Habitación Popular* (Popular Housing Fund, created in 1936), apartment blocks became a popular residential type that included semi-public spaces and passages between the house and the street, such as patios and courtyards.[155] While primarily aiming to improve community life, these green spaces also have climatic benefits—especially in today's dense city. The *Caja* set new standards in terms of technology, construction and urban planning, and also by incorporating modernist ideas of hygiene into urban housing.[156] Around 1943, the residential floorspace (36–100 m²); spacing; and the heights, location and orientation of the houses were determined to ensure favorable solar exposure and ventilation.[157] Moreover, public spaces, density and width of the streets began to be regulated.

At first, the government, influenced by the hygienist movement, categorized houses into "healthy" and "unhealthy" (even "unlivable" as described in the Decree-Law 261 of 1925),[158] while other categories—such as "thermally comfortable," "energy-efficient" or "environmentally-fit"—started to replace them later. The most prominent modernist housing projects were introduced in the 1950s and 1960s under the name of *Unidades Vecinales* (Neighborhood Units).[159] These state-planned dwelling units were inspired by the ideals of the garden-city movement. Selected through architectural competitions, they offered residential space for the population's middle class. The inclusion of green spaces was of particular interest in these collective housing projects. Those semi-public spaces opened up possibilities for communal activities, and for mobility between the houses and the rest of the urban space. Considered from an urban-climate perspective, the green spaces were thermal environments that enabled ventilation and cooling of the neighborhood.

Villa Frei as Housing Model

The *Villa Presidente Frei*, colloquially known as *Villa Frei*, is one of those neighborhood units, and is of particular importance because it was a forerunner for many typologies that have since spread all over Santiago. *Villa Frei* resulted from an architectural competition and served as a model for many other constructions of CORVI (*Corporación de la*

Vivienda / Housing Corporation).[160] The proposed housing complex is an excellent example of providing a favorable urban microclimate. The creation of such a beneficial thermal environment is based on architectural solutions, including a park and using outdoors spaces, like loggias, as buffer zones. The 1964 competition was won by Osvaldo Larraín, Jaime Larraín and Diego Balmaceda—three architects who graduated from the Universidad Católica. In their design outline, they referred to the idea of the "neighborhood unit," which had been theorized in the 1920s by American planner Clarence Perry but which became far more *en vogue* in the late 1950s. The neighborhood unit consists of an ideal number of 7,500 inhabitants who live in the same community. Basic services—such as playgrounds, creches and shops—are located in the center of the neighborhood. Perry outlines the fact that particular care should be given to open and green spaces, allowing all the users to enjoy them as much as possible.[161] The *Villa Frei* was planned in three sectors: one for the apartment buildings in blocks and towers; one for the civic and shopping center, school, fire station and hospital; and the last, for single-family houses. There are several housing types in the apartment section–namely, simplex and duplex blocks (four to five floors), towers (ten to fifteen floors) and single houses (one to two floors), all made of a concrete structure with partitioning brick walls.

The simplex block consists of four rooms organized around a central hallway. The balcony to the north and the loggia to the south function as exterior hallways that connect all rooms. The building is oriented on an east–west axis, with the living and bedrooms towards the north for optimum insolation. This orientation also permits ventilation as this façade is open along its width. The "humid zones," including kitchen and bathrooms, are relegated to the southern part of the apartment.

The duplex block has the most recognizable features, with its exterior passages and the bedroom units over them. These blocks are oriented on a north–south axis. On the ground floor, the flats are directly accessible from outside. This allows inhabitants to appropriate some outdoor spaces as private gardens, which, in turn, act as buffer zones between public and private spheres.

The ten-floor tower contains four flats on each floor, each one composed of three bedrooms, two bathrooms, kitchen and exterior loggia. Similar to the simplex block, the living room, and two bedrooms open towards the exterior and share the loggia as passage. The tower of fifteen floors is almost identical to the ten-floor tower.

The one-floor house has a similar plan to that of the simplex blocks. In addition, a wall between the sidewalk and the front lawn acts as a filter between the inside of the house and the outside of the compound space. As it is made of bricks and was quite easy to demolish, many owners decided to get rid of it and extend their personal gardens.

The two-floor house hosts apartments of four bedrooms, one living room, kitchen and two bathrooms. Two of the bedrooms have large balconies, similar to the passageways of the duplex blocks. Often, having been converted into indoor spaces, these balconies are used as extensions of the bedrooms. Structurally, the house is supported on its perimeter, which allows for great flexibility with interior wall partitions.

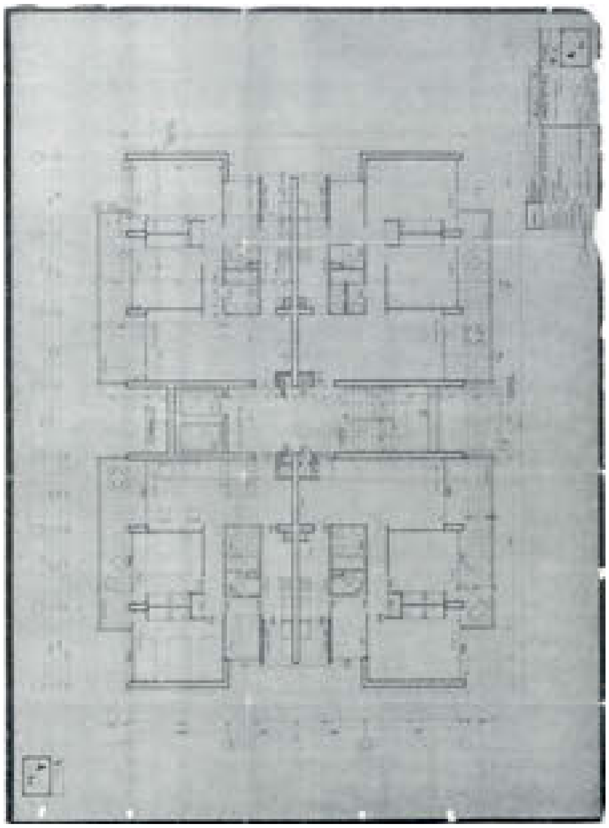
An extensive park links the three sectors and the different volumes, functioning as the "backbone" of the whole housing complex. Even today, inhabitants of *Villa Frei* mention the park space as a plus in the creation of a comfortable environment and express their appreciation for the green spaces. Hetty van El, an inhabitant aged 57, outlines that: "For me, the *Villa* represents a space of togetherness that you do not see a lot in Santiago, with green areas that allow for a healthy and quiet life. This demonstrates that in those times such dwellings and spaces of quality and modernity could be created."[162] Another inhabitant, Hugo Tapia, aged 58, says: "It [the *Villa Frei*] is a lifestyle. It has a strong concept of neighborhood, with constructions of good level and the presence of nature in the surroundings, creating a nice and pleasant environment. An oasis, a green lung for the city."[163]

Of particular interest is the fact that many of the gardens were administered by the inhabitants themselves, who got together to organize, take care of and upgrade the green areas. Gatherings of inhabitants in each housing complex would identify where open collective spaces could be improved, in order to "make the *Villa* greener every day."[164] The integrated park was meant to be traversed and enjoyed by pedestrians even from outside the neighborhood. Unlike other residential compounds in Santiago, *Villa Frei* was not enclosed by metal gates.

In 1969, *Villa Frei* was extended with standardized buildings known as *Bloques 1010/1020* (Blocks 1010/1020), developed by CORVI architects. This model consisted of a simple concrete structure of slabs with masonry walls. Such buildings had three

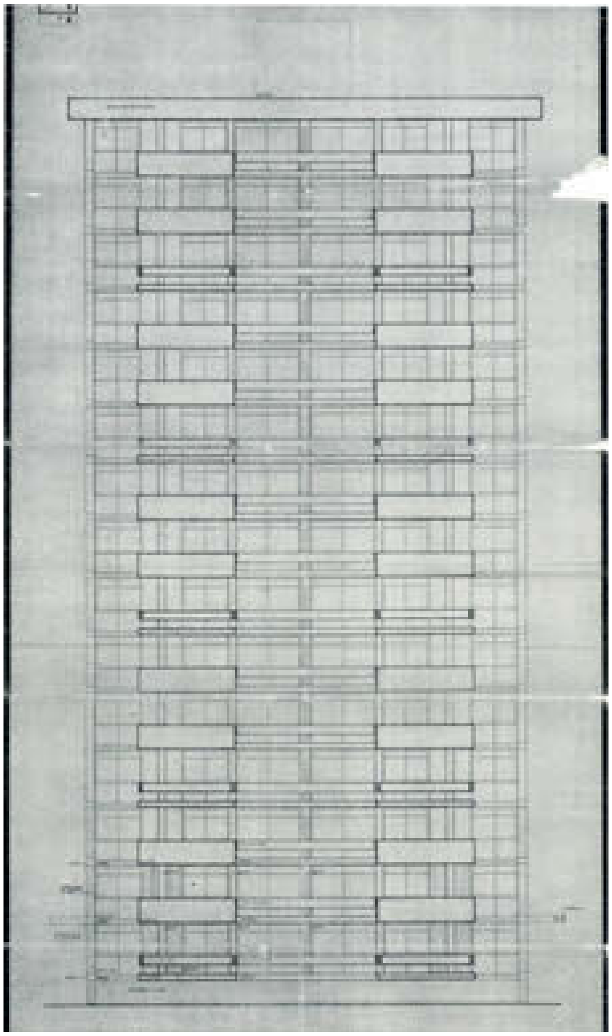
→ figs. 47, 48, 49, 50, 51, 52, 53

47
Aerial image of the entire first stage of *Villa Frei* (1964–68), up to José María Narvona street.



48
Villa Frei, floor plan of a ten-floor tower, containing four flats on each floor.

49
Villa Frei, section of a fifteen-floor tower.



floors and, unlike subsequent social housing, displayed a construction quality that weathered the passage of time well. The apartments are rather generous in size, ranging between 47 and 55 m² for Block 1010, and 66 and 75 m² for Block 1020. Constructed all over Chile with slight variations, they represent one of the most widespread housing types in Santiago. Designed as rational buildings, they used resources and materials highly efficiently. In Santiago, they often enjoy a north–south orientation, which optimizes sunlight distribution for all flats. In *Villa Frei*, the blocks number the same as in the simplex type. The greatest discrepancy between the two types is the lack of any green spaces around many of the later blocks, which results in a less attractive environment.

Another extension of *Villa Frei* was the *Casa Modelo 136* (House Model 136). More in line with the idea of paths and open spaces enjoyed by the rest of the complex, these houses also represent a popular dwelling model for many Chileans. In the 1980s, other block buildings, known as *Vivienda Tipo C* (House Type C), adopted the same construction type. These were built in the urban peripheries, where land was cheaper. Similar to Blocks 1010/20, House Type C also lacks green space and provides only a minimum of habitability and comfort, offering no insolation whatsoever. Although these public-housing projects were constructed at a time when no national legislation for thermal comfort was in place, the emphasis on outdoor spaces shows an awareness of how buildings and urban space can be brought together in a cohesive way.

Legislation and Morphology

As regards modernist housing complexes, we must consider the relationship between the legislative and the morphological. The *Ley de Propiedad Horizontal* (Law of Horizontal Property) sets the legal definition of the collective space, including the rights and duties of tenants. Without defining their morphology in detail, the law stipulates that "common spaces" are necessary for the "existence, security and maintenance of the building."[165] Such spaces include not only green areas, but also the semi-public spaces of the patios, gangways, lobbies, etc., and are regulated through co-propriety agreements. In *Villa Frei*, for example, the repetition of housing blocks allowed the architects to free up the land between, which was then used to design common outdoor spaces. The green spaces there provide thermal qualities (such as shading, or cooling via evapo-transpiration), a smooth transition between outside (the traditional public space) and inside (the flat or domestic realm), as well as a collective space for the inhabitants and friends to enjoy. Most of the *Villa Frei*'s green areas have been preserved as per their original design to this day. However, green spaces in other neighborhoods constructed in the same time period have been built over—as is the case with the *Unidad Vecinal Portales*. While the municipality supported 80 percent of its land being conserved as public/green area,[166] many spaces among the blocks of *UV Portales* have been used for the construction of smaller one-floor units rather than as connection and recreation areas. At the same time, those spaces can no longer be used by all members of the community. As such, the increase in housing demand over time has affected the availability and use of public spaces. It is here that legislation and morphology can collide—the latter, being imposed over time, altering the former.

Tracing the historical development of residential complexes using the example of *Villa Frei* demonstrates the thermal relevance of outdoor spaces beyond the built structures. These freely accessible spaces constitute an urban commons, and support a sense of community through the partial participation of residents who care for these spaces. Since the 1980s, the focus of residential construction has generally been on providing the building rather than its surroundings. For real-estate companies, open spaces are neither affordable nor profitable in contemporary Santiago. Public space is, rather, seen as negative space, a "leftover" once the building has been placed on the plot in a way that fulfils the neighborhood's density requirements. Land values are key in the site selection. If the building contains environmentally fit features—such as natural ventilation, sun exposure, passive heating and cooling systems—it is often at the expense of a good location and public infrastructure. This results in half-measures, wherein a building might perform quite efficiently in terms of coping with standards, but fails to react to its surrounding climatic and microclimatic conditions. In the modernist housing complexes, the idea of the "neighborhood unit" offers some coherence for the grouping of buildings. Today, some of these modern complexes are regarded as worthy of conservation and preservation for the sake of aesthetics, "style" and community. Even if these settlements often have an "urban island" character, they represent key pieces in the built fabric of the city—both as consolidated communities and as socio-cultural residential patterns. Some experts would also consider Blocks 1010/20 worthy of a heritage citation. As outlined, they were reproduced many times all over the country. In total, more than 2,000 Block1010/20 typologies were built all over Chile.[167] It is precisely this feature of reproducibility that

→ figs. 54, 55, 56, 57

makes them key candidates for re-evaluation and adaptation to newer urban and environmental conditions. Their construction quality was higher, and apartment layouts, more generous with regard to floor space, than models in the following decades.[168] The blocks can be configured in various ways to form urban ensembles. Planners often consider topography and context when grouping blocks together. In some places, Blocks 1010/20 are used to enclose the parcel of land that they occupy—forming, at its center, a sort of semi-public, inner space for the community.[169]

In conclusion, public housing in Santiago shifted from an avant-garde solution influenced by the ideas of international modernism in the 1960s to a more standardized model in the 1980s and 1990s, at which time Chile embraced neoliberal policies that subjected housing production to land-market mechanisms. Consequently, house designs faced a simplification and lost some beneficial attributes that they had enjoyed hitherto. With land maximization as one of the priorities of the privately led projects, for instance, public spaces and green areas have diminished. The case studies in this section have outlined the manifold interactions between urban features, property law and the collective appropriation of spaces that intervene in the creation of beneficial thermal environments.

2.2 The Climate of the Business District: Voluntary Thermal Standards Imported by International Companies (2000–20)

Since the 1990s and the development of sustainability-certification labels and schemes, such as the pioneer BREEAM from the BRE (Building Research Establishment) and the later emerging LEED, we have witnessed a rise of "green capitalist" approaches towards sustainability in general,[170] and energy efficiency in particular. Popularized at the "Earth Summit" in Rio de Janeiro in 1992, this growth-oriented strategy did successfully foster innovation and engage changes towards the vague objective of ecological sustainability. However, in the design and building arena, the trend went in the direction of privatization of urban development, since market efficiency and service delivery essentially dominate the discussion about concerns of ecological sustainability, democracy or social justice.[171] These market-based systems function as a "set of principles"[172] that fail to consider equity or societal differences. When environmental issues began to be discussed globally at the end of the 1980s (triggered by the fa-

50
Villa Frei, semi-public green spaces between buildings offer climatic benefits.

51
Villa Frei, façade of a “Duplex block.”

52
Villa Frei, green area between blocks.

53
Villa Frei, freely accessible, car-free and shaded neighborhood spaces as urban commons.

mous “Brundtland report” in 1987), sustainable development was considered compatible with economic development. In the 2000s, this led to an urban planning that integrated “green solutions” such as green roofs; dense and compact planning; energy-efficient, high-performance buildings; and the reuse of existing infrastructure. The “neoliberal city” incorporated the goals of the “sustainable city.”[173]

Score sheets for LEED-certified Buildings

Since the turn of the 21st century, Santiago, like many cities worldwide, started to certify buildings for energy efficiency with global standards. In order to analyze how global standards, local norms and expert activities intervene in constructing buildings, I here focus on the Avenida Apoquindo, which I call “LEED Street” because almost every building on the avenue is LEED-certified. LEED Street is located in the northeast of the city towards the *Cordillera*. This area has developed over the last 20 years into the new Central Business District, slowly replacing the former city center in the historic part of Santiago. The new Avenida Apoquindo shows the effect that LEED certification has had on the city climate at the district level and on the livability of the street.

The growing number of LEED certifications in Santiago is related to the neoliberal path taken by the city in its expansion and land use with the return to democracy in 1990.[174] The labeling of individual buildings is used by the developing companies to communicate a certain image of themselves, a corporate identity. This reflects a global trend of urban green marketing in the last few decades, and it calls into question the actual relevance of green certification for the regulation of thermal environments. Looking behind the façade of LEED building certification reveals the way in which technical choices rely on factors of culture and politics.[175]

All the buildings on LEED Street that received a certification from the label-issuing institution, the US Green Building Council, have a “scorecard.” This sheet summarizes how many points were earned in which category. The majority of buildings received a Silver or Gold certification; they scored between 50 and 80 points out of 110. The eight categories for obtaining points are quite diverse, and every building has its own strengths and strategies. One of the main features that buildings have to achieve is the use of an efficient window glass, one that lets enough light pass without excessive heat gain. This criterion is quite straightforward and easy to quantify, as it solely depends on the material’s thermal-transmittance value. Other criteria include how the building complies with minimum energy and indoor air-quality performance, or how it deals with waste management. Aspects like interior lightning, water-use reduction or thermal comfort add points to the score sheet. Thermal comfort per se is not a prerequisite, but indoor climate control figures prominently in most buildings.

Through the diverse criteria, points can be obtained in different ways. In the most recent version of LEED (LEED v4, launched in 2013), the emphasis is on the design decision. For example, there are various options for a project to reach “heat island reduction,” described as the intent “to minimize effects on microclimates and human and wildlife habitats by reducing heat islands.”[176] Option 1 suggests “non-roof measures,” ranging from installing structures with plants to provide shade to energy-generation systems (or a combination of both) or using open-grid pavement systems. “Roof measures,” on the other hand, either mean the use of roofing material with a minimum solar-reflectance index or a vegetated roof covering at least 75 percent of the roof area. Option 2 focuses on parking spaces: a project can have parking lots under plant cover, which will, however, grant one point less than for Option 1. This is just a brief example of how the rating works. It gives priority to different areas of a project that are not always related to one another. In the end, they are summarized for the final score. This does not really facilitate a transparent reading of what a building truly aims for or achieves in detail, but the result provides a score that is comparable with those of other certified buildings.

Implementing the Standards

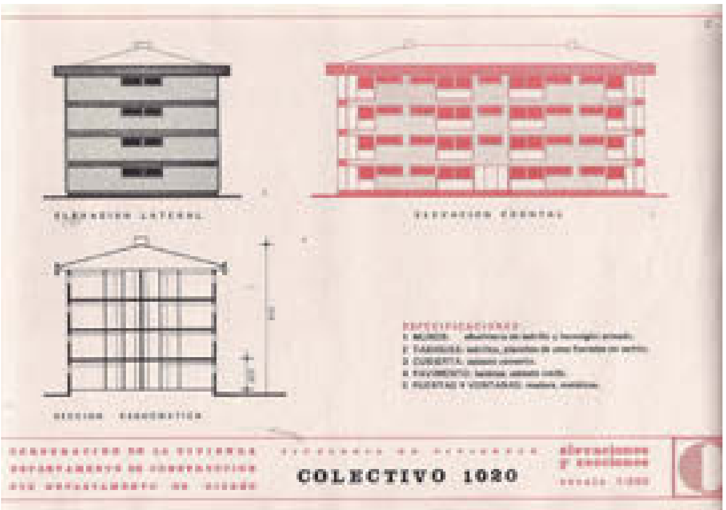
LEED Street partly depends on foreign investment. International companies use the location for the construction of office buildings due to its convenient accessibility along one of Santiago’s main roads and metro line, as well as the fact that it is a rather green area of the city. The good accessibility suits the corporate needs of these transnational firms. Following the same principles used elsewhere, another of these needs is the open-space typology. This led to the glass-façade building as the chosen type that best represents the idea of the neoliberal city. These uniform buildings are the physical form of a free-market ideology, with the curtain wall being now part of a global aesthetic[177] and a symbol of political power.[178]

Being aware of glass as the leading materiality of buildings along LEED Street helps to understand the use of LEED certification as a means to label these

→ figs. 58, 59

54
Block 1010/20, in *La Florida* district.

55
Vivienda Tipo C in *Bajo de Menas, Puente Alto*. These blocks of three to four stories (Type C) by the Housing Corporation/Ministry of Housing became the most recurrent typology in the social-housing programs from the 1980s onwards in Chile.



56
Elevations and section of *Block 1020*.

57
Green courtyard spaces have been built over in *Unidad Vecinal Portales* (1954–65).

buildings' energy performance. Indeed, using glass façades in Santiago's current urban climate means having the resources to finance the huge amount of energy needed for cooling. For indoor comfort, these high-rises require active systems of climate control to mitigate the solar gain they receive during most days in Santiago. I elaborated above that the RT has been developed based on the winter climate; the excessive use of glass makes little sense during the hot summers, especially when considering the future climate scenarios of Santiago with increasing and more extreme episodes of drought and heat waves.

The following two examples of LEED-certified buildings show the interrelations between transnationally traveling standards and local implementation when it comes to the application of technology for indoor climate control. International standards and certifications schemes are generally conveyed by investors or private companies willing to implement them in their offices or housing projects. Their voluntary nature means that the effort required to integrate them into a design must bring clear rewards and values. For the certification process, companies rely on qualified and experienced workers.

Costanera Center: this complex is located at the west-end part of LEED Street close to the Mapocho River and the Titanium Park. It is the tallest building and the largest shopping mall in Latin America, and in addition to the mall building it has two office towers. The *Costanera Center,* constructed in 2012, has a green roof of 30,000 m^2 on the sixth floor of the ensemble; it serves to combat the overheating of the towers through thermal radiation. The indoor environment is controlled via a central air-conditioning system using water-cooled condensing units with heat recovery functioning with water from the nearby canal. This high-tech system of climate control represents a common solution for high-rise buildings all over the world. The building owner, Cencosud, hired "Daikin Air Conditioning Chile, S.A." for the installation of the conditioning system and its service. Daikin is the Chilean branch of the well-known Japanese multinational HVAC (Heating, Ventilation, Air-Conditioning) manufacturing company. The dissemination of standards such as LEED is often backed up by such big companies, which have accumulated experience in the field and become leaders in achieving certification for their customers. At the *Costanera Center*, the development of the whole energy system was realized by a team composed of representatives of Daikin Chile, Daikin Japan, Cencosud's own technical team, a consulting firm and a Santiago-based engineering office. These experts from different coun-

58
“LEED Street” Avenida Apoquindo, aerial view looking towards the east and the *Cordillera* from the viewing platform of the *Gran Torre Santiago*.

59
LEED Street/Calle Apoquindo, aerial view looking towards the west and the city center.

60
Interior space of the *Transoceánica Building*, Santiago.

61
LEED Street, *Nueva Manquehue Building*.

tries exchange knowledge and practices using the LEED requirements and standards as their "common language." For the actual installation, the tenant was responsible for connecting the pipes in the rooms to the central machinery provided by Daikin Japan. In practice, the tenant decided that the indoor conditioning had to be adjustable for different occupancy patterns and users. Therefore, temperature in each room is individually controllable.

The *Transocéanica* Building in *Vitacura*, Santiago, is the headquarters of the eponymous firm, whose energy concept was designed by an engineering office in Germany, "Bohne Ingenieure." During the design process, it was decided to aim for "LEED Gold" certification. To reach this objective and make sure the construction would follow the principles planned by the German engineers, the contractor hired German workers who came to Chile for the sole purpose of constructing this building. The "social network" of this building thus reaches far beyond its local context, with its whole design-and-construction process being outsourced to a European company. Such transnational alliances are quite common in today's globalized architectural practice. Nonetheless, this model also reveals how the voluntary certification scheme, instead of supporting the use of fewer and more local resources and energy-efficient building, can in effect be energy- and cost-intensive by involving different actors from a variety of places.

An analysis of LEED certification processes reveals innumerable intermediate steps that must be taken between the decision of implementing a standard as written rule that forms a corpus of technical specifications and the realized built object, which might be called an assemblage of all these specifications. Along the way, things are added or subtracted but nevertheless often act unforeseeably upon the final expression of the standard. Decisions and practices can be of a material nature—for instance, in the use of a product that did not exist before or was not accessible. Additionally, as is very much the case in Chile, a qualified workforce is not always available—such that adaptations and apprenticeships are frequently needed to reach the execution of the standard.

In interviews, some architects mentioned the different time horizons they had in mind when discussing the energy concept and overall quality of a project with a real-estate or construction company. The developers often asked how long it would take to elaborate an improved quality in design. When the architects said it might take a year, or even two, to have a fully fledged and well-rounded design solution, the developers almost laughed and told them they were not interested because projects usually have to be finished in five to six months.[179] The time factor and pressure to respond to market demands can clearly intervene in the implementation of the standards.

Indoor/Outdoor Separation

Along LEED Street, one glass-façade building sits next to another. This creates a kind of regular pattern all along the way, climbing towards the east and the mountain range. The buildings are arranged along a wide street where the asphalt surface gets very hot in the summer months from December to March. These buildings seem to be cut off from their immediate surroundings, creating well-protected indoor spaces. Many of the buildings along LEED Street have a free-standing character due to the relatively low-rise surrounding built fabric. The area along the street does not invite pedestrians to stay, as car lanes are quite wide and traffic intense. Car and speed prevail over body and immobility. Pedestrians are left exposed to the weather and the strong winds when walking along the wide space of the thoroughfare. The true character of LEED Street is that life happens inside the buildings rather than on the street itself. This contrasts with other areas of the city, which are usually crowded with people (such as *Plaza de Armas* in the city center, or Pio Nono Street). On LEED Street, the private/public and inside/outside divide is sharper and has less threshold as one moves eastwards. At the end of the street, residential housing starts to take over from office buildings, but still in a more or less clear withdrawal from the public space. These private houses with gardens, hidden behind gates, complete the cityscape around LEED Street. The two contrasting building types (high-rise glass building and low-rise dwelling) create a kind of compartmentalized thermal condition, and a fragmented environment.

The area around LEED Street offers far more green space than the rest of the city does, and so contributes to a thermally beneficial environment. Moreover, compared with the densely overbuilt regions of the city covered by asphalt and pavement, it provides cooling effects from the vegetation. However, most transportation is in private cars, leaving few enjoyable spaces for pedestrians outside of the designated parks. Besides office buildings, exclusive high-rise flats and condominiums are available for those who work in the area. Pockets of green space and larger parks like the *Parque Titanium*, a four-hectare park at the foot of the three LEED-certified Titanium towers, or the nearby golf course offer some green spaces

→ figs. 60, 61

between the buildings. The heat is felt most among the buildings, whose glass façades produce heat by reflecting the sun. Some projects combat the heat with green façades like the "*Consorcio* building," designed and built in 1993. This heat-mitigating strategy, however, has been used only sparsely for office buildings in Santiago to date.

Navigating LEED Street and learning about its morphological and physical aspects, as well as describing the professionals who shape it, has already provided a glimpse into the working of a certification scheme with regards to thermal environments. Even if such certification schemes have some positive effects on a building's energy efficiency, their voluntary nature and checklist system often make them merely a marketing tool. The energy-efficiency effect of LEED is indisputable, but its relationship to the local climate must be critically reviewed.

Outlook

LEED starts to make its way into national building codes and laws in some countries. In the US, for example, some municipalities demand that building projects reach a minimum of points in the LEED system, or that developers are at least able to show that their projects *could* be certified.[180] Voluntary certification schemes are not entirely isolated from local regulations, but influence them or are even incorporated into them. In Chile, the Ministry of Housing (*Ministerio de Vivienda y Urbanismo*, MINVU) has collaborated since 2017 with universities, research-and-development centers and BREEAM assessors to develop a "Code for Sustainable Homes." The oft-perceived divide between global standards and national laws is more complex than it seems at first. The example of LEED Street shows that there is hardly a single organization that both gives form to the standard and administers its repercussions.

In practice, the Green Building Council has developed the rating system and is successful in selling it worldwide, but many other institutions have an impact in shaping the standard in the course of its implementation. In the case of Santiago, these range from ministries and the Institute of Construction to the Institute of Normalization. Different ideas and practices by organizations and individuals mold the way it is being executed, sometimes including the local or foreign workforce. It is, therefore, important to investigate not only what thermal standards do but also who "does" the thermal standards.

Chile is in the Top-10 list of countries with regard to the amount of LEED-certified buildings, a status that is related to its comparably stable political and socio-economic situation, as well as its recent construction boom, especially along Santiago's LEED Street. On the institutional side, the lack of governance in Chile leaves room for international standards. Indeed, with no improvement in the mandatory building codes concerning climate control of buildings but with clients, public and private developers willing to reach higher goals of energy efficiency, voluntary standards find a fertile ground. Using LEED as an example, I intended to open up the standards' "black box" in order to understand their relationship with the city climate. The examples have shown that certification schemes such as LEED focus more on individual buildings than on the urban environment into which they are inserted. This results in an urban climate characterized by a highly pronounced thermal "cut" between inside and outside.

2.3 The Climate of the Self-Built Settlement: Creating One's Own Thermal Environment in Elemental's *Lo Barnechea* (2010–14)

Self-building is a driving force in creating and regulating one's own private thermal environment. To inquire into the modification of buildings, a project by the architecture office Elemental in *Lo Barnechea* has been investigated. It was finalized in 2014 and inhabitants of each of the houses did individual modifications on the existing building. *Lo Barnechea* is located in the northeast fringes of Santiago, at the foot of the mountains. It is a high-income district bordering *La Dehesa*, the richest community in the country—one consisting mainly of private villas with swimming pools, and a golf course. The property where *Lo Barnechea* is located is on the banks of the Mapocho River, which features a lovely park. A good location (close to public services, recreational spaces and job opportunities) is one of the key features that architect Alejandro Aravena and his team at Elemental established in their "ABC of incremental housing."[181]

Thermal Practices

Lo Barnechea, Santiago's largest informal settlement, houses a total of 880 families. The plan was to provide quality housing to these families, without relocating them too far from their jobs, schools, health services and public spaces. Elemental constructed 150 units in a first phase, each unit measuring 44 m² (up to 69 m² after expansion) and costing 7,700 USD

→ fig. 62

each. A total of 2,300 USD was paid by the families themselves; the rest was subsidized by the municipality and Ministry of Housing.[182] The units are organized around a courtyard, which creates a sense of community and offers a threshold between public and private spaces. Some inhabitants have appropriated those communal spaces by building up the entrances to their homes, offering an additional transition from outside to inside. Further, the courtyard is used to relax or barbecue in summer. What I noticed while exploring the settlement are the numerous additions to the houses, such as balconies, which were not originally planned.

Through Elemental, I came in contact with a three-person household in *Lo Barnechea*: Father Carlos Gana, mother María Teresa Muñoz and their daughter, Karla. When I arrived at their house, Carlos was in the middle of conducting some extension works on the upper floor. Seeing him work, I got to know how he operates and what kinds of materials he uses. The family house is made of masonry, reinforced-concrete walls with wood beams for the structure, wooden paneling and gypsum board for the interior, and galvanized corrugated steel for the roofing. The building has three stories, two full floors and a mansard. On all floors, the family made adaptations to the initial building: on the ground floor,[183] they added a bedroom for their daughter, who uses a wheelchair. On the first floor, they made one large bedroom for the parents rather than two smaller bedrooms as were in the architect's original plans. Carlos is currently doing an extension of a bedroom on that same floor. The last floor, which contains a small bedroom for friends or guests, is located right below the roof, so it can get quite hot in summer and rather cold in winter. To heat the rooms, the family uses electric heaters, a common device in Santiago. In summer, my contacts practice cross-ventilation on each of the upper floors, through windows that face one another, to cool the indoors.

In general, the family is satisfied with the house and, in particular, they like its dimensions in comparison with other social-housing units in the city. Living in *Lo Barnechea* has also allowed them to stay close to their jobs and to enjoy the proximity of the river and park. In terms of thermal comfort, they made no comment. I suspected that, out of courtesy, they did not want to critique the architecture as it offers them a rare opportunity to inhabit a spacious and generous home. As is usually the case in buildings in Santiago, they tell me that they keep their jacket on or put on warm clothes when being indoors in winter.[184] Every bedroom has an electric heater, but they emphasize that they would not switch it on all day long for cost reasons and personal preferences of comfort. The key feature for the family, however, is the possibility to extend the ground floor for their handicapped daughter. This extension has already led to yet another space above it. I could assess how Carlos was building: using wooden frames and filling them with expanded polystyrene. Such materials can be bought in the "Sodimac" nearby, a DIY store very popular across the country. For the construction work, Carlos relies on his personal experience, and he seems proud to "repair stuff" around the house.

The SantiagoTe Brick

Regarding the thermal performance of the *Lo Barnechea* buildings, it is telling that the masonry is made with SantiagoTe bricks. This is a standard in Chile and it is produced by the country's biggest brick factory, *Cerámica Santiago*. Even though the brick is far from energetically efficient, it is accepted in the RT's requirements for new buildings. This type of brick was produced by *Cerámica Santiago* who funded the studies on brick resistance that led to the definition of the resistance standard (U-value). SantiagoTe bricks are affordable, and therefore preferred by many home builders. They have a low resistance value, which especially impacts indoor temperatures in winter.

During the introduction of a new regulation, professionals will hope to see it aligned with practices in their field and will try to lessen additional costs and risks as much as is practicable. The building sector, for example, will try to make it compatible with the market construction feasibility or traditions as much as possible. In the second phase of the RT's creation, bricklayers first lobbied against it using the prevailing argument of the construction sector: it is easier to stay with a "business-as-usual" scheme. The standard is not necessarily the technically most advanced outcome. It often emerges from people who have an interest in the market, as was the case for SantiagoTe bricks. The material characteristics were defined rationally, but with some adaptations fulfilling the manufacturer's technical possibilities and financial strategy.

In regular projects, the architect leaves the construction site once the buildings are completed. This was not the case at *Lo Barnechea*: Alejandro Aravena, the architect from Elemental, informally followed the works in the community. Carlos told me that one day Aravena came to see him and was impressed by the works he had carried out. The architect only offers consulting if needed, but the decisions are made by

→ figs. 63, 64, 65, 66, 67

inhabitants themselves. This is an example of how the profession of the architect has become more and more complex. Aravena has expanded his role as mediator beyond the actual construction itself. He is not merely an innovator but rather the executor and coordinator of the work of various experts, even including the inhabitants. While he sets some construction standards initially, he also gives advice on adapting the building in practice afterwards.

The thermal conditions provided by the same regulation are experienced and lived differently among individual dwellers; diversified perceptions simply fall out of the standards' scope. Most people in Chile own their own home and modify it according to their preferences and financial means. In the throes of designing and building, regulations of all kinds are not independent of social forces. Actually, regulation is translated and transformed by the different professionals who assess and interpret the various standards.[185] Looking at the incorporation of built structure into everyday life helps outline the nuances that standards reach in the building. That also takes account of the specific materiality manifest in the details of windows, doors, roofs, balconies and other parts of the buildings. While the role of the expert lies in deciding on the execution of building standards and designs in construction, the users participate as self-builders in housing production with non-standardized ideas. In practice, the choice of certain standards is complemented by factors such as socio-cultural preferences and economic resources.

3. When Global Standards Meet Local Norms

Today, the construction sector worldwide cannot ignore thermal standards and certifications; they have become powerful tools by which to address energy-consumption issues. What differs across countries is the role of the state and other institutions in the implementation of those standards. Social norms of thermal comfort are embedded in forms of building construction, heating or cooling. Such norms are linked to a local place while, at the same time, influenced by international best practice. The proliferation of air conditioning in cities all over the world is one example for the global mobility of thermal-comfort-related technologies. Beyond the national organizations involved, transnational labels such as LEED provide place-independent guidelines for energy-efficient construction. In the case of LEED Street, foreign firms use voluntary standards to develop their projects somehow independently from localized, technical–political imbroglios. It is apparent that standards are not ready-to-use principles that automatically assure the best possible outcome. They are merely institutionalized means for ordering building methods—and, as such, are enforced by the ruling power and its bureaucracy.[186] Standards are one way of "settling things" by optimizing the state of the art. In the building industry, they were primarily developed for the sake of stabilizing and facilitating the control of indoor temperatures.

Before a thermal standard is applied to a built structure, it must have already passed through a number of stages. First, a scientific method defines the thermal standard; secondly, a technical laboratory calculates resistances and U-values for different materials; and finally, authorities define building standards in written regulations. What sounds simple is the result of a highly political process involving questions of legitimacy and power, despite a common view that "standards organizations promise technical expertise without political entanglements."[187] Administrative and political institutions that are setting up this regulatory framework rely, for the most part, on a technocratic view of the building process: solutions are found in new products or technologies. Architects, on the other hand, like to find solutions in the available materials, experimenting with them rather than seeing themselves as simple translators of standards into some built form. Bioclimatic architecture is one example of how some architects deal with the environmental conditions of a place and respond to it accordingly. While architects are not able to master the entirety of a project's sequences, they are part of a multi-disciplinary entanglement of expertise and practice that brings standards from the written page to the constructed building.

As soon as a building enters the social realm through inhabitation, it is influenced by more forces than are belied by mere technical considerations and neat calculations. In the case of *Lo Barnechea*, inhabitants adapt the existing buildings by adding new rooms and envelopes that will affect their thermal environment. With regards to the growing energy need within the building sector, many experts are convinced that increasing the standards' values is no answer to curbing energy consumption. Even though newer technologies might be "more efficient," they still rely on the same cultural and societal conventions as older ones.[188] We base our current energy-transition policies mainly on our trust in technological change and evolution, but avoid addressing how we might change energy use in everyday practice. In addition, the current logic is fully embedded in a neoliberal market

→ Figs. 68, 69

62
Lo Barnechea, situation on the banks of the Mapocho River.

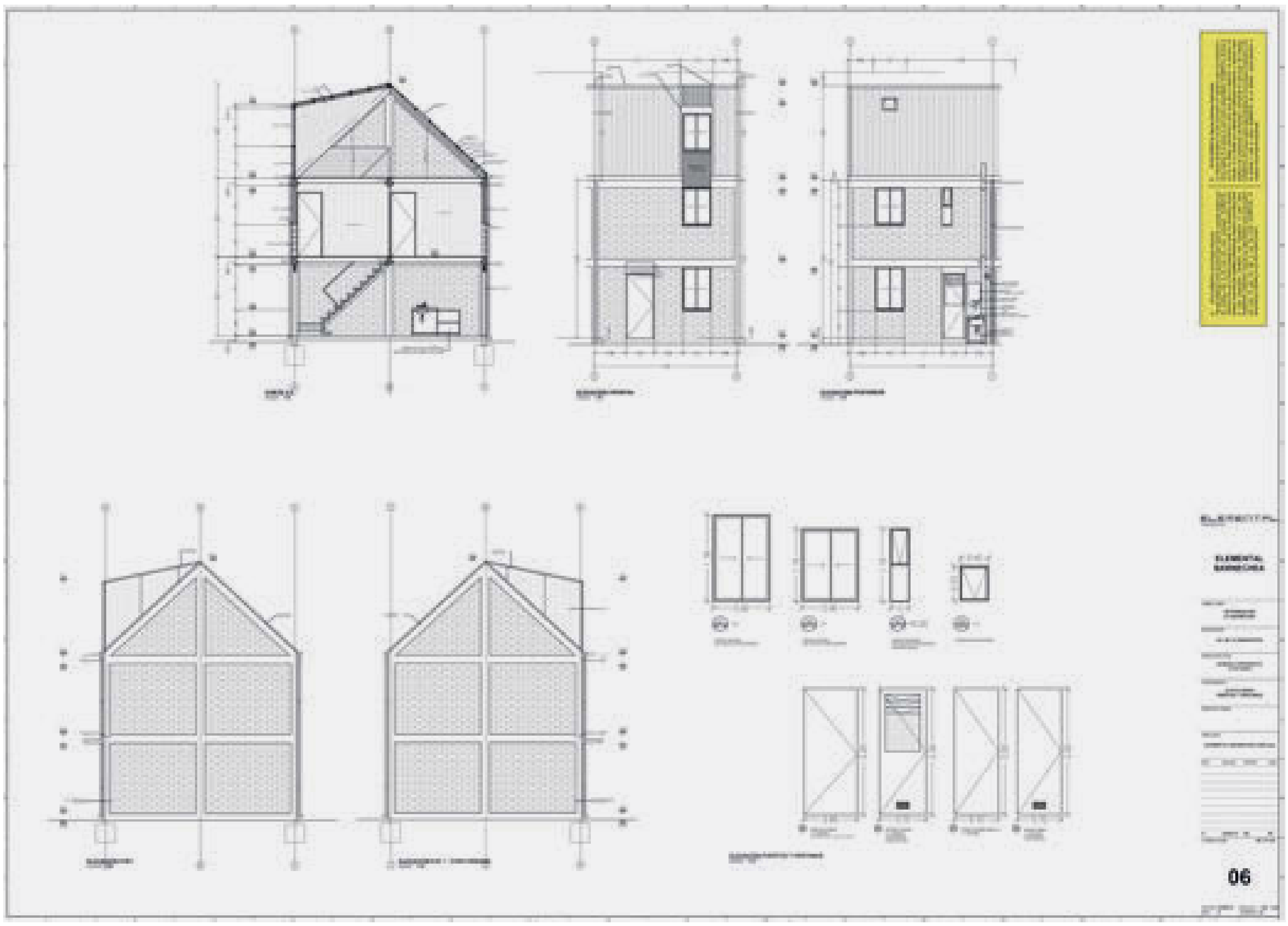
64
Lo Barnechea, gate to the community.

63
Lo Barnechea, courtyard between the buildings that creates a sense of community and offers a threshold between public and private spaces.

65
Technical Specification of SantiagoTe brick by the company *Ceramica Santiago*.

66
Lo Barnechea, building extension by the Gana family.

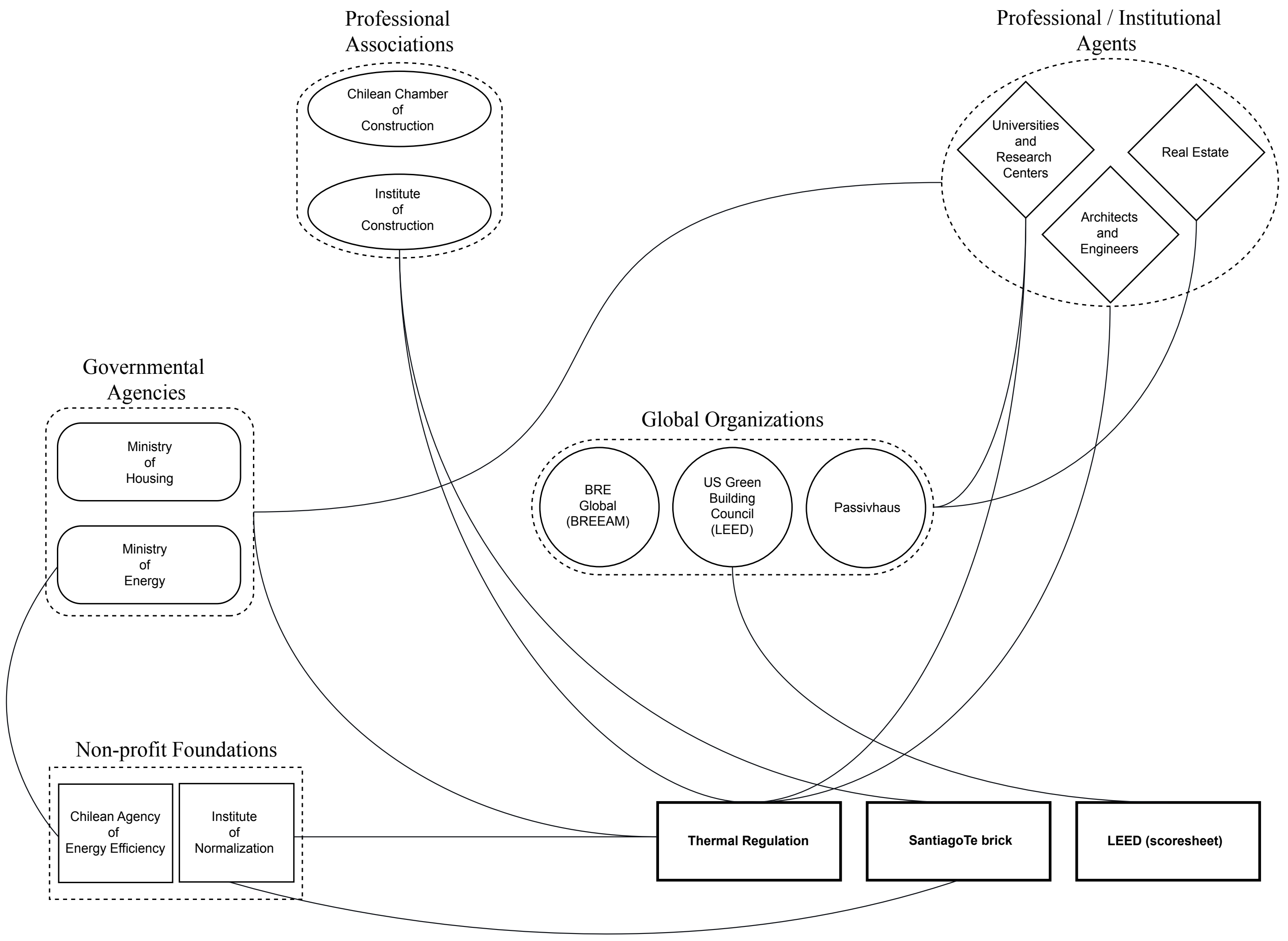
67
Lo Barnechea, building extension on the upper floor by the Gana family.



68
Lo Barnechea, section and elevations by Elemental.

economy. Therefore, as Elzen, Geels and Green note, “system innovations not only involve new technological artifacts, but also new markets, user practices, regulations, infrastructures and cultural meanings.”[189] By taking the case of Santiago de Chile, I have shown how standards, building codes and social norms closely follow the political changes that have taken place in the last few decades in Chile.

An analysis of the various standards involved in construction in all three cases from Santiago (*Villa Frei*, LEED Street, *Lo Barnechea*) outlines the need to think beyond the individual building. The modernist constructions from the 1950s and 1960s all paid great attention to establishing green spaces for leisure, interaction, gardening and mobility between the houses—and also in *Lo Barnechea*, the courtyard space that serves for community activities. But thermal comfort is not solely confined to the building’s interior; urban architecture should pay more attention to including the neighborhood in thermal planning. Transnational voluntary standards like LEED, but also Chile’s RT, poorly consider the public spaces surrounding houses. These spaces are not merely an addition to thermally insulated interiors but should be considered as complementary to them. And what is considered comfortable in the end not only depends on measurable variables such as temperature and humidity but also on a social sense of place, and on “thermal delight.”[190] This means that we must investigate thermal standards beyond the mere construction of a building, including an understanding for how people both live in it and adapt to it.



69
Actor-Network-Theory diagram depicting the intertwined political ecology of standardization.

Chongqing (People's Republic of China): The Electrification of the Urban Fabric

On Governing the Built Environment's Seasonality

Madlen Kobi

More specifically, this chapter examines the networked implications that electrification has had in Chongqing, a metropolis of roughly eight million inhabitants in southwest China. I investigate the ways in which decarbonization is used to relieve the urban climate, as well as how urbanization and the shift towards renewables have altered the environment in and beyond the city itself. In addition, the study of thermal–material culture in and around buildings highlights the indispensability of electricity for thermal well-being indoors, both in winter and in summer, which has opened up new lines of socio-economic stratification in post-reform China. Altogether, the different scales of governing energy infrastructure towards electrification draw the contours for reconsidering both the potentials and the obstacles of the *electropolis*.

1. Electropolis: Towards a Post-carbon City

Cities at the beginning of the 21st century epitomize what is considered an anthropogenic landscape. Far from existing apart from nature, "cities are dense networks of interwoven socio-spatial processes that are simultaneously local and global, human and physical, cultural and organic."[191] Various environmental problems have emerged with the concentration of built structures, energy flows and population density in urban areas worldwide. With regard to urban climate, air pollution and urban heat-island effects pose serious threats to human health. In large part, these are related to the excessive energy consumption for both cooling and heating interiors—systems that are mainly fossil-fuel generated, and affect both local and global climates.

Under the premise of the Anthropocene, these urban environmental challenges foster a reassessment of energy infrastructures and the demands for a substitution of fossil (oil, coal) with non-fossil energy (wind, solar, water). Efforts are being taken in cities worldwide to curb carbon emissions, change the type of energy used for heating and cooling, improve the energy efficiency of electric devices and target the airtightness of building envelopes.[192] If the ideal city of the future is to be carbon-free, transportation and climate-control technologies will have to be electrified to prevent carbon emissions. This chapter questions the idea of such an *electropolis*[193] governed by "clean" electricity. It outlines the complex social, political and environmental implications of electrification that emerge with the production and consumption of energy for cooling and heating interiors.

1.1 Energy Challenges in Urban China

Cities in China are particularly suited to engaging with the consequences of the global trend towards electrification. On the one hand, energy demand for construction and maintenance in the housing sector continues to rise. This demand is related both to rapid urbanization and to the rise of consumer desires that marked China's development after the economic reforms of the 1980s. On the other hand, the country's energy supply depends heavily on coal, a major carbon emitter. In 2018, for example, coal still accounted for some 67 percent of the national electricity mix,[194] and one in every four tonnes of coal used globally today is burned to produce electricity in China.[195] Decarbonization and the need to rethink energy production, a pressing issue for the Chinese government, deeply affects regional dynamics within the country. One of the greatest problems is that the highly populated cities along China's eastern coast count among the country's highest energy consumers, but the possibilities of their tapping renewable wind or water resources are limited.[196]

Since the 1990s, electricity consumption (*dianli xiaofeiliang*) in Chongqing has increased more than six-fold.[197] This is attributable to the growing energy-intensive industrial sector (with factories for iron and steel, nonferrous metals, the chemical industry and building materials)[198] as well as the increase in cooling and heating practices.[199] Household energy consumption related to electrical devices in urban China has risen steadily in the post-reform period: in Shanghai, for example, almost half of the energy demand in summer 2005 was related to air

70
“The Mountain and Water City Chongqing. / 山水重庆.” Chinese stamp depicting Chongqing at the confluence of the Yangtze and Jialing Rivers. China Post, 2014.

71
Washing clothes in Yangtze River near Wanxian (neighbouring town of Chongqing), 1980s.

72
Drying clothes outside of windows, 1988. These buildings with single-glazed windows are characteristic of the socialist period.

73
Chongqing Nanshan Thermal Springs in the 1980s.

74
The Three Gorges Dam started to operate in 2012 as the largest hydroelectric power station in the world.

conditioning.[200] These numbers are comparable with Chongqing, where, between 2002 and 2012, the number of air-conditioning units doubled from one to two units per household.[201]

Further, electricity consumption in Chongqing is greater in the winter months because central-heating installations are virtually non-existent there. The lack of a heating network in the southern part of China is a legacy from the socialist period, and something we refer to as the “Great Heating Divide”.[202] During the first Five-year Plan in the 1950s, the Chinese government issued the *Huai River Heating Policy*, which stipulated that for economic reasons, district-heating infrastructure should only be installed in the northern part of China, in the area above the roughly east–west-oriented divide following the Huai River and the Qin Mountains.[203] Chongqing’s winter temperatures on coldest days range between 5°C and 7°C, as the city is located right below the dividing line. This zone includes several mega-cities: Wuhan, Shanghai, Nanjing and Chengdu. With the rising incomes of urban residents, the desire for a warm indoors in winter has spurred an increase in electricity consumption for running air conditioning, small heating devices and electric underfloor heating.

1.2 Riverside Climates in Chongqing

Within China, Chongqing belongs to the “summer-hot-winter-cold zone” (*xiare dongleng diqu*),[204] with a subtropical climate. The city is known under three denominations that point directly to its climatic characteristics: together with Wuhan and Nanjing, it belongs to the three “furnace cities” (*san da huolu*), a designation which, for each, reflects the unbearable heat of their summers. In July and August, temperatures can reach an average of 33°C and rise to more than 40°C on peak days.[205] The nickname “Mountain City” (*shancheng*) refers to the urban territory’s hilly landscape. And “Fog City” (*wudu*) alludes to the few sunshine days in winter when the constant cloud cover creates a misty atmosphere.[206]

Chongqing’s location on the banks of the Yangtze River was a key impetus for urban development. At the end of the 19th century, the port attracted merchants who were trading in the salt, fruit and timber that was shipped eastwards, to settle there.[207] Unlike the many other Chinese cities laid out in a grid pattern, Chongqing’s undulating territory along the river has had a profound impact both on microclimatic conditions and the built environment; the city is characterized by tropical green vegetation; long staircases that rise up from the riverside; and underground air-raid shelters that, while they date back to the war against Japan in the mid-20th century, are still embedded in the hills. Before aircon became popular, the Yangtze River shore was a favorite place for children to play in the water and cool down, while adults went with bamboo mats to have a rest along the riverside.

With the widespread electrification of the city in the 1980s, cooling or warming oneself was relegated to indoor spaces. The first installations of an energy infrastructure delivered electricity for public buildings and schools in the 1950s and 1960s. In the 1970s, the network was extended and included street lighting, among other innovations.[208] Only in the 1980s were the majority of private households connected to the grid. Electrification then enabled private lighting and electric cooking, but also air conditioning and the running of heating devices to control indoor temperatures.

Based on an analysis of the historical trajectory of climate control in Chongqing since the 1950s, this chapter brings together different scales of thermal governance to examine how thermal control indoors is intertwined with its urban environment. I alternate back and forth between individual thermal household practices; urban climate challenges, such as air pollution and urban heat-island effects; and state decisions that have pushed electrification since the 1980s. Interweaving household practices with the energy transition raises awareness of the “strong conflicts among economic growth, environmental protection, and social justice.”[209] Placed within larger debates on clean energy futures, individual practices for cooling and heating in Chongqing are scrutinized with regard to energy policies, infrastructure subsidies and the historical legacy of the built environment.[210]

The material presented relies on a mix of qualitative data gathered between 2017 and 2020. Primary knowledge was gained from four months of ethnographic fieldwork in Chongqing in 2017/2018, at which time empirical data was collected—both through investigative visits in private households and through semi-structured interviews with residents and experts from different sectors of the building industry (e.g. heating engineers, architects, cooling-device sellers). Other qualitative methods—such as photography, mapping, walking and participant observation—complement the ethnographic approach. I also rely on oral histories on the urban development of *Huangjueping* neighborhood, stories compiled

→ figs. 70, 71, 72, 73, 116

75
Construction site of Raffles City Chongqing, landmark architecture on the Yuzhong peninsula, completed in 2019.

76
View from the 16th floor of the residential compound *Qiushui Changtian*. The hilly urban territory defines the arrangement and heights of old and new buildings in the neighborhood.

77
Old postcard of stilted houses next to high-rises in *Caiyuanba*, probably 1990s.

78
An old wooden-stilted building in *Shibati* neighbourhood in 2010 surrounded by modern apartment buildings. Note the “breathable” bamboo walls.

mainly by an assistant in 2020. Further, published data on housing in Chongqing in the 20th century was analyzed in order to trace the constructional characteristics of different building typologies with regard to climate control—especially stilted houses, socialist-era buildings and high-rise architecture.

2. Governing the Seasonality of Architectural Typologies

The role of buildings in household energy consumption is of particular relevance because their construction and maintenance rely on considerable amounts of energy and resources. In addition, indoor thermal control depends on the materiality of buildings: with most houses being uninsulated, indoor spaces in Chongqing rapidly cool down or heat up depending on the season. In order to trace the role of the built environment in thermal practices, I will address two different architectural typologies that are characteristic of Chongqing's cityscape today: the multi-story houses built in the socialist period between the 1950s and the 1990s, and the high-rise buildings that have emerged since the 1990s. In both building types, the indoors are mitigated by a mix of passive and active forms of climate control, but they were constructed under different thermal premises: while the socialist-era houses and neighborhoods were constructed before electrification, the idea of thermally controlling the indoors through air conditioning was already a given when the first high-rises went up. In the case of the socialist-era buildings, I use an oral-history approach to outline how the summer heat was mitigated before electrification. When analyzing thermal control in the high-rise, I discuss both the need for air conditioning in summer and the mitigation practices of the winter cold today, 70 years after the introduction of the Great Heating Divide. Beyond the presentation of oral history and ethnographic data from individual households, the analysis focuses on the relationships between thermal structures, thermal practices and thermal regimes manifest in the efforts towards a post-carbon city.

2.1 Urban Climates in Socialist-era Houses

The *Huangjueping* area in the *Jiulongpo* district is a fine example of the various architectural developments that have taken place in Chongqing in recent decades. The area is nestled into the hilly topography of a peninsular terrain that ranges down to the Yangtze River, and its name, "Huangjueping," derives from the Huangjue, the white fig tree (*Ficus virens*) popular all over Chongqing but especially common in this area, that offers plenty of shade, and thus comfortable thermal conditions during the hot summer days.

Relocating Air Pollution

Huangjueping's history is closely linked to the city's industrial history and air quality: while in the socialist period, it was an industrial and labor-intensive area dominated by two large work units (a coal plant and a railway station), it has since become a popular residential area for artists given its location around the old campus of the Sichuan Academy of Fine Arts. The transformation of the district was largely driven by the history of the coal-run Chongqing Electricity Plant (*Chongqing Fadianchang*), built in 1952 as one of 156 key development projects in China that were supported by the Soviet Union. In operation from 1954 until 2014, the plant emitted high levels of airborne pollutants.

Electricity production in China is closely linked to deteriorating air quality because coal is the main energy source. The electricity, produced mainly in northern China, is consumed for industrial and residential purposes in urban areas all over the country.[211] In 2018, 46 percent of the total energy-related CO_2 emissions in China fell on the electricity and heating sector, followed by industry (31 percent) and transportation (10 percent).[212] Urban inhabitants' health was severely affected by air pollution up until the 2000s, given that many electricity plants were located in urban or suburban areas. Since then, a number of government measures all over China, often forced by nongovernmental organizations (NGOs) and other civil-society organizations, have worked to curb pollution from coal production, whether by "emission controls and monitored facility upgrading (higher chimneys, new fume filters, etc.) […] [or] the much more radical shutting down of whole factories and power plants in or near residential areas."[213] Such measures to improve air quality were also followed—in Chongqing, for example—by the "Clean Energy Movement," launched in the year 2000. This policy accepts the necessity of coal-produced electricity but invests in cleaner technologies, thereby lowering the consumption of sulphur-content coal and developing alternative energy sources.[214]

Having hosted one of the major electricity plants in Chongqing, residents in *Huangjueping* have experienced first-hand how the rising electricity demand

→ figs. 79, 82, 83

has impacted the air they breathe. While the industry generated numerous workplaces, and brought a certain living standard to *Huangjueping*, it also seriously affected people's health. Until the mid-2000s, streets in *Huangjueping* were covered with black dust. Freshly washed clothes hung outside to dry had black stains in the evening because the soot concentration in the air was so heavy.[215] The closures of both Chongqing Electricity Plant in 2014 and that of the nearby Jiulongpo Plant led to a 9 percent reduction of PM 2.5 (particulate matter) concentration in the city. Further, 9,980 tonnes of sulphur dioxide, 10,900 tonnes of nitrogen oxide and 910 tonnes of soot were prevented from entering the urban climate annually.[216]

Obviously, the relocation of industries from city centers has improved air quality in *Huangjueping* and other urban areas—but coal-polluting electricity production is ongoing, both in suburban and more rural areas of the country, in order to meet the demands of industry and residential housing. To protect the growing urban middle class from health problems, the polluting industry has been relocated to the less-regulated hinterlands.[217]

Mitigating the Summer Heat Outdoors

Until the mid-20th century, Chongqing's building stock was dominated by the popular residential form of houses on stilts, dwellings constructed of wood (*mu jiegou diaojiao lou*, lit. "wooden hanging feet building"), and, later, of bricks. These houses took advantage of the microclimatic conditions of the riverside and the hills. Ventilation was facilitated by the slopes, where cold air from the river moves uphill through natural microclimatic wind movements. The use of "breathable" walls (*hui huxi de qiang*) made of bamboo helped to combat the high humidity.[218] The materiality and design of housing changed in the 1950s, when companies such as the Chongqing Electricity Plant began to dominate state-led construction projects. In *Huangjueping*, the company constructed housing for its employees: the so-called Electricity Villages (*dianlicun*). Some 10,000 people—all of them employees at the Electricity Plant or relatives, including managers, office staff and workers—lived in these neighborhoods.

Such residential areas (*xiaoqu*) were built according to the common typology of the Chinese work unit (*danwei*), which, in socialist times, not only provided housing but also included schools, post offices, shops (initially with rationed goods), playgrounds, sports arenas and other necessities for daily life.[219] The Electricity Plant work unit even had a public swimming pool, indicating the wealth of the unit. The housing typology of the compound followed a residential model that was implemented all over China after the communist government under Mao Tse-tung came to power in the 1950s. These Soviet-inspired buildings, first one-story and later mostly three to four, were often composed of brick walls, tiled roofs, and wooden floor plates, and their north–south orientation provided optimal insolation.[220] Houses were arranged in rows, and had sanitary facilities (kitchen, bathroom, toilet) that were shared between neighbors. At that time, the main construction materials were available locally: slabstone (*pianshi*) or rubble (*maoshi*) for house foundations; and earth (*tuqiang*), stones (*shitou*) or bricks (*zhuan*) for the walls.[221] The scarcity of materials made housing construction stagnate during the Cultural Revolution in the 1960s and 1970s, at which time it was difficult for urban residents to find a house at all. A saying goes that "it was easy to find a mate, but difficult to find a house" (*zhao duixiang rongyi, zhao fangzi nan*).[222] From the mid-1970s on, apartments were mostly built with brick walls and prefabricated concrete floors.

One of these characteristic residential compounds in *Huangjueping* that dates back to the socialist period is *Xiao Meishu Xueyuan*, which is located opposite the main gate of the Sichuan Academy of Fine Arts Campus. The seven residential buildings that make up the core of the compound today were built between the 1970s and the 1990s. They replaced a row of one-story buildings dating from the 1950s, which were demolished in the early 1970s. The new, multistory buildings were a measure to accommodate the population growth at that time. The construction was co-funded by the inhabitants, which, according to one of them, guaranteed a better-quality houses inasmuch as more resources were available.[223] The original apartment owners were employees in the work unit of the Academy of Fine Arts, and bridged all social strata from canteen cooks to teachers. Today, *Xiao Meishu Xueyuan* counts as a lower-middle-class compound with quite run-down apartments that are sold or rented out on the free real-estate market (*shangpinfang*). Conversely, other compounds at the Academy still offer employees partly subsidized apartments.

The microclimatic conditions in and around these houses is characteristic of those in which a whole generation of occupants has lived, in similar residential compounds in Chongqing: the layout of the houses and the compound, with its integrated green public spaces, provided some cooling in the summer

→ figs. 77, 78

months. Stories about coping with the extreme summer heat before the widespread use of air conditioning abound. Until the 1990s, and because temperatures in the rather small apartments were often as unbearable as those outdoors, sitting under the trees in the backyard was a common habit. As to former cooling practices, Mrs. Hu,[224] a woman in her sixties, remarked: "Outside it was sometimes maybe even a bit cooler because there was a breeze."[225]

When remembering summer practices in *Xiao Meishu Xueyuan* before electrification, long-term residents often mentioned the use of specific objects or how they relocated at different times of the day. Many, for example, used a bamboo mat on the bed instead of a bedsheet. Sometimes, the mat was wetted to boost the sensation of cold. Others took advantage of the slightly cooler nocturnal outdoor air to fall asleep. Especially in the older socialist-era buildings, where everyone living in one building worked in the same work unit, it was common for residents to gather on the rooftop to sleep. One 55-year-old Chongqing resident's oral account of earlier thermal practices during the hot summer days summed up the recollections of many: "In earlier times, when we didn't have air conditioning, we used to sleep outdoors on the rooftop. In the evening, we went up there, took our bamboo beds, sat together, wagged our hand-fans and looked up into the sky, waiting for the air to cool down. That's when life was still delightful. Now with the aircon, everyone sits in his own bubble."[226] Without an entertaining television in an air-conditioned living room, the time before going to bed meant relaxing on bamboo mats and chairs, generating cold air with the hand fan, drinking Laoyin tea and exchanging the latest gossip. Those who preferred to sleep on a bed indoors would usually leave all their windows open, or would pour cold water on the apartment floor before going to sleep—so the floor, and then the air, would cool down through evaporation.[227]

For indoor climate control, socialist-era buildings such as those in *Xiao Meishu Xueyuan* relied mainly on passive means such as cross-ventilation (facilitated by narrow buildings with windows or door openings of apartments on two opposite sides), solar gain,[228] the inclusion of apertures in the walls of apartments or staircases; double-T-shaped houses that guaranteed a maximum ventilation for all apartments by maximizing exterior wall surfaces, or the construction of staircases on the building's west side to prevent the strong afternoon sun heating up the apartments. Balconies, individual kitchens and restrooms in the apartment were only provided from the 1970s on. The inclusion of greening in the design of public spaces in the compound and passive means of climate control in the built structure can be partly attributed to a lack of economic resources in socialist and early post-socialist times. While electrification was already common in European cities, the Chinese socialist government in the 1960s and 1970s had few means to invest in infrastructure development.[229]

2.2 Perceiving the Season in the High-Rise

After the death of Mao and the accompanying economic reforms in the 1980s, urban areas in China began to expand rapidly, the construction of high-rise buildings being that growth's most visible marker. The urban building stock almost tripled between 1995 and 2005.[230] With a reorganization of land-property rights, the state was no longer the main builder; instead, private and semi-state companies became the drivers of the real-estate market, with work units remaining strong actors in the construction and allocation of housing.[231] While building designs became more diverse, residential properties remained organized in compounds. In post-reform Chongqing, the explicit aim of the Communist Party and the State Council was to improve urban housing and speed up urban construction.[232]

The emergence of the high-rise typology came along with pronounced changes in the urban climate. Urban density, together with the gradual shift of building materials from former wood-and-brick constructions to heavy mass structures with solid brick or concrete walls and larger glazing surface areas, had an impact on the overheating of urban districts in summer.[233] In addition, the geographic location of Chongqing in the Sichuan basin, from which humidity and hot air from southern winds struggle to escape, the booming construction industry and the increasing number of cars and tarmac streets have all contributed to rising inner-city temperatures over the last three decades. In a 2010 analysis of Landsat images, the average difference between urban and surrounding rural areas was measured as 9.7°C. And today, city-internal temperatures differ between the slightly cooler river shore and the central areas of the densely built-up *Shapingba* district, by some 5°C to 10°C.[234] Although Chongqing faced hot summers throughout the 20th century, the light construction of its stilt-houses and the low-rise socialist-era buildings—as well as the river breezes—prevented the dense concentration of heat that oppresses today's concrete city.

→ figs. 75, 76, 80, 81

As in other cities worldwide,[235] air conditioning in Chongqing has become the norm for coping with urban heat. When summer temperatures climb above 35°C outdoors, the indoor temperatures in both socialist-era and high-rise apartments often reach similar heights. In Chongqing, many households adjust their air-conditioning system to 26°C, which is also the standard indicated in commercial leaflets from cooling-technology companies.[236] Such higher indoor temperatures, which in fact exceed the global norm, are related to political concerns of energy efficiency: in the peak summer season of 2009, for example, the Electricity Company publicly appealed to industries, companies and organizations in Chongqing not to air-condition below 26°C in order to prevent a breakdown of the electricity infrastructure.[237] In government offices, summer indoor temperatures of 28°C are the norm to save energy costs.[238]

From an energy perspective, central cooling solutions would, in fact, be more efficient than running cooling devices in each apartment individually. So far, however, only a few developers in residential compounds for Chongqing's upper-class clientele provide central cooling—as, for example, is the case in the upper-price-range area of *Jiangbeizui CBD* (Central Business District) in *Jiangbei* district, where river water is used for cooling the interior of office and residential buildings.[239] Such projects not only benefit from the abundant water resources of the Yangtze and Jialing Rivers, the use of local energy production also prevents electricity having to be imported from other provinces.

The everyday life of Wang Tong, a 30-year-old landscape architect, is exemplary for today's cooling practices in a high-rise residential environment. She and her parents live together in an apartment in a high-rise building in the *Jinyu Tianyi* residential compound in *Dadukou* District, just west of *Huangjueping*. The arrangement—with its five, almost identical high-rises—is surrounded by a fence, and creates a compound identity that is very common to modern Chinese cities.[240] Completed in 2013, the site comprises an area of 27,447 square meters. With a greening rate of 36 percent, the ground between the buildings is covered with a lush, tropical spread of green trees and bushes. A swimming pool at the heart of the compound invites residents to cool down but is empty for the most part, as residents have to pay an entrance fee and many among them refrain from using it because they cannot swim.[241]

On a hot summer day when visiting Tong's family, after entering the high-rise, we first cross a comfortably cooled entrance hall where some women are playing cards in a sofa corner of a stone floor. The transition from the hot and bright outdoors to the semi-dark lobby is a thermal relief to the body. On the 27th floor, we step out of the elevator, cross an artificially lit corridor and enter the family's bright three-room apartment, which features a spectacular view of the surrounding high-rises. The two humming ventilators in the living room distribute the cold air emitted by the in-ceiling built-in air-conditioning unit. The rhythm of when, and what kind of, cooling devices the family uses depends on the daily activities in the different rooms. As Tong explains, "[a]part from the built-in air conditioning in the living room, we have an air-conditioning unit (*gaitiao*) in every room. When cooling the living room, we close the doors to the bedrooms. When we leave the apartment, we turn off all devices. […] I don't like sleeping with the air conditioning on, because I think it's unhealthy. But I often cool down my room for one to two hours before bedtime, and then I turn it off again before falling asleep."[242]

Different places in the apartment are assigned different thermal qualities; for example, one chair in the living room is apparently "the coolest place in the apartment" since it is located in front of the air-conditioning unit's cool air stream. Inasmuch as the apartment's main windows face east, the indoors get terribly warm in the morning—so the family installed heavy curtains towards the veranda, which they close in the morning to prevent the sun heating up the living room. For most of the high-rise's floors, no trees provide shade—in contrast with the socialist-era compounds, whose buildings are seldom more than ten stories high.

Staying cool in urban Asia and other cities worldwide despite scorching heat outdoors is considered part of a modern and urban way of living.[243] But cooling does not come without a cost: even though the Chinese government subsidizes energy, making it quite affordable for the middle and upper classes, not everyone can afford to cool his or her home. For the elderly with few financial means, a social-welfare program provides air-conditioning devices for free—but the running costs for electricity have to be paid by residents themselves, and the cost can be considerable. Tong and her parents consciously use electric devices to save money. In any case, in the summer, the family spends some 700 RMB (Renminbi) a month[244] on electricity bills, while in months when cooling devices are not needed the amount goes down to about 70 RMB.[245] The family is pleased to be able to air-condition, but its members seem indifferent to the

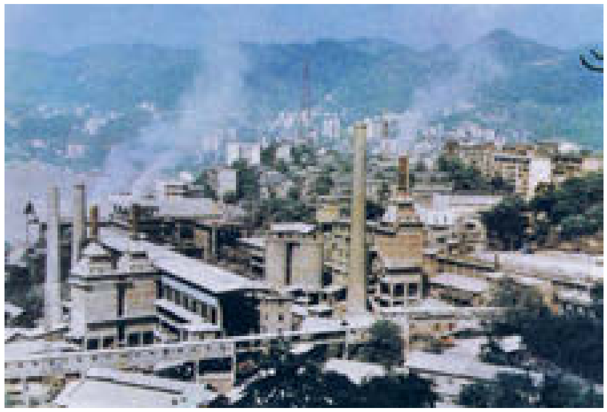
→ figs. 86, 86, 89, 90, 91, 93, 118

79
Buildings remaining from the former Electricity Villages (*dianlicun*) in *Huangjueping* area.

80
Xiao Meishu Xueyuan, communal green spaces between buildings.

81
Xiao Meishu Xueyuan, side façade of an apartment house from the early 1990s. Note the staircase built with "ventilation bricks" (*tongfeng zhuan*), rain protection above the windows, and the self-installed window and split-unit air-conditioners.

82
A serving tray in a private household picturing and celebrating the 30-year anniversary of the Electricity Plant, object probably from the 1980s.



83
Chongqing Cement Plant (重庆水泥厂), established in 1937. Note the obvious air pollution from the industrial activities. At that time, cement was mainly produced for the construction of roads, bridges and military infrastructure. Only later did it serve building construction.

84
Tanzikou residents using rationed honeycomb briquets for cooking and, sometimes, heating—probably 1960s or 1970s. *Tanzikou* is a village a little way outside of Chongqing, but the situation looked similar in urban areas.

85
Former inhabitants of *Xiao Meishu Xueyuan* sitting in their living room with jackets and scarfs on a winter day in the 1960s.

ecological impact of their energy use. Others, who cannot afford huge sums for air conditioning, might choose an electric ventilator or leave their apartments during the hottest days to stroll in cooled public spaces such as shopping malls or underground markets. Further, the hilly, urban territory offers many shady spaces thanks to the man-made transportation infrastructure—namely, bridges, where residents find relief from the heat.

The trend towards conditioned indoors in Chongqing has had a profound impact on the urban climate. It is a vicious circle: the more urban residents switch on their air conditioning, the more heat is emitted from split units towards the outdoors—thus, further contributing to heat-island effects. And the increase of hot days, in turn, propels the retreat towards the cooled indoors. Many informants think the summer months in Chongqing are getting hotter, and this is backed by statistical measurements: 2013 was the hottest summer ever recorded: there were 5–10 more high-temperature days than usual with measurements above 35°C. Because electricity is relatively affordable in Chongqing, the media have, since 2009, reported a new electricity-consumption record almost every season: a record clearly related to the trend towards airconditioned indoors.[246]

Oral histories in the socialist-era residential compounds before and after electrification, and the realities in the high-rise today, all emphasize that indoor–outdoor relations have changed in post-reform Chongqing. Until the 1980s, and due to limited access to resources such as housing or electricity, residents even of different social status used to share the shady compound spaces as thermal commons. Besides just cooling down, sitting under the trees meant socializing, exchanging news and spending time together. Yet, especially in summer, people tend now to retreat indoors rather than cool down collectively in the shade of the Huangjue tree. Winter practices, on the other hand, have changed only for those who can afford to run electricity-dependent devices; others rely on the same techniques used in the 1970s—namely, wearing particularly warm clothes.

Mitigating the Winter Cold

The experience of winter in the "summer-hot-winter-cold" zone is largely defined by the lack of heating infrastructure as a legacy of the Great Heating Divide: in cities in northern China, almost everyone enjoys the amenities of a highly subsidized heating system. Keeping warm in Chongqing, however, is a luxury not all residents can afford.[247] Whether living in a socialist-era or high-rise building, many residents often simply sit in uninsulated buildings in their jackets or other warm clothes next to open windows when temperatures range between 8°C and 15°C. Surprisingly, native Chongqing residents emphasize that they actually enjoy the cooler temperatures because summer is so arduous.[248] The many decades of living in and with the winter cold has made residents resilient to temperatures that, in other parts of the world, are unanimously labeled "uncomfortable."

To cope with the cold, some residents also plug in electric heaters or turn on their air conditioning for warm air—unlike in the 1970s, when, as one woman commented, residents used to warm themselves with "indigenous methods" (*tu banfa*).[249] This included, for example, filling glass bottles with warm water to use as warming bottles. Mr. Long, who lived in *Xiao Meishu Xueyuan* from the 1960s to the 2000s, recalls that in winter his family used to close all the doors of the apartment and warm themselves with a brazier. In the 1970s, before electrification, most households had only one such device, and moved it around in the apartment depending on where in the dwelling they were. But many families had to use their rationed coal briquets (75 kg per family, per month) for cooking rather than for heating. Mr. Long recalls that "it was common not to heat. It was not like today when you have heating and can just switch it on in winter."[250] Until the late 2000s, socio-economically weak, urban households in the "summer-hot-winter-cold" zone still relied on braziers.[251]

With electrification, heating practices in Chongqing changed because open fires in apartments are considered a fire risk. Further, air pollution from unfiltered smoke constitutes a health risk. Despite new electrical devices, living in a high-rise apartment means coping with the same cold as in the buildings from the 1970s.[252] In late December 2017, I visited 35-year-old Huang Chongshi in his two-bedroom apartment on the 20th floor of one of the high-rise buildings of *Qiushui Changtian* (lit. "The Vast Sky of Autumn Waters"), a middle-class residential compound in the *Shapingba* district. The compound, constructed in 2008, includes 2,128 apartments in eight high-rise buildings of different heights, depending on their location on the sloped terrain along the Jialing River. The layouts of the buildings vary, but all are characterized by a large exterior surface that, compared with a rectangular shape, is suboptimal when it comes to thermal heat transfer with the outdoors. In addition, the large number of windows in the paneled façade reduces indoor thermal quality: while insolation is desired in winter, it heats up apartments in

→ figs. 84, 85

summer. Before indoor conditioning became possible, urban building façades in southern China were commonly oriented towards the south for heat gain in winter. Such passive means of climate control seem to have had only a minor impact on contemporary high-rise design, and the structures' façades are testimonies to electrified cooling practices: self-installed split-unit systems are fixed in a shaft designated for those devices, and also hung next to the balconies.

Entering Chongshi's apartment, I am surprised that the balcony door, oriented towards the northwest, is wide open. It is common practice in Chongqing to cross-ventilate in winter: open windows and running heaters seem no contradiction. Asked why people cross-ventilate excessively, many mention that this helps combat the growth of fungi and mold on furniture, clothes and internal walls. There is little heat loss through the opening of the windows since houses are often deficiently insulated, and the cold sneaks in through the thin walls and single-glazed windows anyway. Indeed, the indoor temperature of 12°C on the day of my visit seemed of no great concern for Chongshi. He had grown up in a rural area in neighboring Sichuan province and moved to Chongqing five years ago for his job at nearby Chongqing University. For him, winter in this region was climatically negligible, as "you can use another blanket in bed, or you can just dress warmly and then easily survive. In summer, however, there is nothing you can do. You are like dead tired all the time. The only relief is the air conditioning."[253]

However, despite his stating that, in winter, he "just wears a bit more" to compensate for the permeable walls, a closer inquiry into Chongshi's daily rhythm shows that he has developed a set of strategies to stay warm. Of particular interest is the fact that he alternates his two bedrooms during different seasons of the year: the larger one (ca. 12 square meters) is his summer bedroom, given that, according to him, its ventilation works better than that in the smaller room. The main reason for moving into the smaller room (ca. 9 square meters) in winter is its better heating. Chongshi heats with an electric radiator (*nuanqi pian*) that he sets next to his legs, and closes the window and door to create a comfortable working atmosphere. With his average university salary, he can afford the several hundred RMB that the electric heater costs over and above his monthly rent of 1,600 RMB.[254]

Many of my informants mentioned the fact that their everyday practices serve more to warm the body than to warm entire rooms. Given the non-existent heating infrastructure, one encounters no heated indoors—but when entering an apartment, instead of taking off clothes, one changes into warm house shoes, pajama trousers (*shuiku*) and the frequently worn quilted indoor jackets. Warming bottles, electric heating patches or heaters are additional aids to comfort. Further, people emphasize the warming effect of local spicy foods, hot tea and the popular practice of a warm foot bath (*tangjiao*) to stimulate blood circulation.

The choice of such objects and devices, however, largely depends not only on the socio-economic means to purchase them but also on the ability to pay for the related electricity costs. Other factors—such as age, gender and personal experience—also affect the possibilities of mitigating the cold. A new trend among the upper middle class is the installation of electric underfloor heating for entire rooms or apartments. Nonetheless, many refrain from buying this, arguing that winter in Chongqing is too short to make up for the cost of installation and maintenance.[255] The head of a heating-installation company stated that since starting his business in 2009, the number of people interested in installing underfloor had steadily risen. In his opinion, "heating is not a necessity in Chongqing, but with the rising quality of life in Chinese cities, those who can afford it invest in comfortably warmed apartments."[256]

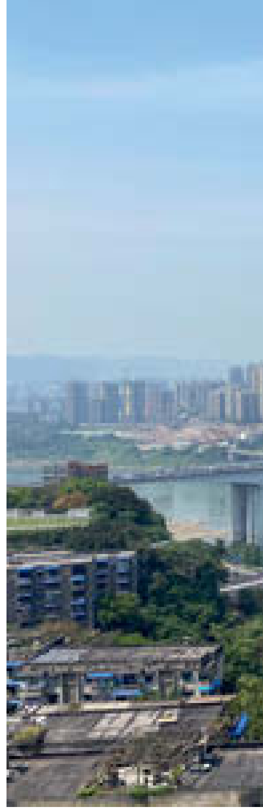
2.3 Lowering Electricity Consumption Through Design

The example of Chongshi's winter practices emphasizes the fact that seasonal climates are, in reality, being perceived in the living room. No clear-cut thermal division exists between indoors and outside. Apart from the small bedroom, all the rooms in Chongshi's apartment have the same temperature as outside. This is largely the result of the materiality of the buildings in Chongqing; apartment walls are neither insulated nor soundproof. One informant called this the "famous Chinese quality" whereby one can hear neighbors talking and even smell what they are cooking. Another informant mentioned that more noise comes in through the walls of his multi-story apartment than through the recently replaced windows.[257]

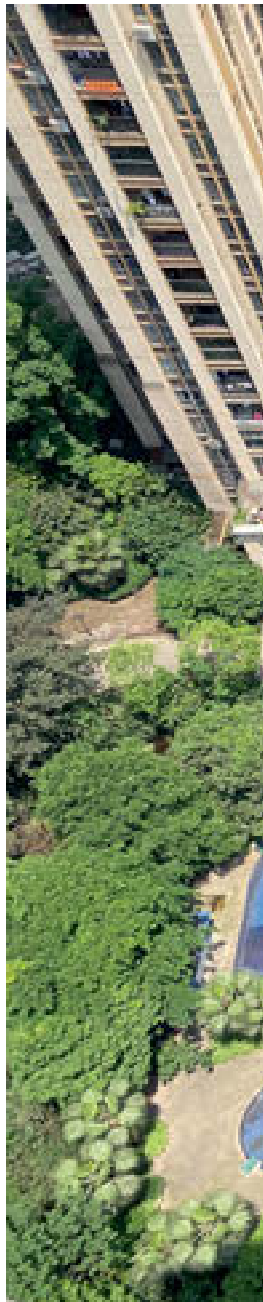
The problem of thin walls applies mainly to houses built in the 1980s and 1990s, right after the economic reforms. Before that, in socialist-era times, walls were often built of bricks at a width of 60 to 70 centimeters, thus providing insulation through thickness.

→ figs. 88, 92, 94, 117

86
Jinyu Tianyi residential compound, cooled entrance hall of a high-rise building.



88
Qiushui Changtian residential compound located on the shore of the Jialing River.



89
Jinyu Tianyi residential compound, compound greening seen from Wang Tong's apartment.

87
Jinyu Tianyi residential compound, ventilation shaft where split air-conditioning units emit hot air to the urban atmosphere.

90
Jinyu Tianyi residential compound, the mostly unused swimming pool in the communal area.

91
Jinyu Tianyi residential compound, view from Wang Tong's apartment.

From the mid-2000s on, however, a new awareness of the benefits of insulated walls with regard to energy efficiency gained momentum.[258]

Permeable buildings are characteristic of both typologies discussed in this chapter, but they manifest themselves differently. In socialist-era buildings, permeable walls, built to mitigate local climate conditions passively, featured open staircases, single-glazed windows and greened courtyards. In the built fabric today, however, the permeability of high-rise buildings is the result of climatic concerns rather than any response to the lack of insulation materials and the self-installed split-unit air-conditioners that can cause air leakages in the façades. Further, construction companies often save on the quality of the materials they use, leading to deficient insulation, low airtightness and low-quality glazing and frames.[259] For the walls, builders often use aerated bricks (*jiaqizhuan*), light bricks that let the air through but which, according to a local architect, are an advantage in Chongqing's humid climate, since they reinforce the walls' permeability.[260]

Insufficient insulation is a direct result of the political economy in China. Despite the recent proliferation of government policies that support green, energy-efficient construction with subsidies and regulations, the construction market has, so far, shown little interest in improving insulation. In the 1990s and early 2000s, the lack of available quality materials and components outside the large cities along the coast—items such as fireproof insulation panels, double-glazed vinyl windows or casement windows—explained the difficulty in complying with energy efficiency requirements.[261] Today, however, even if developers invest more in wall structures, the decreasing residential floor area diminishes their financial return.[262] According to the architects interviewed, passing the investments in better materials for insulation (e.g. triple-glazed windows) onto apartment purchasers seems to be impossible. Occupants have little interest in paying more for better thermal structures. Rather, when purchasing an apartment, residents consider location, provision of communal green space, appropriate management of the residential compound, available parking spaces and health issues with regard to the toxicity of integrated building materials. Even if a warm apartment contributes to people's health at a fundamental level, especially for elderly people and children, it seems a minor consideration when buying an apartment. These deficient material structures reinforce the need for electricity-driven devices to cope with different seasons. Electricity provision seems indispensable to dealing with extreme heat in summer and the a non-existent heating infrastructure in winter. Thermal control of the indoors today complements passive means (such as warm clothes, blankets, closing doors or going outdoors) with electric devices such as ventilators, air conditioning and electric heaters.

Extreme summers and winters without central-heating installations also challenge local architects to explore new ways to cool the indoors passively. For example, to reduce energy use, architect Liu Jiakun integrated ventilation features into the wall structure of the Department of Sculpture of the Sichuan Academy of Fine Arts. Lattice walls, two-story indentations, double outer walls that work like chimneys from which hot air streams out in summer and natural light for as many rooms as possible all help control indoor climates.[263] Several climate-related elements also characterize the design of the Chongqing Taoyuanju Community Center by Vector Architects, which features green rooftop spaces, the use of underground coolness, natural lighting of interior spaces through the integration of two exterior courtyards, a large central atrium and vertical wooden louvers to filter direct sunlight to the inside.[264] Safdie Architects have revived terraced housing for an upper class in the Eling Residences.[265] Through their construction along the hillside, the buildings benefit from the natural ventilation of breezes rising uphill from the river, and from being built into the terrain such that they are cooled from the rear. Overall, these examples emphasize the fact that the role of architecture in Chongqing's energy transition is hardly negligible. By improving structural insulation, however, electricity consumption could be significantly lowered, both in summer and in winter—thus relieving household budgets, the energy infrastructure and air quality.[266]

A recent trend among Chinese planners and architects is to bring together "nature" and "the city" in and through their designed landscapes. This conscious aim has shown itself especially prevalent since 2007 and in the proclamation of the 17th National Congress of the Communist Party, which aimed to rethink the relation between nature and human dwelling under the idea of an "ecological civilisation."[267] Architectural design proposals such as the "*Shanshui* City" (mountain and water city)[268] by architect Ma Qingyuan (MAD Architects) or the "designed ecologies" by Yu Kongjian (Turenscape) are examples of this trend.[269] These proposals, however, often cannot fully mitigate the climatic challenges in places such as Chongqing. Living with "nature" in a high-rise sounds romantic, but today it means coping with excessive heat in summer and a cool indoors in winter.

In order to avoid these uncomfortable microclimates, residents have to employ energy-dependent objects and devices that link the microclimate of the indoors to the climatic conditions outdoors. As such, recent energy-transition discussions in urban China have had to consider the questions of what kind of infrastructure the government should provide, and to what degree the thermal control of one's body is a private issue.

3. Energy Transition and Urban Climate

Despite the steadily increasing demand for electricity for cooling and heating, Chongqing residents face relatively few power blackouts compared with other growing urban areas worldwide.[270] This is mainly the result of the strong steering role of the Chinese state in energy governance in two fields: first, the state is present in giving a hand to the coal sector, the country's largest provider of electricity. State governance keeps electricity prices low; price fluctuations for coal, for example, are often not passed on to end consumers.[271] In order to guarantee a steady energy supply, Chongqing imports electricity from provinces in northwest, north and central China.[272] Second, the de facto prohibition on heating-systems installations avoids investments in heating infrastructure and also lowers energy consumption in these more temperate climate zones of the south.

The Great Heating Divide as Thermal Regime for Decarbonization

The Great Heating Divide has had drastic consequences for winter practices in the "summer-hot-winter-cold" zone. On the national level, the policy has saved on energy costs and prevented carbon emissions, but annually leaves some 500 million people (covering 42 percent of the national urban building stock) in a cold indoors.[273] These residents themselves are left responsible for the ways and means of keeping warm. The growth of residents' socioeconomic status since the 1980s divided society into those who could afford to warm their apartments with a costly underfloor-heating system and those who had to keep warm by wearing quilted pajamas. Further, a "comfort generation gap" opened up between an older generation used to living in the cold and a younger one, born after the 1980s, that would prefer a heated indoors.[274] While the Great Heating Divide in the 1950s was meant to create equal conditions for all—namely, non-access to heating infrastructure in southern China—market reforms have led to a kind of thermal inequality based on socio-economic status.

Far from a mere technical problem, the heating question has become an issue closely related to China's decarbonization politics. Not providing a heating network to the southern regions was, at one time, attributable to economic reasons, but today it also poses an ecological question: How can the energy supply be provided by renewable resources at a time when energy demand is still rising? Huge costs for the construction of the heating infrastructure, as well as a rise in energy demand to feed such a network, are arguments against the installation of a heating system in the south. In 2004, for example, space heating of its northern areas made up some 40 percent of energy end use in China.[275] If district heating were to be installed in the south, even more of the national energy end use would go into heating—and carbon emissions would most likely rise. Consumption of central heating would far exceed the punctual energy use now generated by small electric heating devices.[276]

In 2020, President Xi Jinping made ambitious commitments, first, to bring China's coal emissions to peak before 2030 and second, to make China "carbon neutral" by 2060.[277] Owing to the dependency on coal as an energy resource that enables the economic growth and well-being of Chinese society, the energy transition makes slow progress. Since the 2000s, and especially with the Renewable Energy Law coming into force in 2006, consumption of non-fossil energies—such as hydro, nuclear, wind and solar energy—has increased.[278] Nonetheless, in the same period, the consumption of coal and petroleum has also been rising. The continuing energy demand caused by industry and growing living standards has thus surpassed energy gains achieved through energy efficiency and the use of non-fossil fuels.[279]

Hydropower: A Clean Path Towards Electrification?

Chongqing is a good case in point: with some 30 percent of its energy stemming from hydropower,[280] Chongqing is one of the few Chinese provinces that can make use of its water-abundant territory. Both the Yangtze and Jialing Rivers have defined the urban landscape and self-assessment of Chongqing residents from the time theirs was an early port city through to today, with ship cruises travelling through the Three Gorges. While up until the 1980s, the river served locals' daily necessities, such as for washing clothes, hydropower projects tap the river's energy potential at present. The Three Gorges Dam started

→ fig. 74

93
Example of an in-ceiling built-in air-conditioning system (top center behind the light bulbs) in the living room of a high-rise apartment in Chongqing.

92
A new trend among the upper middle class is the installation of electric underfloor heating for entire rooms or apartments, as here in a new apartment in *Shapingba* area.

94
Huang Chongshi in his winter room with a small electric radiator under the table.

operation in 2012 as the world's largest hydroelectric power station. Today, its electricity is transmitted to the growing metropolitan regions along the coast (such as Shanghai or Guangzhou), but also partly to cities in its surroundings: Chongqing, Chengdu and Wuhan.

While hydropower production causes less air pollution than fossil-fuel use, it does not come without environmental and social costs: the construction and maintenance of the Three Gorges Dam, for example, has had serious environmental impact: the flooding of ecosystems, the extinction of species and the new sedimentation dynamics in its catchment basin. In addition, the flooding of human settlements caused the relocation of 1.13 million inhabitants and an additional environmental emigration wave owing to the loss of the fish population that had long supported the livelihoods of many.[281] Such ecological damage wrought by a post-carbon energy strategy seriously calls into question the perception of a "clean" path towards electrification. At the same time, whether the Chinese energy sector can supply enough renewable energy to meet rising demand in the coming decades remains unclear.

Urban decarbonization policies, and the relocation of polluting industries to rural areas in particular, benefit urban residents equally, but the means to cope with heated-up or cooled-down rooms are distributed unequally within society. The way towards an *electropolis* in China is accompanied by social-justice implications that relate to dependency on electricity for thermal indoor control in the post-reform, urban nation. Energy governance by the Chinese state—in particular, the continuity of the Great Heating Divide and the widely available electricity based on coal subsidies, taken for granted as the energy source for indoor climate control—has led to a socio-economic stratification within Chinese urban society. While those who are well-off can afford the installation of underfloor heating or permanent air conditioning, those with modest financial means have to consider more carefully whether, when and where to use thermal devices. In summer, they may use the cooled shopping-mall spaces, while in winter relying on passive means of climate control such as quilted pajamas and blankets.

So far, debates on urban climates have largely been conducted separately from discussions on the energy transition, even though the changes in production and consumption of energy used for cooling and heating have direct impacts on urban environments. The case of Chongqing outlines exemplarily the fact that the energy transition in China is accompanied by huge climatic and socio-political challenges. Household energy consumption, in large part with climate control, has not only driven climate change globally but has also affected local urban climates: health-threatening air pollution is largely the result of coal burning for electricity production and industries, and waste heat from air conditioning reinforces urban heat-island effects.[282] Political efforts towards decarbonization may have relieved urban climates of air pollutants, but they are, in fact, passing on the environmental costs of energy production to other regions. The networked consequences that electrification brings to the Chinese city outline ways in which "anthropogenic processes intersect with the historical production of infrastructure, how they reconfigure socio-natural relations and what the political, policy and social-justice implications of these dynamics are."[283]

The interweaving of ethnographic, historical and policy-related data for Chongqing raises awareness of the interweaving of indoors and outdoors, city and nature, architecture and infrastructure, and practices and policies. Buildings are not detached entities whose inhabitants simply control the indoors. Rather, they are part of spatial infrastructure networks, connected through grids and pipes that, themselves, are subjected to state governance and expand beyond the city territory to the energy-producing industries in the hinterlands. In urban-climate discussions, architects and urban planners must carefully consider the spatial implications that designs for improving air quality and lowering local heat-island effects may potentially have on ecology and energy provision, both in and beyond the city. The *electropolis*, as an ideal of a city that has banned coal from its territory for the relief of urban air, is accompanied by both new socio-economic and environmental challenges.

Cairo (Egypt): The Domestication of Urban Heat

On the Everyday Production of Microclimates

Dalila Ghodbane

1. Urban Planning in Cairo

In the word "microclimate," the prefix *micro-* suggests the reduced space to which it refers as well as the boundaries that define it. While the problem of urban heat, linked to the larger problem of climate change, is difficult to address, the notion of microclimate is more easily graspable. Microclimates are relatively sizable spaces and their temperature, humidity and insolation can be manipulated through the form and adaptation of the built environment. This chapter outlines how the options for designing microclimates come in several forms and manifest themselves at various scales.[284] The context explored in this chapter is Cairo, the Egyptian capital. As is often the case with big cities, Cairo has exceeded the geographical landmarks that originally determined its location, justifying the term "Greater Cairo Region." The construction of the Great Aswan Dam in Upper Egypt in 1960 stopped the Nile from flooding the city; the river's meanders and seasonal rises had imposed safety restrictions on human settlement as far back as the 10th century AD.[285] Moreover, since the 1950s, Cairo has developed on the fringes of the desert to the west, extending well beyond the river and its lush green banks, and to the east past the rocky hill of the Moqattam, which many Cairenes still climb today to enjoy fresh air and a view at the end of a hot summer day. Yet, what makes Cairo's climate is not limited to the land's natural topography and meteorology.[286] The city's built fabric, traffic and industrial activities have developed to such an extent that they now compete with the natural elements by influencing the climate at the urban scale and beyond. This upset balance translates into several paradoxes, one being that it can make the desert's residential suburbs cooler than parks in the city. This is an anomaly because in the desert, the circulation of wind is unimpeded and there are fewer buildings that re-radiate the heat stored during the day. Moreover, atmospheric pollution has become characteristic of Cairo, as well as a serious public-health issue.[287] According to a study published in 2014, some 35,000 people in Egypt die from that pollution every year. A recent report ranks Cairo as the most polluted city in the world, with nearly twelve times more fine particles than the safe level set by the World Health Organization (WHO).[288]

Relative to the climate of the larger region in which it is located, the city of Cairo is a microclimate—but one made up of several microclimates within the urban territory. The multiple microclimates within the city depend on localized contexts, which, taken together, form a mosaic with various thermal environments. These specific settings interact with natural elements, such as proximity to the Nile or altitude, but they are also shaped by those who live in or formerly lived in the area. In that sense, a microclimate depends on its local context—namely, the physical surroundings as well as the socio-economic situation of the neighborhood, both which partly depend on the inhabitants' attempts to mold it according to their needs and wishes. The reverse is also true, since close context also influences the ways in which individuals shape their living environment. There is a cogeneration both of the microclimate and its surrounding climate, and between natural elements and habitat. This process of reciprocity is not unilaterally influenced by the climate only, but also shaped by other social and individual factors as well as by the prevailing modes of intervention in the built environment. As the number and intensity of heat waves increase in cities around the globe both the concept of microclimate, in its fragmented dimension and the principle of reciprocity generate an understanding of the phenomenon of urban heat through localized human actions.

1.1 The Lack of Affordable Housing

Solving urban-heat and public-health problems entails a consideration of potential channels of action that go beyond the traditional institutional tools of master plans and legal guidelines. Indeed, the history of urban planning in Cairo has relied mainly on approaches that have proved inadequate in solving the problems originally addressed. The case of affordable housing from the 1930s onward is a telling example: governmental initiatives systematically remained at an embryonic stage despite initial ambitions. While those initiatives sometimes resulted in a few successful model buildings scattered here and there, especially in the 1930s and 1950s, the efforts never moved beyond that stage—largely due to political changes

→ figs. 95, 97

and economic fluctuations.[289] In the 1970s and 1990s, some governmental plans for social housing materialized as housing projects that, however, missed the targeted population. Indeed, the initiatives never reached a level that could effectively challenge the scale of the successive—real or speculative—building shortages.[290]

What's more, the lack of affordable housing spurred the encroachment of urbanization on agricultural land. Climate-wise, one of the consequences has been an increase in urban heat. In spite of the various governmental measures' and master plans' intentions to organize the city's development and prevent the loss of even more fertile land, satellite towns were planned around Cairo to absorb the demographic growth.[291] In actual fact, though, this did not prevent people who could ill afford housing on the legal market finding solutions; they were drawn to the settlements built illegally on available land close to the city, land initially dedicated to agriculture.[292] Today, these neighborhoods, known as *'ashwā'iyyāt* (haphazard settlements),[293] house the majority of Egyptians living in the capital, and together they take up more than half the city's surface area. The settlements' tightly aggregated high buildings, made of uncoated red bricks and grey concrete, stand out in Cairo's landscape, but their configurations and lack of free space considerably limit the possibilities for cooling during the summer heat waves.[294] In short, then, these informal neighborhoods are the embodiment both of the gap and of the imbrication that exists between the logics of institutional urban planning and the urban production mechanisms actually at work.

The relative failure of urban-planning attempts in Cairo to control the built environment points to the existing gap between legitimized architectural knowledge about climate (the information circulating in publications, museums and teaching activities, for example) and the actual position of thermal concern in today's construction practices and peoples' daily lives. On the one hand, a plethora of architectural publications document what should be a virtuous relationship with the climate. Recommendations for reducing urban heat include maximizing the surfaces of green spaces, creating wind corridors and using adapted materials.[295] As for building parameters, windcatchers, window filters, thick walls and courtyards are ubiquitous archetypes in the Middle East. Yet, this extensive technical knowledge remains marginal in everyday practice. That distance between what is prescribed—*al-mafrūd* (supposedly), as my interlocutors often said—and what is actually implemented is what this chapter investigates. The difference between what is meant to be good and what ends up materializing determines the mutually exclusive realms of intervention possible for architects and inhabitants alike, by outlining what is inside or outside both spheres.

1.2 The Microclimates of Domesticity

The consistency of this distinction between virtuous models of urban and architectural design and what is actually being built over time is the hallmark of current urban production. Rather than having been exclusively planned with large urban schemes, Cairo's built environment has, for the most part, been formed through the accumulation of actions on smaller scales—both of self-construction and timely real-estate development. That said, I should make clear the fact that bureaucratic urban planning and individual building actions are not opposites. Quite the contrary: by exploring the distance between the prescribed and the implemented, I question the relationship between the two. Indeed, some works can only be carried out by the state or large companies, such as energy, road or rail infrastructures. Other urban issues seem to challenge the capacities of the planning authorities: affordable housing, for example. And since there are signs that agents other than the state address this issue, for better or worse, there are valid reasons to take a closer look at how they function.

In view of such an inclusive approach to planning, the work of Jean-Pierre Olivier de Sardan is useful. His definition of a mode of governance as "any institutional arrangement that delivers public or collective services and goods according to specific norms (official norms and practical norms), and specific forms of authority"[296] is particularly helpful. Such an understanding, based on the process of providing a service rather than on the normative organizational scheme, allows us to account for how things happen on the ground. Coining the term "practical norms," Olivier de Sardan sheds light on the informal practices that exist within the bureaucratic modes of governance. These interpenetrations compel us to investigate the actual agencies at work, those understood as "choice(s) among a repertoire of regulated options"[297] that actors can use according to their interest at any time. In that sense, this chapter considers possible modes of thermal governance not only from a bureaucratic point of view but also by encompassing the diversity of actors, along with their formal and informal practices, while leaving space to rethink norms and structures accordingly. Rather than argue against any kind

95
Agricultural land on Dahab Island seen from the ring road.

96
Warraq Island.

97
Moqattam Hill, April 2019, 5pm. Many Cairenes climb it to find a bit of cool respite and a view at the end of a hot summer day.

of planning, then, this chapter raises the question of *what* we can plan when we advocate planning the city's microclimates?

By choosing the perspective of the domestic scale, this chapter focuses on the inhabitants' thermal agency when facing hot summer temperatures in Cairo's metropolitan environment. Interrogating the logic that drives the creation of domestic microclimates in context offers appropriate, albeit underestimated, tools for an efficient mode in which to care-take cities. By thermal agency, I mean the capacity to influence one's domestic microclimate—itself, partly dependent on the nature of the built environment, including the buildings' heights, their materials, the space around the buildings, the green spaces, the streets' width, etc. Beyond the use of electric devices such as air conditioning and fans, the creation of a satisfying microclimate is integrated within a wider nexus of social practices that range from the single room to the neighborhood. I will analyze which aspects of the dwelling the thermal practices of Cairenes focus on, and examine how they are related both to the immediate environment and to the social and material organization of the urban space.

2. Thermal Navigation in and around the House

Domestic space and life share a reduced spatial scale and a cyclical time (around the day, the seasons, etc.) that is opposed to the temporality and spatiality of the urban and the architectural projects planned in offices. Such anchorage in space and time determines the conditions of action and the scope of individuals' agency. In other words, it dictates a different definition of the urban project since these forms of small-scale interventions, more or less planned and more or less improvised, add up to generate the city. Such a perspective echoes the combination of microclimates that shapes the climatic urban ensemble, as previously introduced.[298]

This study relies on architectural ethnography conducted in Cairo over 16 months in 2017 and 2018. For the present chapter, I have selected four houses in neighborhoods that have different built fabrics (more or less densely built, green, ventilated) and social compositions (from well-off to popular areas). The four case-study dwellings are neither models nor prototypes, nor are they meant to represent all the households in Cairo.[299] The method used combines both an extensive survey of the material details in the house and participant observation of the thermal and constructive practices of my interlocutors. Beyond the static architectural representations, the ethnography exposes the dynamic relationships people have with their houses and their environment. It shows houses not only as outcomes, but also as processes that exceed the sole framework of construction as regards microclimates. Other aspects—such as kin relations, cultural norms or socio-economic status—also intervene in the making of these houses. It is from that multilayered process that I believe we can learn and consider efficient ways to mitigate the urban climate.

2.1 *Faysal*: Choreographic Thermal Routines

I am invited for lunch at Maryam's house, in *Faysal*.[300] When I go to her place, I usually choose to take the metro from one of the downtown stations, which is cheaper and more punctual than taking a cab. This time in September, the outside temperature is around 32°C, which feels quite comfortable compared with the higher temperatures we have become accustomed to during the summer. Once underground, however, the atmosphere is heavy, and the few fans that circulate a saturated air on the platform provide little relief. The arriving train is an old model which is not air-conditioned. In the compact crowd of the car, I try to move and turn my face to avoid the airflow that a greasy and dusty fan embedded into the ceiling blows at passengers, as we pass the stations. Approaching *Faysal* station, the train is already out of the tunnel. The air outside, although loaded with exhaust fumes, feels fresh as it streams through the open windows into the car. The metro slows down, stops and the doors finally open on an open-air platform. Mechanically, as is often the case with public transportation, I walk to the nearby bus station, which is not far, so I do not need to walk under the midday sun. After a stop at the small market to buy some fruit for my host, I climb into the microbus and take the front seat. I like to see the road and sitting against the door makes it easier to get off quickly, since I do not intend to stop at a formal stop but on the road right in front of Maryam's building. Sometimes, passengers who do not want to have a neighbor sitting in the front seat near the driver purchase two tickets. When I feel very warm and prefer not to have body contact with a neighbor, I sometimes indulge in this modest luxury. Being warm depends less on the temperature than on whether I am carrying a heavy bag, or have walked for a long distance beforehand. This is how most people navigate through Cairo, weighing the efforts between their various duties, the expectations of those they are visiting, the time available to them, etc. They identify the possible moments and places of respite on their way. A thermal cartography of the city emerges from such assessment of the nooks and crannies, the potential refuges from the cold, heat, rain or wind, which each person assesses according to his or her condition. Unlike Maryam, for example, I am free to move about without constraints. For her, every trip is an adventure. Since moving around with her three young children is a challenge, she usually takes a taxi, where she is sure she can keep her two boys under control—her older daughter being less unruly.

My watch reads 1:15pm I reach my destination, and am about to get in the elevator when Maryam's boisterous children run towards me. They are coming home from school with their mother. She is visibly exhausted from trying to channel their boundless energy while walking in the streets full of microbuses, cars, autorickshaws (*tuk-tuk,* pl. *takatīk*) and scooters that are rushing in from all sides. The children have few opportunities to be outside, given the scarcity of accessible public spaces. And as they lack experience of the streets, they are unaware of the dangers there—which makes Maryam nervous and even less willing to go out with them. As a consequence, most of their life goes on indoors. Fortunately, it is September, and the heat is less overpowering than at the beginning of summer. Nonetheless, once through the door, seven-year-old Maher rushes into his room, undresses and sinks into his bed, his arms and legs akimbo. Maryam hastily takes off her *higāb* (headscarf) and waves it like a fan for relief. She offers me looser clothes while ordering her youngest son, four-year-old Karim, to go to the bathroom. The corner bath serves as a water tank in case of a power cut, so Maryam showers her son on the floor, which explains the tiled platform on which the washing machine is raised. Then eleven-year-old daughter Omnia cools off under the water, while Maher has fallen asleep in his underwear in the semi-darkness of his room. The rhythm slows, the children have calmed down and are ready to have lunch at the table that Omnia has unfolded in the living room while her brother was showering. This transition from outside to inside accommodates each of the occupants of the house successively: changing clothes, lying down, showering, sitting, etc. Daily repetition of the same ritual fits the domestic space, evades the weight of the outdoor climatic conditions and has become a part of a choreographed thermal routine.

Maryam lives with her three children in an apartment on the eighth floor of a twelve-story corner building in *Faysal*. It is a residential tower with three apartments on each floor, and two elevators. A doorman (*bawāb*) lives on the ground floor with his family. The construction is of concrete pillars filled with red fired bricks, a standard for house-building in Cairo since the 1980s. The façade is painted in two shades of yellow, now faded by exhaust fumes, sun and dust. Like most buildings in Cairo, the walls are not insulated yet are in good condition—a standard that targets a middle class. The neighborhood was built between the left bank of the Nile and the pyramids of Giza. Its main artery, Faysal Street, named after the King of Saudi Arabia,[301] parallels Pyramids Street, known in the whole Arab world for its nightlife. Seven kilometers long, Faysal Street is one of the busiest boulevards in the city and it features a large number of commercial ventures. Satellite images show that the first buildings appeared in the 1980s on what, then, was agricultural land (leftover green plots), but construction accelerated during the 1990s. Today, the area includes households of diverse social classes, a pattern that is visible both in the buildings and the urban fabric. Maryam's husband, Marwan, an engineer who works in the Arabian Peninsula, supports the family by sending back part of his salary to his wife.

Thanks to the metro, *Faysal* is well connected to the rest of the city. Microbuses, taxis and rickshaws circulate constantly, and all sorts of shops and services are available night and day. The disadvantage, however, is the uninterrupted ambient noise that comes with congestion and crowds. Some, such as Maryam's brother, do not have words hard enough to express how much they hate some areas of the neighborhood—considering them ghastly, filthy places that are chock full of drug dealers and stalkers. Maryam could afford to move with her family out of this crowded area. Indeed, her husband would prefer them to live in one of the remote desert cities such as *Sixth of October*, *Obour* or *Shorouq*, which are less packed and which, supposedly, have a better reputation. He assumes that being isolated from the crowd would make his family safer. Nevertheless, Maryam prefers to stay in *Faysal*, where she enjoys regular visits from her family and friends who live in Cairo, and is able to grab anything she needs at any time by just going down the street or ordering from the shopkeepers. She often tells me about her disagreement with her husband around this issue, each time adding another justification for staying in the neighborhood: the closeness to family and friends, the fact that she has a spacious flat, the children's schools and activities nearby, and so on.

→ figs. 101, 137, 138

98
Seasonal sand-
storm in Cairo,
January 5, 2019,
3pm.

Despite her desire to stay in the district, Maryam has ambivalent feelings about the neighborhood of *Faysal*, which affect the organization of the apartment. Placed in the corner of the building, the longer façade opens on a narrow street while the shorter one has a small balcony overlooking a large dusty avenue, a line of palm trees and a garbage dump. On the inside, the bathroom and kitchen have windows oriented towards the inner light-well (*manwar*), as is often the case in Cairo. Both the high position of the flat and the generous dimensions of the air shaft enable drafts to ventilate the rooms. However, the only source of natural light is the blurred glass of the bow window in the main living room. The rest of the windows are carefully closed: shutters, glass and nets are embedded within the frame and curtains. On one of my regular visits, I opened the shutter of the dining room to enjoy the natural light. As soon as Maryam entered the room, however, she quickly pulled the shutter back in its place, explaining that the woman who lives across the street watches her. Later, she added that her neighbor's whole family lives and sleeps on the roof terrace, an extension of their flat that parallels the one in her own house. Maryam considers her neighbors' exposure of their family life inappropriate. They dress lightly, she says, and do not behave properly. It should be noted here that rooftop housings in Cairo are generally inhabited by socio-economically poor families. Since the houses are prone to overheating, the roof terrace is used extensively for a range of domestic activities. Maryam takes care to protect herself from the gaze of her neighbors as if there was a risk of sharing their misery. She shields herself from their sight, echoing the ambivalent feelings she has about her own presence in the neighborhood. Further, this behavior concretely impacts the way she inhabits the space of her house.

In winter, when temperatures drop and the nights become colder, Maryam moves her son Maher's bed away from the wall and pushes it towards the beds of his sister and brother. She believes that the cold of the outside wall causes his occasional incontinence. The children also sometimes gather in Maryam's bedroom if the night is very cold and they cannot warm up. Like the beds and the fans, tables and chairs are also mobile: during the school period, the lunch table is moved from the living room, and the television to the stage in front of the bow window, where daughter Omnia can do her homework by daylight away from her brothers. Moving the furniture around the house is part of the logic of compensating for the walls' thermal defaults.

Domestic practices thus counterbalance what the walls of the house do not do, providing an environment ready for the body to rest. This series of habits resulting from the daily experience of the home and its atmosphere is particularly visible when Maryam entertains guests. She brings the flat's two standing fans, which usually stand next to the entrance, into the living room and places them to blow air straight into her guests' faces. Creating a cool atmosphere for visitors and offering drinks belong to the hospitality one should show visitors. In a way, offering freshness is like inviting the guest to go through the same ritual of crossing the doorstep and cooling down the body that he or she might enjoy at home. But paradoxically, this mode of operation underscores the fact that the space is not welcoming enough in itself. For it to be so, even artificially, the room would have to be fully air-conditioned so that the body would not have to do anything to cool itself.

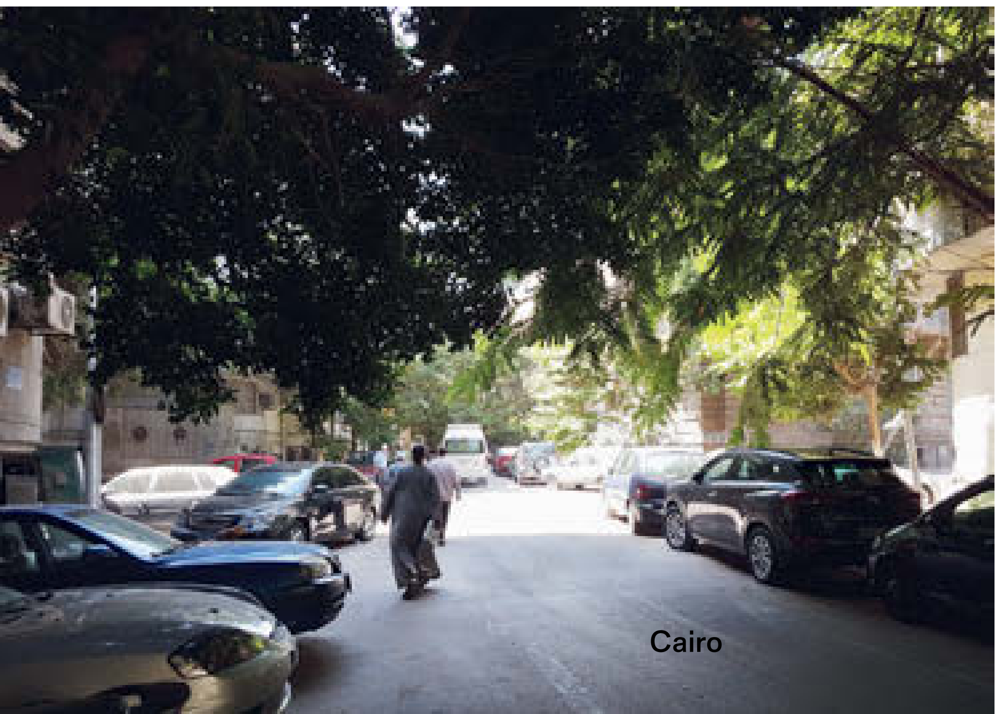
Air-conditioners are often used with great caution, if at all, because they consume so much energy. According to CAPMAS (Central Agency for Public Mobilization and Statistics), and based on a sample of 10,967 households in Egypt that represented 43,940 inhabitants, 19.4 percent of urban households in the country had air conditioning in 2015, and 93 percent were equipped with electric fans.[302] The price of electricity was rarely cited during my fieldwork, but electricity prices are tending to rise. Middle-income households, whose average monthly consumption is estimated at 215 kW/h, saw their monthly electricity bills rise from EGP (Egyptian Pounds) 23 to EGP 79 between 2013 and 2017, even though my observations show that for the same category of household the amount is closer to EGP 150.[303] Electricity remains largely subsidized,[304] but the government agenda is aiming for drastic cuts, in line with the demands of international donors. The future rise in energy prices threatens the autonomy of households.[305]

2.2 *Garden City*: The Privilege of Thermal Comfort à la Carte

Like Maryam in *Faysal*, Magda also faces a dilemma as regards her neighborhood, *Garden City*. By contrast, though, she lives in a large flat in a central, well-off neighborhood together with her engineer husband, Mina. Having always lived in the area, the couple recently bought the apartment. During our conversation, unexpectedly, Magda explained why they did not live

→ figs. 103, 106, 107, 108

99
A building in the area of *Garden City*.



100
Street scene in *Garden City*. Magda appreciates the green environment where she lives.

in one of the suburbs built around Cairo, such as *Sheikh Zayed* or *Madinaty*, where, as she says, most of the upper class implicitly tends to move. Among the reasons for why she stayed in the center, she cites the neighborhood often being congested on weekdays even though, because she works in another area, she does not suffer much from it. This reverse commuting spares her the traffic—which is at its highest from 3pm, the time most civil servants finish their working day. In addition, Magda uses her cell phone to locate any traffic build-ups on her way home. Depending on whether the roads appear in green, orange-red or bold dark red on her GPS navigator, she decides how and when to drive from her office in the far western suburbs to her home in the center. Lucky enough to enjoy relative autonomy and independence at work, Magda also appreciates the green environment of the area in which she lives—an environment that is quite a rare thing in central Cairo.

Like Maryam, Magda is concerned about the mobility and access to services she will have once she reaches old age—also on behalf of her two daughters, who do not drive. Magda's flat is on the eighth floor of a twelve-story, modernist building that predates those around it by something like a century. Her building's relationship to its surroundings plays a role in the way Magda planned her own home's ambiance. Nothing seems to hinder her intention to enjoy the outside: she said she added a window to enjoy natural light, something I rarely heard from my other interlocutors. She also broke one of the side walls of the loggia to enlarge the view on the city's landscape. In her words: "At work, I once had an office with a tiny window, and with it, a vis-à-vis. That was a nightmare. Thank God, there was central air conditioning. I had the feeling of entering a cell, so I didn't want this feeling at home. I prefer an enlightened place, especially in the morning (*nūr rabbinā*, the light of our Lord). The idea of everything dark oppresses me. [...] Also, it was impossible for me not to have a balcony. Even if I don't sit on it, I want to be able to go and see the world from it."[306]

When she redesigned the house to her family's taste, she paid special attention to the openings that impact ventilation. In the master bedroom, for example, she decided to turn the existing loggia into an indoor alcove with the option of opening a window as widely as possible. She cites it as the most important window inasmuch as it faces the dominant wind from the north. She wanted to be able to open this *bahrī* window (oriented to the prevailing wind) completely, using two casements, but in the end installed the sliding window she had wanted to avoid, allowing for only half of the original opening. Such aluminum sliding windows are popular. The organization of the entire apartment is thus oriented towards the outside. Contrary to Maryam's apartment in *Faysal*, the light shaft is described by Magda as a gloomy staircase that brings little air to the kitchen. There is a door and the combined fan-and-window set known as the *shaffat* found in most Cairo kitchens, which sometimes features a side window. To compensate, Magda chose to create a window between the kitchen and the dining room, both for a modicum of natural light and for better air circulation. This spatial organization allows for interacting with the outdoor space without being bothered by obstacles such as immediate neighbors or heavy traffic.

Thermal Comfort à la Carte

Magda's apartment has many rooms: two bedrooms, four living rooms, a library, a dining room, a kitchen, three bathrooms, a terrace and a balcony. Each room has its microclimatic particularity. In her case, the members of her family and her guests enjoy thermal comfort à la carte. When I first came to her place, she asked me to choose where I would like to sit. She outlined the fact that in winter the family would stay in this one room where the temperature would be high, given the sunlight coming in. "We call it the *sūba* [a greenhouse].[307] In summer, it's okay," she said, "but with more than three or four people here, we have to turn on the air-conditioner. If only Mina and I are watching TV, it's fine. It's tiny and cozy. Sometimes we stay in the large [one], but always with the air-conditioner on; it's necessary. In winter, we never go to the big rooms at all. It's not that it's cold, but in winter, you want to stay in a cozy corner, like here."[308]

The location of the room they call *sūba* today was originally on the outside of the building. A recess in the façade, it ran the full height of the building. Only Magda's flat and the one below hers have an additional room in this space. However, the room's roof is light and the outer layer is a galvanized-steel sheet. The sun hitting the steel roof heats the room nicely in winter, but is more constraining in summer—hence its "greenhouse" nickname. Still, it always offers an effective alternative for drying laundry during the *khamaseen* season in spring, for example, when the wind from the south is apt to fill the terrace with sand and soil the clothes.[309]

In addition to the big rooms Magda mentions, there are two living spaces in the continuation of the dining room. In the three defined spaces, she chose to install two, rather than three, air-conditioning devices since she does not have guests all that often. For her, turning on the two devices with the doors shut cools the space sufficiently. The representational function of these rooms is mentioned explicitly by Magda, who, after voicing her frustration over some poorly executed finishes, added: “Anyway, the important thing is that those who come from outside see and find that it looks good.”[310]

Magda made sure that the rest of the flat offers other options according to the occupants’ preferences. As such, her husband can sleep with the air-conditioner on and her daughters sleep in a room that is protected from direct sunlight, and both can enjoy the night’s draught or the fan’s blow. For Magda, the tiny alcove in her bedroom formed by the closing of the balcony makes what she calls a tiny living room for herself. Here, she can enjoy the *baḥrī* wind while training on her exercise bike. Magda and her family do, of course, enjoy a privileged living situation. People in less-favorable circumstances find other means to evade the relative thermal precariousness of their lives, as is the case for Maryam in *Faysal* and Dr. Hisham and his family in *Munib*.

2.3 *Munib*: Thermal Escapes from Overheated Walls

In some places, it is hardly possible to enjoy the outdoor surroundings. In *Munib*, for example, the buildings are so densely grouped together, that the house of Dr. Hisham has only a single façade. Its other two sides are attached to other buildings, and the last is a blind wall oriented towards another land parcel. This is often the case in such informal neighborhoods, where builders and investors want to maximize the built space. The façade is not plastered and the bricks are left exposed, as if waiting for finishing touches. Nonetheless, the building already looks inhabited; it has curtains, clotheslines on its tiny balconies and a large opaque wrought-iron gate. On the rooftop, pillars and steel reinforcements point skywards as if to announce the continuation of the vertical construction. In the same unfinished way, many streets are neither paved nor asphalted but covered instead with a mixture of earth and dust.

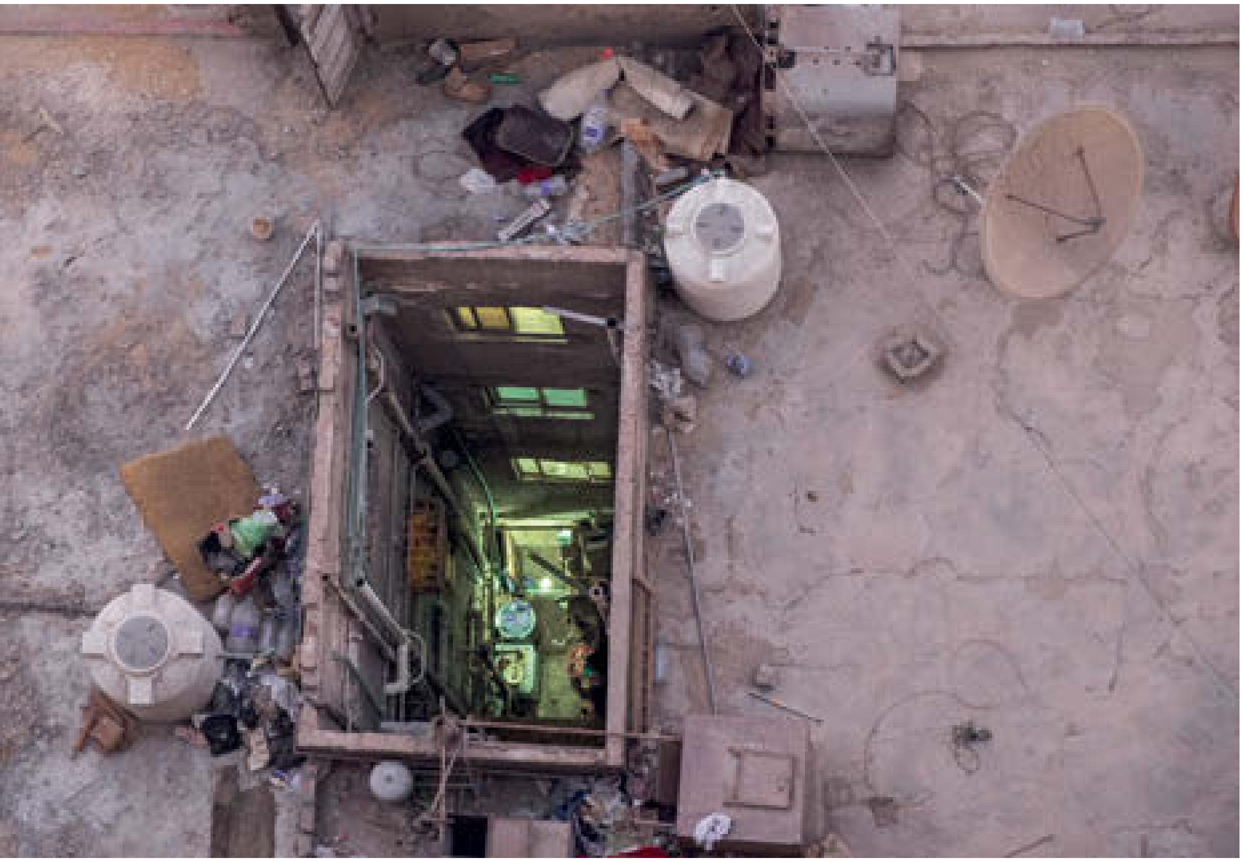
Dr. Hisham is a professor at a university in the Nile Delta. He lives with his wife, Sana, and their two children (aged ten and thirteen) on the uppermost floor of a three-story building that was built around 2010. Considering to its surface area, the apartment has few windows. The rest of the openings are onto the lightwell (*manwar*) that is supposed to allow the ventilation of the rooms that have no direct access to the exterior. The windows in the master bedroom, kitchen and bathroom have openings onto this two-square-meter shaft. On one hand, the possibility to cross-ventilate is limited. The entrance door sometimes remains open, to activate the draught from the staircase through the flat. On the other hand, the one blind façade facing south is the longest wall of the house. No more than ten centimeters thick, it consists of a single row of bricks. On a summer afternoon, I found out accidentally that the wall’s surface is so hot that touching it with the palm of the hand is hardly bearable. Pointedly, however, at no time do my interlocutors mention the heat of the flat. It only comes out in fragments: when a visibly pregnant cousin is gently chased out of the tiny kitchen, for example, where dishes are being cooked in the oven and on the gas cooker at full heat. Sana declined her assistance, suggesting that the room might potentially be detrimental to her own health. In summer, the fan in the living room stays on around the clock.

The fact that the residents do not openly speak of the overheating does not mean it is not problematic for them. When other interlocutors raised the topic, they reflected on what to do to improve the house’s comfort. Any vocal formulation of the problem implies the availability of resources for possible action. In the case of Dr. Hisham, I believe the absence of heat as a conversation topic suggested he felt there no resources at his disposal for improving the situation. Nonetheless, he did mention some escape routes and talked repeatedly about his love of the seaside, which he visits as often as he can. He mentions the espresso he sips there every week on his way to the university. The flat he regularly rents with his friends in a popular seaside resort has a spacious terrace, where the breeze never stops blowing. Several times, he also mentions a subsidized housing unit he bought in one of the satellite towns around Cairo. Here, too, he is not short on details: it is an apartment bought off-plan, in a building with three to four flats and surrounded by a garden. As for the level of finishing, he says it is ready to be occupied: *“mutshaṭṭab sūbir lūks* (finished super-luxe).”[311] Whether he will move there or sell it again to generate profit is unclear; he embellishes the description of this remote project as much as he belittles that of the neighborhood in which he currently lives.

To him, *Munib* is not what it used to be. During the last few years, the population has grown to a level that the infrastructures of the neighborhood can no longer sustain. The sewage system breaks down regularly, and the supply of water and electricity was frequently

101
The busy streets of *Faysal*.

102
Over the rooftops in *Mounira*, Cairo.



103
Light-well (*manwar*), a common architectural feature supposed to allow the ventilation of the rooms that have no direct access to the exterior.

104
Shreds of curtain remained hanging on curtain rods attached to the front of Umm Rania's building.

105
Insulating the rooftop of Umm Rania's apartment.

interrupted.[312] Dr. Hisham explained that in the past, good relations with neighbors reigned over what was happening in the streets and ensured relative safety. Today, however, he laments that, owing to the newcomers, this is no longer the case. Now there are thugs and drug dealers on every corner, he says, and the name *Munib* can be spotted regularly in the "news in brief" sections of the newspapers. Although several members of his family live close by, he also considers moving out. While he is often away, his wife and children actually benefit from the solidarity network into which they are integrated.

Dr. Hisham's polarized discourse perfectly illustrates the tension previously mentioned between what should be (*al-mafrūd*) and what is done (*al-ma'mūl).* A university professor and intellectual deserves better conditions, whether by the sea or in a building surrounded with gardens, like in his descriptions of cooler places. However, this not being the case, the doctor leaves Cairo at least twice a month. This distance between what should be and the conditions in which he actually lives with his family is common to all inhabitants of the four case-study dwellings and resonates with the situation of most of my interlocutors in Cairo.

2.4 *Khalifa*: Moving Furniture and Self-Building

In large apartments such as those in *Garden City*, residents like Magda move around their dwelling following the seasons. Such mobility is non-existent in smaller apartments, but compensated for by moving objects and furniture around the home—whether carpets, blankets, curtains, seats or mobile heaters. Occasionally, more structural work is done in the home to achieve more satisfying microclimates—as in the case of Umm Rania in *Khalifa*. A divorced mother in her early forties, Umm Rania lives in a small apartment located on the outskirts of the *Fatimid* neighborhood, on the uppermost floor of a two-story family building. The house was visibly built in several stages: the ground floor, made mainly of stones; the rest, concrete and bricks. The roof, once a wooden structure above the first floor, was removed to add Umm Rania's apartment. The house has a southwest-oriented rear façade where windows open onto a lower building's rooftop. In front, the lateral blind gable of another building is some five meters away from her window.

Umm Rania has two teenage children living with her: 15-year-old Rania and 17-year-old Ahmad. Her apartment features three rooms, a kitchen and a bathroom. Located on the uppermost floor, almost its entire surface is exposed to the sun—making it quite warm in winter, but extremely hot in summer. In that season, the temperature in the kitchen rises to a degree that the refrigerator cannot withstand, so it breaks down. It must, therefore, be moved away from the kitchen wall and installed in the entrance hall (*sāla*). The refrigerator itself then produces heat in the center of the apartment. In addition, it occupies the space of a folding table that the two teenagers usually use as a study surface during the school year: September to June. As soon as autumn arrives, the fridge goes back to the kitchen, carpets are laid on the floor, blankets are thrown on the red sofa and the blades of the ceiling fan are covered with a red cotton cover. This protects the fan while it is at rest during the coolest few weeks of the year around January. These examples outline how seasonal rhythms influence household life and the organization of domestic space.

When the Sun Sets: In Search of Cool Outdoor Spaces

Talking about seasonal "migration" around the house equates to finding or creating microclimates according to the outdoor climatic conditions. This quest is equally expressed in the way Umm Rania and her family move around and across their neighborhood. In summer, most of their outdoor activities happen after 7pm when the sun sets. But it is even later, sometime around midnight, that Umm Rania usually ventures out to the market. At that time, the crowd has dispersed and some of the vendors receive their fresh vegetables and fruits. In the earlier evening, Umm Rania used to take me out to the busy nearby neighborhood of *Sayyida Zaynab*. Shops install their goods outside on the pavements, coffee shops take their tables out and street vendors sell seasonal fruits—including prickly pears; bananas; and, among others, ground cherry—from their carts. In the winter, sellers offer baked sweet potatoes from wheeled ovens. Walking around outdoors is only pleasant if punctuated by breaks in a hot or cool spot, depending on the season: resting behind the counter of a juice bar to finish a glass of sugarcane juice, sitting down for a cup of tea or entering an air-conditioned store and pretending to look at the items just for the fresh air, as Umm Rania sometimes does.

Just like the Moqattam Plateau, which some Cairenes climb to find a bit of cool respite, some places in the city proper see people spending time at night just en-

→ figs. 135, 136

joying the outdoors and the relatively fresh air. These include the few parks and green spaces, such as the lawn of the Adbeen Palace downtown where Maryam, when on a visit to her mother's place, occasionally brings her children. Among the rarer places visited are the zoo at Giza[313] or the bridges over the Nile that welcome walkers at night. Vendors sell lupines, toys, sweets and serve drinks, while others just take a break to enjoy the breeze. Loud music, photographers and other activities make the bridge look like a fairground party. In the suburbs, air-conditioned malls are also appreciated for being inclusive of families—but getting there and consuming drinks or food can be expensive for some, making them something of an exceptional meeting point to spend a whole evening.[314]

In the *Sayyeda Zaynab* neighborhood, people settle down on the few modest patches of grass in front of the mosque to stretch out or picnic, even if surrounded by the roar of cars, microbuses, autorickshaws and the crowd. During the month of Ramadan, which, in 2018, fell in summer, *Sayyeda Zaynab* is a place where, traditionally, people from all over the city come to stroll around, eat, drink and enjoy a convivial atmosphere (*al-gaw al-sha'bī)*. In *Khalifa*, just as in the whole *Fatimid* area, people often gather in public places for concerts, shows and other activities, or they go to the mosques for the traditional reciting of the Quran after the last prayer of the day. Umm Rania took me to one of the monumental Mamluk mosques of her neighborhood, where we sat with others in the four big alcoves in the cubic, marble-floored, carpet-covered, open-air courtyard. There are a few trees around the monument, and low walls and steps where visitors like to sit while their children run around. The scarcity of outdoor places for resting make any potential open-air rest area fill up fast. And these areas are even more limited for women, whose presence in most public spaces in Cairo is welcome only under certain conditions—when they are being accompanied, for example. This is especially true for Umm Rania: a rather shy, divorced young woman. For the most part, her life is organized around the space of her house, which explains the special care she gives it.

Rooftop Insulation and Neighborhood Solidarity

Umm Rania's house is located in what is called a *hara* (*hāra*), a narrow lane traditionally constituting a small neighborhood.[315] In this case, it is a dead-end street some three to four meters wide, which one extended family uses as an extension of their domestic space. For example, the women sweep the floor every morning, and in the evenings one of the neighbors sits on his outside bench to smoke his daily water pipe after a long day of work. Children play freely and can be easily seen from the windows. During celebrations such as Ramadan,[316] the neighbors contribute financially by decorating their *hara* with tinsel. Due to the neighborhood being contained, outsiders are automatically detected—which makes the *hara* both a semi-private space and a social unit on its own. But such exposure within the neighborhood may also be limiting. When the family who lived in the house in front of Umm Rania's moved out, fearing their building might collapse, Umm Rania and her daughter didn't hide their joy: they could again open the shutters widely without risk of being seen in their living room.

The special care Umm Rania pays her house showed itself clearly in the insulation of her rooftop, whose construction work I outline below. The work underscores the importance of the materials and available human resources in the project design, as well as the correspondence between the resources. The decision to take action parallels the situation of Dr. Hisham in *Munib*. When Umm Rania sets about insulating her rooftop, she insists on her neighbor bringing her a translucent, corrugated polyester sheet to create a shade above her windows and staircase. She has seen it in other neighbors' homes and aims to affix the same at the exit of the stairs to the rooftop, and use it for canopies on the old metal rods in the façade above the windows of her living room. Scraps of the curtain consumed by the sun's rays still hang down to the side, traces of the many previous attempts to protect the apartment from the heat. Her two neighbors brought 50-millimeter-thick boards of white expanded polystyrene and placed them on the rooftop surface, having painted them first with a layer of bitumen.

The shading canopy was cut with the kitchen knife that Umm Rania brought to the neighbor who worked for her on this occasion. The sheet was temporarily stabilized with a broomstick and a wooden beam stored at the bottom of the stairs. Later, the neighbor returned to fix the sheeting to the low wall using nails and flattened soft-drink bottle caps that had been converted into rivets.

The neighbors, all of whom work in the construction industry, are particularly helpful to Umm Rania. They regularly repeat their loyalty in their interactions with her. It seems to me that showing availability to her has become part of their duty, especially given that she has neither father nor husband to undertake work considered to be reserved for men. Umm Rania would probably have undertaken the work differently had she

→ figs. 105, 112, 113, 114, 115

106–107
Maryam’s apartment. The openings are carefully controlled and shutters are closed.

108
The only source of natural light in Maryam’s apartment is the blurred glass of the bow window in the main living room.

109
Dr. Hisham's living room. Considering to its surface area, the apartment has few windows.

110
The built-in fan (*shaffāt*) in Magda's kitchen.

111
The "greenhouse" in Magda's apartment. The sun hitting the steel roof heats the room in the background nicely in winter, but is more constraining in summer.

not been able to call on the expertise of her neighbors—those neighbors being in the best position to implement an appropriate technical response to her initial project, despite having never done any roof insulation per se. In this case, the search for a craftsman or a worker is done primarily through the known social networks. The duty of solidarity and the material and relational resources that Umm Rania can mobilize are clearly intertwined, and they determine both the existence of the project and the form in which the work is carried out.

Several situations during my investigation showed the interweaving of thermal considerations into a broader regime of constraints. Indeed, thermal comfort rarely exists as an objective in itself. It is indexed along with other aspects, the imperatives of domestic life—for example, the availability of materials—or the association of certain tasks with unavoidable heat constraints, such as cooking. Take the example of air circulation. In Umm Rania's home, the ceiling fan stays on during the summer evenings despite the twilight wind that crosses the living room. Focusing on the aspect of thermal comfort alone, this redundancy might seem sheer nonsense. However, the open window and curtain let the air in, but also the flies; as such, the fan is used to limit them. Similarly, on hot days, people tend to keep their windows closed so as not to let warm air flow into the house. They open them from dusk onwards only, when the north wind blows. In autumn, Umm Rania continues to keep the windows closed and the ceiling fan switched on, despite the outside air having finally softened. The reason for this is that the tall tree in front of the window, which used to protect her from the summer sun, loses its tiny leaves in that season—leaves that then fall onto the living room carpets. As these examples show, it is the overall constraints that define what a satisfactory domestic microclimate is. Thermal consideration is but one aspect among many. These flies, the dust, the noise, the leaves—or the intrusive gaze of neighbors, as in the cases of Maryam and Umm Rania—do not appear on the plans, sections or charts commonly used in architecture and urban planning. Drawing an ethnography of the forms that thermal issues take in domestic life informs us about these interwoven constraints that govern the creation of a satisfactory environment in the eyes of the inhabitants. Such research provides a better understanding for the ordinary situations of contemporary domestic environments in cities such as Cairo.

2.5 Social Representation and Thermal Precarity

Despite living in very different environments, Maryam; Magda; and, to a lesser extent, Dr. Hisham share the need to justify why they live in their respective neighborhoods and not elsewhere, supposing that this elsewhere would be more in line with their social status. The recurrent justifications of their choice to live where they live, as other informants have contended as well, show how expectations shape social norms and lead to the perceived gap between what is and what should be. They fill this gap with arguments as to why they stay in a neighborhood that many around them dislike. And in all the cases I have encountered, this has concrete consequences on the indoor microclimates that each of the informants creates. Their domestic spaces are sometimes changed in light of opposition, sometimes in accord with the literal and symbolic climate surrounding the house.[317] The gap between the place where my informants should live according to their own assessment and the place where they finally do live has concrete, driving effects on the way they arrange their thermal practices. Take the case of Dr. Hisham, living in *Munib*, who tells stories to escape his "socio-climatic fate." To bridge the difference between what the position of professor at a university should be offering to his family and his actual situation, Dr. Hisham offers a narrative of brighter horizons since he cannot remedy the situation in actual fact. There is greater room to maneuver for families in more favorable geographical and housing situations. Thus, through various canny arrangements, sometimes with great difficulty, some people tinker with their thermal comfort at home. These tricks are among the many attempts to reduce the gap between what should be—the conditional in sum—and its fulfillment. Understandably, this gap is not the same for every household. Magda is able to play with various nuances of thermal ambiance to suit her wishes, while Maryam struggles to meet the expectations of her guests. Observing the ways in which the individuals in the four case-study dwellings create a satisfactory thermal atmosphere at home shows social inequalities in context through the lens of climate. In other words, analyzing the thermal practices of residents underlines how they compensate for the shortcomings of the existing thermal structure in which they are living.

However, the thermal practices that I describe are not only symbolic; they are also instrumental. Offering freshness is a sign of hospitality that plays in the demonstration of one's social status. The use of air conditioning gives a physical consistency to this exercise of representation, one which goes beyond mere sight and involves the sensations of the body at rest. Turning on the air-conditioner means adjusting to the supposed expectations of others and to an imaginary picture of what is luxurious "elsewhere." In the case of Maryam in *Faysal*, Yusef, her close friend, does not hesitate to tell her on almost every one of our visits that she should finally install an air-conditioner in her living room. Adding the thermal perception to the concern for representation and status complicates the issue beyond the visual aspects alone. The relationship between appearance and usage is not simply a random one. Installing a marble stage seemed disproportionate compared with Maryam's use benefits, even if in line with and appropriate to her mother-in-law's concern for the way it will look during an important moment of public representation: the wedding of her granddaughter.[318] The idea that the air-conditioner is a display of prestige is not enough.[319] If its practical dimension is concealed, its representational value is virtually annihilated, just as in the case of the marble stage. Air conditioning not only awards status, it also gives the body a rest—sparing it from changing, showering, lying down to calm and refresh itself.

Some of my interview partners committed themselves to changing their material environment to influence the climatic atmosphere of their homes. Indeed, one of the most striking aspects of the survey was the sustained pace of repair, change and adjustment actions in the dwellings studied. From the addition of a simple curtain to the insulation of a flat roof, it seems the objects used to manipulate the thermal environment are most often already available in the home. Perhaps more than their original functionality, it is the material of the objects that is significant.[320] For instance, my interlocutors all criticized the use of wood on external walls for its vulnerability to sunlight, bugs and fire. Nevertheless—whether they concern moving furniture, installing a door or insulating a roof—technical solutions are designed according to the resources immediately available. This leads to the tendency to accumulate objects that appear to be of no immediate use. Roof surfaces are often used as storage for these objects.[321] In addition, stories about craftsmen or workers cheating on materials or their prices are frequently heard. Using a circle of known individuals for construction work serves to limit the risk of being "taken for a ride" on services; construction scandals are common in Egypt due to the lack of effective oversight institutions. As a result, it is not uncommon to give advantage to the solidarity networks linking clients and craftsmen to a given worker's recognized quality. The material resources available, and the extent of the networks of artisans who can be trusted, thus delimit the range of techniques employed. This is true for Umm Rania in *Khalifa*, Magda in *Garden City* and other informants who spoke at length about their difficulties in finding the right people to carry out the renovation of their apartments.

Domestic thermal practices are a projection towards a more desirable climatic life, and as such reaffirm the distinction between an outside and an inside delimited by the boundaries precisely creating the microclimate. Using the example of the dichotomy between private and public, Susan Gal argues that these notions cannot be understood as static facts but are private or public *in relation to* a situation of reference. The street outside is public compared with the house indoors, but the living room is public compared with the bedroom within the house.[322] This understanding of the inside/outside relationship in constant redefinition is relevant to the notion of microclimate, and the case of Maryam is quite telling in that sense. When she closes the shutters of her living room, she protects that private space from her neighbors' gaze in the public space. When she receives visitors, however, the living room becomes the space dedicated to the public, to outsiders, and is set accordingly: she wears her headscarf when the visitors are male; she brings the fans and turns them towards her guests.[323]

The road to creating microclimates is fraught with pitfalls that are more or less restrictive depending on the household situation. The multiple arrangements that people make are all attempts to bridge the gap between what they experience and what they desire. They find alternative means to circumvent the thermal precariousness of their living environments. The various infrastructures meant to provide city dwellers with energy and services do not satisfy their needs equally. Therefore, dependency on energy infrastructure remains loose.

3. A Microclimatic Approach to Cairo

A microclimatic approach to Cairo suggests that the thermal environment is a collective construction. This contradicts the image of a chaotic and "out of control" city, to paraphrase the title of a now-classic monograph by David Sims.[324] Consequently, the climatic environment is no longer simply the result of weather conditions but is part of social and spatial structures within which the conditions for gathering resources and technical tools are important. Studies focusing on thermal control in architecture often deal with the indoor or outdoor climate, or with the atmosphere of a place as an object. Hence, the way in

112
Streets around the *Fatimid* area of Cairo.

113
A market at night in the central neighborhood of *Sayyida Zaynab*.

114
A mosque in *Khalifa* during Ramadan.

115
A man carries blocks of ice to cafés and street vendors selling drinks, in the area of *Dokki*.

which architectural and urban-planning expertise approaches thermal control proceeds primarily from a quantifiable and measurable angle with regard to temperature, air speed and humidity. Architectural knowledge of climate tends to focus on the purely material and mechanical aspects of the relationship between building, climate and residents, excluding the social dimensions of the living experience.[325] But the microclimate is also the result of a set of interactions between individuals who are necessarily codified socially. This contrasts sharply with the surrounding and encompassing character of heat, a single variable that is inseparable from the concrete situations in which it may be one of many variables.

The reciprocity between the neighborhood and the dwelling is key to understanding the mechanisms that drive the creation of the home and its microclimates. In an extended form, such relations produce the city at large. The ways in which those living in the case-study dwellings presented occupy their urban space both illustrate and offer keys to understanding thermal agency. Indeed, the places identified as appropriate for a break in the navigation from one point to another in the city vary according to a series of more or less changing criteria. Factors such as age, gender and social class influence the perception of these places and condition access to them. Taking a nap alone in the courtyard of a mosque to wait for the afternoon heat to cool down is, for the most part, a male activity, for example. Likewise, the use of cafés known as "traditional" (*baladī*), while open to the outside world, is likewise reserved for men. When women—and strictly middle- and upper-class women—go to cafés, they are generally accompanied, and the branches of a coffee-shop chain they might frequent are indoors and air-conditioned.[326] Microclimates and the capacity to produce them are an integral part of everyday material and social life. Yet, it is circumstances that determine the thermal agency of the individuals. From that angle, we can establish the fact that creating microclimates follows the principle of reciprocity between given spaces, their creation and their uses, and is a potential foundation for an efficient plan of the city's microclimates. Each space is qualified with reference to another, and each microclimate is defined by another microclimate of reference. In that sense, there is a reciprocal definition of the qualities of a space: creating a microclimate cannot be envisioned in a detached way, but only in relation to other microclimates.

Looking at the thermal map of Cairo from this dynamic point of view, we can see the city as a series of microclimates. City dwellers both identify and generate them, flee them if they are unbearable or take advantage of them if they are welcoming. This approach has the advantage of underscoring the individuals' capacity to act on the variety of microclimatic spaces. It opens up real levers for action that extend far beyond the macroscale of urban planning. In that sense, it is remarkable that planners increasingly consider the variety of thermal ambiences in their master plans, as exemplified in Philippe Rahm's planning of the Jade Eco Park in Taichung (Taiwan).[327] What is at stake today is the imagining of ways in which such logic could be implemented in a context where action on the urban space is more than the responsibility of the planners alone.

A fragmented approach to urban space is relevant to developing new perspectives on the methods of urban planning. The lessons of recent urban planning in Cairo, as well as the new challenges especially related to climate change, are similar to those emerging in other cities of the world. They must lead us to rethinking ways of planning cities. The idea that political will, or the lack of it, is understood as the state's action to solely determine the future of cities shows as much a lack of imagination as it does a lack of observation. Such a contention is based on the mistaken assumption that only governments can develop cities. Even if the state in some contexts is an efficient planner, Cairo is a blatant counter-example, one which clearly demonstrates that the state is not the sole acting force. Indeed, this deceptive intellectual impasse should not blind us to seeing other dynamic forces capable of co-constructing urban microclimates.

A variety of actors in the field of construction gravitate between the institutional level (namely, design and decision-making) and concrete implementation and direct assistance to those implementing or deciding about what to implement.[328] Craftspeople, workers, helpers, contractors, material resellers, engineers and architects all belong to these agents of urban production. Among these professionals, some are more flexible than others due to the indefinability of their skills in the eyes of society.[329] Moreover, for architects, there is the challenge of diversifying their interlocutors to include those who are used to building without their intervention. The case-study dwellings presented in this chapter are relevant both to architecture and to understanding how the thermal issues manifested in these homes are a first step, for their occupants, towards tackling climatic issues more efficiently in concrete situations The architect's quest for a new, relevant position—both in the field of construction and vis-à-vis the pressing urban challenges such as the city's climate changes—echoes the need to rethink the current logics of planning.

II

Architecture and Thermal Governance

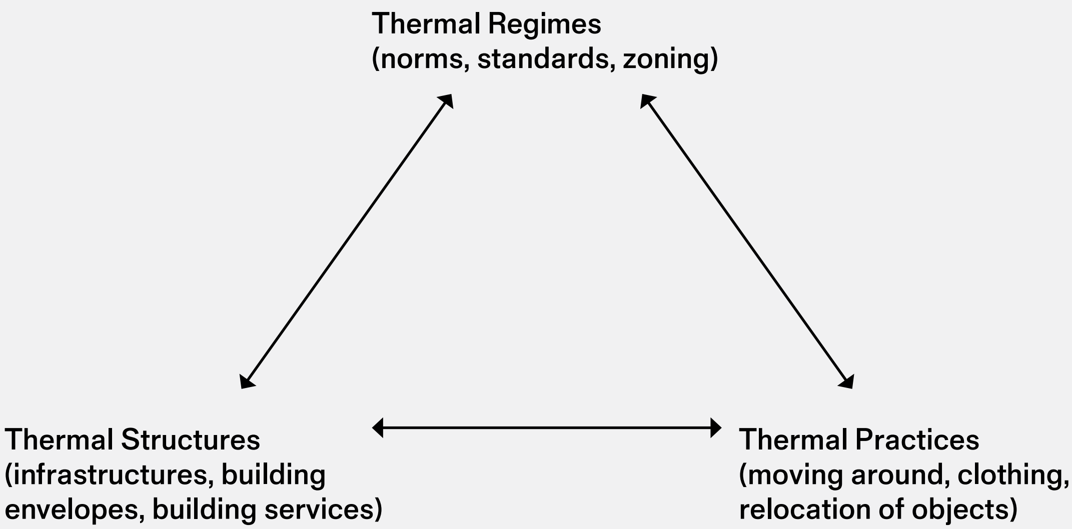
Six Components

Sascha Roesler, Madlen Kobi, Lorenzo Stieger

Framework

In this book, we define thermal governance as the synergetic operation of thermal regimes, thermal structures and thermal practices. Such an approach integrates different elements: the vertical governance of public authorities, in the sense of top-down decisions; and horizontal governance, including the multiple agencies that co-shape urban climates and influence behaviors and norms. Government-issued regulations are meant to determine any city's built structure, but can only do so through the actual practices of officials, scientists, engineers and architects. Further, once a house is constructed, its inhabitation, maintenance and adaptation by residents and other professionals (such as facility managers and craftspeople) all add other layers to the interplay of regimes, structures and practices. Thermal governance shapes urban climates through place-specific human / non-human arrangements.

Putting architecture at the core of conceiving future thermal governance, the four case studies herein raise awareness of what the built form of cities reveal about urban society's relation to climate. Without exception, all the case studies point to interlinked thermal indoor–outdoor spaces. The practice of climate control relates to the urban climate in various ways. While buildings embody the technological knowledge of a given era, their use is also indicative of the place-specific relationships between citizens and their urban environments. The alignment of representative, 19th-century buildings along Geneva's waterfront derived value, both from thermal relief at the lakeside and the viability of water for on-site power generation. In the chapter on Santiago, semi-public spaces integrated into collective housing developments are highlighted as thermally favorable environments within the larger urban fabric. The example of Chongqing



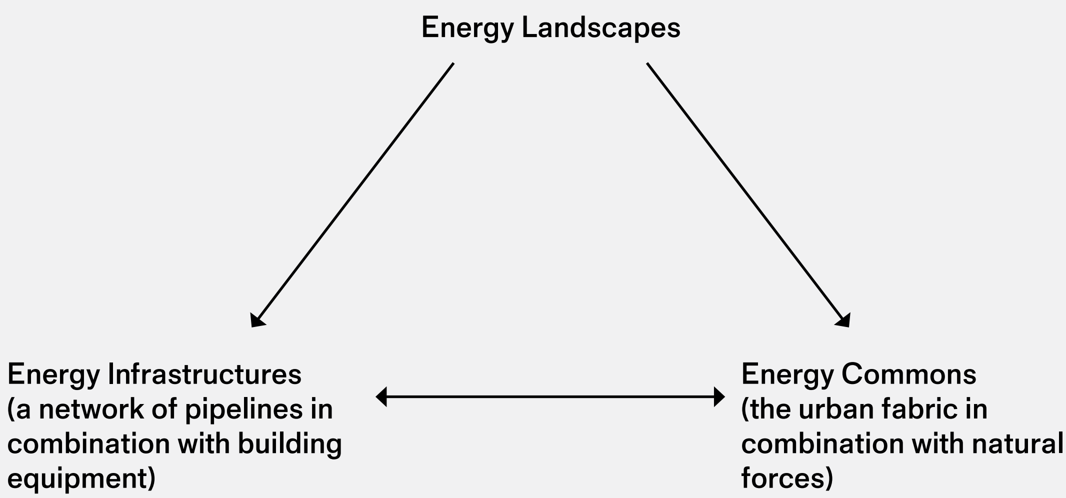
illustrates how the electrification of the city has affected both the indoor and outdoor climate of the high-rise environment. And the analysis of domestic practices in Cairo underscores the ways in which climate mitigation intersects with social relations in the making of a home. The case studies emphasize the fact that the different scales of urban climates—from the room to the house to the neighborhood to the city—are interrelated in the everyday practice of climate control. Cities are not easily governable entities, but are, indeed, "the communities, spaces and political arenas through which change is invented, implemented, enacted and experienced in always specific and different ways."[330] By describing how typologies, floor plans and construction techniques of houses (from high-rise to informal, from communal housing to commercial real estate) have developed historically and are embedded socially, the four chapters point to both the local specificities and global commonalities of a thermal-governance practice.

In the following text, we outline six architecture- and urban-design-related components of thermal governance that shape citizen–climate relations. Following the different traces of thermal governance described in this volume's chapters helps develop a more comprehensive approach to coping with urban climates. Consideration of climate control in the sense of climate adaptation is an essential aspect of thermal governance's efforts towards the energy transition. Thermal governance is also in operation where it is not actively targeted but appears as a by-product of the built fabric: Microclimatic benefits are experienced in the shaded courtyard of a compound that enables inhabitants to congregate, or in the possibility of expanding one's own home through self-build. Microclimatic conditions that deviate from today's thermal standards do not necessarily imply a loss in comfort, but point to an appreciation for the thermal diversity throughout the city and of a lower energy impact. Such diversity offers urban societies new scopes of action for addressing climate adaptation and the energy transition simultaneously. The components of a future thermal governance rely on new perceptions; new constructions; and, eventually, on new communities too.

Component: Energy Landscapes

The energy transition and urban climate adaptation have to be conceived as one and the same process. A new understanding of the contemporary city as a single, integrated energy landscape is a prerequisite for a future thermal governance, one which will intervene at various levels of energy generation, distribution and consumption. Energy landscapes are "palimpsests" (André Corboz),[331] in which human-built systems and natural forces overlap. This energy-related reading of the city's urban climate relies on the idea of the productive urban environment, in which the built fabric, topography, soil, bodies of water, green spaces and the urban climate (sun, wind) all serve as potential energy sources. Understanding the many layers of the energy landscape builds the basis for reducing the energy needed for the construction and maintenance of buildings, shifting towards local energy production and benefitting from the digitalization of energy infrastructures.

Beyond the focus on energy reduction and energy efficiency, however, the case studies in this volume offer a more spatial understanding of what constitutes the energy landscape of the contemporary city. Geneva's energy landscape has been investigated by mapping the water ecologies of the city, which represent an often-unseen territory. The interweaving of natural and man-made elements illustrates how energy was anchored in the territory historically and how it spatially affects the city, its hinterland and everyday life between the neighborhood and the home. Chongqing's energy landscape today was heavily influenced by the 1950s *Huai River Heating Policy*, which divided China into a heated northern part with state-subsidized heating networks and a southern part, where indoor climate control was dependent on residents' socio-economic means. The current trend towards electrification (shifting from polluting coal to carbon-free energy production) affects the social stratification of thermal practices. In Cairo, hot temperatures, the very dense urban structure and the lack of common infrastructure constitute the energy landscape and are manifest in thermal navigation practices and household energy use alike. These cases demonstrate the fact that energy not only fuels the operation and maintenance of buildings but can also be found in the urban environment at large. Such an understanding allows the entire energy potential of a city to be tapped and harnessed in the deliberate design of microclimates.



→ figs. 17, 27, 30, 74, 105, 115, 116, 123, 143, 144, 145

Making thermal governance operational also means that more attention needs to be paid to the material culture of energy landscapes and the related socio-cultural practices.[332] A city's energy landscape is inscribed in bricks and houses, in wires and ducts, in air conditioning and electric devices.[333]Although the materials and technologies used—such as insulation panels, electric heaters and air-conditioners—are similar around the world, the different case studies emphasize how local climate sensitivities, norms of modernity, socio-economic practices and cultures of political and commercial contexts intervene in the application of these items.[334] In Geneva, the couple living in a former industrial building developed a set of material and non-material techniques to control the thermal flows between studio and apartment space. Chongqing residents combined bamboo mats with air conditioning for cooling, while, in Santiago, inhabitants outlined the fact that, besides wearing more clothes in winter, they additionally warm themselves with electric heaters. In Cairo, air conditioning is too expensive for many residents, but for reasons of social status most tend to have it installed. Not only for its use but also as an object, the device is meaningful in meeting thermal expectations.

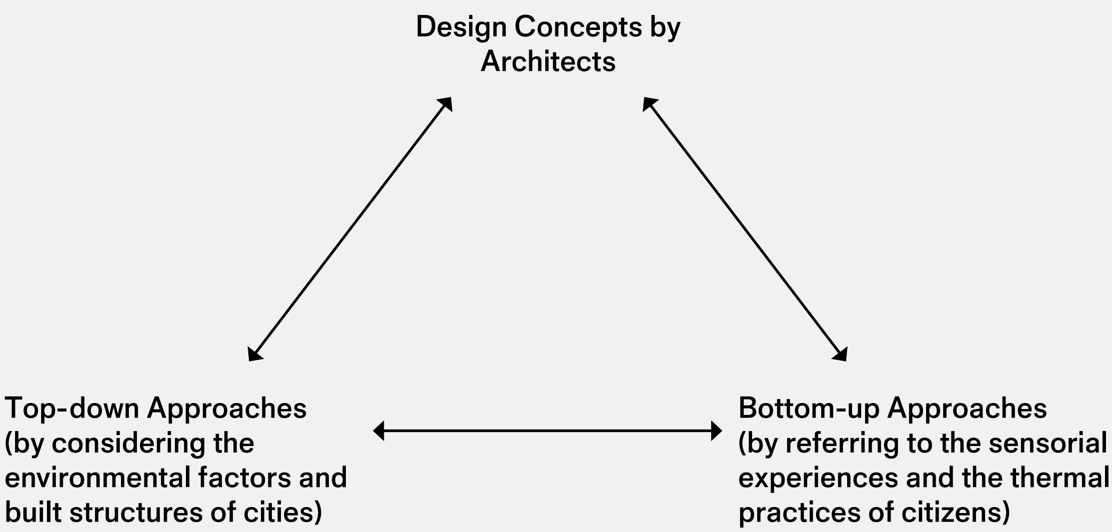
Our ethnographic data outlines the fact that microclimates are closely embedded in everyday rhythms and activities. Retiring to a cooled or warmed indoors is not the only solution sought when trying to stay comfortable. Rather, residents create and make use of different microclimatic conditions, both indoors and outdoors, depending on their socio-economic status and perceptions of comfort. The examples from all four cities outline the fact that energy-dependent devices do not simply replace former non-electric objects for climate mitigation but complement them. By examining the interaction between the individual and microclimates at the interface of the object world, thermal governance promotes a combination of practices, materials and devices to cope with climates. Their assemblage represents "the myriad ways in which people change their energy landscapes in unexpected ways as they go about completing their daily tasks."[335] Thermal governance means first and foremost creating a comprehensive knowledge base of the material culture of a given society that is part of the urban energy landscapes.

→ figs. 38, 78, 109

Component: Thermal Communities

The four case studies promote an understanding of the multifaceted experiences of microclimates and consider the complexity of forces and actors that co-produce urban climates.[336] The diversity of human and non-human factors that may intervene raises awareness of the fragmentation of urban climates in what Dalila Ghodbane refers to as a “mosaic with various thermal environments.”[337] Inhabitants make thermal places in and beyond the dwelling itself. In daily movements between home and work, when doing errands or visiting friends, our informants have made us aware of the inseparable relationship between the climate and other aspects of urban life. Urban climates are experienced by citizens heterogeneously, and depend on status, neighborhood, gender and so forth. The emerging need to think of indoor and outdoor spaces as a single entity stems from the insights of individual residents in all the four cities investigated.

Thermal governance recognizes the different qualities of microclimates in the city and seeks to strategically incorporate the climate-specific practice of thermal navigation into urban development. Thermal navigation can be understood via a sequence of hotter and colder microclimates: an individual strategy to deliberately mitigate heat stress or counter cold. The psychological component of being able to change one’s thermal situation in a given location contributes greatly to overall satisfaction in regard to comfort, even if a microclimate may not seem particularly favorable in terms of its quantifiable characteristics.[338] As the example of Cairo shows, a city may not only lack adequate state management of housing and regulation of its construction sector, but most of its urban area might also lack access to essential infrastructure. Within that dysfunctional context, inhabitants navigate through the city and back to their homes in line with personal knowledge about specific places that offer favorable thermal conditions as relief from the desert’s heat. In an analogue to the Situationists’ drawing of the city as a series of spectacles, our



→ figs. 112, 113, 114, 115

Cairo interlocutors, over time, acquire comprehensive knowledge of locations that are accessible to them and offer some kind of thermal relief. These include shaded alleys, the prayer area of a mosque, the local ice vendor's on the street corner, an air-conditioned mini-market or an underpass to the subway station. Given their daily routes and routines, citizens draw a mental map of the city that connects these different thermal places into a comprehensive urban experience. Cooling in Cairo is described as a multi-scalar strategy between the neighborhood and the domestic space—a continuum of fractionated microclimates, which, taken together, are directed towards cooling the body and, accordingly, make living in the city more bearable.

To guarantee access to the various thermal places within a city, we propose that thermal governance include the idea of thermal communities not necessarily administered by authorities or official bodies but by private initiatives, generating a thermal network based on individual interventions. City governments, such as Cairo's, do not often invest in creating thermally diverse neighborhoods. Therefore, residents could adapt and promote thermal governance at the communal level in their daily lives. Loose associations of actors could contribute to increased comfort in a neighborhood, both by creating thermally pleasant spaces and by making these localities accessible to the general public. In Cairo, thermal agents include inhabitants, shop owners, mobile street vendors, religious venues, supermarket chains, homeowners, landlords, etc. Together, they form a thermal community that is in close contact with the residents of the neighborhood. As an organization, they could orchestrate the collective thermal knowledge of a certain area in a city and could advise on how, in the future, to best adapt neighborhoods to changing climatic conditions. By leveraging the resources already in place, such associations could likely act in a fraction of the time it would take authorities to accomplish the same or similar (thermal) results. The coordination of a thermal association based on a multitude of individual decisions might be best tackled at the scale of the neighborhood or the district. Led by an elected collective, the association could help coordinate various thermal initiatives, serve as a reception center and function as a mediator between the government and the residents. Such organizing principles can be well established—as shown, for example, by the case of the *Association d'Usages des Bains des Pâquis* in Geneva. There, the collective contributes not only to maintaining the bath as a place of thermal relaxation but also to promoting various cultural initiatives, thus creating a meaningful interface among people from different social backgrounds.

However, public authorities also bear a responsibility for thermal governance. They can establish key localities for cooling or warming as urban thermal infrastructures. Public buildings, greened alleys, blue infrastructure or park spaces could readily function as thermal escapes to mitigate urban climate effects. One such example can be found in Santiago's socialist housing project, *Villa Frei*, whose integrated park spaces became a kind of urban commons that was enjoyed by residents even from outside the neighborhood. Privatizing greening and reserving green spaces for the well-off in gated compounds both undermine the right to create a wide variety of microclimates. Similar to what 20th-century planning concepts envisioned for Geneva, thermal governance advocates for meaningful links between the various thermal communities and sites within a given city.

→ figs. 23, 25, 50, 53

Component: Infra-architecture

The recent debates on the energy transition have given buildings new relevance in governing urban environments.[339] The close interdependency between architecture, infrastructure and governance is apparent in all chapters. Whether we talk about electricity infrastructure in Chongqing, water infrastructure in Geneva or oil infrastructure in Santiago, the construction, maintenance and inhabitation of architecture depends on energy provision that is distributed through specific facilities and governed by both public and private entities. Through this process, the urban built environment becomes "inherently political, social, and dynamic, extending beyond its merely functional value."[340]

Lorenzo Stieger's notion of an "infra-architecture" addresses this extended meaning of architecture particularly. Taking Geneva as a case study, he demonstrates that infra-architecture not only includes the tubes and hydroelectric plants but the cultural and climatic value of Geneva's waterfront, as well. Water infrastructure here contains much more than simply a means for energy transfer. To date, it has provided a wide range of ecosystem services: from the enjoyment of waterfront promenades in the 19th century to the natural restoration of select riverside areas and installation of ever more bathing opportunities in recent years, to the technological exploration of the water resource to heat and cool buildings. In short, natural elements become thermal infrastructures of architectural and social relevance. The analysis of the historical development of Geneva's waterfront illustrates how urban nature, energy concerns and socio-climatic requirements manifested over time, and how a complex infrastructural system was integrated into the physical and cultural fabric of the city. In its spatial dimension, infra-architecture also reaches far out into the surrounding territory while appearing differently in various localities. Depending on the context, natural, technical or structural elements of this infra-architecture predominate, emphasizing features that resemble aspects of either green or blue infrastructure. Socio-cultural aspects, such as tourism or bathing, are well established in these meeting places, and are physically manifest through architectural expression.

The more likely it is that challenges related to urban-climate and energy issues are embedded in a functioning state system with the appropriate financial resources, the greater will be the prospects of addressing urban climate change through a synergistic interplay of urban nature, architecture and infrastructure. As highlighted in the case studies, this publication argues, in light of the energy transition, for novel advances at the interfaces of these three domains. While the interaction between two—for example, urban nature and infrastructure,[341] urban nature and architecture[342] or infrastructure and architecture[343]—has been well explored for energy production and climate control, the amalgamation of all three aspects has not, to date, evoked a precise imaginary in terms of their technical and formal aspects.[344]

Infra-architecture as such has yet to be developed, and its interdisciplinary dimension requires close collaboration between architecture, administration, industry (e.g. energy companies), environmental and even cultural institutions to fully realize its potential. By controlling the urban climate in central locations in the city, infra-architecture has the potential to shape the nature of the city as a collective experience and influence the sphere of everyday urban life.

→ figs. 20, 22, 23, 28, 30

Component: Urban Façades

Conceptualizing the façade as a space-creating urban interface is part of a long tradition in architectural and urban history: public spaces—such as colonnades, atriums and arcades[345]—as well as semi-public spaces such as porticos, hallways and winter gardens are familiar representatives of the spatial mediation between the outer and the inner spheres of the city, especially as pre-dated the proliferation of energy-intensive building services.[346] In the words of Indian architect Charles Correa, "[b]etween the closed box and open-to-sky space there lies a whole continuum of zones with varying definitions, and degrees of protection. One steps out of the box to find oneself … in a veranda, from which one moves into a courtyard, and then under a tree, and beyond that to a terrace covered by a bamboo pergola, and then perhaps back into a room and out onto a balcony … and so forth. The boundary lines between these various zones are not formal and sharply demarcated, but easy and amorphous."[347]

The case studies in this volume emphasize the need for an urban scale of climate control and energy conservation. The formulation of an energy-related successor to architectural designs that systematically emphasize buffer zones has yet to be developed on the scale of the city. Although in the field of architecture there are numerous references to the energy implications of winter gardens, glazed loggias and other buffer zones, the approach remains limited to the individual building and was developed within the applicable legal framework.[348] By spatializing the thermal interface between indoor and outdoor conditions, thermal governance will enable residents to experience various microclimates and deal with energy challenges in new ways. We argue that rather than living in conditioned indoors or unconditioned outdoors, a fundamental shift for pushing the energy transition in architecture is possible. It demands reconsidering the role of buildings—not as autonomous enclosed containers but in terms both of their relationship to their surroundings and their influence in creating urban microclimates.[349] Urban design can control the circulation of heat, cold, wind or humidity between and within buildings depending on the positioning and materiality of the built environment.[350] However, on an urban scale, it is still undetermined whether the characteristics of urban intermediate zones would resemble indoor or outdoor conditions and how they should ultimately be used as (urban) space. Appropriate functional dedication of these intermediate zones, which also serve as thermal buffers, is decisive for targeted energy savings.[351] Which uses can best be implemented at such thermal interfaces might best be determined and supported through thermal governance.

→ figs. 6, 38, 50, 105, 134, 138

To consider the city as one indoor environment allows us to challenge the fundamental role that the insulation layer has played in the last few decades, and the common perception of its value in saving energy. In our current understanding, the insulation is not accessible nor does it have any representative or social value as a climate-mitigating strategy. By rethinking the façade as an accessible and usable interface, rather than as a divider between internal and external microclimates, thermal governance aims to reduce the energy required for climate control indoors. That prospect includes the ways in which neighborhood spaces, rooftops, hallways, semi-public gardens and public squares are interlinked, but also features interfaces that break with clear-cut thermal boundaries. Following Abbé Laugier's famous *Essai sur l'architecture* of 1753, which states that the design of a city's "façades" cannot be left to the will of individuals, contemporary thermal governance advocates for façades as space-creating urban interfaces and serves as a leading tool for the climate-responsive urban design of the future.

A new, multi-scalar urban architecture that takes interrelations between spaces into account aims to challenge the current understanding of comfort that relies on the idea of a sharp division between inside and outside. Vast amounts of energy today are invested to sustain this thermal division for the sake of indoor comfort. Technical innovation in the fields of (active) thermal infrastructures and devices do not sufficiently counterbalance, or even reduce, the energy needs for climate control. It is, therefore, inevitable that space-based interventions in architecture and urban design beyond the technical domain of building equipment should be targeted for development. To this end, new thermal governance must critically examine existing laws and regulations that emerged from the carbon-based urban-planning arena.

Component: Thermal Zoning

Zoning is the fundamental procedure for administering the urban spatial order between public and private.[352] A new zoning practice, which takes the urban climate into account, will affect a large number of stakeholders; it will require substantial revision of current zoning regulations in cities across the globe. Many interests would be affected by such considerations, and clearly challenged by new design principles that claim urban land for a collective thermal cause that lies beyond individuals' own financial means. Historically, the city of Stuttgart (Germany) has been exemplary both in developing superordinate zoning criteria for urban design and in providing an "urban climate primer"[353] for architects and urban planners alike.[354] Since thermal zoning considers the dynamic character of climate, a new understanding of equity must be created. Current zoning postulates equal "rights" (such as building heights) and "obligations" (such as spacing) for the same type of development in a given area. A superordinate perspective that considers climatic factors implies that interactions between buildings require the acceptance of physical "inequalities" on similar plots to establish cooperation between natural processes and the built environment. Formal differences may be balanced by other means to ensure equal economic value for property owners.

In the future, government institutions, in collaboration with urban planners and architects, will be charged with developing urban landscapes that mitigate overheating and other climatic threats. Providing green and blue spaces throughout the city via zoning is one way to intervene in urban temperature management, one that makes thermally beneficial outdoor spaces accessible to everyone. Even on a smaller scale, be it a street or a house, thermal zoning allocates the necessary space for (thermal) interventions. Depending on local climatic conditions, the clever integration of the available energy sources at all scales—be it solar, wind, hydro or other renewables—is a prerequisite for the city of the future. Affirming that the use of the outdoors is more season-dependent than that of the indoors, thermal governance must value the capacity to regulate heat in public spaces. In times of ever-warmer urban microclimates, energy-independent outdoor spaces have a key role to play in architecture and urban planning. Urban heat-island effects emerge due to densely built fabric and its materiality. Even Geneva, the smallest of the four cities, reports temperature differences of up to 10°C between the inner city and the surrounding countryside, and the same difference has been measured in Chongqing. Although cities like Cairo have always dealt with hot summers, man-made changes in recent times have exacerbated heat-related problems. The inclusion of climatically effective public spaces in urban design by means of thermal zoning will not only influence the well-being of residents in the future but will also have an impact on the real-estate sector and the economic attractiveness of cities.

→ figs. 29, 71, 96, 97, 141, 142, 144, 145

Reconceptualizing the relationship between inside and outside from an urban climatic perspective means that access to favorable outdoors—including green spaces, water bodies, shaded places, etc.—must be the imperative for new architectural concepts. All of the cases in this publication emphasize the sensitivity and inventiveness of residents to search for and enjoy outdoor spaces, depending on the season and time of day. Cairo residents make use of cooler outdoor temperatures at night to do errands or to gather socially along the cooler Nile riverside. In Chongqing, the lack of heating infrastructure makes people's apartments cooler in winter, so residents take walks in their neighborhoods to keep warm. Dipping in Lake Geneva was a way to get relief from urban heat well before the first public baths were built at the turn of the 20th century. While individuals mitigate warmer temperatures through their own choices (such as seeking shade, adjusting daily rhythms or clothing), governments have a responsibility to provide consensus-based solutions that benefit all segments of the population. A contemporary thermal governance must not only consider inequalities in accessing microclimates, both indoors and outdoors, but must also develop thermal zoning on the scale of the city to overcome potential barriers between private and public interests.[355]

Component: Maintenance and Care

Since cityscapes emerge over decades, climatic interventions must address both the existing and the planned building stock. In this sense, consensus-building between all the stakeholders affected by an intervention typically takes a long time and is no guarantee of a successful outcome. In particular, urban development based on democratic principles is hardly compatible with the large-scale concepts of popular master plans. Time-critical solutions can therefore fail at an early stage or are not considered at all, given the dire prospects for their completion.

There are limited resources that any society can devote to the provision of private or public infrastructure and its maintenance. Decaying or collapsing infrastructure systems in industrialized countries are proof of high financial investment being a major obstacle to securing the long-term benefit of collectively used structures. Future investments in urban climate adaptation and the provision of mitigation infrastructure have to be mindful of funding and maintenance challenges. Infrastructures are very likely to be neglected if the economic power of a state decreases. Already today, the proper maintenance of centrally located, open spaces requires very high "energy inputs," as Michael Hough notes, referring to the two landscapes coexisting in cities: the "nurtured 'pedigree' landscape" and the somewhat forgotten "fortuitous landscape."[356] Wastelands in urban areas could be revitalized for thermal governance, yet they are often deemed "leftovers" while, in fact, they could offer a breeding ground for botanical diversity and social activities.[357]

The maintenance of climatically beneficial spaces on a smaller scale should rest in the hands of city residents, and not only for financial reasons. Particularly in dense urban areas, an increasing number of dwellers who have lost touch with the rural environment cherish the notion of managing and maintaining some sort of green space. In northern countries, this is reflected in the high demand for a balcony, terrace space or participation in a community garden.[358] Urban climate-change strategies postulate the need for such spaces in cities, which city dwellers could develop and maintain. Thermal communities could play an important role in managing open spaces or in defining specific purposes for climate-change mitigation and adaptation, should government funding be insufficient or entirely unavailable. This requires the state to allow public space to be cared for and maintained by individuals and communal organizations. The work-time investment of individuals would, in turn, be gratified by access to these spaces, thermal benefits and even financial gains. Cities could well benefit from the inventiveness that results from such bottom-up space management. The potential richness in solving climate issues from the perspective of city dwellers could both reduce costs and increase efficiency in future planning. Furthermore, the identity of a specific area could be strengthened if administered by the local community. Thermal governance takes place on different scales and must enable different actors to maintain urban microclimates. Bottom-up interventions to make green spaces accessible for everyone are as much needed today as the governmental intervention to guarantee access to blue infrastructure.

→ figs. 57, 75, 96, 100

Toward a Design Methodology

Since the second half of the 20th century, the built environment in cities around the world has been shaped by the legacy of fossil fuels. The energy that continuously flows through our pipes, grids and power plants in the form of oil, gas or electricity builds a framework for the materiality and maintenance of urban architecture.[359] Burning fossil fuel has left traces not only in the urban climate in the form of pollution and urban heat but also in the spatial organisation of the city. According to Elisa Iturbe, “architecture cannot address the causes of the climate crisis without recognizing carbon modernity as a continuous cultural and material foundation for building and form.”[360] The imperative of integrating indoors and outdoors to reduce environmental and thermal loads in cities is the primary challenge identified within this publication. Thermal governance challenges the existing notion of climate control for individual buildings by promoting synergy and coordination within the urban built fabric.

Having relied heavily on the prerequisites of infrastructure, modern architecture has failed to recognize energy potentials that could be found in its immediate surroundings. To investigate synergetic relationships between elements of the built environment, the unseen components that shape the urban climate must first be made visible (to architects and planners) and their impact made explicit (to governmental figures and investors). The mapping and simulation of climatic conditions are important means of visualization and, as such, drivers for adapting microclimates consciously. The elaboration of the properties and dynamics of the microclimate’s constituent elements gives them an object character and, consequently, an objective character. As in the Geneva case study, the use of technical equipment to record indoor and outdoor atmospheric conditions is a key step in collecting the necessary data. A second step is to simulate and predict urban climate dynamics by using computer models, a technique many city administrations use in order to develop climate scenarios. In the future, microclimatic factors will have to play a central role in architectural design, as well as in the procedures of administration and planning, if the discipline aims to make a recognized contribution to climate debates and resource conservation. Including climatic factors in the decision-making process will also contribute to the development of solutions for energy conservation.

→ figs. 4, 11, 32, 58, 98, 143, 146

However, quantitative data is only one of the components that inform the qualitative discourse on urban microclimates. Urban planners and designers must also consider thermal realities experienced by residents in the places of intervention; they should understand the economic, political, social and cultural aspects that intervene in climate control. Energy pricing, governmental infrastructure investments or social expectations impact urban climates just as wind speed and humidity do. Ethnographic research can provide valuable knowledge about the interactions between societies and climate. Investigating everyday practices around dwellings that include the inhabitation and maintenance of built structures is crucial for the comprehensive thermal-governance perspective for which we advocate. The education of architects towards climate-sensitive design must be informed by both quantitative meteorological and qualitative socio-climatic data. The exchange of urban-climate-related information has yet to be established in educational institutions. Climatic and energy arguments must be integrated into the syllabus and design rationale of contemporary architecture and competition calls. A willingness to reshape the microclimatic landscape of the urban environment extends well beyond the technological progress made in one building. Rather, the recognition of urban microclimates as cultural artifacts spurs the development of architectural responses that meet the social demands of the city's inhabitants and creates thermal connections between its urban spaces as well. The four case studies provide initial approaches to formulating relevant components of thermal governance. However, new design methodologies that address urban climate as a core issue of the future city should aim to continuously identify additional components and continuously expand the body of knowledge about thermal governance. Thermal governance would do well to combine insights from urban climatology, ethnography and architectural design practice.

New Urban Climate Protocols

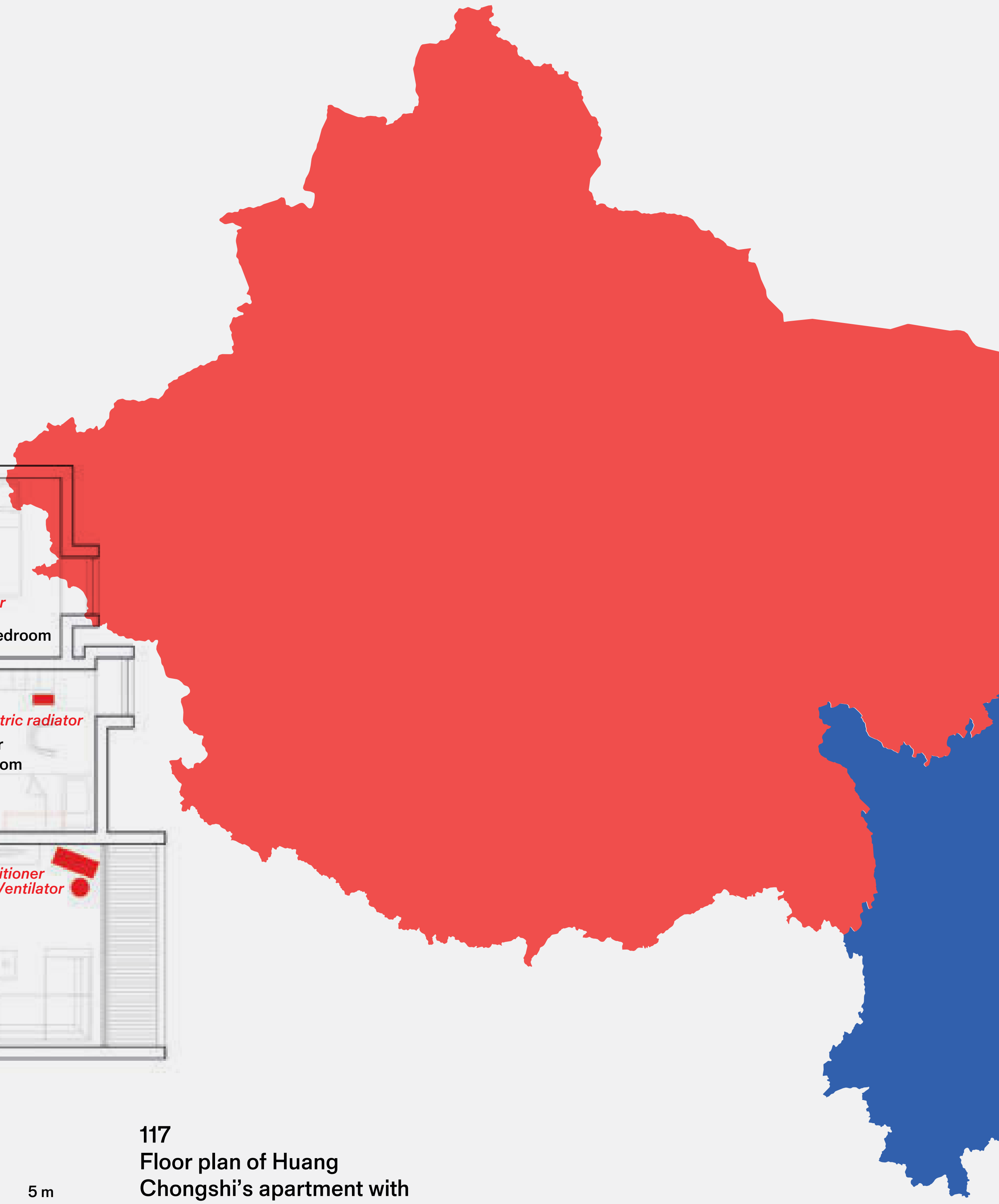
Visualizing Socio-climatic Differences

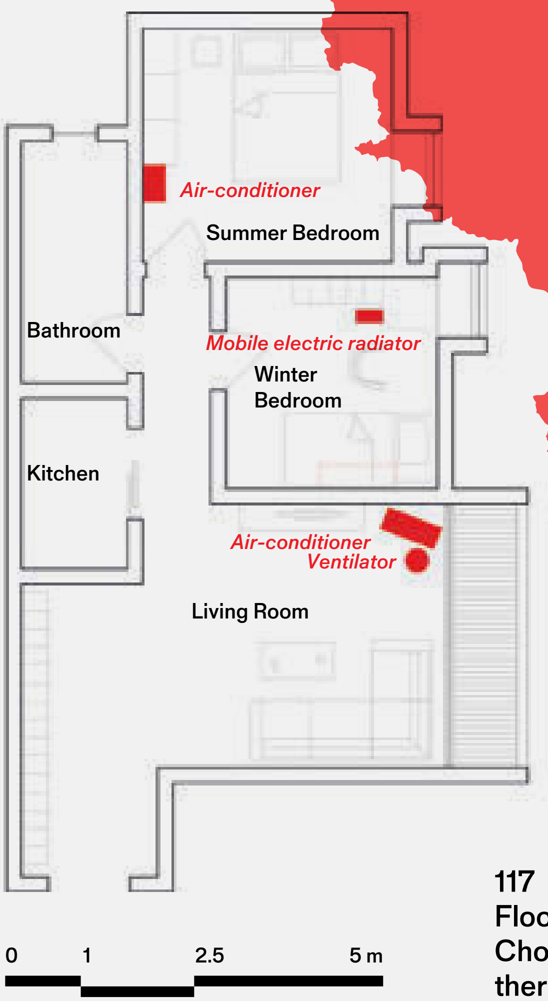
Sascha Roesler, *Madlen Kobi*, *Lorenzo Stieger*, *Chandrasekhar Ramakrishnan*, *Adrian Ehrat*; with the support of *Lionel Epiney* and *Dalila Ghodbane*

For each of the four cities, mappings and visualizations have been generated based on seven parameters: surface temperature, population density, income distribution, real-estate prices, topography, urban green and water bodies. The data sets were collected from different sources to visualize select factors that interrelate with the man-made character of urban climates. By overlaying physical and anthropogenic parameters graphically, patterns can be extracted that illustrate how urban climate must be considered a fundamental player in contemporary urban design. One of the pressing issues of the 21st-century city concerns the impact that the urban climate has had, both on inhabitants' everyday life and the socio-economic configurations inherent in the built environment. The implications of urban climatic change on the economic and social aspects of urban societies deserve more attention.

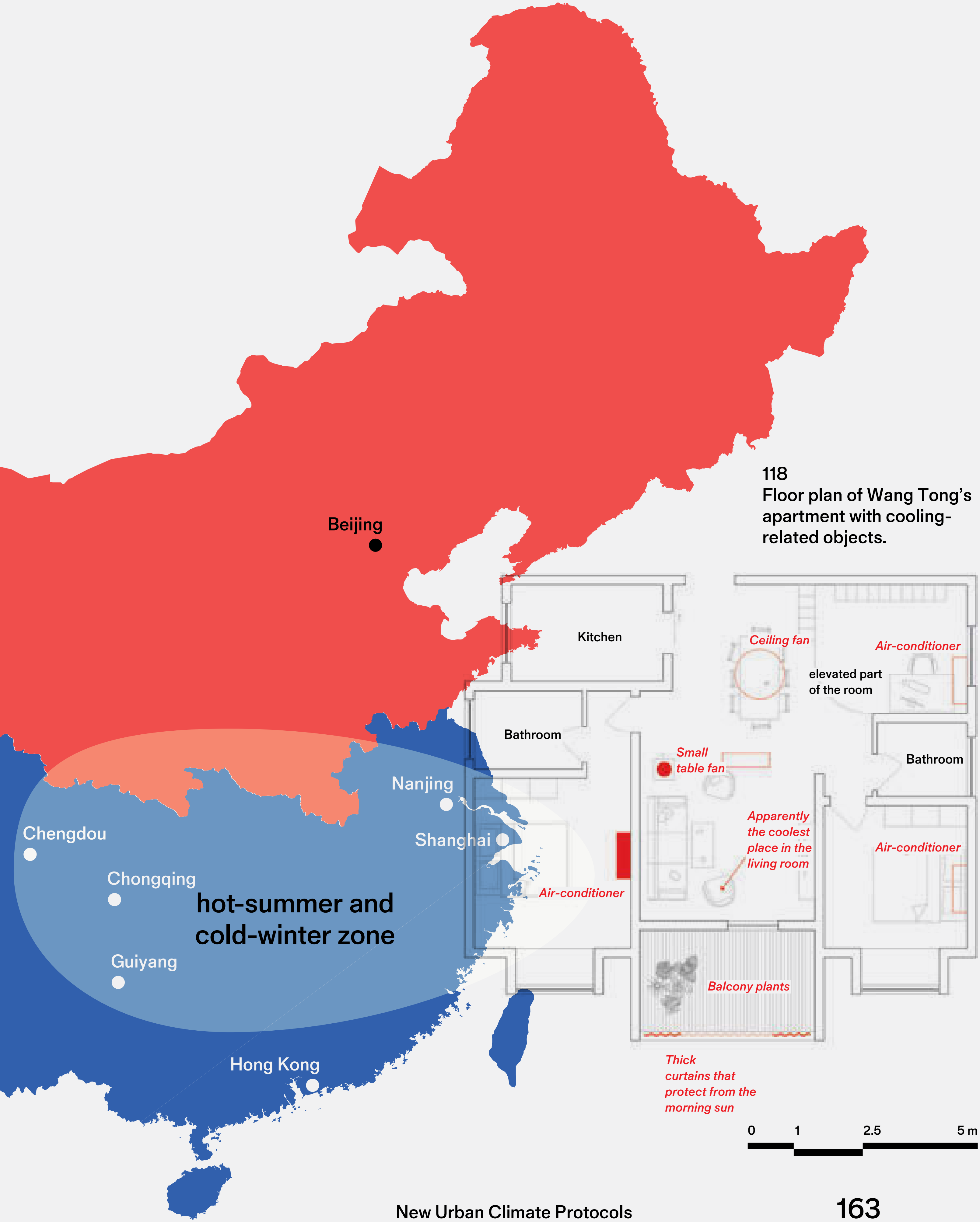
These Urban Climate Protocols document a new methodological approach that highlights the interplay between urban climate and urban dwelling. Despite the striking differences between the four cities studied and their geographical locations, the Urban Climate Protocols formulate initial theses concerning the interrelationships between climate, urban architecture and citizens. The analysis gives insights into the general thermal conditions in the four cities, but also points to potential scope for future thermal governance. The comparison tests the extent to which generally valid statements can be applied to a work area that, globally, is increasingly gaining in urgency.

116
China’s Great Heating Divide, dating back to a policy from the 1950s when the communist government under Mao decided to install heating infrastructure only in the northern part of the country.





117
Floor plan of Huang Chongshi’s apartment with thermal objects in red.



118
Floor plan of Wang Tong's apartment with cooling-related objects.

Mapping Methodology

Our critical goal is that the visualizations enable comparisons, both within each city and across different cities. To avoid confusion, we have standardized all data on a resolution of five levels for each parameter, ranging from “lowest” to “highest.” The data was provided in various formats by the authors of the individual chapters, depending both on availability and accessibility. The level of detail and accuracy of information varied widely across the four case-study countries. While GIS-based file formats were the easiest to work with, the greater part of our information had to be derived from documentation in pdf-format, or extracted from pre-processed graphic images in the format of jpeg and alike.[361]

To make comparisons between the four cities possible, the following challenges related to the heterogeneity of the various data sets had to be overcome. Their diversity derived from differing scales, resolutions, quality of information and boundaries of the data provided:

- ↘ One source of heterogeneity is the fact that the regions are different in fundamental ways. This informed our decision to visualize by using relative scales within each city—a choice made in order to emphasize the local variation, even if at the expense of some global variation.[362]

- ↘ Another source of variation is the fact that the data sets had different data resolutions, sometimes even within a single region.[363]

- ↘ A further discrepancy between data sets was the geographic area span. As in the other cases, this manifested in two ways: first, regions may be larger or smaller (Chongqing, for example, covers an area larger than Santiago); second, not all the data sets within one region encompass the same area.[364]

In a first step, images were geo-referenced by our data-visualization specialist. Subsequently, and by using a color-value analysis, the image material was converted into geographical data so that it might be analyzed and compared. While relatively complete data sets were available for Geneva and Santiago, the data sets for Chongqing and especially Cairo remained incomplete. However, the Urban Climate Protocols do not rely on quantitative data alone but always include the comprehensive knowledge of the individual authors based on their own field research. The Urban Climate Protocols try to draw a plausible picture of the four cities’ socio-climatic differences.

Surface Temperature

Pronounced heat-island effects are a common characteristic of urban climates today. In Cairo, Chongqing and Geneva, several areas with very high temperatures are located within the city. In Santiago, on the other hand, urban heat tends to be concentrated in the northwest of the city and fades out towards the southeast.[365] While in Santiago, urban areas with low temperatures tend to be characterized by high real-estate prices, this correlation between urban temperatures and social strata is less evident in Chongqing. There, high real-estate prices are found in both low- and high-temperature areas and different socio-economic classes live dispersed over the city territory. In Cairo, temperatures are high in all areas—in the city center, owing to the sheer mass of tall houses built very close to one another, and, in the suburbs, because of the lack of shade in the desert. Interestingly, the comparison with economic data shows that in Cairo and Chongqing, people with higher incomes tend to live in areas with high surface temperatures. Whereas in Chongqing, they tend to be located in the (overbuilt) inner city, in Cairo, that financially sound group tends to reside both in the inner city and the satellite towns in the desert.

Population Density

Population density illustrates which areas of the investigated cities have the highest number of inhabitants per square kilometer. Based on population density, specific conclusions can, in most cases, be deduced about the building typology and the type of settlement patterns. Depending on the context, a historical assessment of architecture, combined with city-specific knowledge, provides further insight into the urban and social conditions of a particular area. Santiago's population is relatively evenly distributed throughout the urban area, while Geneva, Chongqing and Cairo have pronounced population densities in their centers. Apart from selective high-rise areas in the east of the city, Santiago is predominantly characterized by low-rise, low-density architecture. Poorer, middle and wealthy strata of the population are equally represented by this form of urbanization. In Geneva, it is primarily the lower and middle classes who live in multi-story apartment buildings in the center while a large part of the population prefers the single-family house, often located on the outskirts of the city, to other forms of housing. Chongqing's middle class, in particular, lives in high-density, high-rise housing developments—dwellings shared by lower-income people who prefer to live in both higher- and lower-density neighborhoods, depending on whether they live in low-rise suburban areas or in newer mid- and high-rise buildings. While the densest area in Geneva has some 20,000 people per square kilometer, the densest area in Chongqing houses around 40,000 people per square kilometer.

→ figs. 119, 120

Income Distribution

Urban areas are unevenly populated by different socio-economic groups. The spatial patterns of affluence reveal the socio-economic stratification of a city. In most cases, such distribution also provides information about the infrastructural development of an area. While cities like Santiago feature clusters where the wealthy live, other places, such as Chongqing or Geneva, see socio-economically poor and rich people intermingling more.[366] Geneva shows quite an even distribution of green space between different income levels in the canton. The numerous smaller villages scattered throughout the Greater Geneva area that are part of the analysis perimeter, and the historically based urban-planning concept of interlocking the city with green spaces, are two of the reasons why Genevans with lower incomes also benefit from access to green spaces.

Real-estate Prices

Real-estate prices reflect the land value in different parts of the city, their distribution showing specific local patterns of site developments and the attractiveness of certain areas. Depending on available data, the maps represent either rents or land prices per square meter.[367] Up until now, the real-estate markets in cities such as Geneva, Chongqing and Cairo have neither taken urban climatic conditions into account nor classified the market price of rental flats according to locational advantages—namely, the central location and attractiveness of neighborhoods. In densely populated areas, thermal and green conditions are most likely to be negated due to urbanization pressures. High temperatures and high real-estate prices in the urban center are congruent in the cases of Geneva and Chongqing. In Chongqing, high property prices show a preference for certain areas—namely, those already heavily built-up and well connected through transport infrastructure—but their temperatures tend to be even higher (around Jiangbei International Airport in the north, on the *Yuzhong Peninsula* and in *Shapingba* district). Prices fall in less-central or less-attractive locations, even though they sometimes offer better living conditions from an urban-climate perspective. In Geneva, the central location of water bodies and the associated aesthetic enhancement of outdoor space are a larger driver of real-estate prices than green spaces are.

→ figs. 121, 122

Topography

Hills and plains strongly influence both the layout of a city and its urban climate. While the topography maps provide an overall idea of altitudes, the altitude range in Cairo only varies some 200 meters (between 4 and 223 meters above sea level) and some 800 meters in Chongqing (between 175 and 1,000 meters above sea level). In Chongqing, areas with low temperatures are those in the hilly and green surroundings, which are typically less populated. However, there is no significant relationship between a particular modern building typology and settlement pattern with the corresponding topography of the urban area. In Santiago, on the other hand, the highest real-estate prices are paid in the hillside areas near the mountains—especially in neighborhoods such as those in *Lo Barnechea*, *La Dehesa* or *Las Condes* to the east of the city. Here, the temperatures at night can be quite low. In the other parts of the city proper temperatures, however, temperatures tend to be in the middle range, since Santiago has a temperate climate with some temperature variations between day and night.

Urban Green

Chongqing and Geneva are both very green, with the outer edges of their urban areas almost completely greened. Santiago has green patches dispersed throughout the city territory, but least in the western areas of the city. In Cairo, there is a general lack of green spaces in and around the city due to its geoclimatic location. Moreover, the few remaining green and arable areas along the course of the Nile are falling victim to the ongoing urbanization. While Geneva has a good number of public green spaces, Cairo, with its location in the desert, has few parks or green areas. However, middle- or high-income residents in both cities tend to live in green areas. In Cairo, the middle and upper classes live either in the few greener areas in the inner city or in gated communities in suburban areas. As man-made islands that promote greening as locational advantage, these compounds are greener than residential neighborhoods in the central districts.

Water Bodies

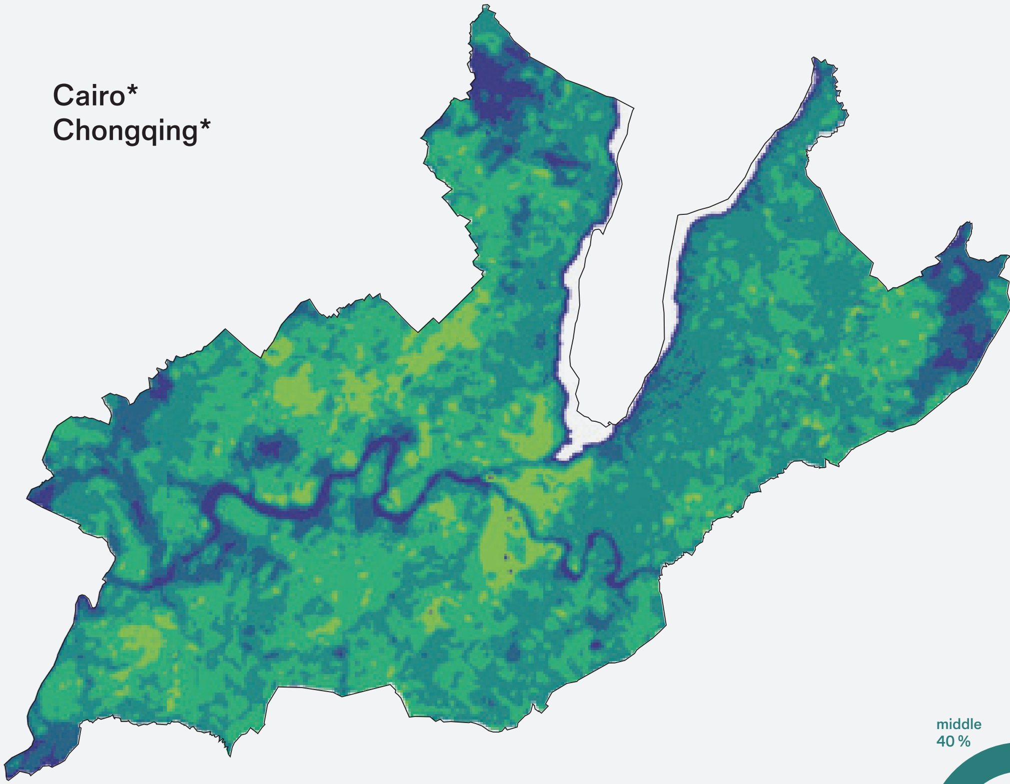
Cairo and Chongqing are situated on two of the longest rivers worldwide, the Nile and the Yangtze. Chongqing promotes itself as a “Mountain and Water City” and its river view represents a locational advantage, although the riverside as urban commons with thermally beneficial conditions, unlike the lakeside in Geneva, is barely exploited. In Chongqing, the river mainly serves for the transportation of goods and tourists alike, but its steep concrete embankment impedes easy public access in most places. In Cairo, access to the banks of the Nile is also very limited but its reclamation for the general population could, conceivably, make an important contribution to counteracting thermal stress in the neighborhoods. With the Nile, Cairo would then have an exceptional blue infrastructure of territorial scale that could provide public spaces with cooler conditions. Geneva is characterized by its location at the southern end of Lake Geneva and by the several rivers that flow through the city’s territory—rivers which were formed by glaciers, first in the Ice Age but still today. Here, access to the water was secured for the inhabitants, whereas a direct influence on the thermal characteristics of the different residential quarters cannot be proven. By contrast, Santiago is relatively water-scarce with only the Mapocho River in its north, whose water level is highly dependent on seasonal characteristics. As such, open waters have little influence on Santiago’s urban climate while other natural features and the general altitude of the city are among the key elements that positively influence its urban climate.

→ figs. 123, 124, 125

119
Surface Temperature

Geneva
Santiago de Chile

Cairo*
Chongqing*



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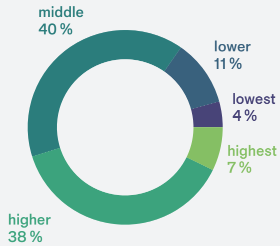

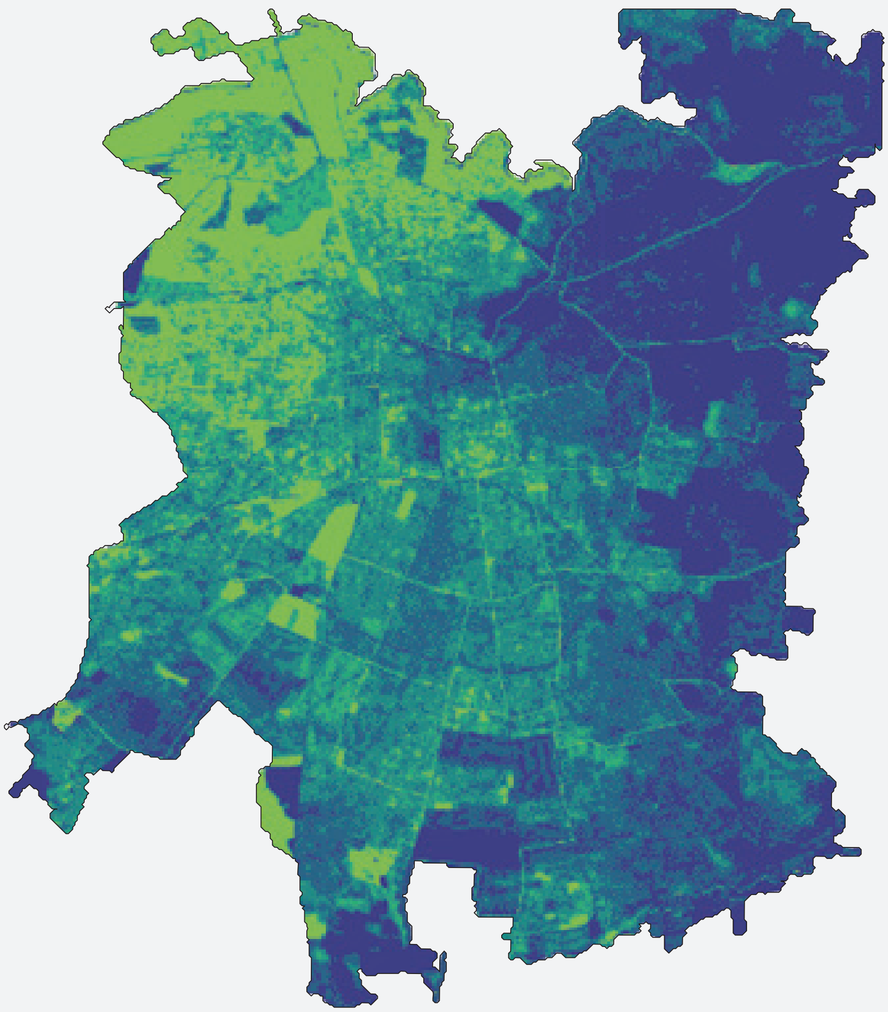

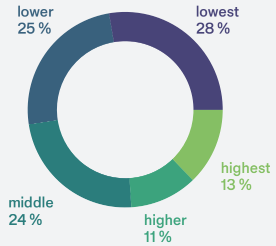

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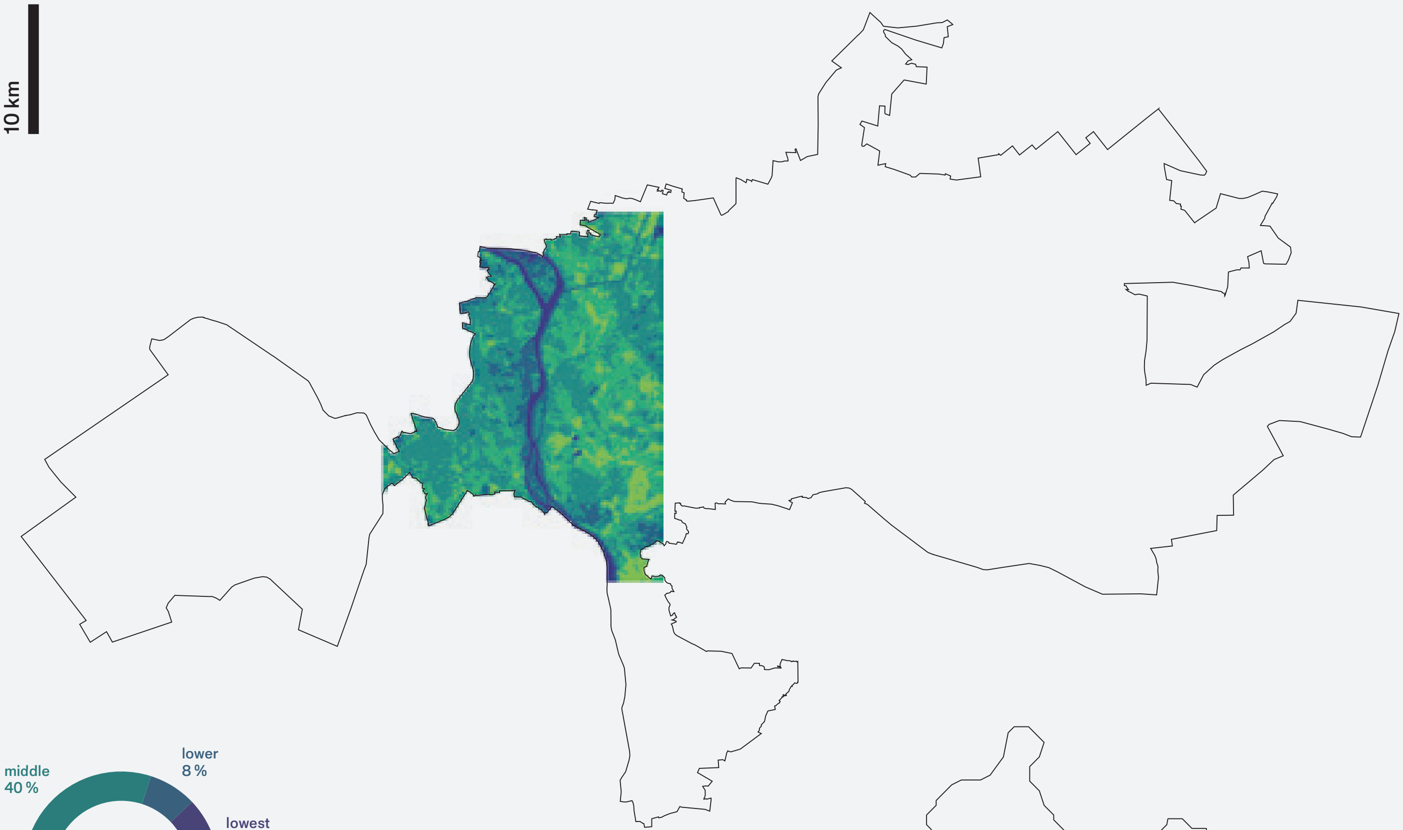

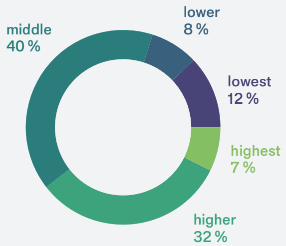

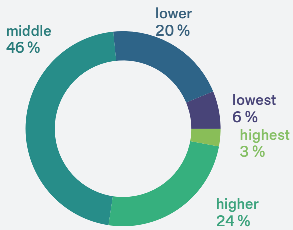

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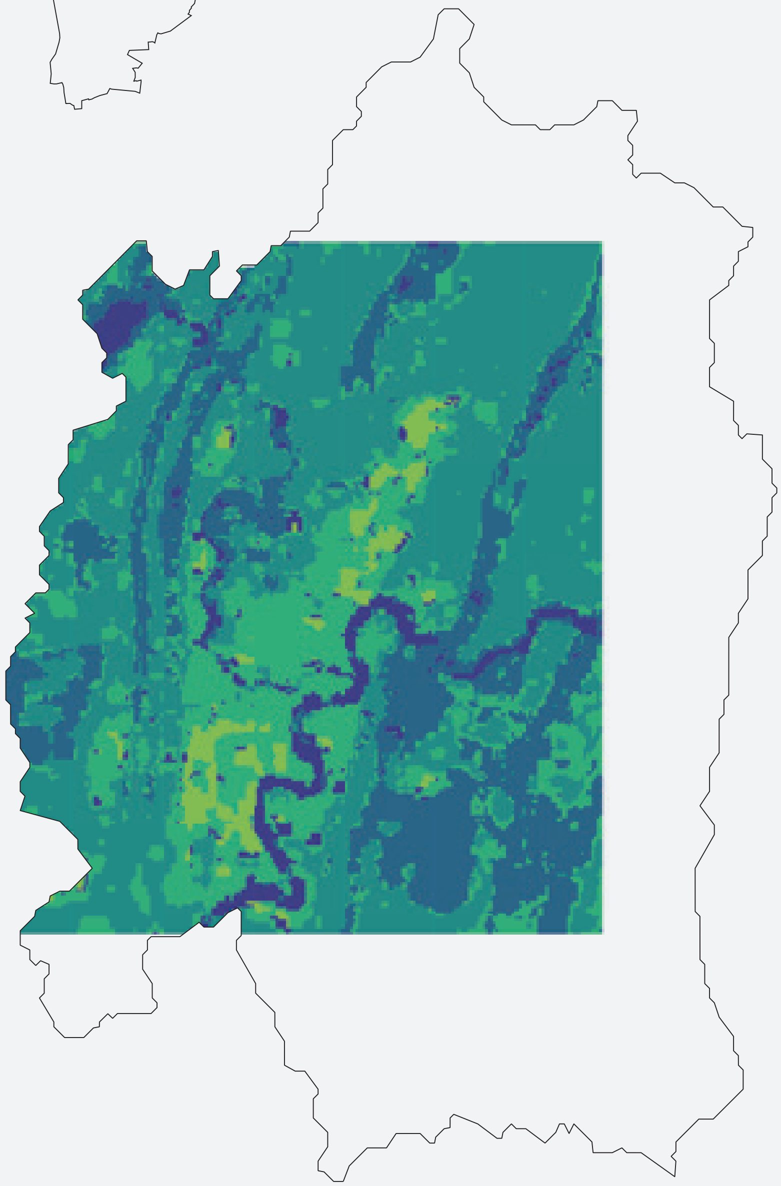


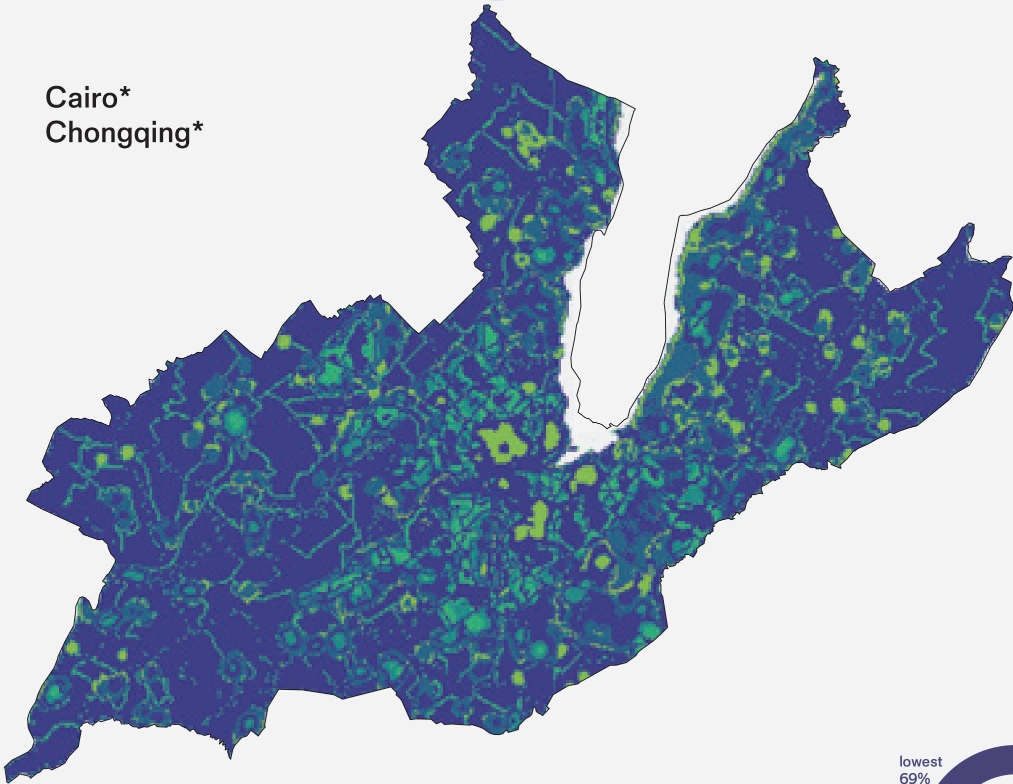
10 km

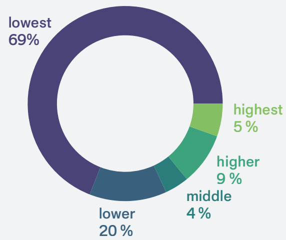
120
Population Density

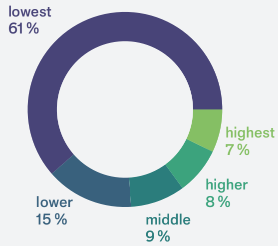
Geneva
Santiago de Chile

Cairo*
Chongqing*

10 km







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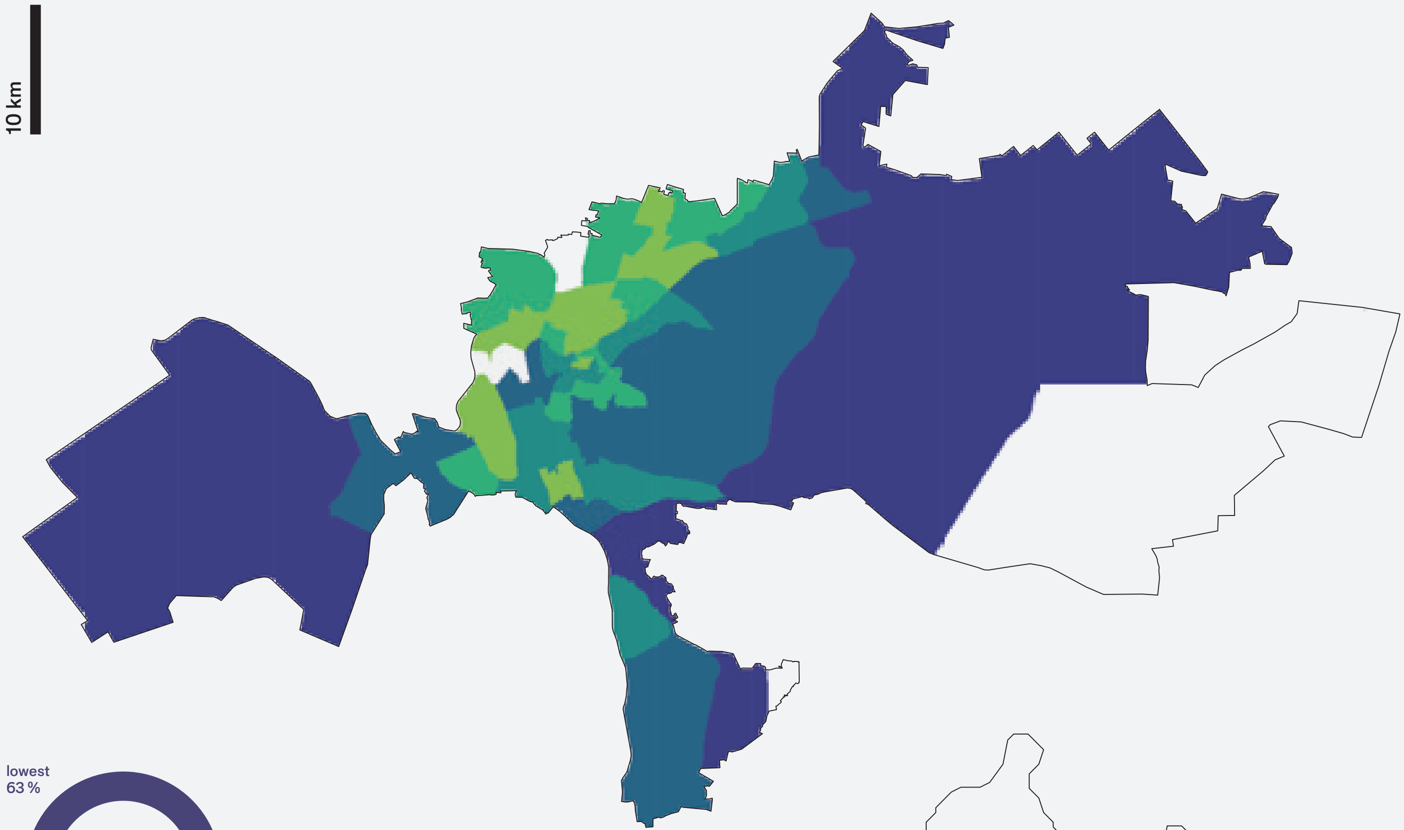

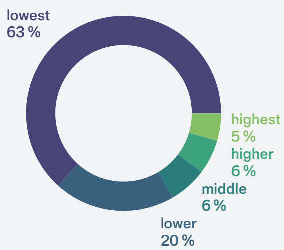

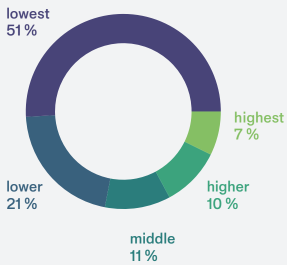

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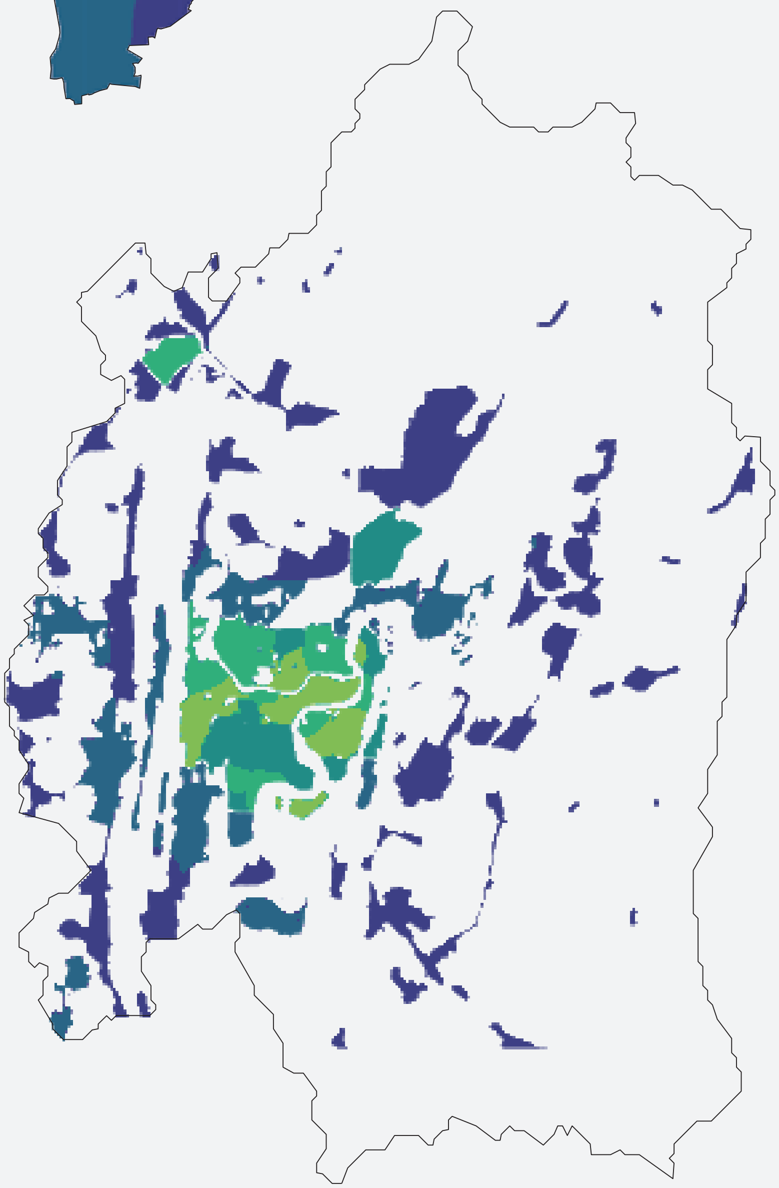
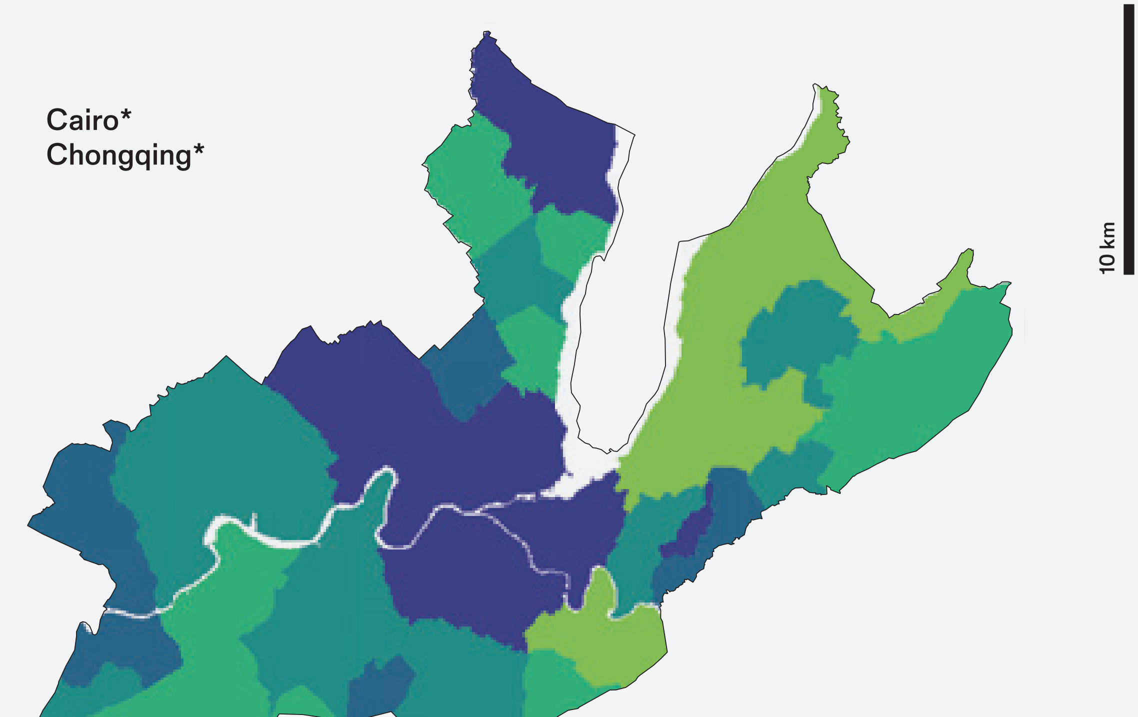
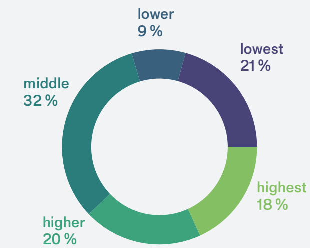


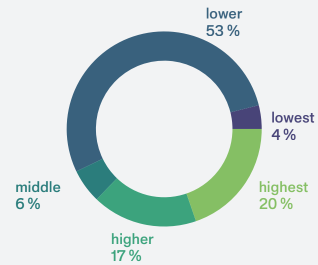
121
Income Distribution

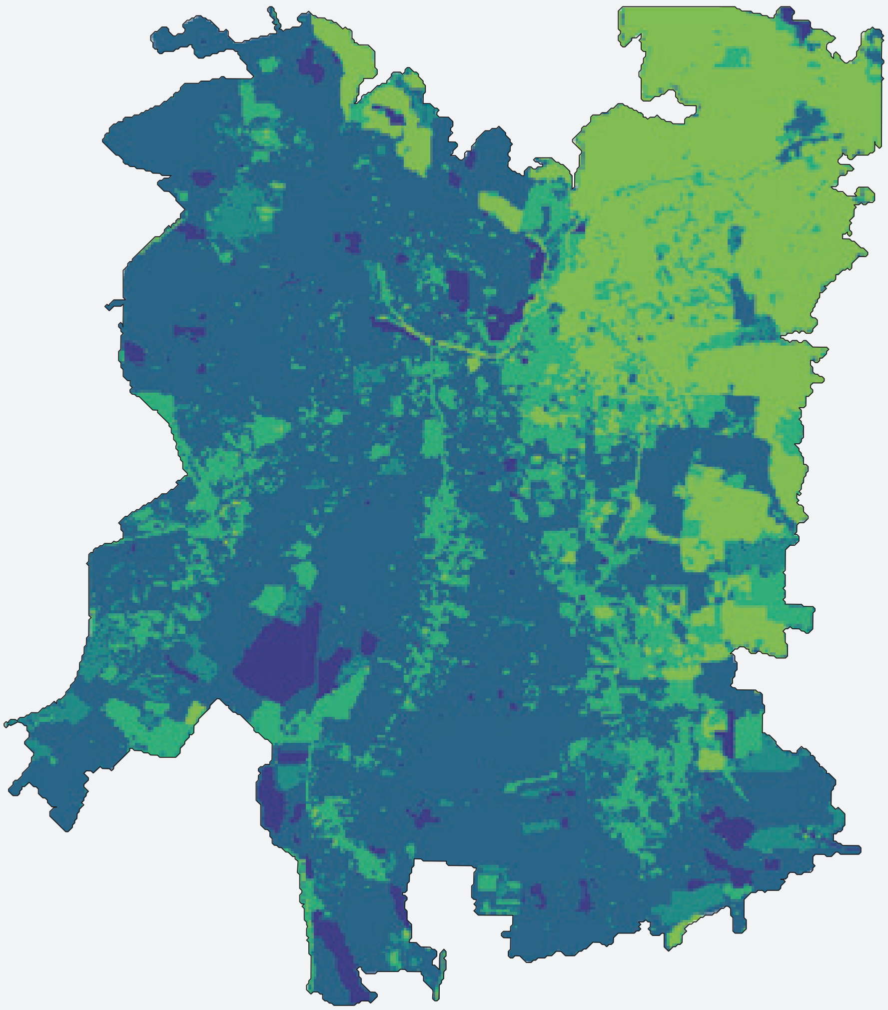
Geneva
Santiago de Chile

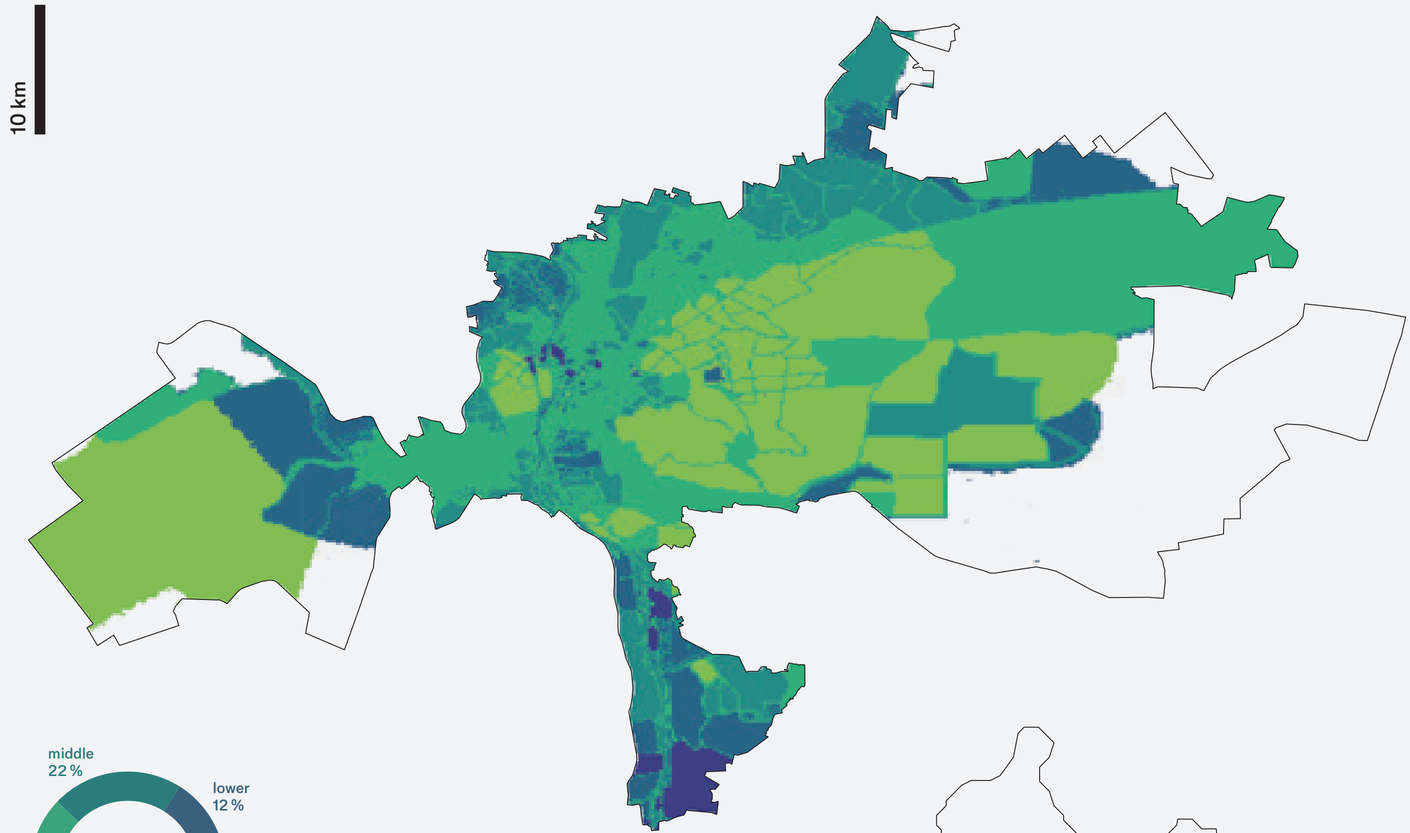
Cairo*
Chongqing*

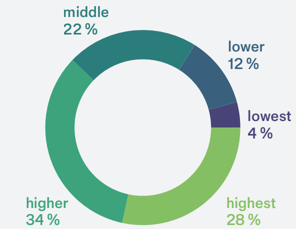


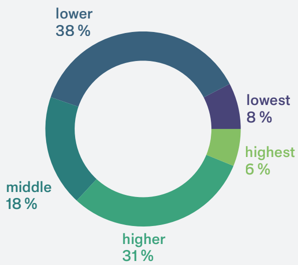












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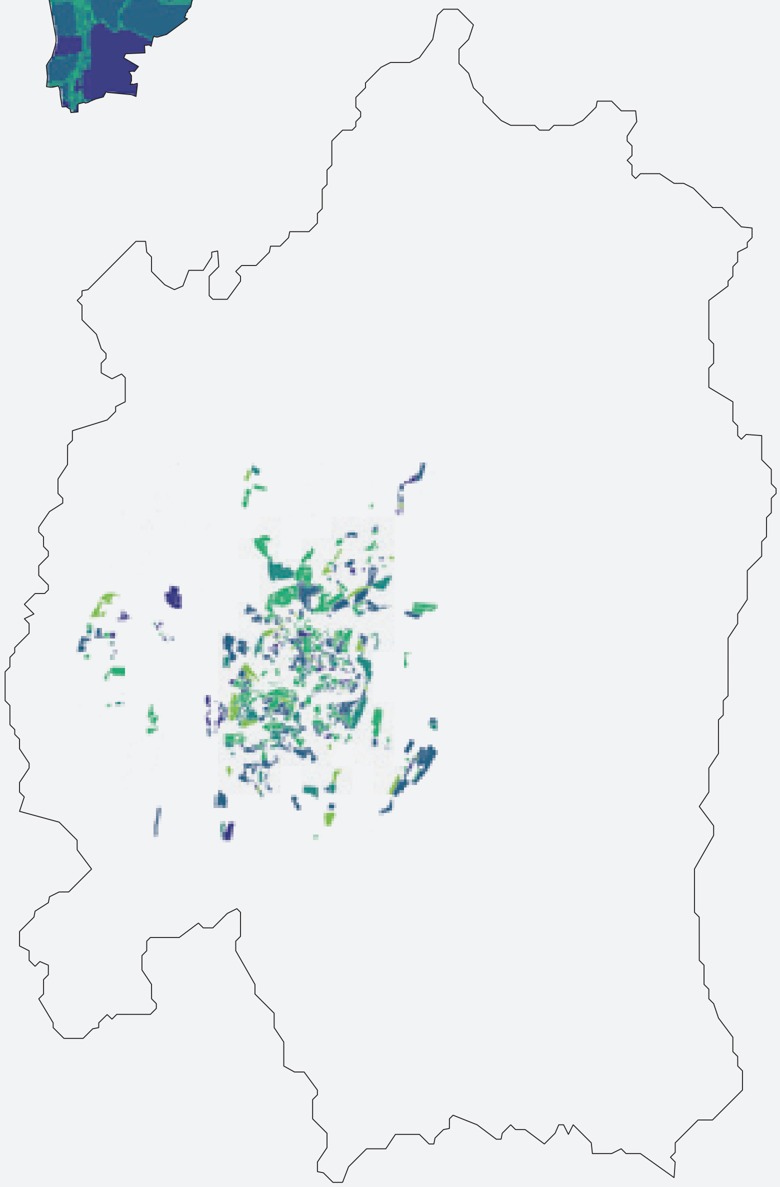
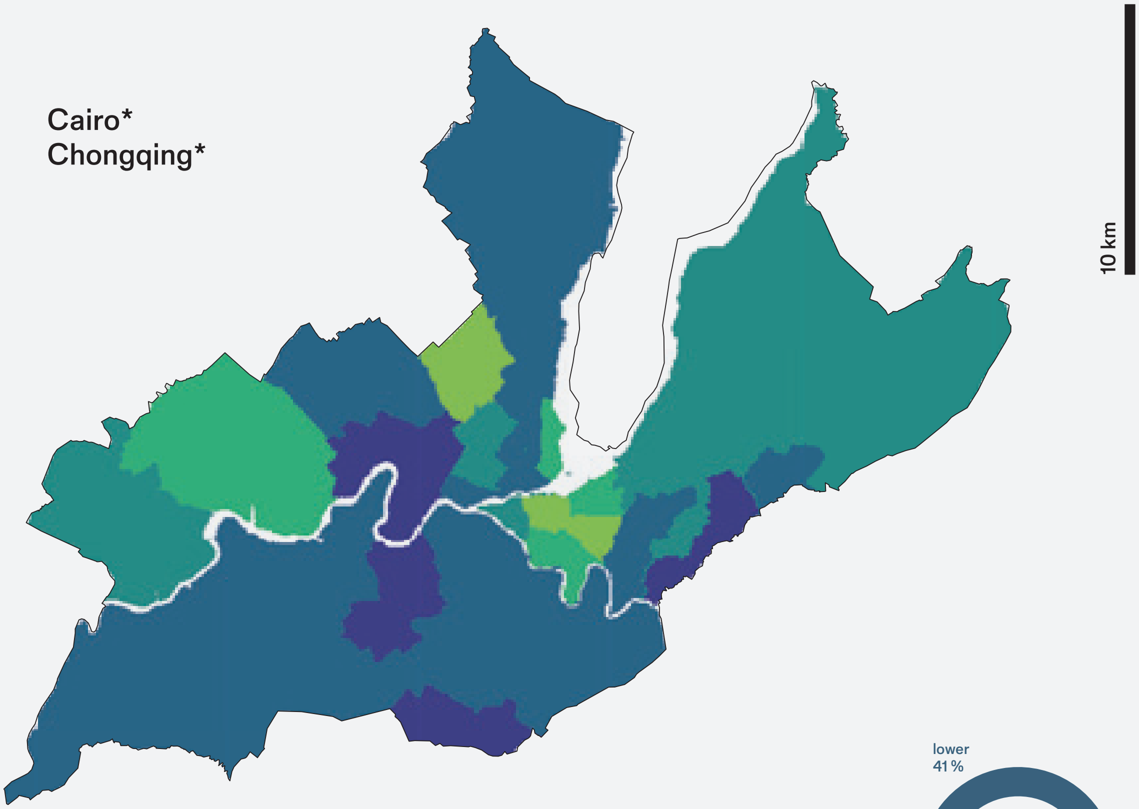
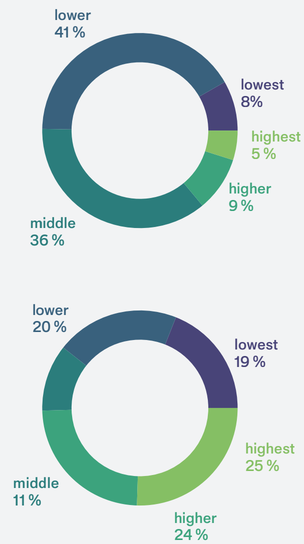


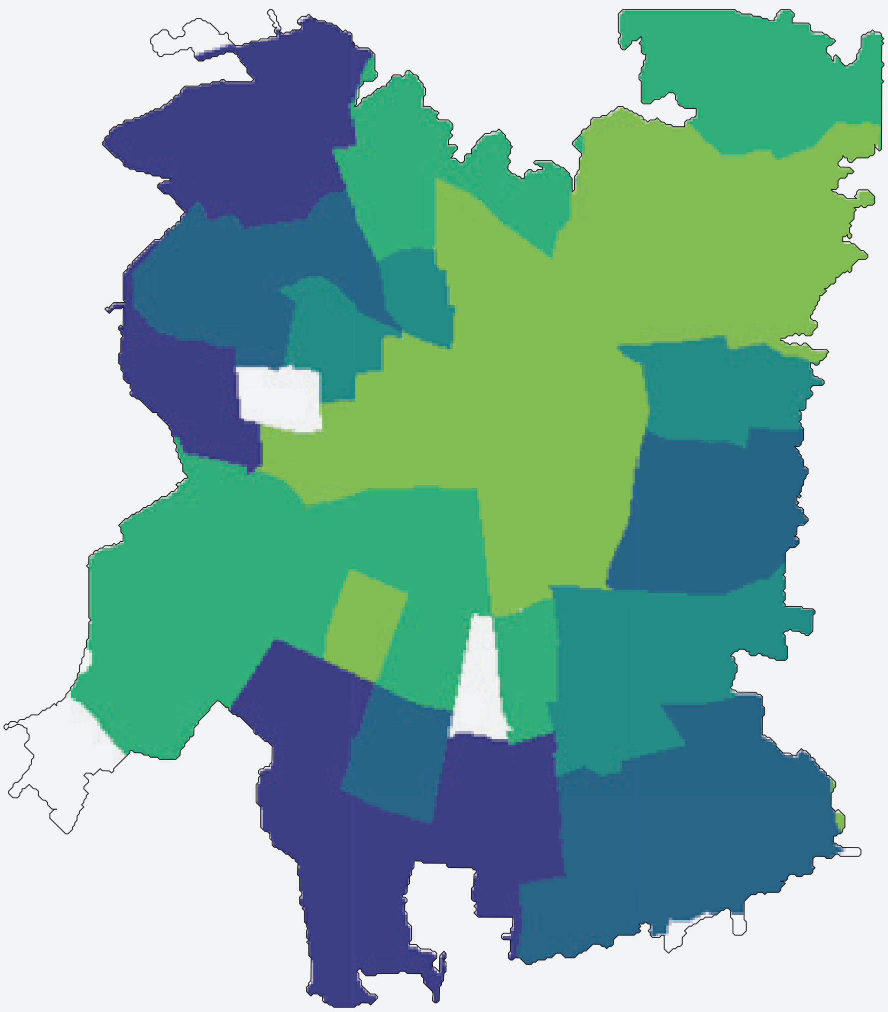
122
Real-estate Prices

Geneva
Santiago de Chile

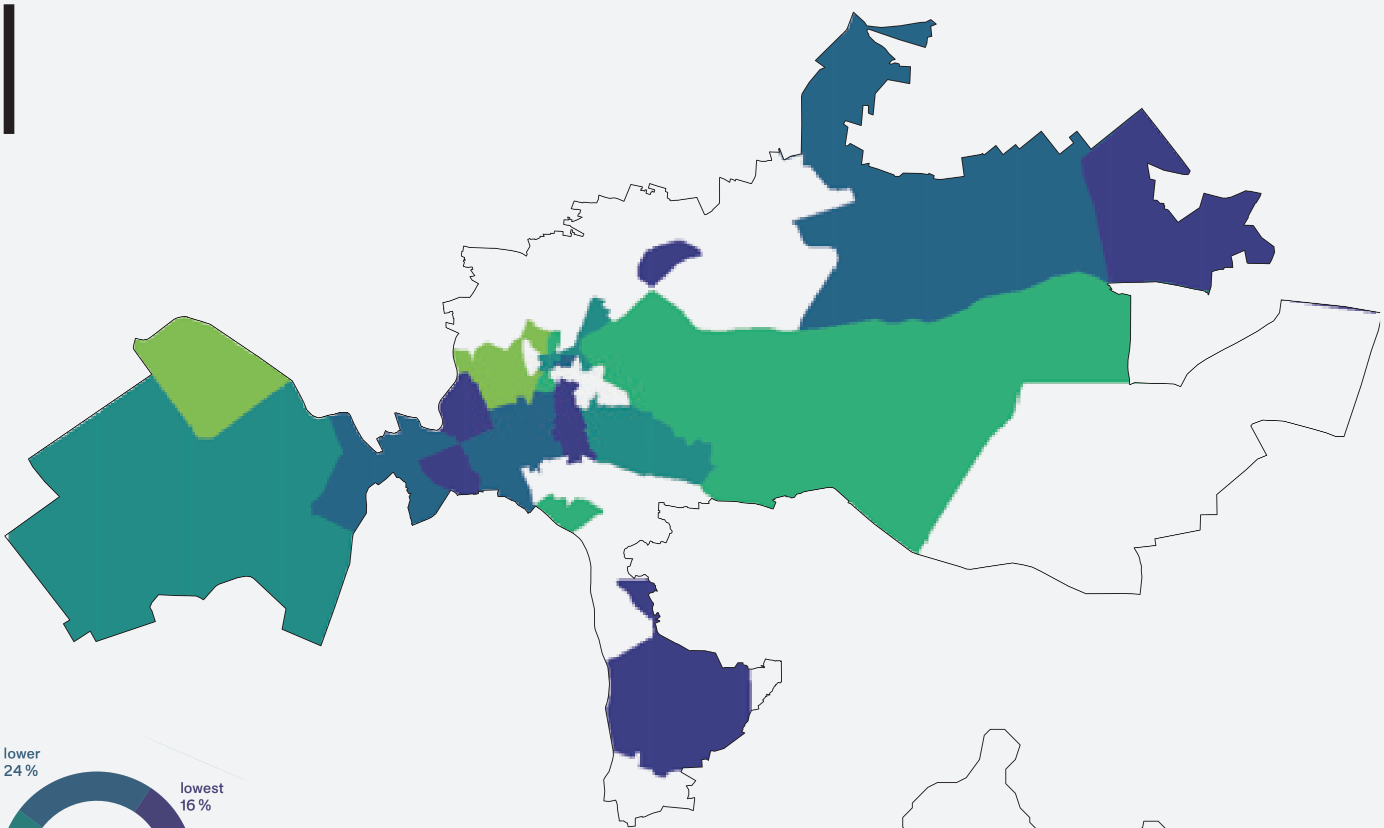
Cairo*
Chongqing*

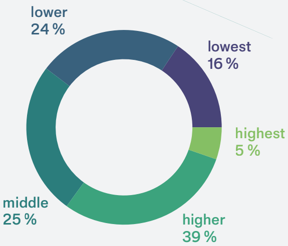


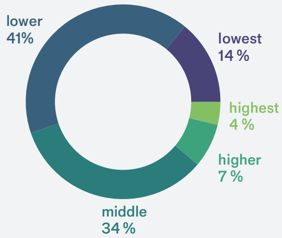




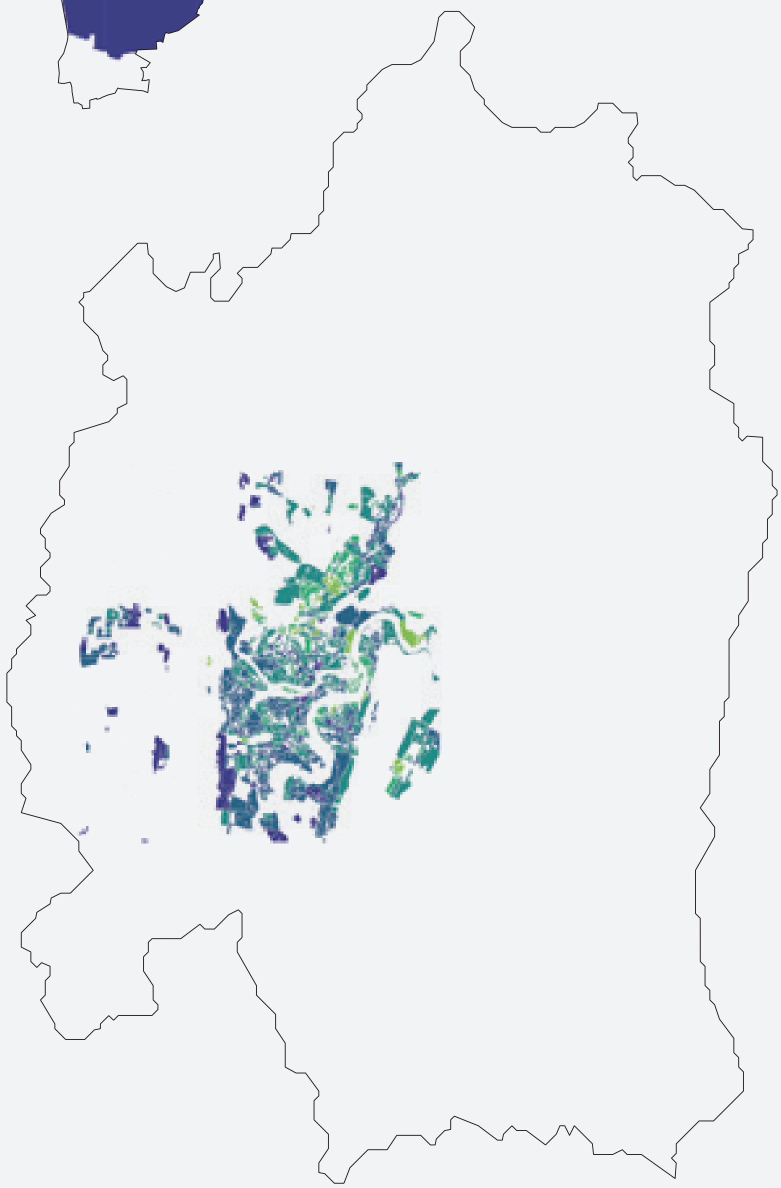
10 km







* incomplete data set

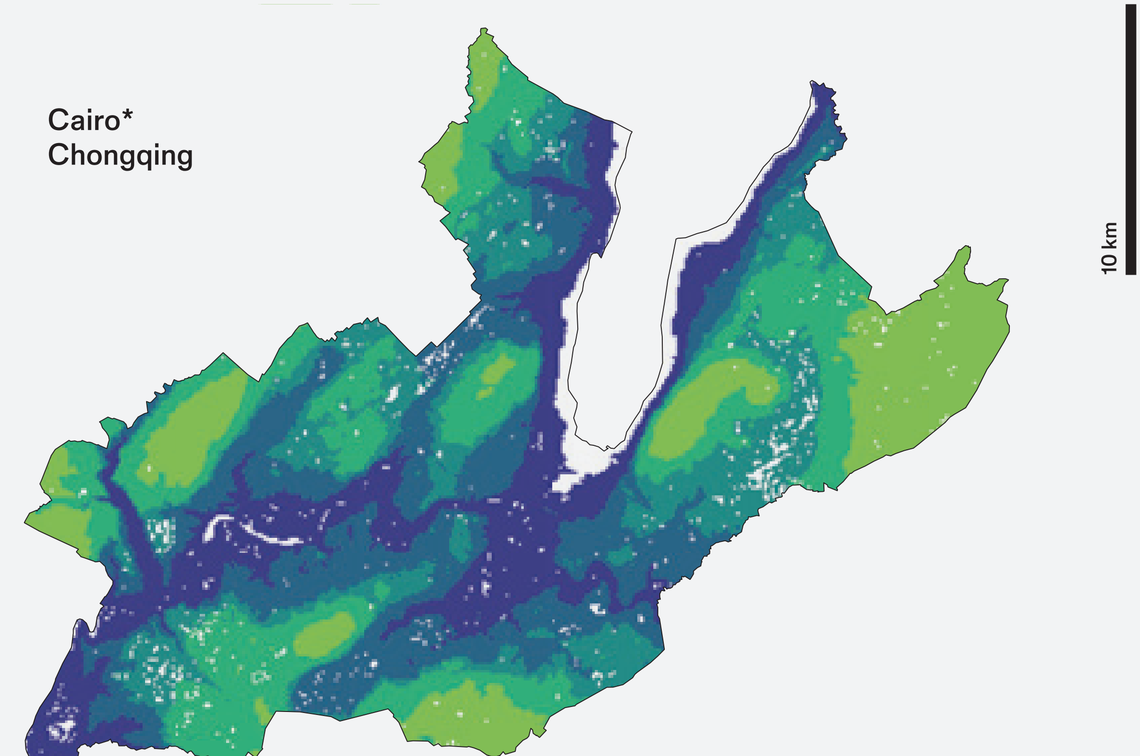


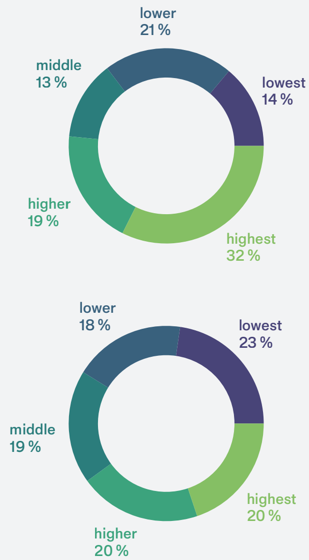
10 km

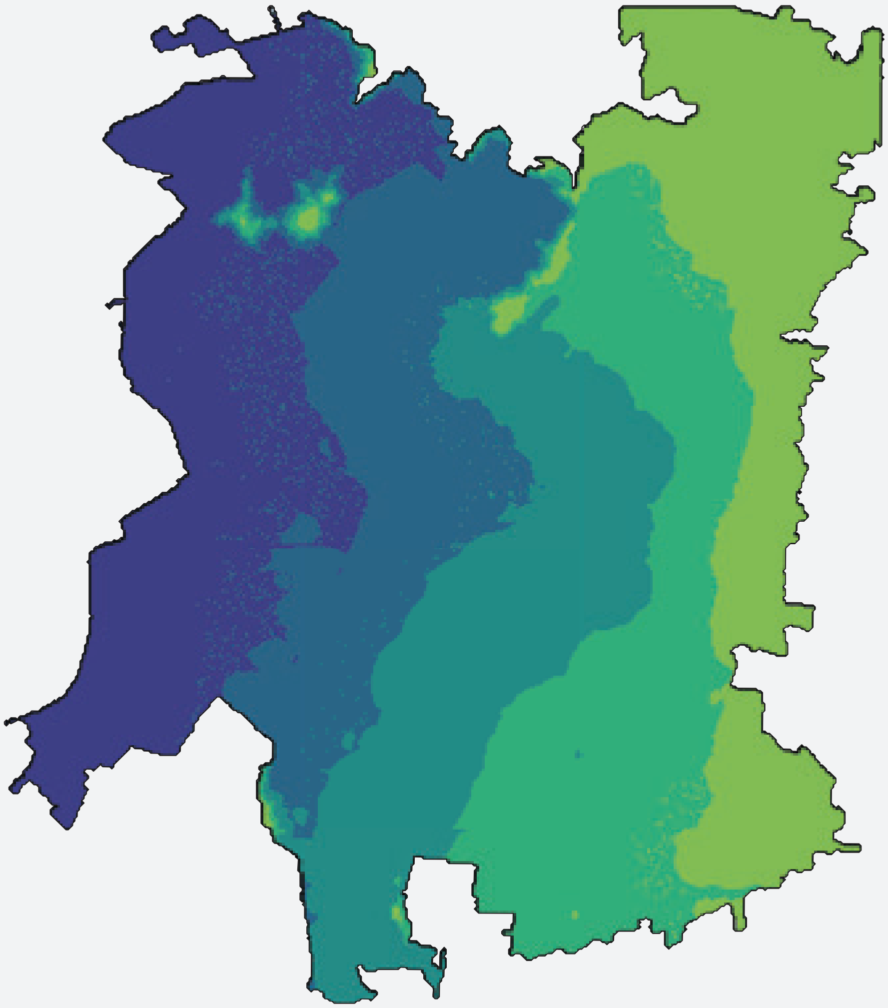
123
Topography

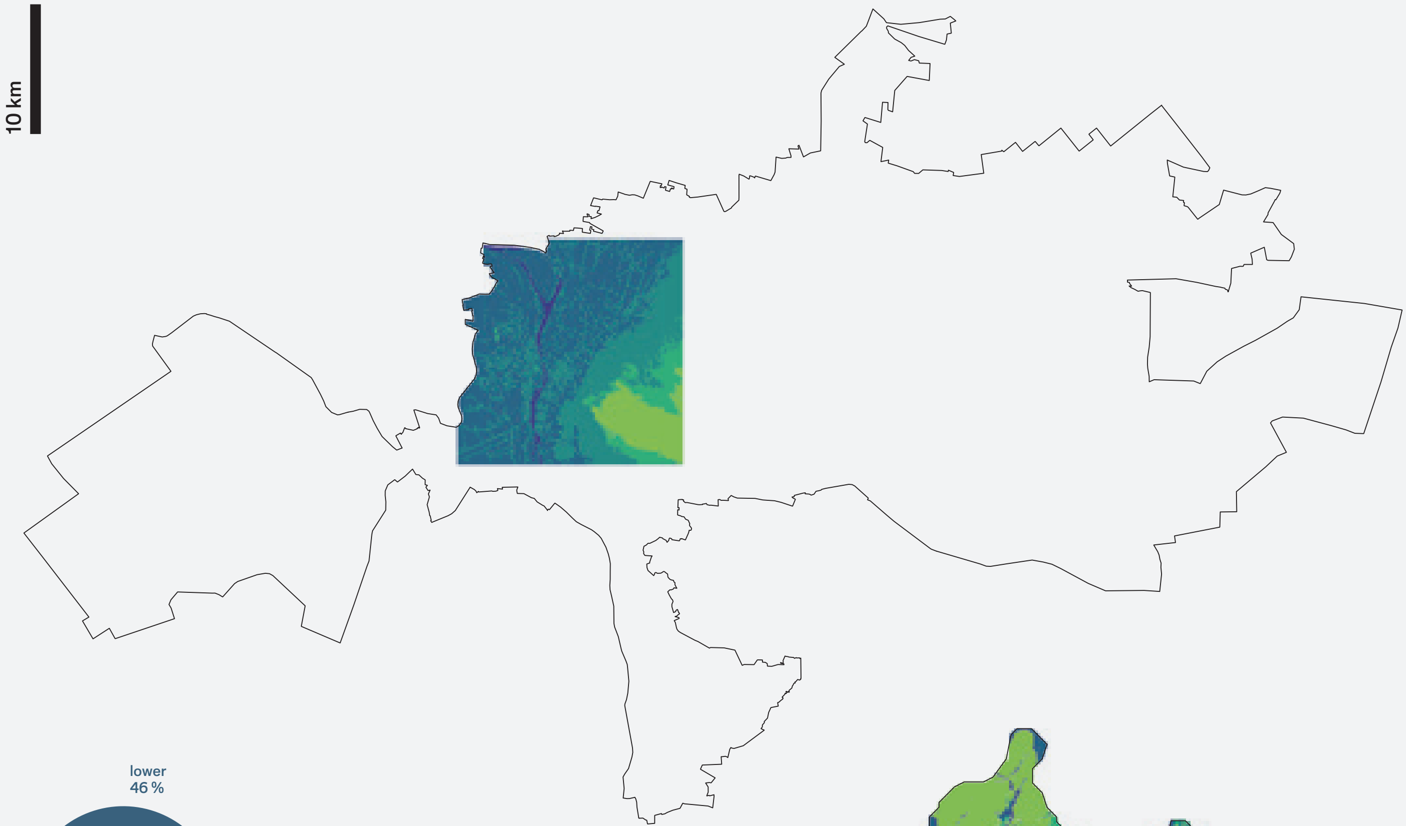
Geneva
Santiago de Chile

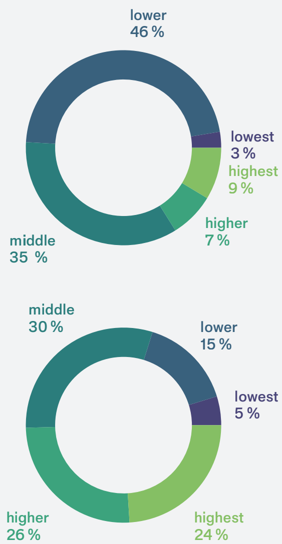
Cairo*
Chongqing



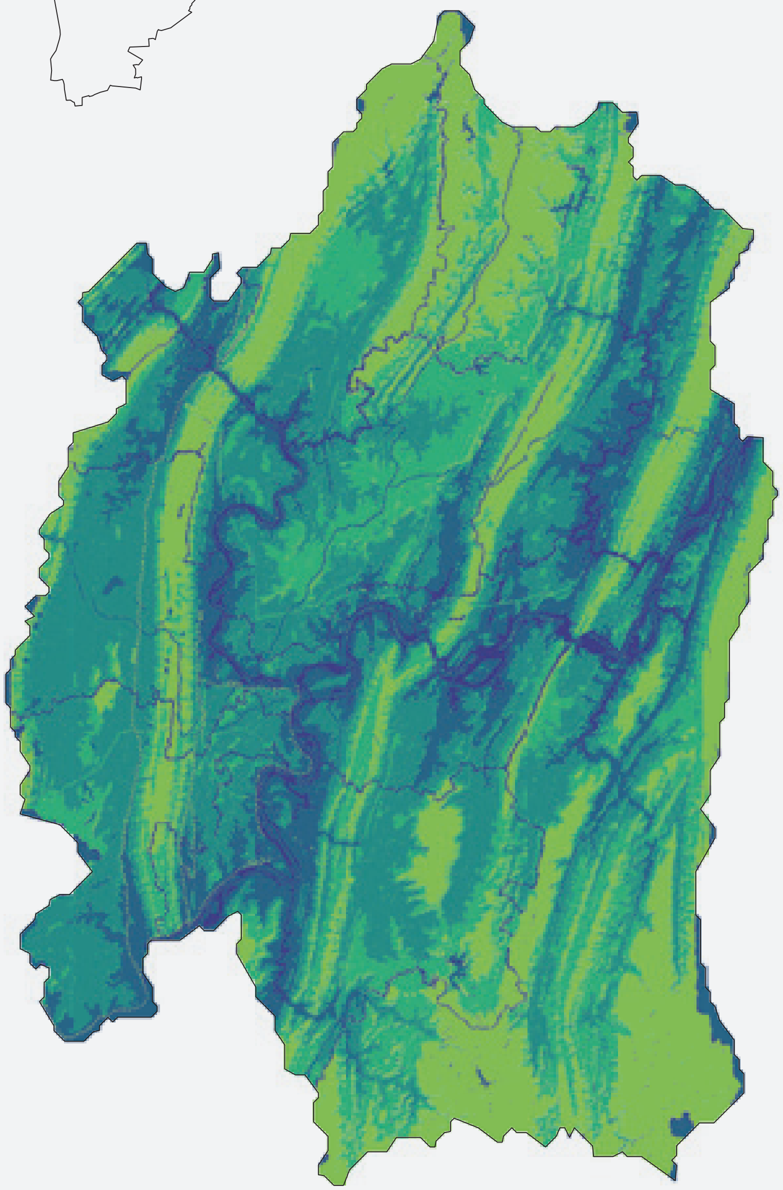








* incomplete data set

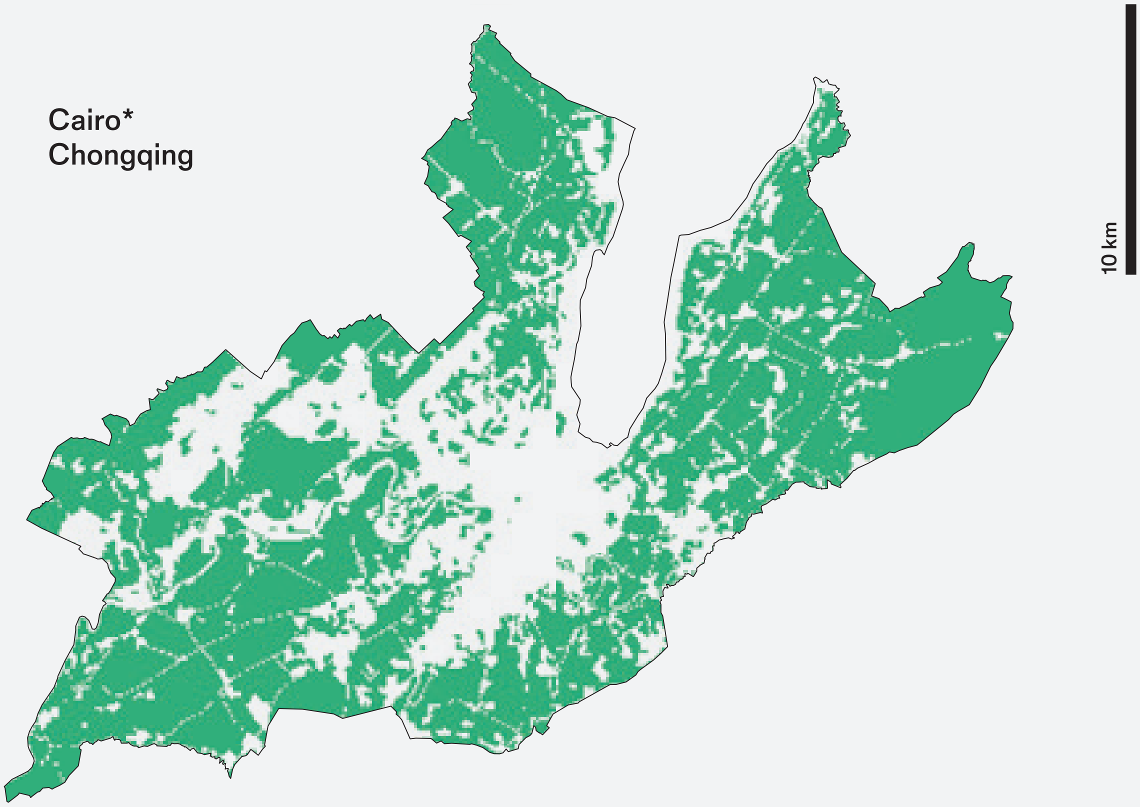


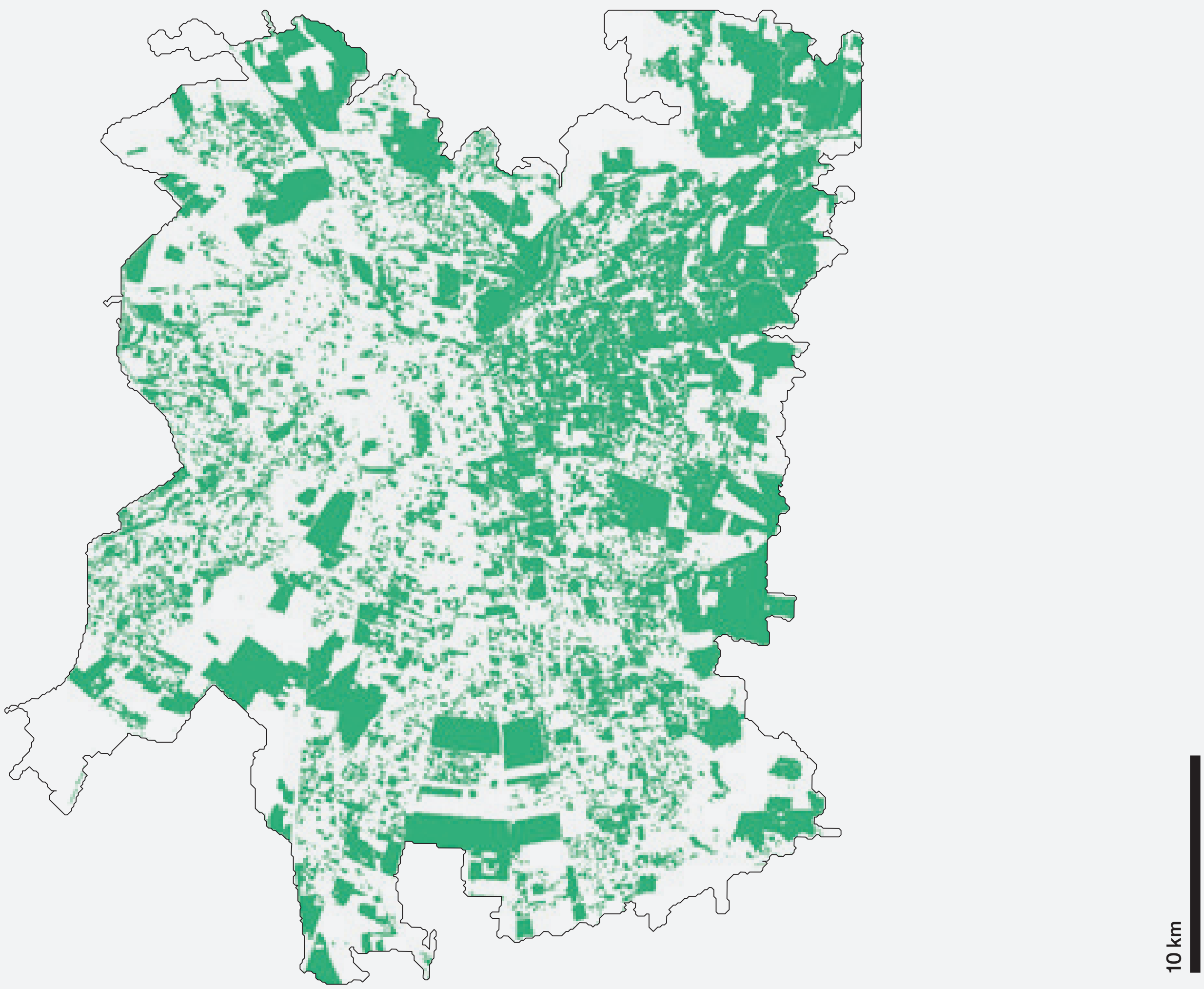
10 km

124
Urban Green

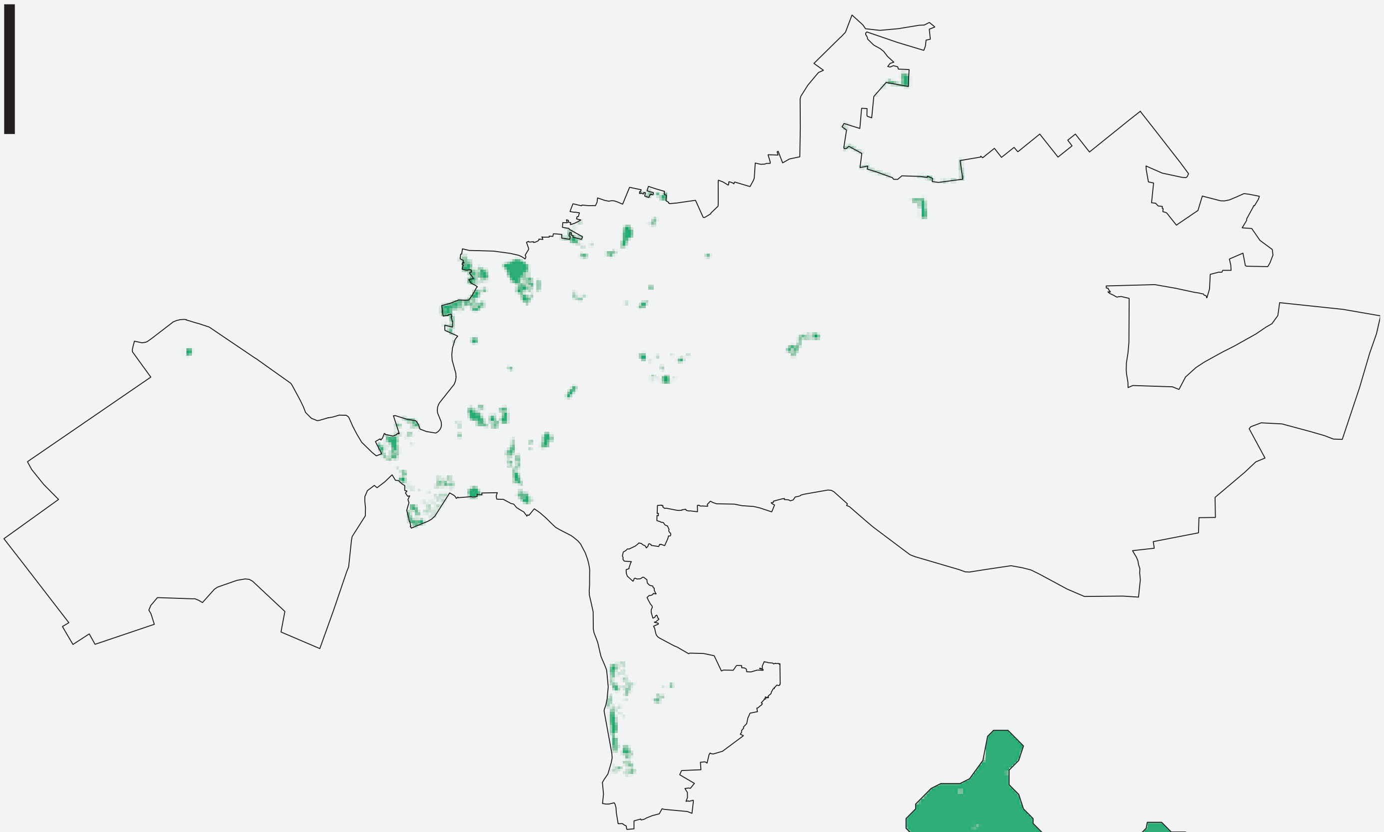
Geneva
Santiago de Chile

Cairo*
Chongqing





10 km



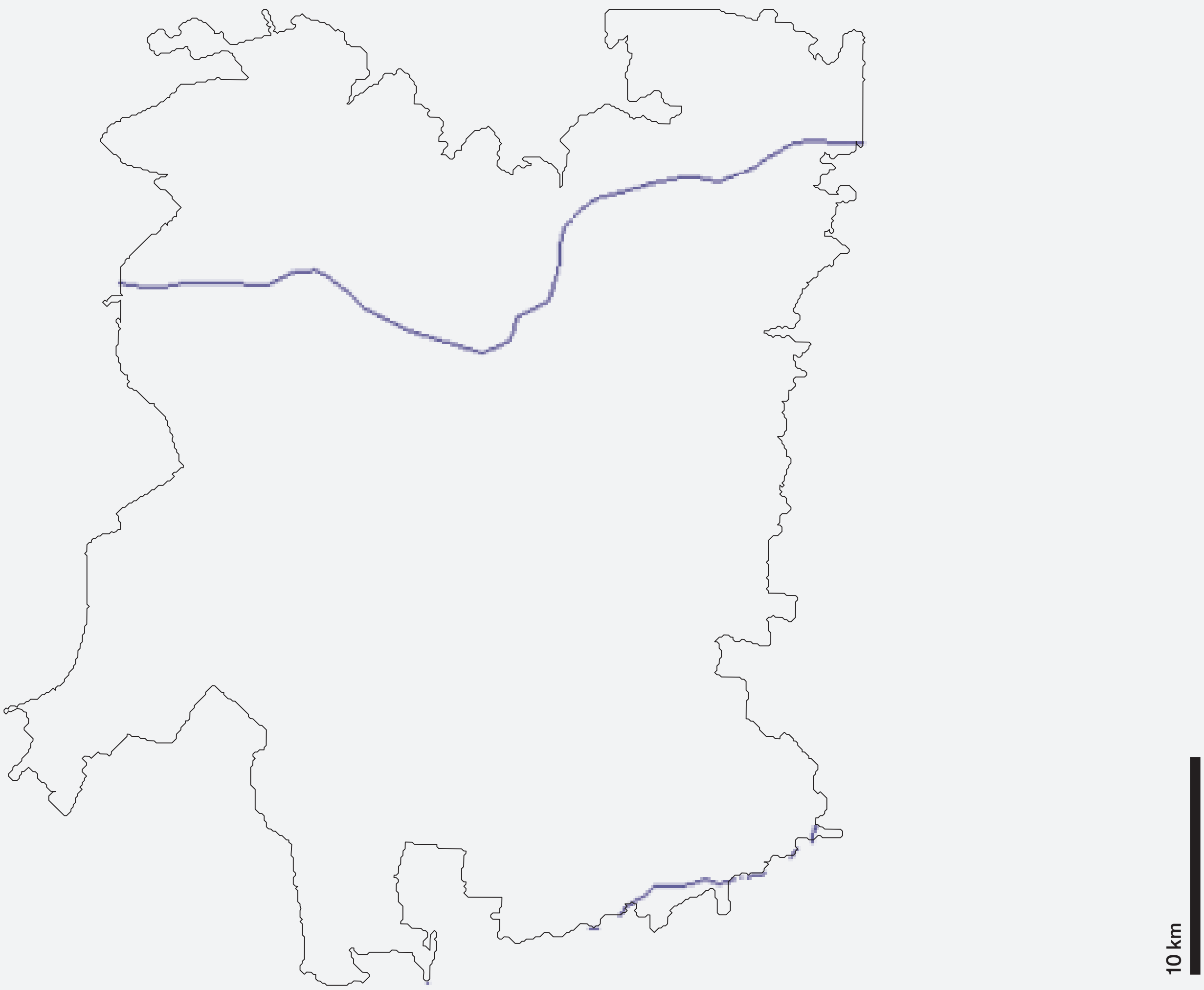
* incomplete data set

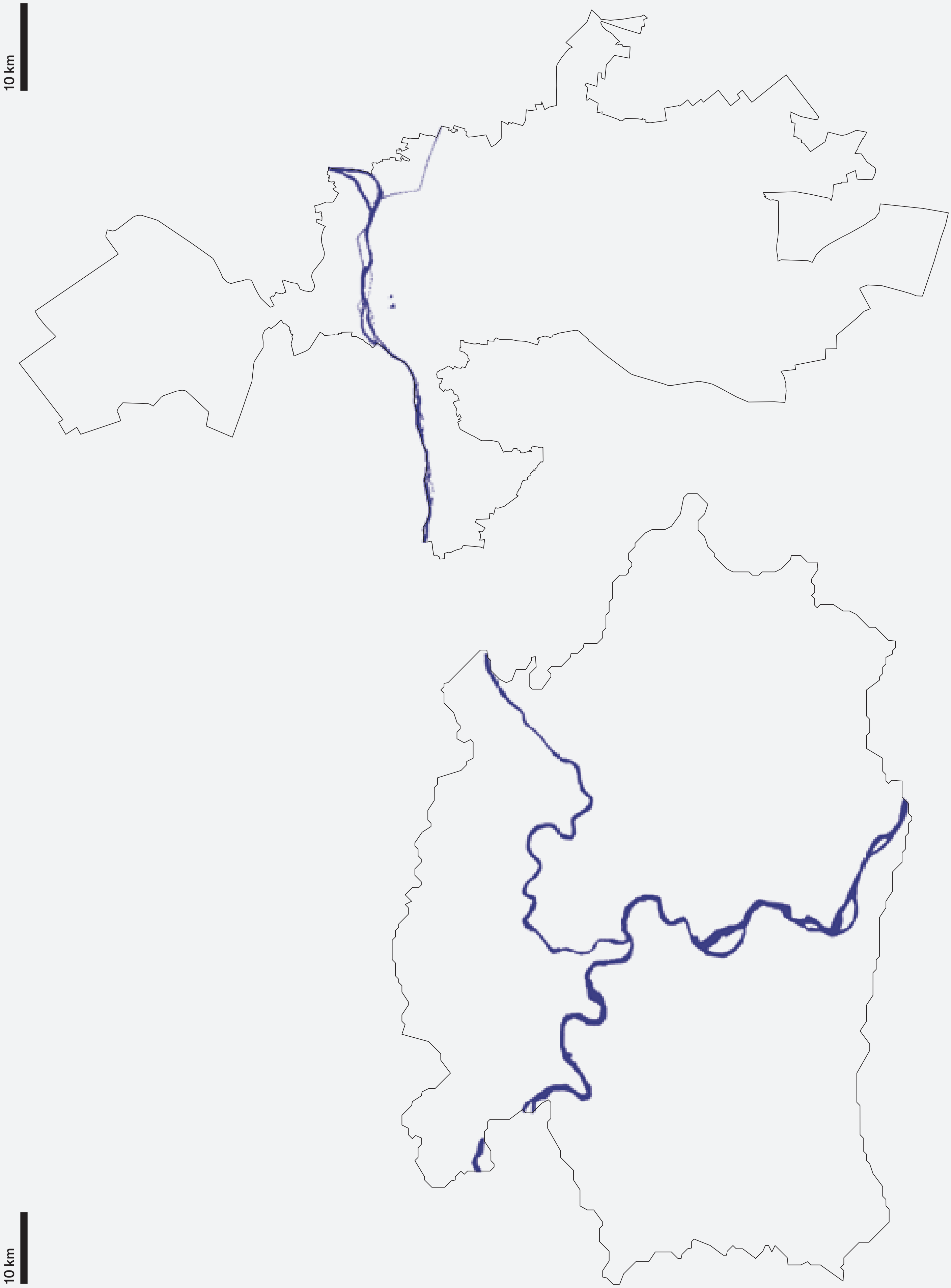
10 km

125
Water Bodies

Geneva
Santiago de Chile

Cairo
Chongqing




10 km
10 km

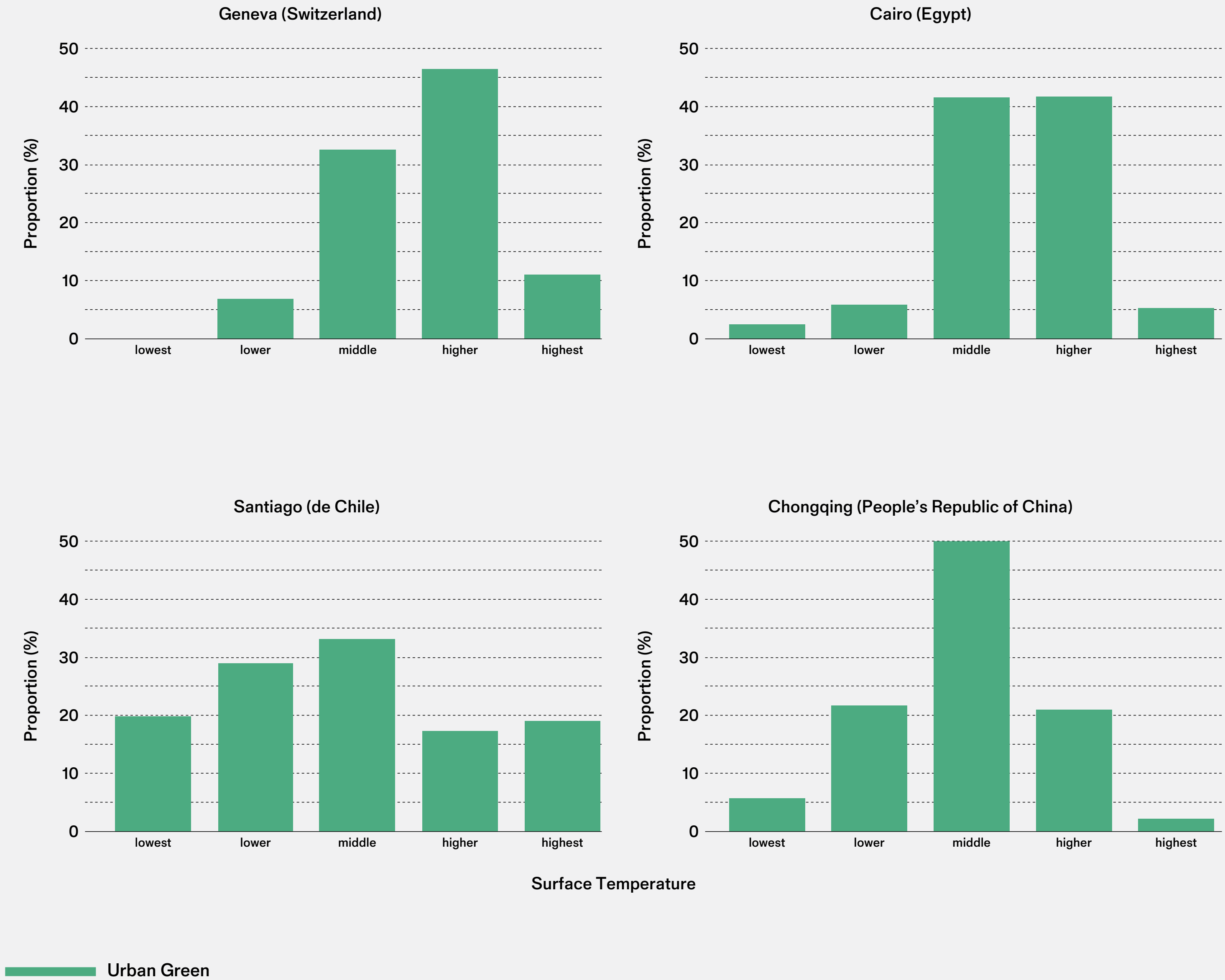
Superimposing Influencing Factors

The assessment shows the limited relevance of landscaping strategies, such as providing more urban green and more unsealed surfaces, for coping with urban climates. In Santiago and Geneva, for instance, there are no clear correlations between vegetation cover and surface temperatures. Indeed, the surface cover can weaken the generally positive effects of green spaces. In certain areas of Santiago, temperatures can be higher despite the presence of green space because wind and air circulation are less pronounced.

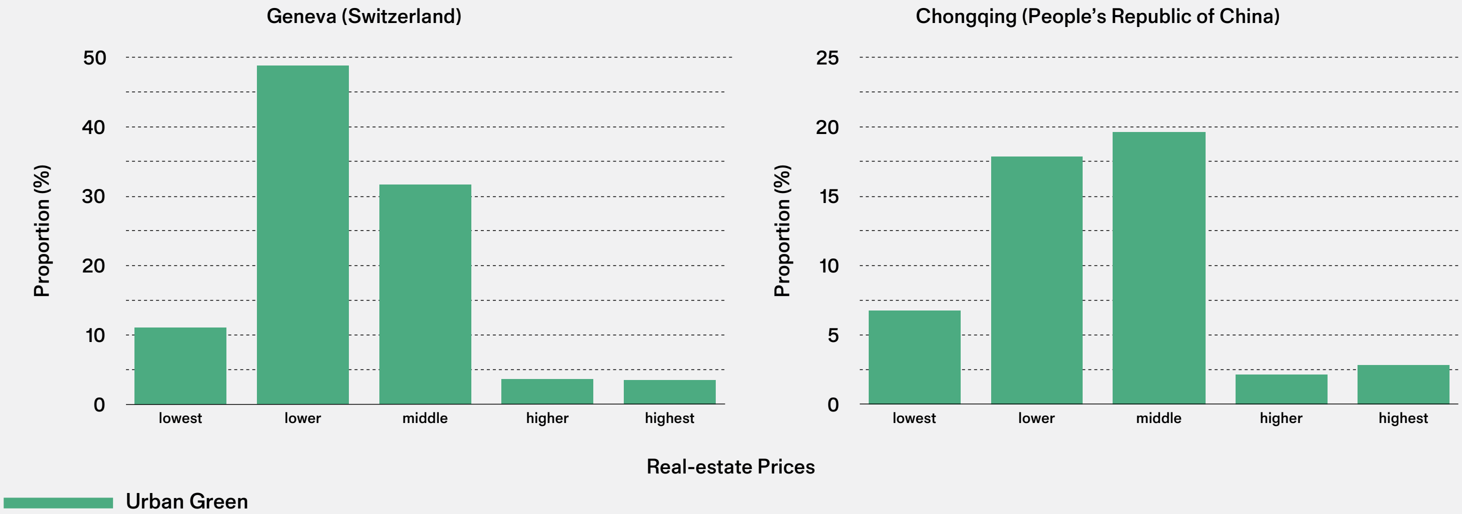
The fact that the greenest areas are not necessarily those with the lowest temperatures, but rather have moderate (average) temperatures, markedly illustrates the fact that other variables—such as building typologies (including height and density), water bodies, wind flows and topography—also profoundly influence (micro)climatic conditions in the city. Therefore, the factors with a more pronounced architectural character have to be taken into account equally and always simultaneously when assessing urban microclimatic contexts.

→ fig. 126

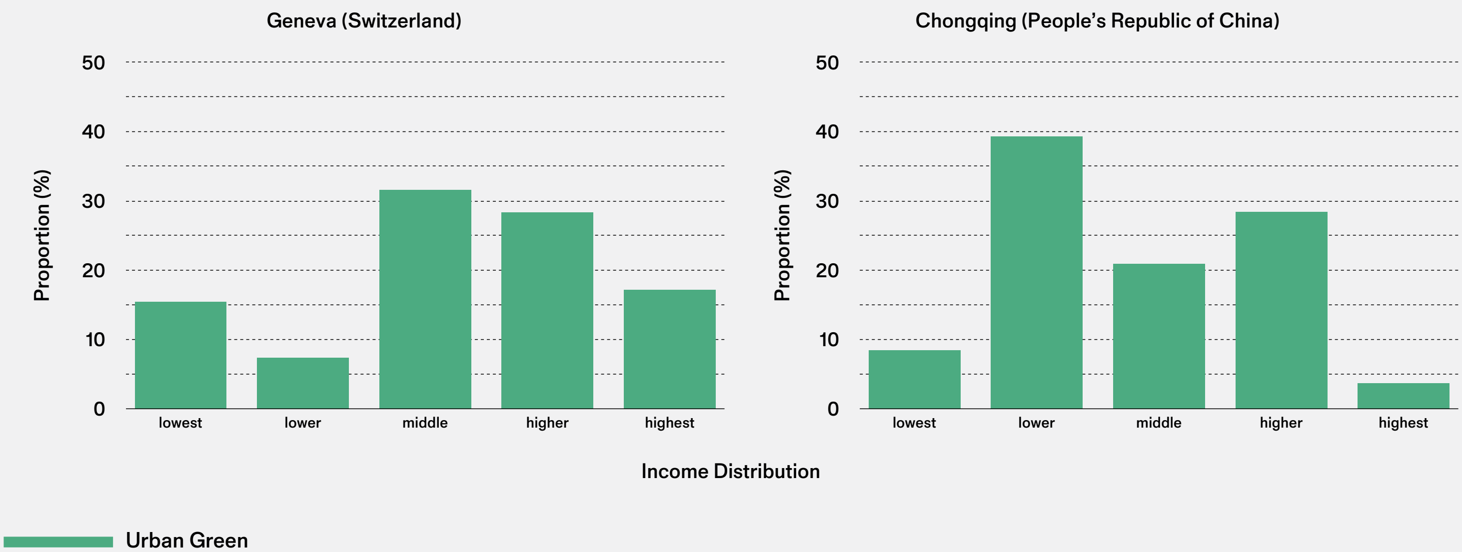
126
Intersection of Urban Green and Surface Temperature



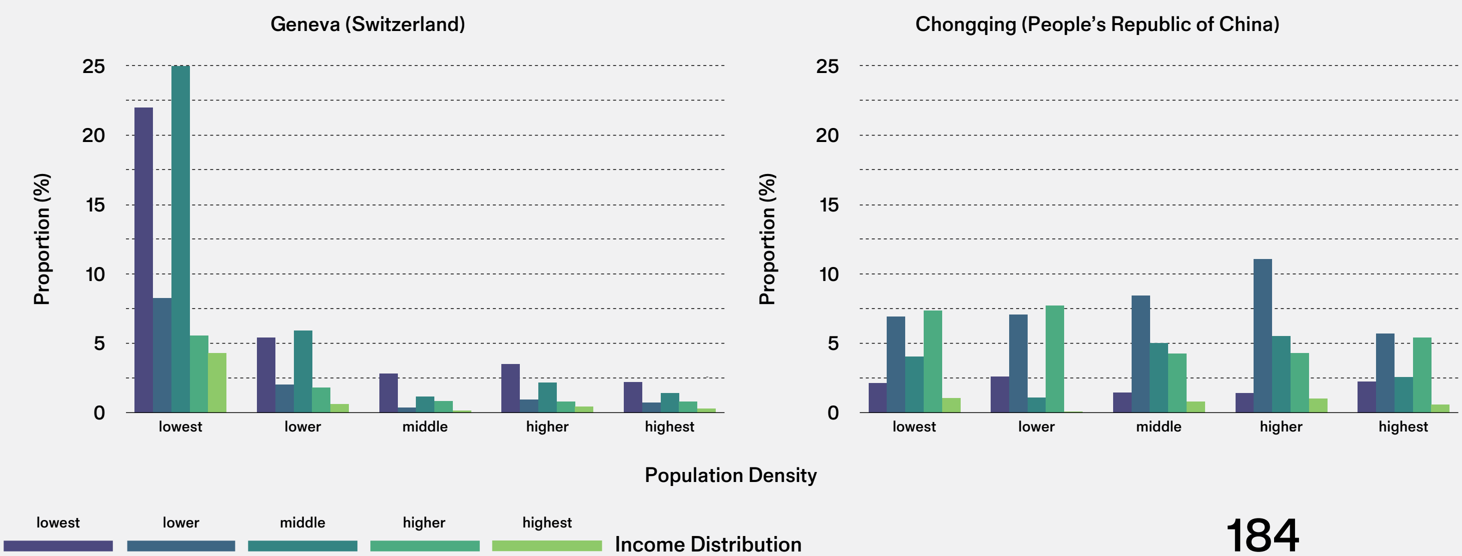
127
Intersection of Urban Green and Real-estate Prices



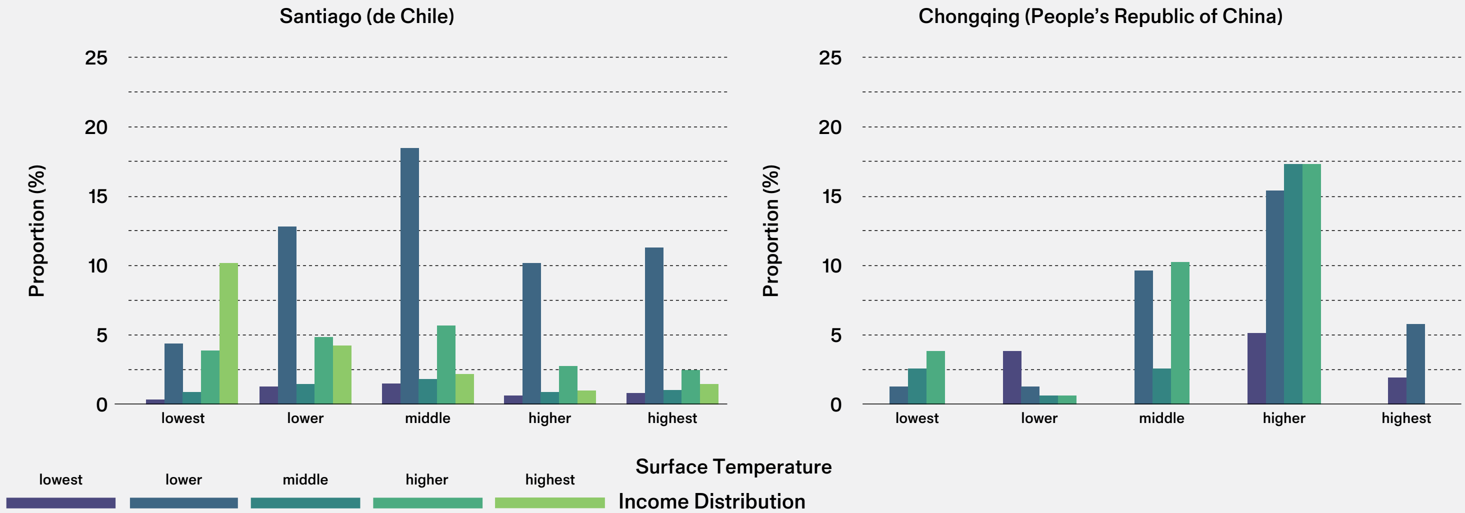
128
Intersection of Urban Green and Income Distribution



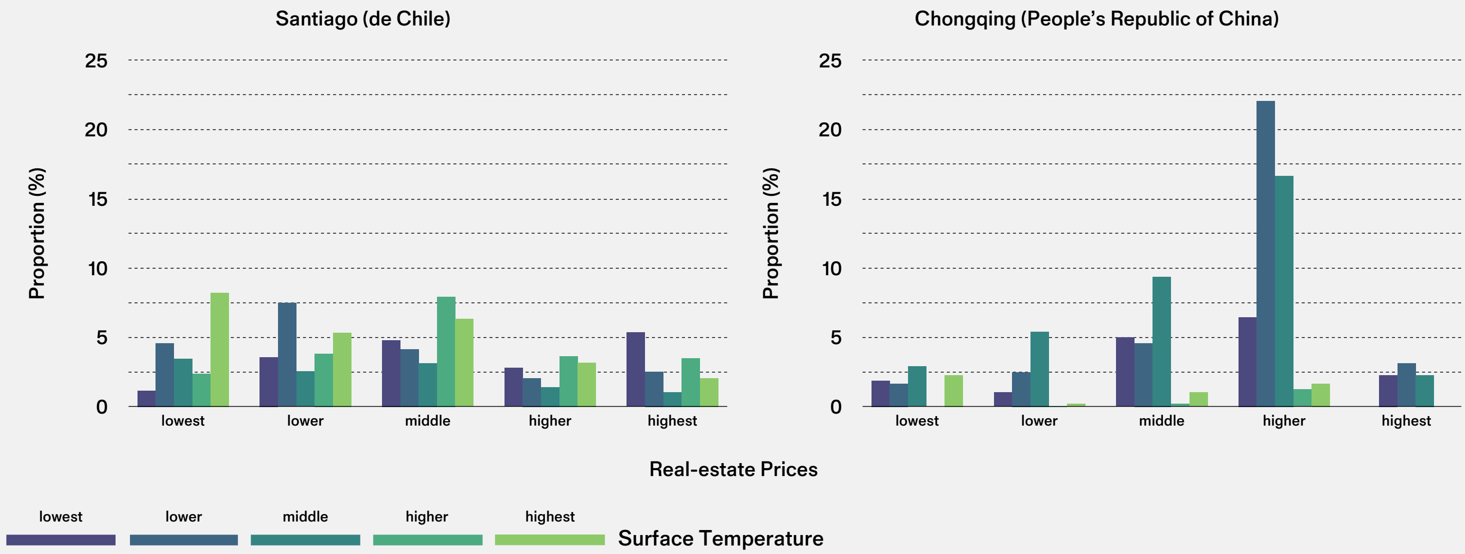
129
Intersection of Income Distribution and Population Density



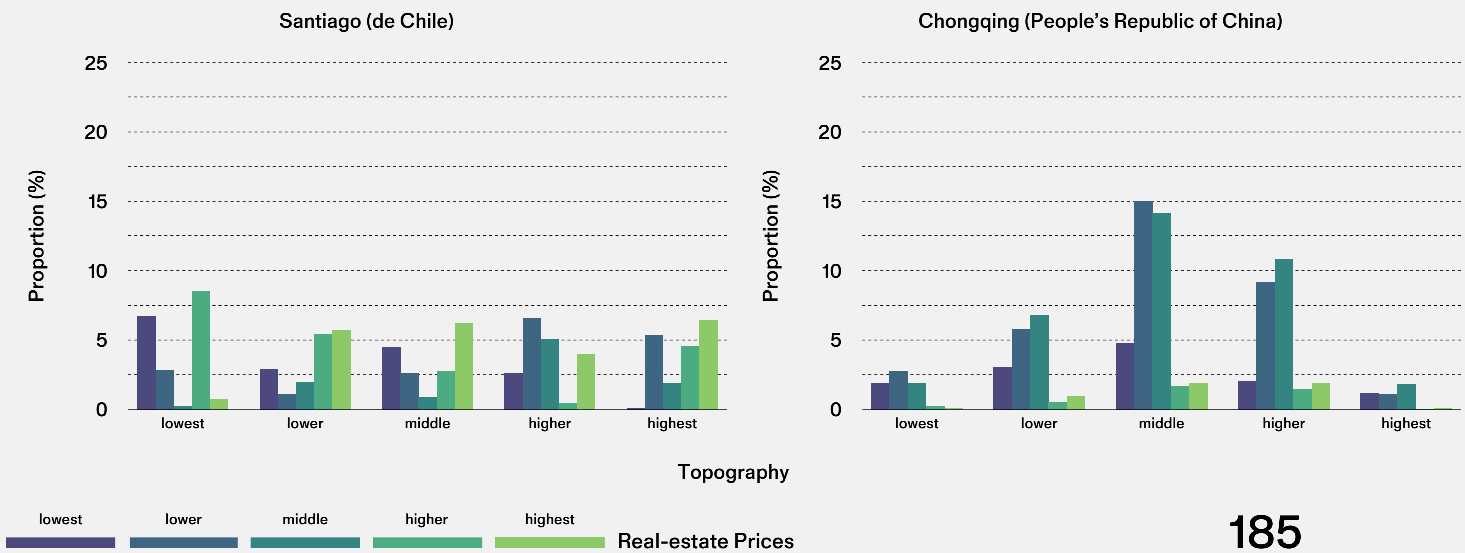
130
Intersection of Income Distribution and Surface Temperature



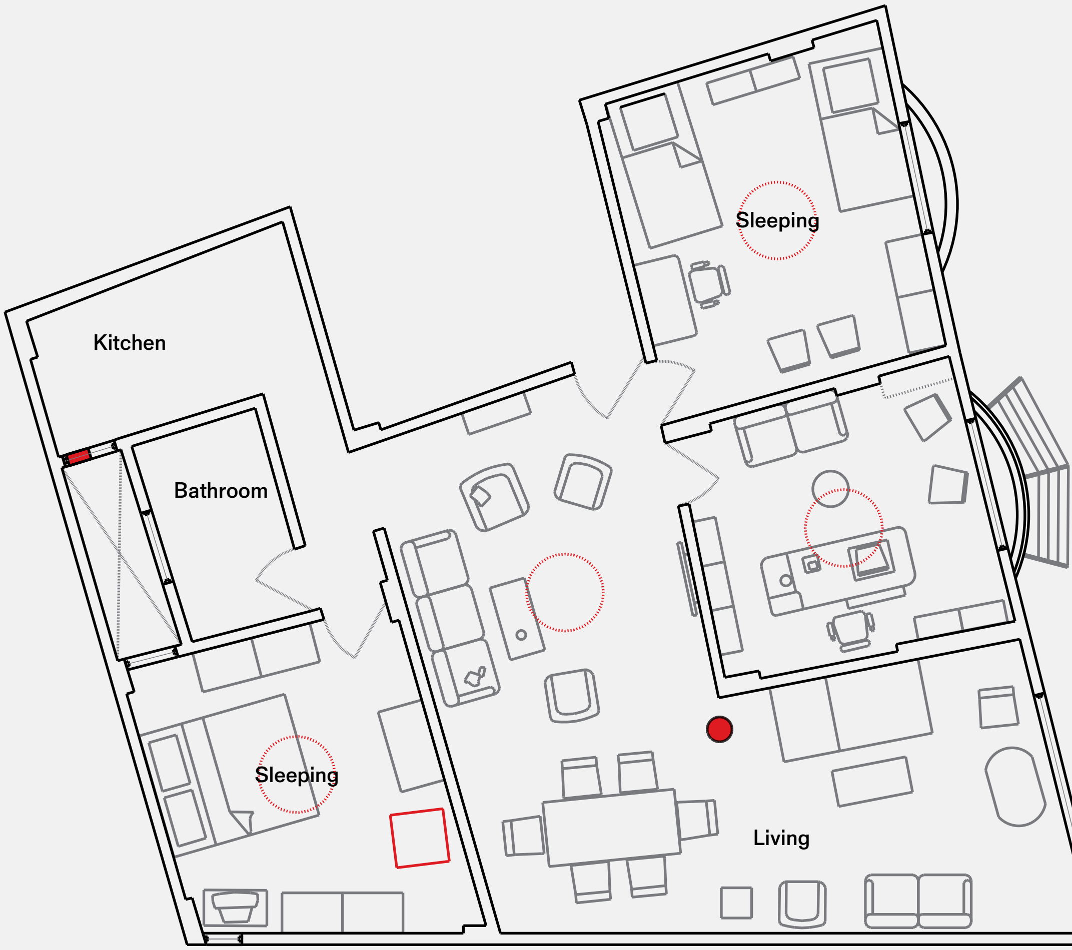
131
Intersection of Real-estate Prices and Surface Temperature



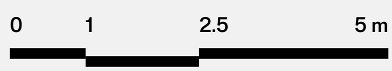
132
Intersection of Real-estate Prices and Topograhy



133
Cairo (Egypt), Munib district. Floor plan of Dr. Hisham's apartment.



On each plan, the thermal items appear in red. The small red items are for fans, the large squares are the refrigerators when not located in the kitchen; the large rectangles are the air-conditioning devices and the large dotted circles are ceiling fans. Moreover, in every flat, the tiled floors were systematically covered with carpets.



→ figs. 23, 25, 50, 53

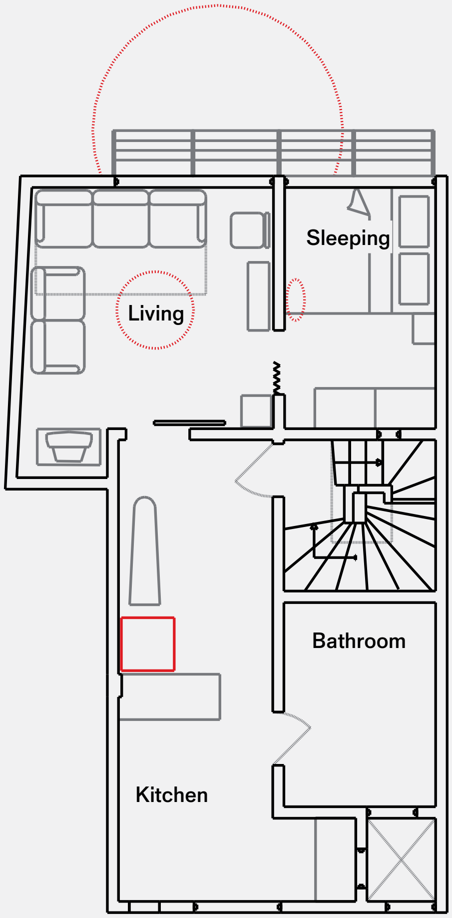
134
Aerial view of Munib, Cairo (Egypt).

→ figs. 20, 22, 23, 28, 30

135
Aerial view of Khalifa, Cairo (Egypt).

136
Cairo (Egypt), Khalifa district. Floor plan of Umm Rania's apartment.

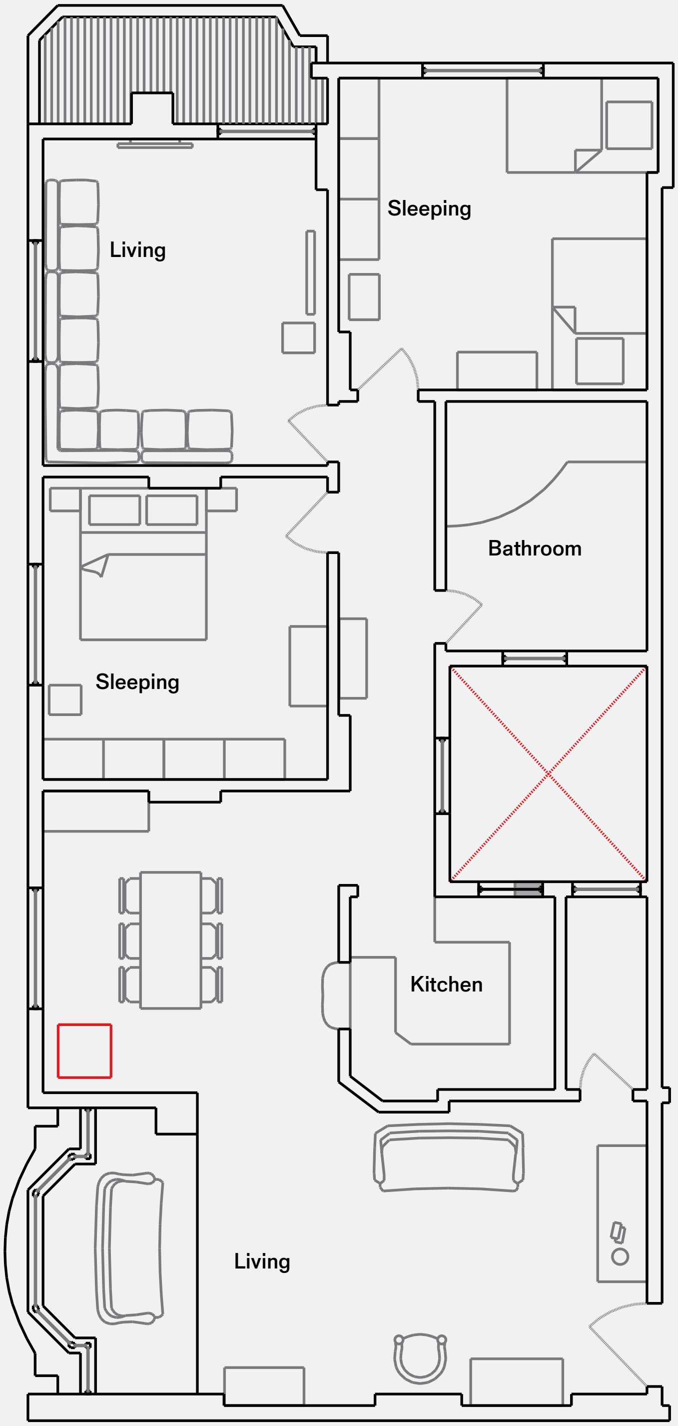
On each plan, the thermal items appear in red. The small red items are for fans, the large squares are the refrigerators when not located in the kitchen; the large rectangles are the air-conditioning devices and the large dotted circles are ceiling fans. Moreover, in every flat, the tiled floors were systematically covered with carpets.

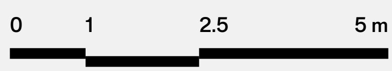


0 1 2.5 5 m

→ figs. 104, 106

137
Cairo (Egypt), Faysal district. Floor plan of Maryam's apartment.





On each plan, the thermal items appear in red. The small red items are for fans, the large squares are the refrigerators when not located in the kitchen; the large rectangles are the air-conditioning devices and the large dotted circles are ceiling fans. Moreover, in every flat, the tiled floors were systematically covered with carpets.

→ figs. 101, 106, 107, 108

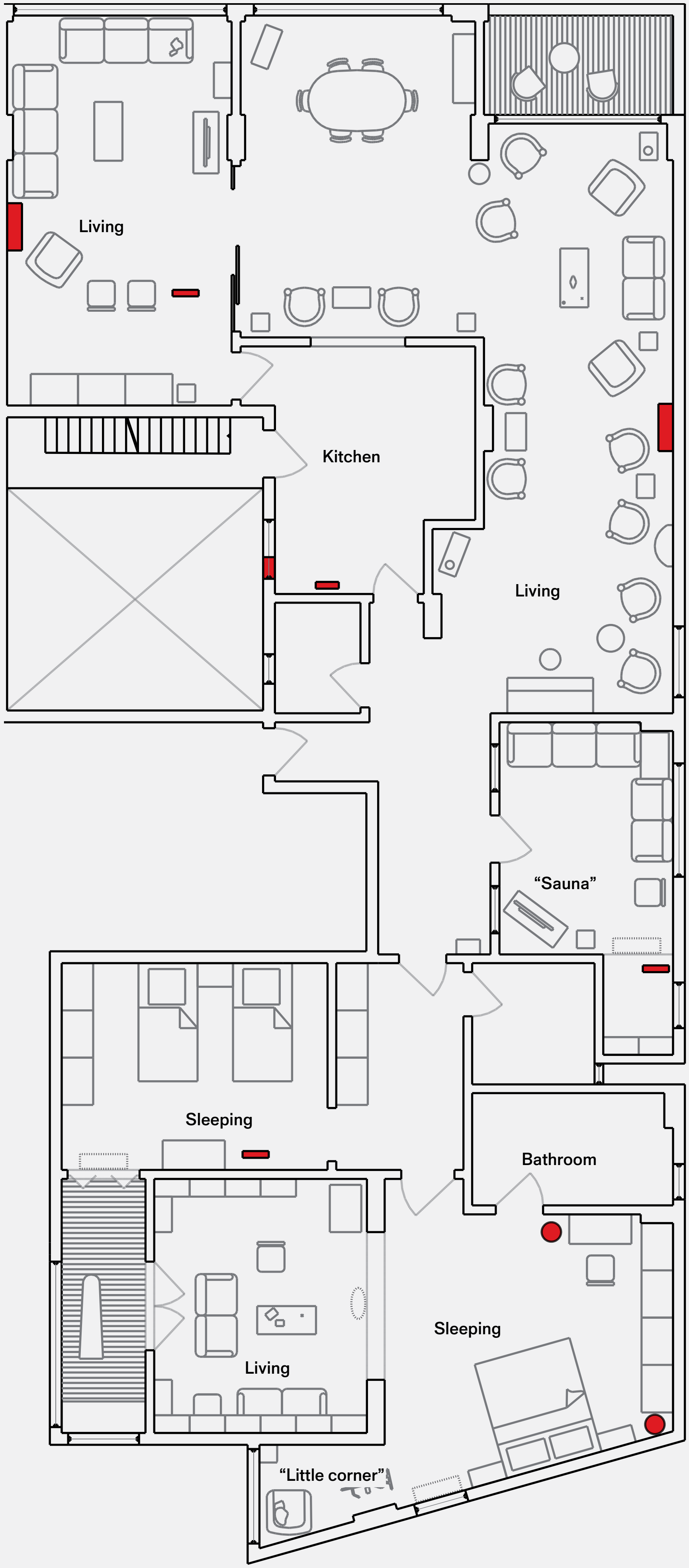
138
Aerial view of Faysal, Cairo (Egypt).

139
Aerial view of Garden City, Cairo (Egypt).

→ figs. 110, 111

140
Cairo (Egypt), Garden City district.
Floor plan of Magda's apartment.

On each plan, the thermal items appear in red. The small red items are for fans, the large squares are the refrigerators when not located in the kitchen; the large rectangles are the air-conditioning devices and the large dotted circles are ceiling fans. Moreover, in every flat, the tiled floors were systematically covered with carpets.



0 1 2.5 5 m

Santiago de Chile and Geneva: Two Contrasting Models

Geneva and Santiago offer examples of two fundamental urban climatic conditions that might well inform future urban strategies of thermal governance across the globe. Santiago is highly segregated and stratified along socio-economic lines, while Geneva, on the other hand, typifies those cities that have a higher socio-economic diversity throughout their territory. Due to the wide variety of development types and complex settlement structures throughout the canton of Geneva, it is impossible, unlike in the case of Santiago, to identify clear spatial correlations between socio-economic and urban-climatic conditions. Comparison of the two cities shows that in Santiago, the natural environment is decisive in shaping the urban climate at a larger scale. The case of Geneva, however, shows that different factors at a small and medium scale make an important case for the fact that a climate–society gap, such as in the Andean city, can be largely avoided. In particular, the interplay of building types, settlement form and natural ground surfaces plays an important role. Local dynamic weather phenomena, for their part, mediate between the large and small scales of cities and their urban climate.

In general, Santiago has a rather low population density and a great number of low- to medium-rise buildings for housing, with most of Santiago's population belonging to the lower income groups. Most of the middle class lives in apartment buildings of more than ten stories, or in the many single-family houses that can be found, for example, in *La Florida*. In Santiago, higher real-estate prices are likely to be found in low-temperature areas, while the lowest prices are apt to be for housing in the middle and highest temperature areas. The richer part of the population can afford to buy or rent housing in climatically favorable areas. In Geneva, most city dwellers tend to be exposed to medium and high temperatures. The historic city center is characterized by high rents and higher temperatures. But the wealthier residents also often live in the peripheral areas and communities: it is the lower- and middle-income groups that are most often exposed to the higher temperatures in the denser residential areas.

→ figs. 128, 129, 131, 141, 142

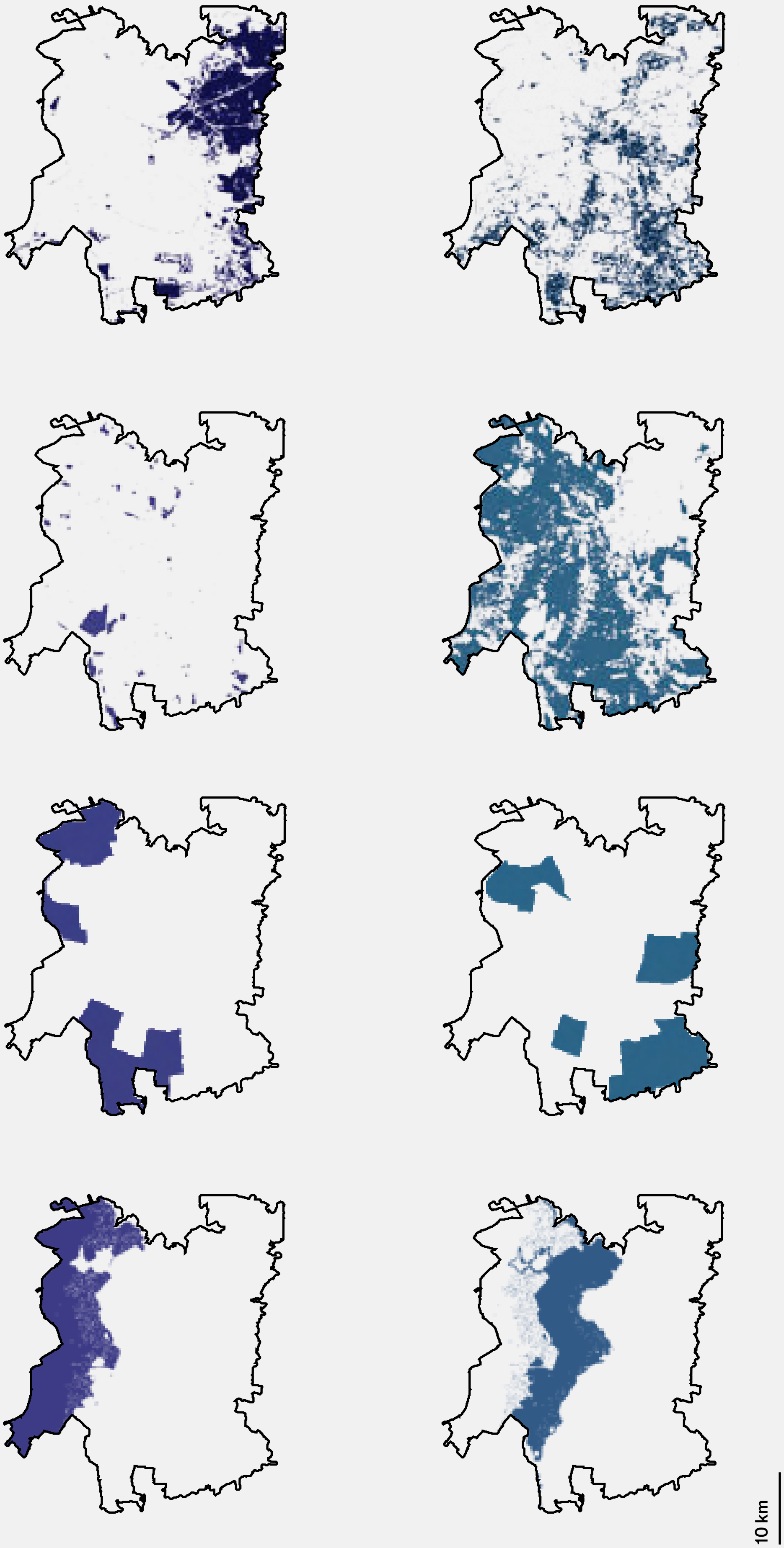
In Geneva's city center, which is characterized by buildings from the 19th and 20th centuries, the population density is highest. It is mainly the lower-middle class that prefers the areas there. In Geneva, people with higher incomes tend to live in villas, single-family houses or in suburban areas—all locations with a high percentage of greening. At the same time, people with lower incomes have as much access to green space as the high earners do. In Santiago, on the other hand, the correlation between income and green spaces shows a clear tendency towards richer vegetation around the middle- and upper-class districts. In the Chilean capital, the poorer neighborhoods suffer from a lack of green spaces and the resulting effects on the urban climate.

Although a home with an alpine view is one of the most sought-after forms of housing in Switzerland, the Geneva basin can hardly offer this, as the city and most of the surrounding villages are located in the flat plain. As such, the price spectrum for apartments, at least in the Geneva region, cannot be linked to a specific topographical feature—even if more expensive apartments are generally offered on sloping terrain. Here, unobstructed views, ventilation and sunlight prevail, as building regulations stipulate a low density of construction. In Santiago de Chile, on the other hand, a clear settlement trend can be identified: the city's most expensive residential areas in the eastern hills have the coolest temperatures, while the western lowlands of the city, with their poorer population, have the higher temperatures of a more hostile urban climate.

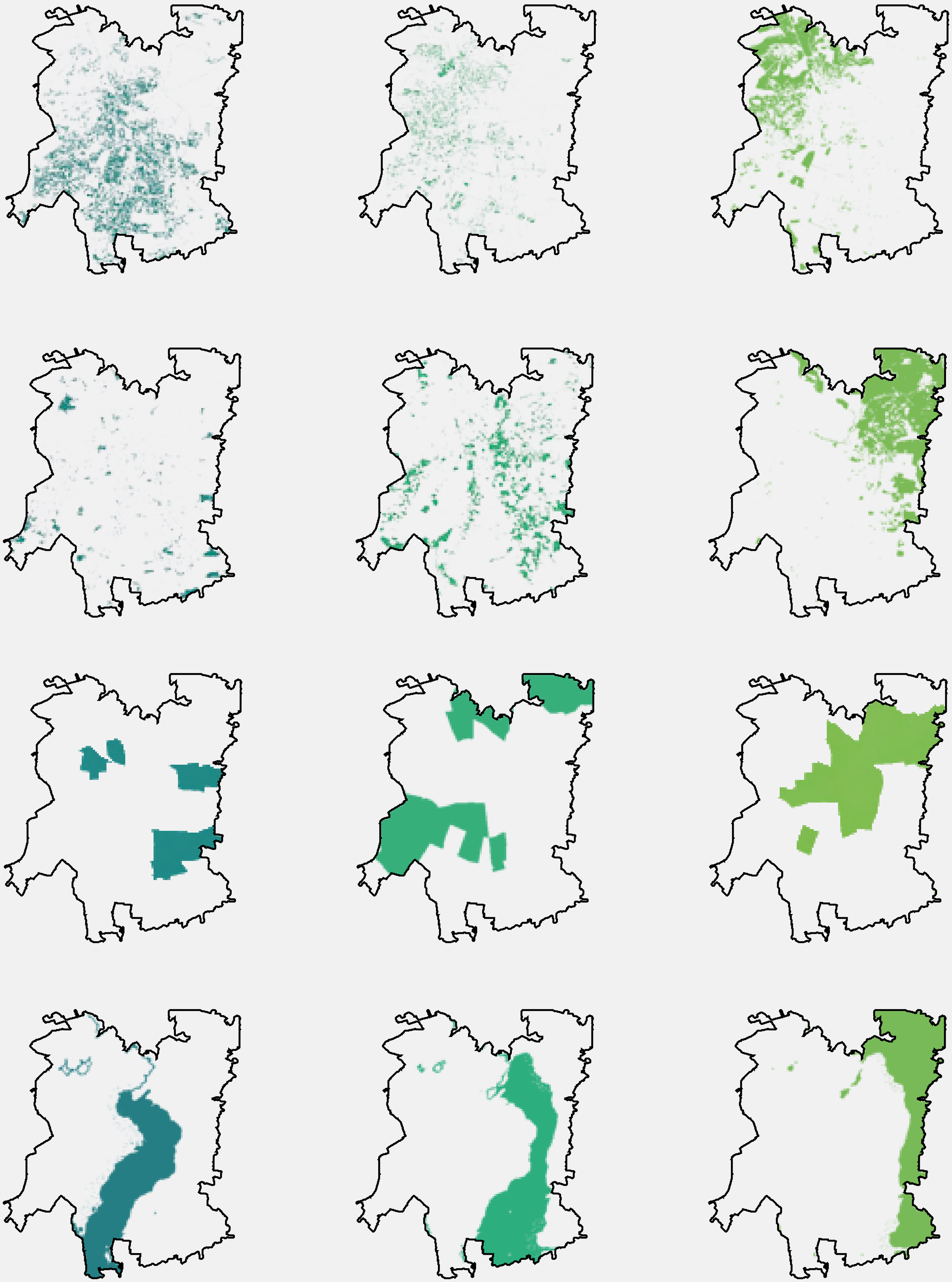
Both cities have so far made only limited use of aspects in planning that positively influence the urban climate. Conscious urban design means taking full advantage of existing potentials and opportunities for climate control to reduce energy consumption and increase quality of life. Architecture, as a key means of climate control in cities, gains particular importance where natural features contribute only to a limited extent to the regulation of the urban climatic landscape. However, the goal here is always an urban design that strives for the synergetic coordination of urban climate aspects at the different scales.

→ figs. 127, 130, 132

141
Santiago de Chile



middle higher highest



middle higher highest

142
Geneva

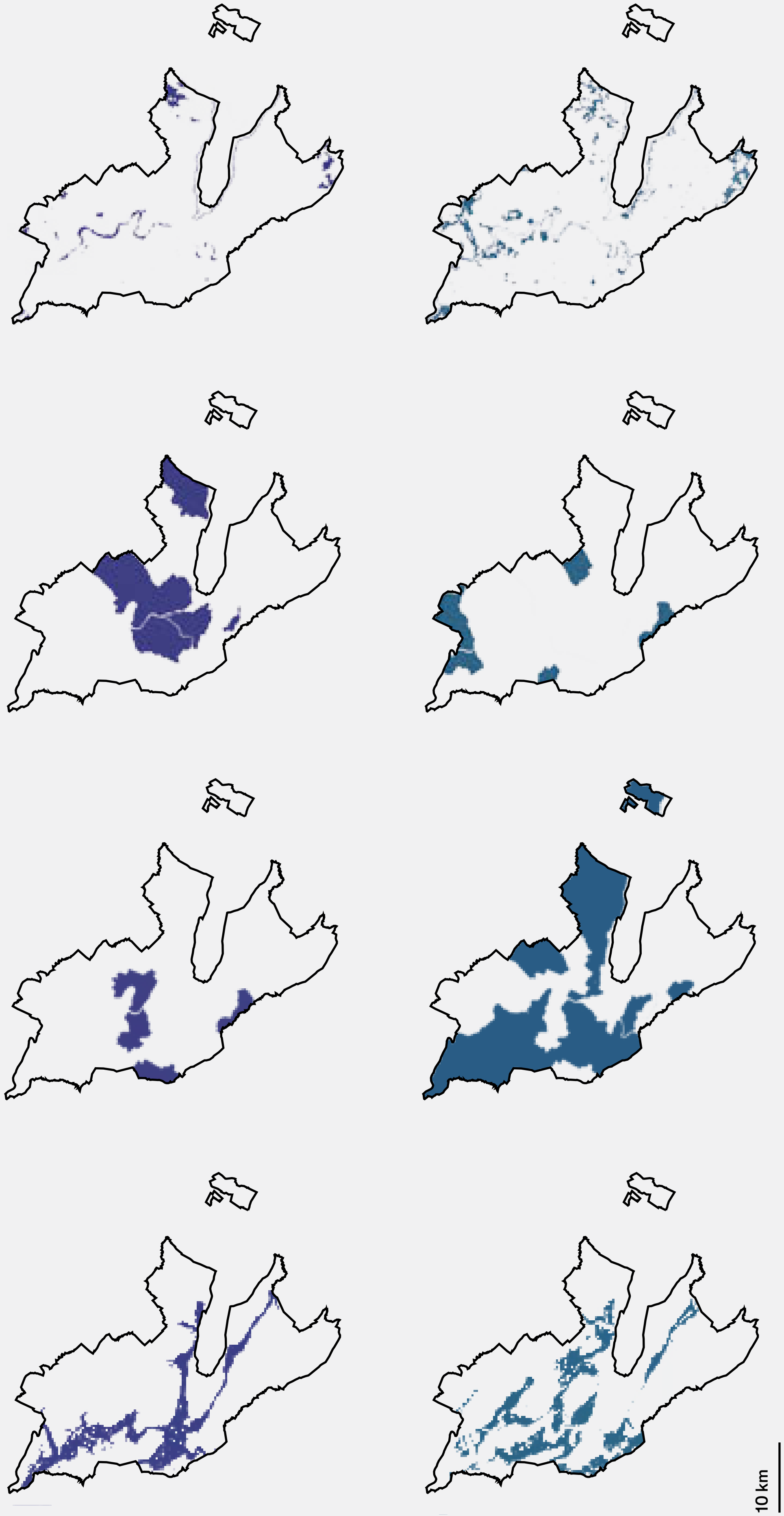
lowest lower

Surface Temperature

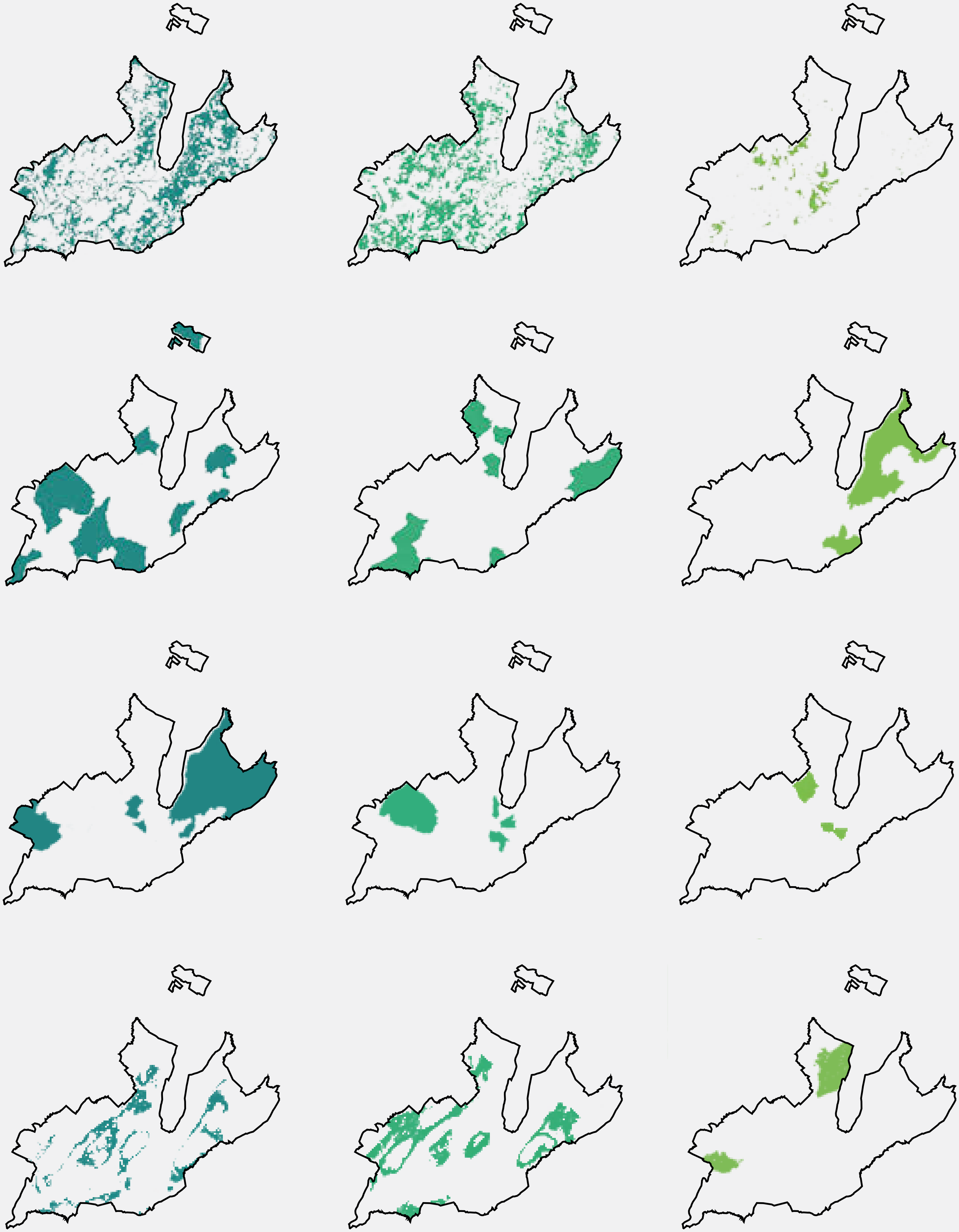
Income Distribution

Real-estate Prices

Topography



lowest lower


middle
higher
highest
middle
higher
highest

143
Map showing Geneva's Energy Infrastructures, which form a cross-border network that is both firmly intertwined with the urban landscape and linked to the world.

The Energy Infrastructures of Geneva

- Petrol station
- Electricity network
- Gas pipeline
- Highway
- Primary road
- Secondary road
- Railway network
- Tram network

- City fabric
- City fabric in 1950
- Large-scale housing project
- Oil and kerosene storage
- Industry and logistics
- Hydroelectric station
- CERN facility

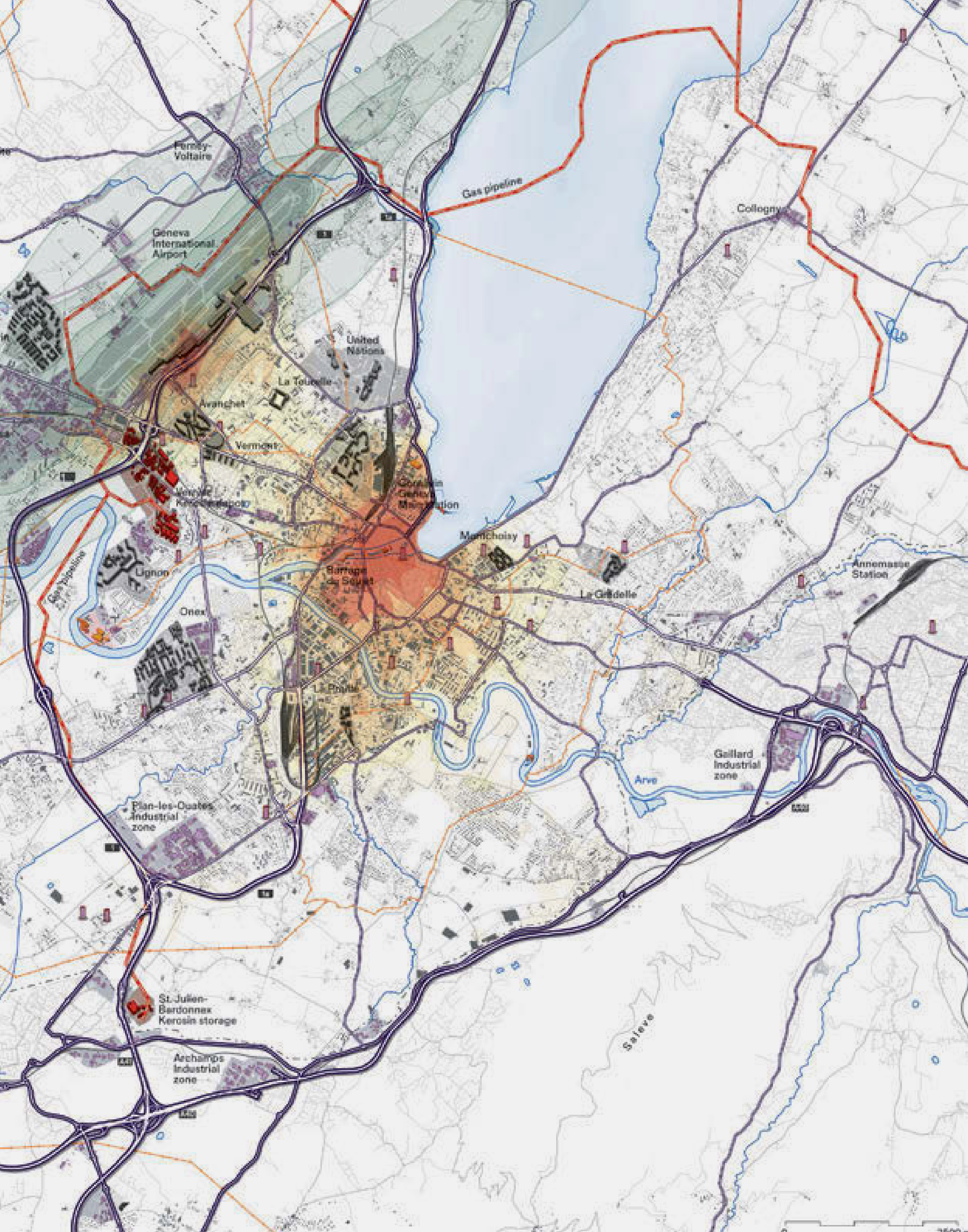
- Main flight corridor
- Airport building and facility

Noise emissions:

- 70 dB
- 65 dB
- 60 dB
- 55 dB

Air pollution, NO_2 emissons:

- 36–38 μg/m³
- 34–36 μg/m³
- 32–34 μg/m³
- 30–32 μg/m³
- 28–30 μg/m³
- 26 –28 μg/m³



Ferney-Voltaire
Gas pipeline
Collogny
Geneva International Airport
United Nations
La Tourelle
Avanchet
Vermont
Montchoisy
Lignon
Annemasse Station
Onex
La Praille
Gaillard Industrial zone
Arve
Plan-les-Ouates Industrial zone
St. Julien-Bardonnex Kerosin storage
Saleve
Archamps Industrial zone

144
Map visualizing Geneva's Energy Commons consisting of natural elements and energy potentials, the various territorial green spaces, the urban environment.

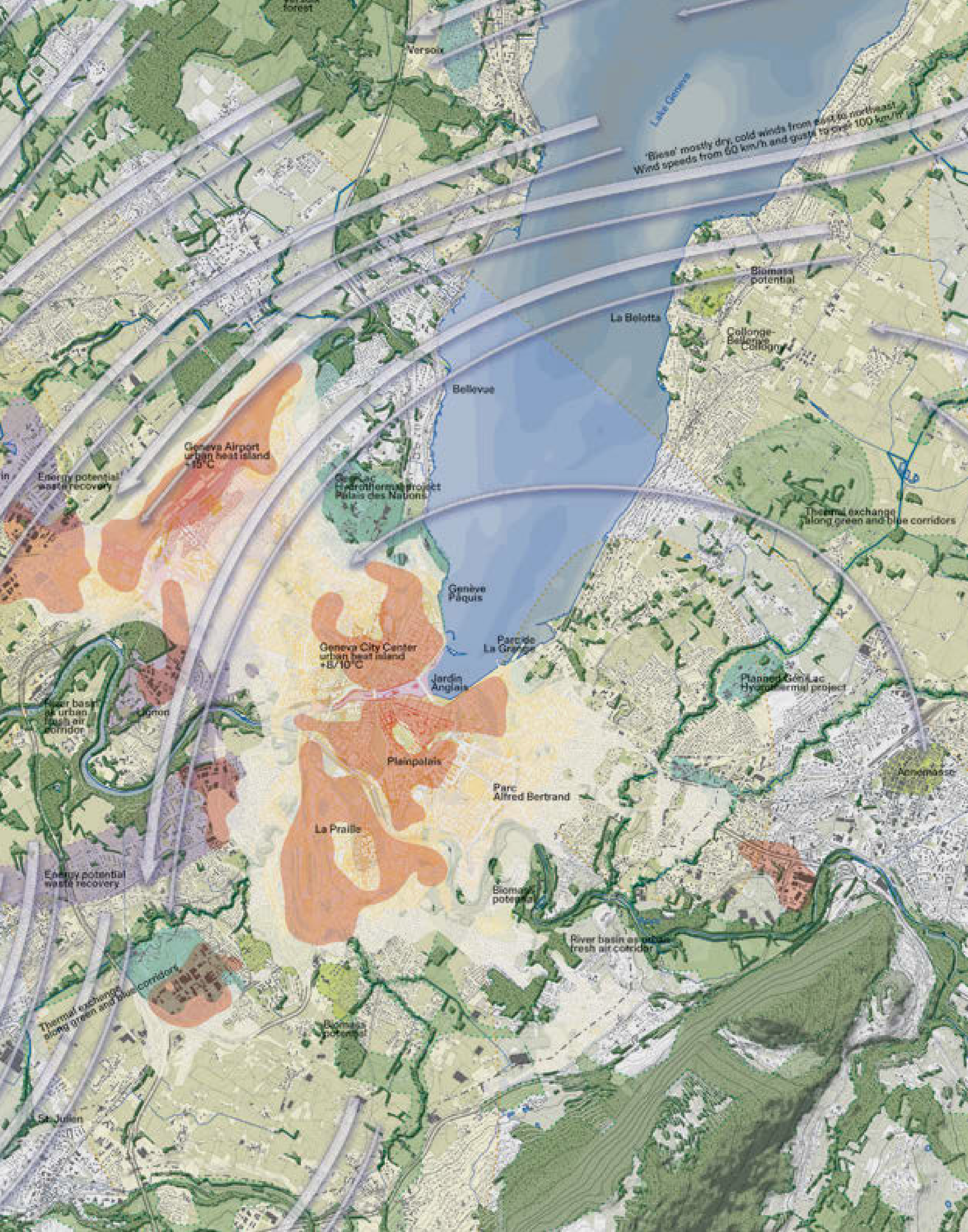
The Energy Commons of Geneva

- Main direction of thermal flow "Geneva Bise" with wind speeds up to 60 km/h and gusts up to 100 km/h
- Main urban heat island Geneva Airport up to 15°C and Geneva City Center with an average of +8–10°C

- Topography "Cuvette Genevoise"
- Lake Geneva
- Lake or other water body
- Main river or stream
- Highway
- Primary road
- Secondary road

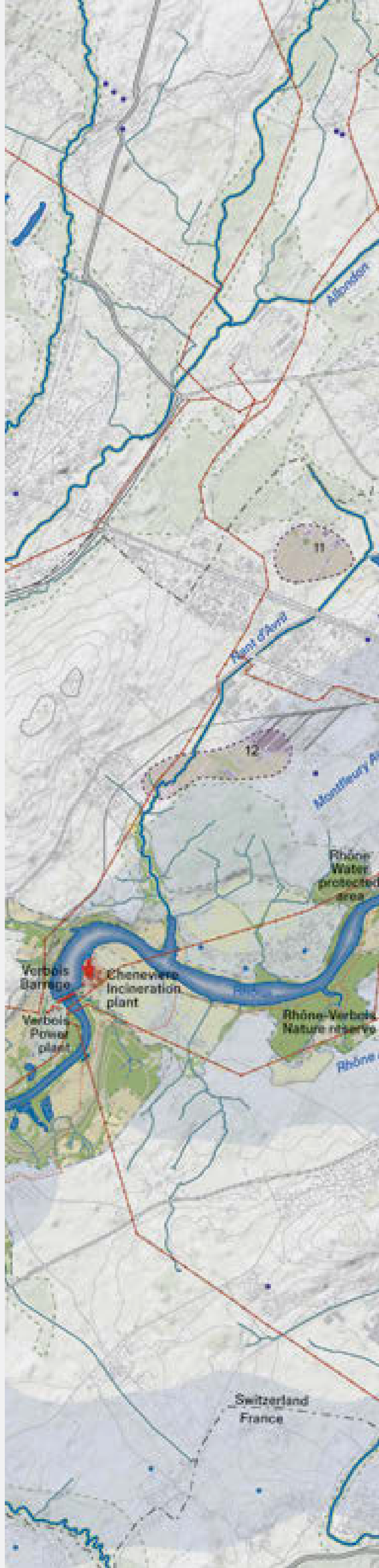
- National border
- City fabric
- Agriculture
- Public park or promenade
- Forest

Energy potentials
- Potential blue and green landscape corridor
- Potential waste recovery
- Potential biogas zone
- Potential natural gas area
- Potential geothermal zone
- Potential hydrothermal zones



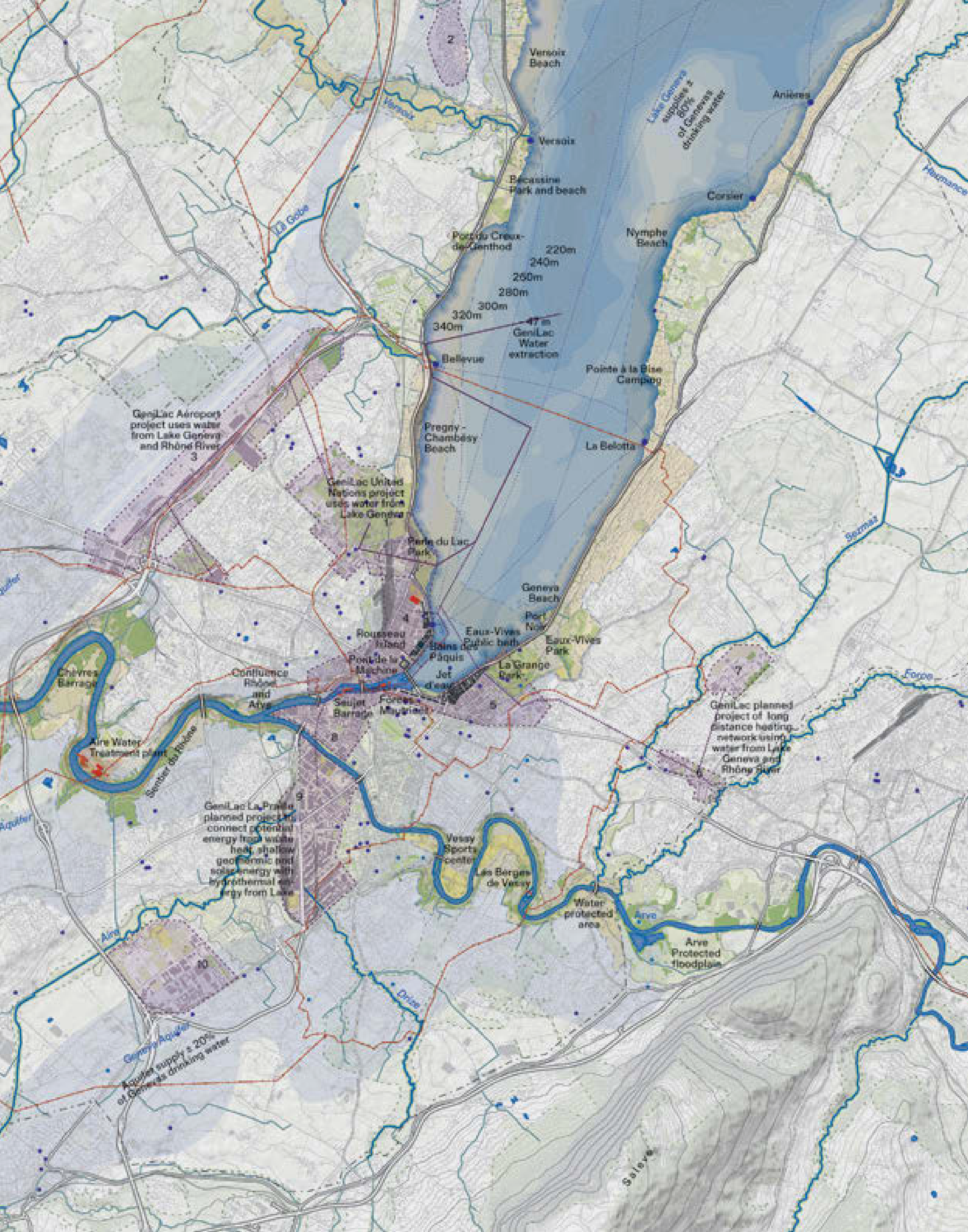
Versoix
Lake Geneva
'Biese' mostly dry, cold winds from east to northeast
Wind speeds from 60 km/h and gusts to over 100 km/h
Biomass potential
La Belotta
Collonge-Bellerive
Bellevue
Geneva Airport
urban heat island
+15°C
Energy potential
waste recovery
Palais des Nations
Thermal exchange
along green and blue corridors
Genève
Pâquis
Parc de
La Grange
Geneva City Center
urban heat island
+8/10°C
Jardin
Anglais
Planned Gen-Lac
Hydrothermal project
River basin
as urban
fresh air
corridor
Plainpalais
Annemasse
Parc
Alfred Bertrand
La Praille
Energy potential
waste recovery
Biomass
potential
River basin as urban
fresh air corridor
Thermal exchange
along green and blue corridors
Biomass
potential
St-Julien

145
Map of the integrated Water Ecologies of Geneva, highlighting the amalgamation of water-related infrastructures for both the production and conservation of energy and urban microclimates.

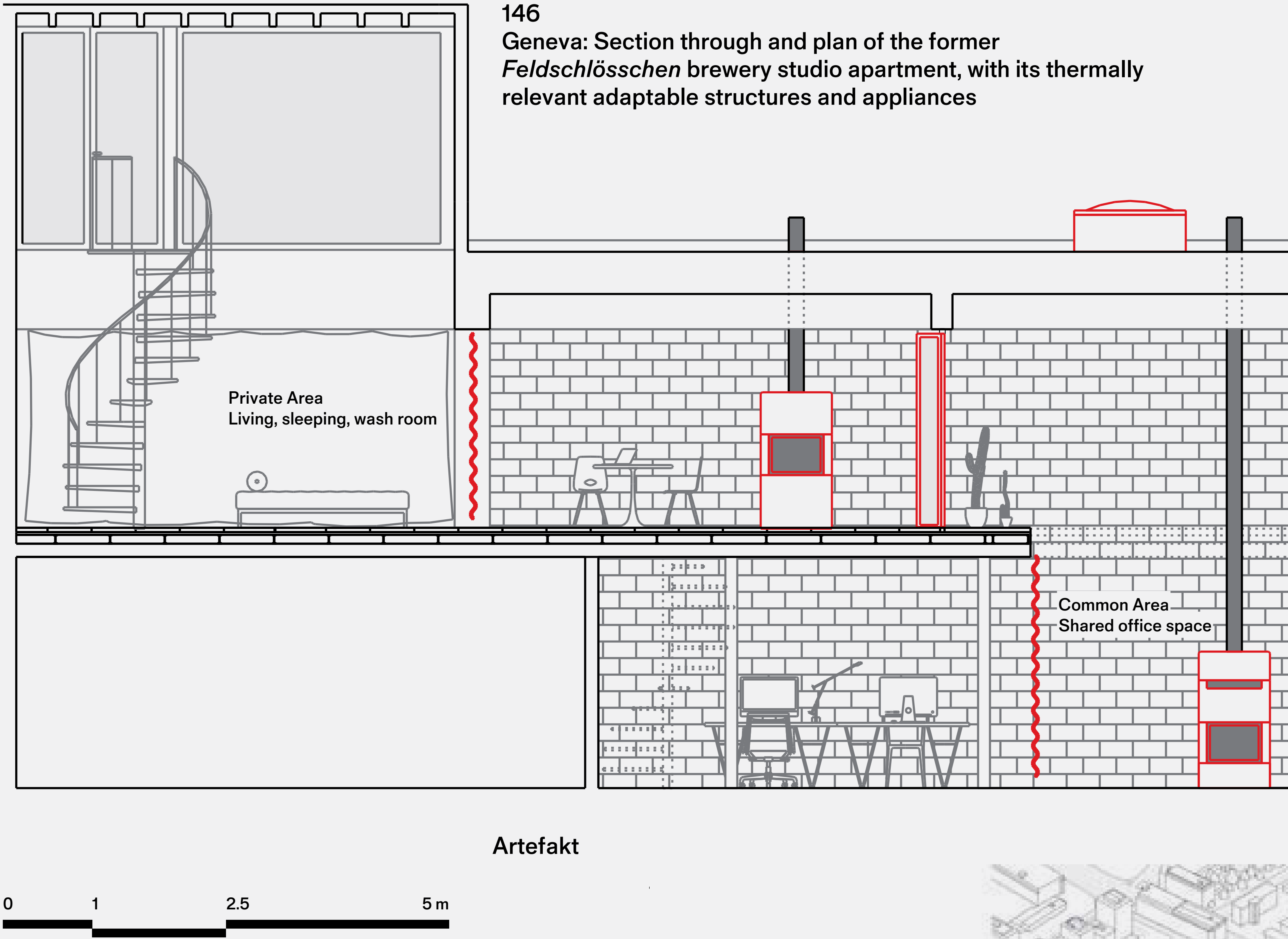


Integrated Water Ecologies of Geneva

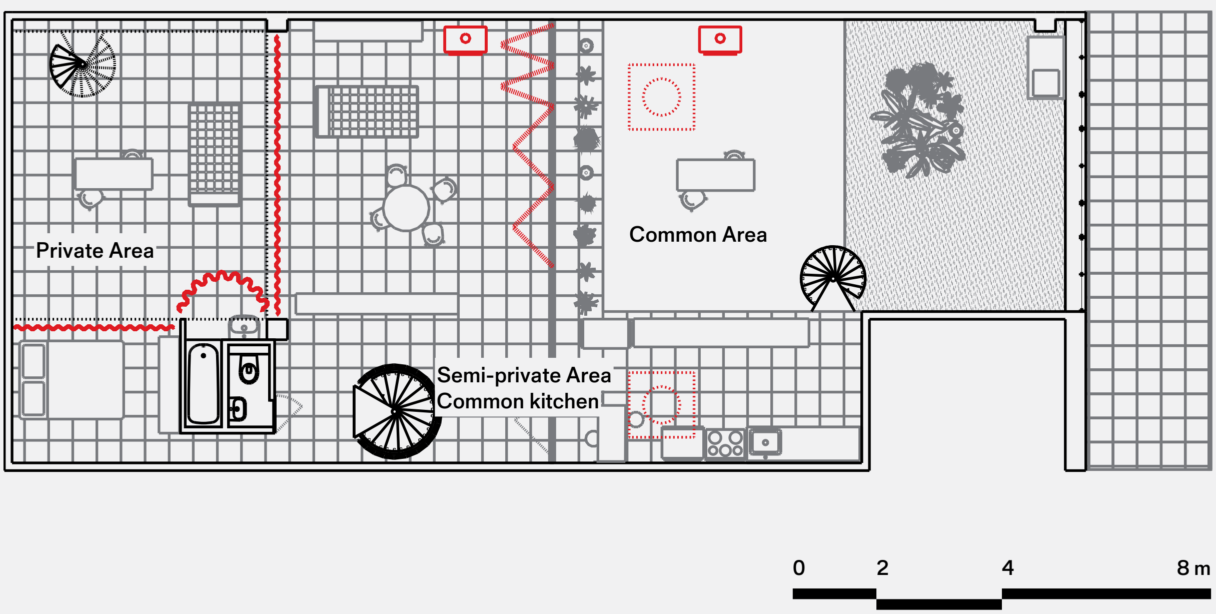
- Lake Geneva
- Other water body
- Main river or stream
- National border
- Ferry terminal or jetty
- Ferry connection
- Fountain
- Waterfront iconic architecture
- Waterfront promenade
- Public beach or park
- Sport field
- Promenade Sentier du Rhône
- Agriculture
- Forest
- Blue and green landscape corridors
- Water protected zone
- Permanent acquifer
- Groundwater well
- Hydrodam or hydropower station
- Main electricity network
- Potential hydrothermal zones, GeniLac projects: 1) Genève Lac Nations, 2) Versoix Lac, 3) Genève Lac Aéroport, 4) Pâquis, 5) City Center, 6) Gare Chêne + Rolex, 7) University Hospital Geneva, 8) Jonction, 9) La Praille Acacias Vernets, 10) ZIPLO, 11) Meyrin Les Vergers, 12) Zimeysa
- GeniLac hydrothermal network
- GeniLac planned hydrothermal network

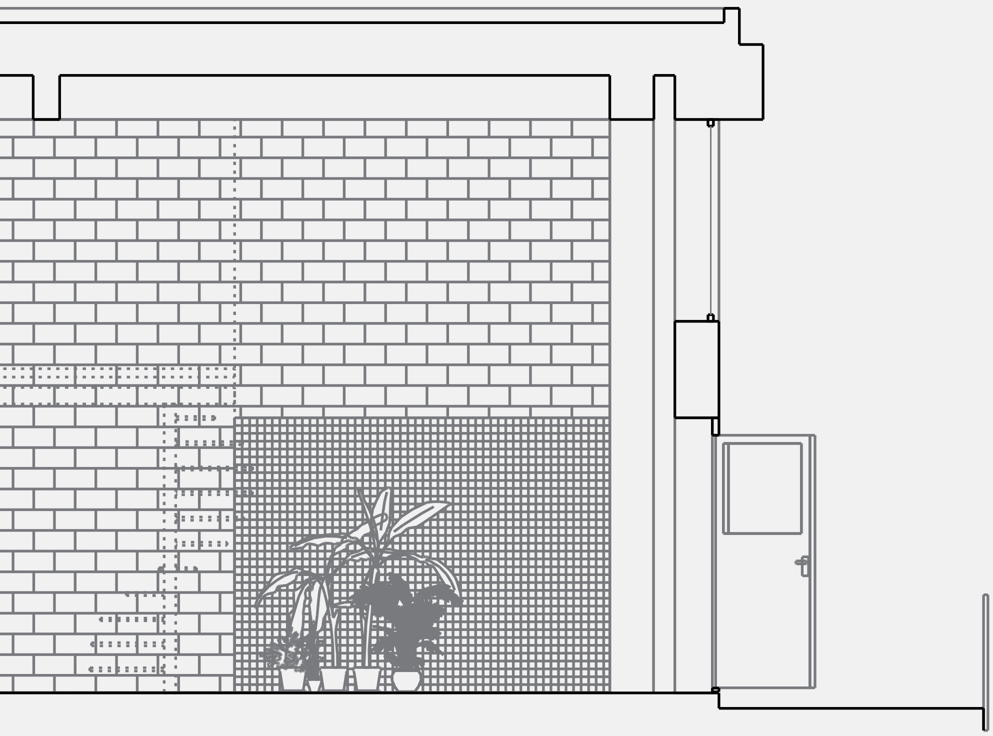

2
Versoix Beach
Versoix
Versoix
Lake Geneva supplies ± 80% of Geneva's drinking water
Anières
Bécassine Park and beach
Corsier
Hermance
La Gobe
Port du Creux-de-Genthod
Nymphe Beach
220m
240m
260m
280m
300m
320m
340m
47 m GeniLac Water extraction
Bellevue
Pointe à la Bise Camping
GeniLac Aéroport project uses water from Lake Geneva and Rhône River
3
Pregny - Chambésy Beach
La Belotta
GeniLac United Nations project uses water from Lake Geneva
1
Perle du Lac Park
Seymaz
Geneva Beach
Port Noir
4
Rousseau Island
Bains des Pâquis
Eaux-Vives Public bath
Eaux-Vives Park
Pont de la Machine
La Grange Park
Jet d'eau
Confluence Rhône and Arve
Chèvres Barrage
Seujet Barrage
Forces Motrices
5
7
Foron
GeniLac planned project of long distance heating network using water from Lake Geneva and Rhône River
6
8
Aire Water Treatment plant
Sentier du Rhône
Aquifer
GeniLac La Praille planned project to connect potential energy from waste heat, shallow geothermic and solar energy with hydrothermal energy from Lake
9
Vesay Sports center
Les Berges de Vessy
Water protected area
Arve
Arve Protected floodplain
10
Drize
Genevois Aquifer
Aquifer supply ± 20% of Geneva's drinking water
Salève

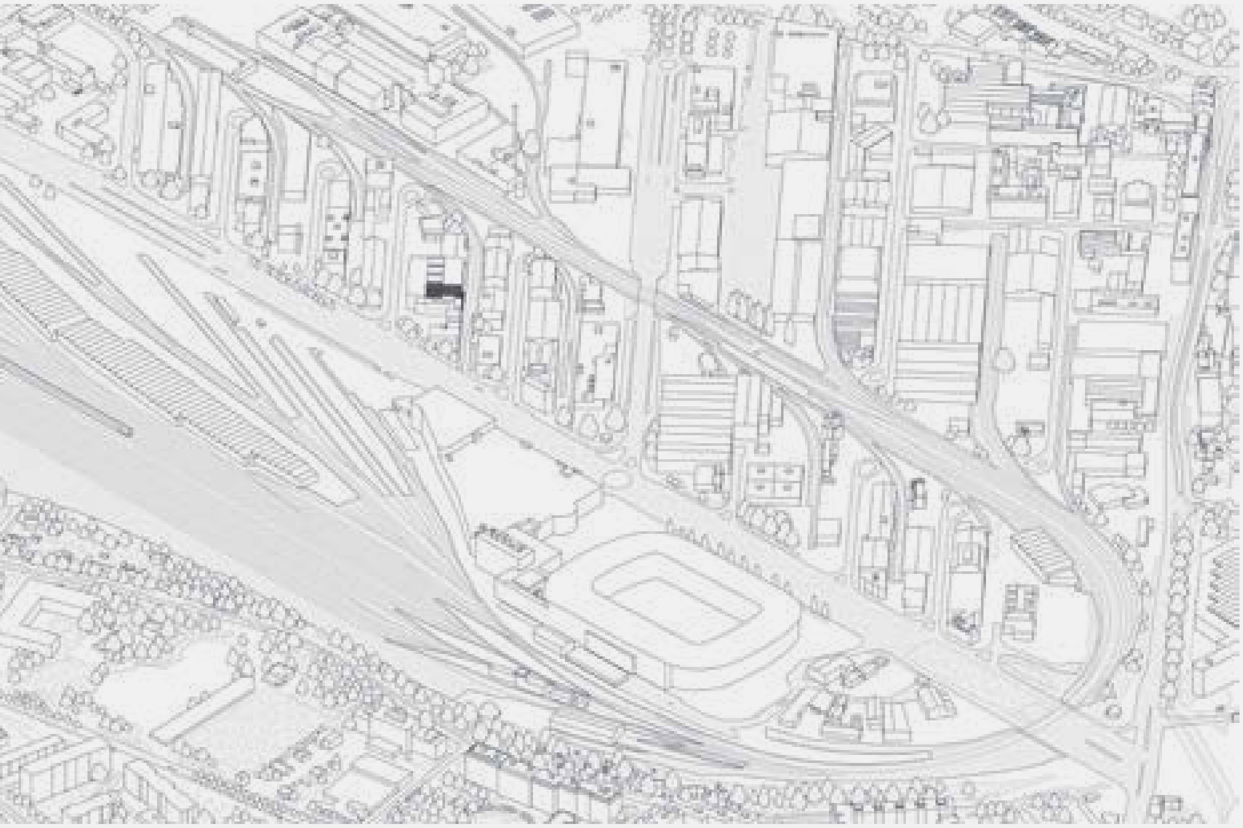
146
Geneva: Section through and plan of the former *Feldschlösschen* brewery studio apartment, with its thermally relevant adaptable structures and appliances



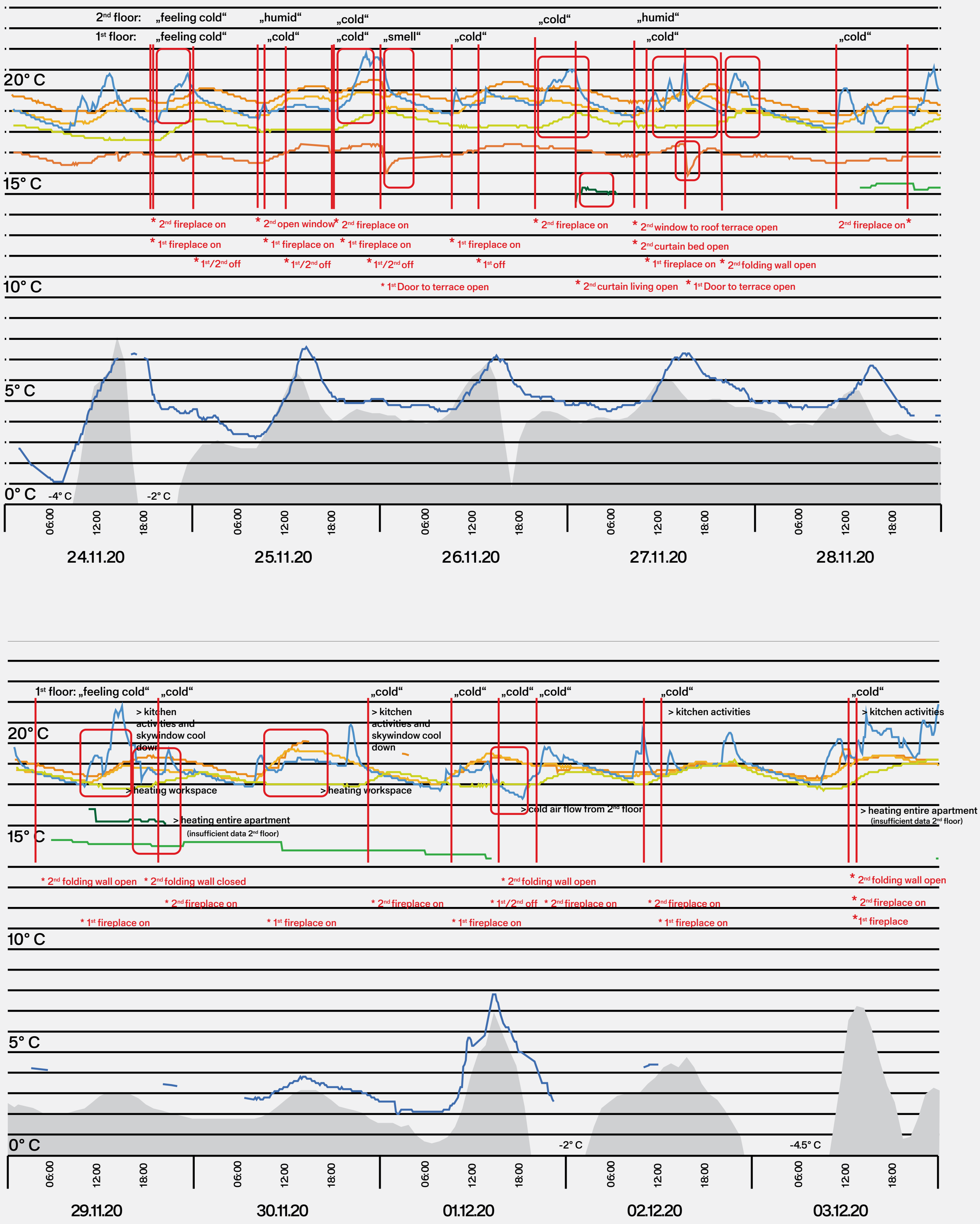
Artefakt







147
Geneva: Axonometric view of the industrial buildings in the development zone Praille-Acacias-Vernets, which is characterized by low buildings and a high degree of ground ceiling. Urban green or water areas are very sparse, and have little to no influence on microclimatic conditions.



- 2nd floor: roof top
- 2nd floor: bed niche
- 2nd floor: folding wall
- 2nd floor: kitchen area
- 1st floor: workplaces
- 1st floor: wall fireplace
- 1st floor: wall to terrace
- 1st floor: outside

148
Geneva: Diagrams that combine weather data, indoor temperatures and thermal actions to analyze the interactions between structural and physical adaptation to thermal conditions in the studio apartment.

Appendices

Endnotes

1 Banham (1960, 172).

2 US Patent 854270

3 Freud (1900).

4 Freud (1982, 241–274).

5 Shove (2009, 37). Being responsible for “one-third of global final energy consumption,” the building-construction sector is also one of the primary causes of “total direct and indirect CO_2 emissions” (“nearly 40%”) and as such, is one of the key drivers of climate change (International Energy Agency 2021a).

6 Bachelard (1994, 211).

7 Mills (2011, 21).

8 Gleich (2018).

9 See the research on ethno-linguistic definitions of climate conducted by the Polish architecture collective CENTRALA, which investigates, for example, the various terms for “snow” and “rain” within the Polish language (Ptak 2018).

10 Shove (2009, 39).

11 Roesler and Kobi (2018).

12 Latour (1993, 11).

13 Soper (1995).

14 “What used to be diverse, seasonally sensitive, ‘local’ indoor weather patterns accompanied also by local conventions and competences in modifying and varying patterns of activity and clothing, are being replaced by a highly uniform indoor climate, itself an outcome of a universalising mode of scientific enquiry” (Shove 2009, 38).

15 “As the legal theorist Michael Gerrard observes, there is a very narrow range of spatial scales on which legislation has addressed the climate problem. To put the issue in historical perspective: we live in the age of the nation-state, in which a single political model is so dominant that it has become difficult even to imagine governance on other scales, despite the fact that most of the world entered this epoch only recently, in the aftermath of the First and Second World Wars. The nation-state model constraints policymaking and even the study of climate change, since ecosystems do not respect political boundaries and science is often a national enterprise” (Coen 2016, 34). Coen mentions Austria-Hungary and Russia as those empires where, already before the First World War, “climate came to be studied as a multi-scale system, from the dimensions of the planet to those of agriculture and human health” (Ibid., 34). She sees the Habsburg Empire as exemplary in its quest towards “a modern ideology of supranationalism;” “the empire’s regions were defined, to a first approximation, by climatic difference” (Ibid., 35).

16 Gramsci (1975).

17 Foucault (1994).

18 Althusser (1995).

19 “It is surprising […] that in the burgeoning literature on environmental sustainability and environmental politics, the urban environment is often neglected or forgotten as attention is focused on ‘global’ problems like climate change, deforestation, desertification, and the like. Similarly, much of the urban studies literature is symptomatically silent about the physical-environmental foundations on which the urbanization process rests. Even in the emerging literature on political ecology […], little attention has been paid so far to the urban as a process of socio-ecological change, while discussions about global environmental problems and the possibilities for a ‘sustainable’ future customarily ignore the urban origin of many of these problems. Similarly, the growing literature on the technical aspects of urban environments, geared primarily to planners and environmental policy makers, fails to acknowledge the intimate relationship between the antinomies of capitalist urbanization processes and socio-environmental injustices” (Heynen, Kaika and Swyngedouw 2006b, 2).

20 On the Marxist notion of “praxis,” see Korsch (1993).

21 Bruno Taut, for example, described in detail the Japanese house with its different types of openings during summer and winter (Taut 1998).

22 Smith and Schmidt (2007).

23 Ingold (2000). / Schatzki (2010).

24 Mauss (1978). / Hall (1990).

25 Roesler (2018).

26 Geiger (1927). / Kratzer (1937). / Brezina and Schmidt (1937).

27 Roesler (2015, 11).

28 Banham (1969, 25).

29 Valdorff Madsen and Gram-Hanssen (2017). / Kobi (2019a).

30 Fitch and Bobenhausen (1990, 37).

31 What Eran Ben-Joseph stated on today’s role of hidden norms in general is especially true for thermal standards: “Standards became the essential tool for solving the problems of [comfort, Sascha Roesler] health, safety, and morality. […] Because so much has been built according to these dictates, the accumulated rules now have the force of universal acceptance–standards have become the definers, delineators, and promoters of places, regardless of variation in landform, natural systems, and human culture. Like genetic code in biology, standards are the functional and physical unit of planning legacy, passed from one generation to the next” (Ben-Joseph 2005, xiii).

32 For the definition of a “global environmental protection regime” see Meyer et al (2005).

33 Eisenberg and Yost (2004, 194).

34 Ibid.

35 Ibid., 195.

36 Ibid., 193.

37 Roaf, Crichton and Nicol (2005).

38 Horn (2018, 18, emphasis in the original).

39 Roesler (2015).

40 It is not only the debate on globalization that takes on new contours in the light of climate change; postcolonial critique itself also undergoes a fundamental questioning. What is needed, as Dipesh Chakrabarty emphasizes, is a link “between the project of subaltern studies and climate change” (Chakrabarty 2016, 27). Chakrabarty reports on extensive flooding in India and also snowfall in Rajasthan, which is one of the hottest parts of the country (Ibid., 31).

41 Latour (2001, 37).

42 Bale (2016, 105).

43 Accordingly, David Eisenberg and Peter Yost point to the need to align sustainable construction with other scales: “The issue of regulatory hurdles with green building is not restricted to buildings and building codes; a new approach is needed as well for the larger issues of land development, zoning, and planning” (Eisenberg and Yost 2004, 194).

44 Freud (1962).

45 The local building tradition leans on a strong, technically, and materially implied separation between exterior and interior spaces. This is achieved through the consistent use of building services and a distinct practice of insulating the building envelope.

46 As Switzerland is located in the cool temperate climate zone, city dwellers experience four seasons with temperature fluctuations ranging from an average of about 0°C in winter to an average of 27°C in the warmer summer months of July and August. This is the period in which the city, in recent years, has been increasingly confronted with severe heat waves—some lasting several days. In 2015, for example, temperature gauges climbed to 39.7°C, setting a national record since the time institutional measurements began. While such climatic events are increasingly characterized by shorter dry periods, the average annual precipitation in Geneva is still relatively stable at 934 mm, and falls in the form of rain, sleet, snow, hail or drizzle, depending on the season. An increase in heat waves in Geneva was carefully documented for the summer months of June, July, and August in the years 2003, 2006, 2010. 2011, 2012 and 2015 (Bey 2019, 11).

47 The canton's *Climate Plan* formulates strategies for reducing emissions and adapting to changing climate conditions in the areas of the building sector, mobility, consumption, spatial planning, health, green spaces and biodiversity.

48 Piguet et al (2018).

49 Ibid.

50 Lotfian et al (2019, 6).

51 Gehrig, König and Scherrer (2018, 26).

52 The old municipal property *Plaine de Plainpalais*, the park *Des Bastions*, the forest *La Bâtie* above the River Rhône and some sports fields were the only significant urban green spaces in public ownership (Bund Schweizer Architekten BSA 1929, 29, 59, 69).

53 Koch (1988, 102).

54 Ibid., 112.

55 Léveillé et al (2003, 72).

56 Salmaso et al (2018).

57 Perroud et al (2009).

58 Raffestin (2010, 37).

59 Ibid., 38.

60 Kuntz (2011, 75).

61 Pflieger (2009, 39).

62 Paquier (2001, 102–112).

63 Cadastral map for average NO_2-emissions in μg/m³ between 2013–2020 (SITG 2021).

64 According to a magazine covering the *Neues Bauen* (New Building), there was already a noticeable improvement in the standard of housing between 1917 and 1931, which included central heating in addition to e.g. hot water (Roth et al 1933, 10).

65 Léveillé et al (2003, 177).

66 Broennimann, Chessex and Gugger (2010, 23).

67 Schweizerische Eidgenossenschaft (2021a).

68 Schweizerische Eidgenossenschaft (2021b).

69 Eidgenössisches Departement für auswärtige Angelegenheiten EDA (2020).

70 Schweizerische Eidgenossenschaft (2020).

71 Ibid.

72 Raiffeisen Casa (2021).

73 Energieheld Schweiz (2021).

74 République et Canton de Genève (2021b).

75 Buson et al (2020).

76 Further insights into the city's energy landscape were gained thanks to an interdisciplinary team of planners (architecture, landscape, transport, infrastructure) working on a research project on the future development of Greater Geneva between 2019 and 2020. See Buson et al (2020).

77 Gandy (2014, 224).

78 Scholars such as Peter Reyner Banham and Alvin Boyarsky used ecological narratives to describe complex natural, architectural, social, infrastructural and economic interdependencies of specific areas of cities delimited not necessarily by a normative definition but by specific relationships among people, nature and the urban (energy) landscape (Boyarsky 1970; Banham 1976).

79 Piguet et al (2018).

80 Corboz (2001, 87).

81 Ibid., 88.

82 Frommel (2010, 9).

83 Laescaze (2007, 6).

84 Perrin (2015).

85 A forerunner was the *Bains Lullin*, which, from 1710, allowed safeguarded, gender-segregated bathing in the lake.

86 Hohler (2020).

87 Among reported thermal effects are earlier onset of stratification, less frequent complete winter overturning, stronger thermal gradients in the thermocline, shallower depths of the thermocline and overall warming of the entire water column (Perroud et al 2009, 1574).

88 Jorio (2015).

89 Services Industriels de Genève SIG (2021).

90 Zogg (2008, 26).

91 Guadard, Schmid and Wüest (2018, 32).

92 The city-wide GeniLac-network consists of the projects Lac Nations, Versoix Lac, *Lac Aéroport*, *Pâquis*, *City Centre*, *Gare Chène + Rolex*, *University Hospital Geneva*, *Jonction*, *La Praille-Acacias-Vernets*, *ZIPLO*, *Meyrin Les Vergers* and *Zimeysa*.

93 Compare the climate analysis maps (*génération d’air froid, zone impact de l’air froid*) provided by the cadastral service of Geneva, SITG (2021).

94 “According to [Arne] Kaijser’s definition [from 1994], infrasystems are large technical systems with a public character—they are equally accessible for all potential users within the geographical area covered by the system. Infrasystems also imply considerable and long-term conditions for public activities. […] From an all-embracing perspective, infrastructure should be understood as a seamless web of technical, economic, social, and political aspects […]. That is to say, infrasystems should be treated as sociotechnical systems, not simply as sets of coherent technical components—they also include the people and organizations that build, run, and use the systems, and the economic and legal conditions for the activities” (Jonsson 2005, 2–3).

95 Office de l’Urbanisme and Département du Territoire (2021, 346).

96 Departmenet du Territoire, Frommel and Arikok (2006, 19–27).

97 Different areas were either planned by the Swiss Confederation, the State of Geneva or the Swiss Federal Railways—or, as in the case of the industrial land, managed by the *Foundation for the Praille et Acacias Industrial Lands* (FIPA becoming FTI in 1966).

98 Departement du Territoire, Frommel and Arikok (2006, 64).

99 Data retrieved from the solar-radiation cadaster (SITG 2021) and a temperature-comparison diagram between the districts during summer days, retrieved from https://ge21.ch/index.php/portfolio/nos-arbres

100 Surface temperature map of Geneva retrieved from https://ge21.ch/index.php/portfolio/nos-arbres

101 Schlaepfer, Amos and Robert (2018).

102 République et Canton de Genève (2015). / CSD Ingenieurs (2014). / Office de l'Urbanisme and Département du Territoire (2021).

103 Schweizerische Eidgenossenschaft (2016).

104 In building ordinances and regulations on thermal insulation, the canton lays down specific requirements for precise constructional and technical implementation (République et Canton de Genève 2021c).

105 République et Canton de Genève (2019).

106 GEAK (2021).

107 République et Canton de Genève (2021a).

108 The energy-consumption certificate ensures compliance with legal requirements and is usually prepared by professional building physicists on behalf of the architect.

109 Fieldwork interview, July 2020.

110 According to its official energy register (energy; building cadaster, indices), the building is indexed among the high-consumption levels of 700–800 MJ/m² (SITG 2021).

111 Fieldwork interview, April 2021.

112 The 2 m³ wood pile, which is sourced by *Landi* within Switzerland in the Canton of the Grisons, is stored within the studio space and shrinks steadily with the heating demand. Fieldwork interview, April 2021.

113 Fieldwork interview, March 2020.

114 SECO (2020).

115 Fieldwork interview, April 2021.

116 Fieldwork interview, April 2021.

117 Temperature records show that the temperature upstairs can drop as low as 10°C during periods when heating is neglected, as was the case during the Christmas holidays between 24 December 2020 and 5 January 2021 when the couple was away.

118 Analysis of data retrieved from measurements and the protocol made in the period between November 24 and December 3, 2020.

119 Guillaume adds other arguments, such as that "equalizing the indoor temperature" has the effect that people no longer open the windows, which results in "missing the experience of the seasons." Fieldwork interview, April 2021.

120 Fieldwork interview, April 2021.

121 SITG (2021), comparing the raster maps "Climate Analysis 2020 – Daytime Air Temperature" and "Climate Analysis 2020 – Equivalent Physiological Temperature (PET)," both showing the air temperature in the canton of Geneva with data modelled using the urban climate model FITNAH-3D. The physiological equivalent temperature (PET) defines the heat-balanced air temperature for a human body, enabling a layperson to compare a complex thermal condition outside (with winds, solar radiation, water-vapor pressure) with his or her own experience (considering metabolism, clothing and work) of indoor temperatures. Especially on hot summer days (+20 Kelvin) and windy winter days (-15 Kelvin), the temperatures perceived by humans can deviate greatly from the actual measured temperature. The PET calculation formula was introduced by Höppe and Mayer (1987), and is used to better assess the thermal comfort of people (Höppe 1999).

122 SITG (2021).

123 Temperature value of 42.4°C in the shade at 2pm on August 20, 2020.

124 Fieldwork measurements, July 2021.

125 Fieldwork interview, April 2021.

126 "The combination of landscape with infrastructure necessarily brings questions of aesthetics and cultural representation into our analytical frame, and immediately unsettles a narrowly social scientific approach to the study of cities" (Gandy 2014, 63).

127 Fieldwork interview, April 2021.

128 Fieldwork interview, April 2021.

129 Urban climate research suggests that individual perceptions of thermal comfort are only 50 percent dependent on actual measurable physical conditions; the other half is psychological and depends on having the "choice" to change one's thermal environment. Prof. Peter Gallinelli in a personal conversation on measuring the urban climate (HEPIA, Geneva, 2020). The fact that the psychological state of consciously having a choice weighs more than the various physical attributes was tested and confirmed in Gallinelli's research project "CityFeel." Using a backpack equipped with a variety of sensors and cameras, the research team was able to propose that although it had no significant impact on the microclimate, people felt more comfortable due to the sheer idea of a mitigating effect.

130 Hough (1989, 201).

131 Knowles (2006). / Schmidt and Austin (2016).

132 Geiger, Aron and Todhunter (1995, 161, 177).

133 Kabisch et al (2017).

134 Shove (2003).

135 Ibid.

136 Worldbank (2021).

137 Gaudichaud (2017).

138 Kusnetzoff (1975; 1987).

139 Ibid.

140 Jirón (2004).

141 Ibid.

142 Haramoto et al (1997).

143 Hassler (1996). / Johansson (1996).

144 De la Puente et al (1990). / Jirón (2004). / Romero (2004).

145 Rodríguez (1973, own translation).

146 Meadows et al (1972).

147 Romero et al (2010). / Romero, Salgado and Smith (2010).

148 San Martín et al (2013). / Bobadilla et al (2014).

149 Castán Broto (2019, 156–7).

150 Rodríguez (1967).

151 Pollitt (2004, 234).

152 Simsek et al (2019).

153 Holifield (2009).

154 For example, the *Población Central de Leche* (1937) and the *Población Huemul II* (1940–43) (Fuentes and Pérez 2006).

155 Valenzuela (2008, 264).

156 Fuentes and Pérez (2006).

157 MINVU (2014).

158 Hidalgo (2002).

159 The most best housing projects are the *Unidad Vecinal Providencia* (1953–65), the *Unidad Vecinal Portales* (1954–66), the *Villa Olímpica* (1960–64), and the *Villa Frei* (1965–68).

160 Later renamed MINVU (*Ministerio de Vivienda y Urbanismo* / Ministry of Housing).

161 Perry (1929).

162 Gertosio Swanston (2016).

163 Ibid., 125, own translation.

164 Comment made by a neighbor in the newspaper *El Vecino* (Gertosio Swanston 2016).

165 Chilean Government, Ministry of Justice, Law 6071.

166 Forray, Márquez and Sepúlveda (2011).

167 Costas (2017, 31).

168 Costas and Torrent (2018).

169 The different possible layouts with Blocks 1010/1020 are particularly evident in the *Población Jaime Eyzaguirre* (1974–75), where one might find isolated blocks as well as assembled ones.

170 Singer (2010).

171 Kipfer and Keil (2000).

172 Agyeman (2013).

173 Krüger, Freytag and Mössner (2019).

174 Vergare Perucich (2019).

175 Indeed, standards are introduced into a country by the people and institutions promoting them, politicians and developers, who superimpose their own views and set of values when selecting them.

176 LEED (2021).

177 Elkadi (2006).

178 Fierro (2003).

179 Fieldwork interview with “Ambiente Consultadores Ltda” in Santiago, 2018.

180 Schindler (2010, 312).

181 This document and the plans of four housing projects are available on www.elementalchile.cl/ The manual is “advertised” by the architecture office as an example to be reproduced through adjusting designs and materials to local regulations and codes.

182 Fieldwork interview with Elemental, 2017.

183 Here, I use the (mostly) European way of designating stories, whereby in Chile “ground floor” is labeled “first floor” similar to the American and Chinese convention.

184 This thermal practice of wearing warm clothes indoors aligns with the findings of Madlen Kobi in Chongqing, China, where central heating is also non-existent (Kobi 2019a).

185 Following the idea of philosopher of technology Andrew Feenberg, who sees reason (including scientific knowledge, technical rationality) as interdependent with experience, I argue that thermal comfort results from the relationship between technology and society. “Reason” here refers to apparently rational decision-making with regards to comfort (based on quantitative definitions of U-values, standard values for indoor humidity, etc.) that is then complemented by “experience,” including individual thermal practices such as keeping a jacket on indoors or adapting the room temperature with punctual heating or cooling devices (Feenberg 2010).

186 Herzfeld (1993).

187 Timmermans and Epstein (2010, 80).

188 Shove (2010).

189 Elzen, Geels and Green (2004).

190 Heschong (1979).

191 Heynen, Kaika and Swyngedouw (2006, 4).

192 Moe (2014). / Iturbe (2019). / Barber (2020). / Knox (2020). / Lis (2021).

193 At the end of the 19th century, the term “electropolis” was used to describe large industrial cities known for their extensive electricity networks. My use of the term is directed more towards an ideal future city wherein all energy-related functions can be covered by electricity instead of coal or petroleum. See also Graham and Marvin (2001, 45–47).

194 Climate Transparency (2019, 7).

195 International Energy Agency (2021).

196 Varro and An (2020).

197 From 177.28 billion kWh in 1997 to 1,186.52 billion kWh in 2020 (China National Bureau of Statistics 2021).

198 Han and Wang (2001, 117).

199 In Chongqing, industry consumes around 65 percent of the city’s energy, while the residential sector only accounts for 17 percent. Air conditioning, however, is not only used to cool private rooms, but is also an energy-consuming activity in industrial buildings, cooling production sites, or for cold storage, etc. (Hossain and Li 2016, 53).

200 Glicksmen, Norford and Greden (2006, 11).

201 China National Bureau of Statistics (2021).

202 Roesler and Kobi (2020).

203 The first investments in central heating benefitted factories, workshops and dormitories. In the 1970s and with improvements in economic conditions, the district heating system also included urban civil buildings (Jiang 2015).

204 China is divided into five major climate zones: severe cold (sometimes, further subdivided into three); cold; temperate; hot-summer-warm-winter; hot-summer-cold-winter. Building construction today has to comply with regulations that depend upon these seven defined climate regions in the official Uniform Standards for the Design of Civil Buildings from 2019 (GB 50352-2019).

205 The Central People’s Government of the People’s Republic of China (2010).

206 Tian and Zhou (2015).

207 Roast (2020, 14). / See also Hu and Song (2011).

208 Committee for Urban and Rural Construction Management in Chongqing and Chongqing Building Authorities (1997, 166).

209 Campbell (1996, 298).

210 “Many of the factors that shape current energy systems, from electricity networks to the type of houses in which people live, have emerged over time as part of a historical process through which different features of energy systems become embedded in our societies and economies” (Castán Broto 2019, 8).

211 Rural households, and those not connected to the energy grid, often heat themselves with coal briquets that lead to rural air pollution. Roughly half of the Chinese population, much of it in more rural areas, heats and cooks with solid fuels. Next to industrial emissions, these household activities contribute significantly to rural air pollution (Aunan et al 2019, 27).

212 Climate Transparency (2019, 6).

213 Ahlers and Hansen (2017, 89–90).

214 Ibid. / See also Peng (2012, 135).

215 Apparently, during that time, shoe cleaners often lined up along the main street to shine the dusty shoes of passersby. Fieldwork interview, June 2020; diverse fieldwork conversations in December 2017.

216 Hualongwang (2014).

217 Ahlers and Hansen (2017, 91).

218 Tian and Zhou (2015).

219 Bray (2005).

220 Peng (2018, 49).

221 Committee for Urban and Rural Construction Management in Chongqing, and Chongqing Building Authorities (1997, 130).

222 Huang (2017, 78).

223 Fieldwork interview, July 2020.

224 To guarantee anonymity, all personal names in this article have been changed.

225 Fieldwork interview, July 2020.

226 Fieldwork interview, September 2017.

227 Fieldwork interview, August 2017; fieldwork interview, July 2020.

228 Peng (2018, 89).

229 The situation was similar in other socialist Asian countries, such as Vietnam, where green design was the result of the political economy. The provision of ample sun, greenery and good ventilation in and between houses of socialist-era compounds was a pragmatic and affordable way to provide comfortable microclimates, albeit not based on eco or green thinking (Schwenkel 2017).

230 Liu, Meyer and Hogan (2010, 94).

231 Zhou and Logan (1996). / Zhu (2002).

232 Peng (2018, 113).

233 Liu and Hogan (2010, 95). / Yao et al (2013, 16).

234 Luo and Li (2014).

235 Ackermann (2002). / Hitchings (2011). / Shove (2012).

236 Fieldwork interviews and material, August 2017.

237 The Central People's Government of the People's Republic of China (2009).

238 Fieldwork interview with an architect from Chongqing University, August 2017.

239 Tengxun Da Yuwang (2017). / Sustainia (2019). In Chengdu, some upper-class compounds advertise underfloor heating (Texeira 2019).

240 Zhang (2010).

241 Fieldwork conversation, August 2017.

242 Fieldwork interview, August 2017.

243 Hitchings and Lee (2008). / Van Leeuwen (2011). / Sahakian (2014). / Horn (2016).

244 Equivalent to approx. 90 Euro.

245 Equivalent to approx. 9 Euro.

246 Yingda Media Group (2013).

247 Kobi (2020a).

248 Fieldwork conversation, December 2017.

249 Fieldwork interview, July 2020.

250 With "heating," he refers to electric heating devices. Fieldwork interview, July 2020.

251 Interview data shows that in the 2000s, 18 percent of residents in the city of Changsha (Hunan province, same climate zone as Chongqing) still relied on braziers (Han 2009, 144).

252 Roesler (2018a). / Kobi (2019b).

253 Fieldwork conversation, December 2017.

254 1,600 RMB is equivalent to approximately 200 Euro. The mean annual disposable income of Chongqing residents in 2016 was 27,239 RMB, approx. 3,500 Euro. It has risen significantly since 1999, when the mean annual disposable income was only 5,915 RMB (approx. 760 Euro) (Han and Wang (2001, 124; Worldbank 2019, 4).

255 In 2017, the installation of underfloor heating in an apartment of 100 m² cost some 30,000 RMB (equivalent to ca. 3,800 Euro) and the running costs can amount to 2,000 RMB (equivalent to ca. 250 Euro) per month, which only concerns the 3–4 coldest months in winter. The high costs stem from its running all the time—contrary to electric or infrared heaters, which are switched on and off when needed. Apart from the high costs, electric underfloor heating is considered only by people buying new apartments when deciding about the interior architecture. Most likely, nobody in an already furnished apartment would seriously decide to tear up the floor and install new heating below.

256 Fieldwork conversation, December 2017.

257 Fieldwork conversations, December 2017.

258 Fieldwork conversation with a heating engineer, December 2017.

259 Cai, Yin and Wennerstern (2013, 330).

260 Fieldwork conversation, August 2017.

261 Liu, Meyer and Hogan (2010, 106).

262 However, one study estimates that simple changes and improvements in construction quality will significantly improve energy efficiency during the lifetime of residential buildings. Estimates predict that a mere 5–10 percent added cost premium in construction would easily yield energy savings, in operation, of 50 percent or more. But these savings go into the pockets of the later occupants (Fernandez 2006, 46; Romano 2014, 238).

263 Klein and Kögel (2005, 82–83).

264 Vector Architects (2015).

265 Safdie Architects (2017).

266 Kobi (2020b).

267 Hansen, Li and Svarverud (2018).

268 *Shanshui* is translated as "Mountain and Water" and is a concept that includes natural surroundings, as inspired by traditional Chinese landscape paintings. See also Mirra (2019).

269 Saunders (2012). / Ma and MAD architects (2015).

270 Silver (2015). / Castán Broto (2019).

271 Denjean et al (2016, 19).

272 Chongqing City Electricity Company (2011).

273 Draugelis and Li (2012, 182).

274 Texeira (2019).

275 Liu, Meyer and Hogan (2010, 97).

276 Liu (2012).

277 Stanway and Cadell (2021).

278 Nielsen and Ho (2013, 14). / Korsnes (2014, 184). / Castán Broto et al (2020).

279 Nielsen and Ho (2013, 5).

280 In 2019, of the 811.55 billion kWh total energy production in Chongqing, 242.27 billion kWh were generated through hydropower (China National Bureau of Statistics 2021).

281 McDonald Wilmsen (2009).

282 Lau (2011, 31).

283 Silver (2015, 1000).

284 On the notion of "microclimate" see Roesler and Kobi (2018).

285 Pictet (1870).

286 In Greater Cairo, January is the coldest month, with an average temperature of 13.8°C, a minimum of 8.8°C, and a maximum of 19.7°C. On the contrary, in July, the hottest month, the average minimum and maximum temperatures are 27.9°C, 22.3°C, and 34.9°C respectively. In January, in the dead of winter, average relative humidity is 67 percent, whereas in May it is at its minimum 38 percent. Rain is absent from April to September. The maximum amount of rain occurs in December—but, not exceeding 6.8 mm, it is insignificant.
Wind speed, in knots (1 kt. is 1.852 km/h), ranges from a minimum of 2.8 kt in October to a maximum of 5.6 kt in May (Robaa 2013).

287 Rosenthal (2012). / Lelieveld et al (2015).

288 Whittaker (2018).

289 Volait (2005).

290 Shawkat (2014).

291 For example, *Sixth of October*, *Tenth-of-Ramadan* and *Badr City* (El Kadi and Rabie (1995).

292 Sims (2010).

293 In this chapter, I choose to transliterate Arabic terms into Latin letters following the system used in the *International Journal of Middle East Studies* (IJMES). One exception is the letter <jim> that I write *g,* pronounced hard *g*, like in the Egyptian dialect. For the names of people and places, I chose between already-existing conventional spellings.

294 Bayat and Denis (2000).

295 Lenzholzer (2015).

296 Olivier de Sardan (2013, 49).

297 Ibid., 55.

298 This *modus operandi* can be read as a precarious attempt to reduce the gap between projected living ideals and the actual setting. Thus, the logic of house-making from its inhabitants' perspective echoes the logic that produces Cairo's urban space. That is why I aim to shed light on how the inhabitants of Cairo relate to the built environment that they primarily control—namely, their houses.

299 They are simply the houses I was lucky enough to access thanks to the people I met during my research. Accessing the houses required building up a familiarity that guaranteed the possibility of repeated visits. For example, I could regularly visit houses where men were absent. Widows, divorced women or those whose husbands work abroad are not bound to organize their lives at home around obligations towards their family unit. For that reason, they are more flexible and welcoming. That was the case with Umm Rania, her mother, and Maryam, whose houses are included in this text. In addition, these women's activities mostly took place at home, since they were unemployed. On the contrary, visiting houses where the whole family was present demanded more organization in accord with the members' schedules. In these cases, I would visit a limited number of times specifically for the study, conducting straightforward semi-structured interviews and surveys, as in the case of Magda in Garden City. As for Dr. Hisham, our relationship is that of colleagues and I was able to befriend his family members, which resulted in being invited to his home some six times during my fieldwork.

300 All the names of informants have been changed.

301 The street was so named in recognition of his historical role during the October War of 1973, when Faysal bin Abdul Aziz decided to ban the export of oil to countries that support Israel—thereby triggering the 1973 oil crisis. He governed Saudi Arabia from 1963 to 1975.

302 CAPMAS (2016, 6).

303 Egyptian Initiative for Personal Rights and The Built Environment Observatory (2017).

304 Vannetzel (2019).

305 The climatic zone in which Cairo is located makes buildings that have no mechanical cooling or heating relatively bearable throughout the year. Otherwise, gas remains a widespread fuel for heating and complements passive modes of cooling and heating oneself. The storage practices I observed, using bathtubs as water tanks for example, show the poor reliability of existing infrastructures. My conversations suggested that rather than caring about electricity for their devices, people's worries were oriented more towards the price of oil, which dictates the price of transportation that, in turn, influences the costs of basic food products, such as meat, vegetables, sugar, bread, etc. The prices of these goods appear to be quite volatile and affect daily lives more readily than deficient infrastructures.

306 Interview with Magda, September 2018.

307 A *sūba* is a "shed in which young plants are cultivated. *sūba izāz* [is a] greenhouse" (Hinds and Badawi 1986, 514).

308 Interview with Magda, September 2018.

309 The *Khamaseen* (*Khamāsīn*) Depression is a strong southern wind that usually blows in spring, even if episodes can occur in autumn as well. *Khamaseen* is the Egyptian version, but it is also called *khamsin* (*khamsīn*), which is the proper Arabic name.

310 Interview with Magda, September 2018.

311 On the Egyptian market, housing is available at various stages of finishing. Companies advertise three possible ways to deliver a house or apartment. It can be unfinished, or *"alā al-tūb al-ahmar"*, literally "on red bricks." This means that the apartment has nothing but a simple entrance door, with the rest being a concrete floor, red-brick walls and openings. Windows, plaster and the door frames are included in half-finished apartments (*nuss tashtīb*), along with electricity and sanitation pipes. Finally, a company can deliver the apartment fully finished (*tashtīb kāmil*)—that is, with the painting, flooring, carpentry and all electrical and sanitation installations done. Beyond these three types, there are four ways in which a house can be finished, from "luxe" (*lūks*), "super luxe" (*sūbir lūks*) to "deluxe" (*dīlūks*) as the quality of materials used increases and includes imported items (wood, ceramic, tiles, etc.).

312 Rabi' (2019).

313 Battesti (2006).

314 Abaza (2001).

315 Hinds and Badawi (1986, 231).

316 Ramadan (*Ramadān*) is a month of the Muslim calendar. Its beginning shifts by about ten days each year with respect to the Gregorian calendar, which explains why it is not related to one season in particular. During this month, Muslims fast from sunrise to sunset.

317 Susan Gal explains that the material basis of such justification discourse is a cornerstone of the principle of reciprocity: "Deictics and other indexicals most often use the speaker's body as an orienting centre so that far from being 'merely discourse,' these processes of 'pointing' away from self and towards self through speech have a strong materiality. Even when recruited—through metadiscursive commentary—for grand political projects, they remain available for creating embodied subjectivities" (Gal 2002, 81).

318 Maryam's living room has a marble stage at the foot of its bow window. She says that the layout of the flat was supervised by her mother and mother-in-law while she was living in the Arabian Peninsula with her husband. Her mother-in-law proposed building the marble stage. Embarrassed at the idea of contradicting her enthusiastic mother-in-law, she accepted. Today, the then-argument of her mother-in-law makes Maryam laugh: she thought that the stage might be a good idea for the future wedding of her granddaughter Omnia, who was then barely five years old.
On that occasion, this could be the stage where the disc jockey will take his place. Here, the design has no immediately conceivable content other than a simple demonstration of status.

319 Van Leeuwen (2011).

320 Ingold (2007).

321 The use of rooftops as storage for potentially inflammable goods was an argument in favor of building domes in Hassan Fathy's first experiment in the rural area of Bahtim back
in the 1930s. Another reason for developing such techniques was to avoid using wood,
due to its high price. Here too, the thermal comfort attached to the image of the dome
is not enough to understand its genesis (Piessat 2018).

322 Gal (2002).

323 This is contrary to the kitchen or the second living room, spaces that are reserved for women and closer relatives. The kitchen and the bathroom are the two places where I have not observed any effort to control the thermal environment. This is mainly related to the fact that they are not likely to be turned public. There, the heat is endured. This becomes explicit when Umm Rania explains to her neighbor who insulates the roof of her house that it is not necessary to insulate the part of the roof that covers the bathroom. Similarly, she found his suggestion to create a window in the bathroom wall to allow for better ventilation ridiculous, since in her words, "it's only a bathroom, it doesn't matter." The re-indexation of the public to the private and vice versa intersects with the recreation of microclimates. It allows for transcending scales and thinking of thermal comfort in terms of agency, both emerging in and through practices.

324 Sims (2010).

325 Shove (2009).

326 De Koning (2006).

327 Rahm (2018).

328 Hence, I do not mean that there is only one thermal agency in the city, which emerges from the inhabitants. That would be a rather simplistic and populist claim. In view of the current logic of urban production, however, I mean to suggest that it is not realistic to expect institutions to implement solutions to the problems of urban heat alone. The plurality of actors shaping the city and its microclimates deserves far more attention, for if action needs to be taken it will be through a variety of these channels: popular, domestic, institutional, formal, informal, industrial, etc.

329 Chadoin (2013).

330 Rutherford and Coutard (2014, 1371).

331 Corboz (1983).

332 Roesler and Kobi (2018). / Valdorff Madsen and Gram Hanssen (2017). / Horn (2018).

333 For a view that expands the idea of politics towards the energy-providing material world, see Boyer (2014). / Von Schnitzler (2013).

334 Guy and Shove (2000).

335 Castán Broto (2019, 53).

336 Ibid., 201.

337 This volume, p. 119.

338 Interview data shows that the predicted physiological comfort based on the measured climatic conditions is often far lower than the perceived comfort levels of people using these spaces. A wide urban diversity facilitates the potential to choose from among different options, the perception of one's having a choice being a factor that increases thermal comfort (Steemers and Steane 2004, 93–95).

339 Lowering energy needs (keyword: zero emission) in households has become a key strategy to combat climate change. It is part of an envisioned energy transition that aims to move from fossil to non-fossil fuels, while also reducing energy demands (Knox 2020, 87; Calder and Bremner 2021).

340 Kobi and Plachta (2020).

341 Heynen, Kaika and Swyngedouw (2006a). / Varnelis and Meisterlin (2009). / Gandy (2014).

342 McHarg and American Museum of Natural History (1969). / Laurie (1979). / Hough (1989). / Spirn (1984). / Gandy (2002). / Ptak (2018).

343 Humphrey (2005). / Seewang (2013). / Stalder and Daro (2017). / Banham (1969). / Banham (1976).

344 One explanation for this may be the integration of systems that were traditionally found inside (building infrastructure) and outside buildings (harvesting of natural processes). Another aspect is the restricted accessibility of certain technical facilities to the public for safety reasons, such as the handling of high energy.

345 Geist (1969). / Potvin (2004).

346 Leggero (2018).

347 Correa (2012, 17).

348 Individual housing designs show that, besides serving as thermal buffers and lowering energy demands, they also provide an enlarged living space and enable other everyday activities, such as hanging out wet clothes—as examples from France and Hong Kong outline (Zhu and Chiu 2011; Petzet and Heilmeyer 2012).

349 Roesler and Kobi (2018).

350 Hough (1989). / Lenzholzer (2015). / Spirn (1984, 244–45).

351 Hawkes (1996). / Hawkes (2012).

352 Hertweck (2020).

353 Amt für Umweltschutz Stuttgart (2012).

354 Reuter (2011). / Hebbert and Webb (2012).

355 Shove (2012).

356 Hough (1989, 6).

357 Gandy (2017).

358 Armstrong (2000). / Müller (2011).

359 Blau and Rupnik (2018). / Hein (2018). / Schubert (2020).

360 Iturbe (2019, 17).

361 Maps and calculations from the following institutions and publications were used to extract spatial information on urban climates in the four investigated cities (listed alphabetically).

Geneva: *Département du territoire* (DT) */ Le territoire Genevois à la Carte / NOS ARBRES – Ville de Genève / Office cantonale de la statistique, Genève* (incl. *Administrations fiscale cantonale*; *Statistique cantonale de la population*) */ Office cantonale du logement et de la planification foncière, Genève / Système d'information du territoire a Genève* (SITG) */ Université de Genève*.

Santiago: *Boletín de Mercado de Suelo*, *Pablo Trivelli / Centro de Inteligencia Territorial de la Universidad Adolfo Ibáñez / Centro de Investigación Social TECHO Chile / Observatorio de Ciudades, Centro de investigación urbano-territorial / TECHO, Un Techo para Chile*.

Chongqing: Chongqing Urban-Rural Overall Master Plan (2007-2020) 重庆市城乡总体规划 / David Rand 2019 (population density): based on Chinese Census, OSM, Atlas of Urban Expansion, DIVAS, and Google Earth / Geographical Information Monitoring Cloud Platform地理国情监测云坪台 / Luo and Li (2014).

Cairo: Aqarmap.com / Bayoumi and Bennafla (2020, 69) / CAPMAS (the office of statistics) */ Centre national de la recherche scientifique* (CNRS) */ Centre for Economic, Legal, and Social Study and Documentation* (CEDEJ) / Open Street Map / Tadamun (2018).

362 For example, Cairo has an inherently warmer climate than Geneva. With a globally applicable temperature scale, local differences within Cairo or Geneva would have been difficult to weigh against the much larger regional temperature differences.

363 One illustration is Cairo, where the topography data contains twelve distinct levels, while temperature contains only six levels. Some maps, e.g. from Chongqing, exclude non-urbanized areas between residential districts from their calculations.

364 To address the first, we use a shared scale for all visualizations. For the second, we draw in an outline of the geographic region so that the data can be seen in context—such that the available data can be associated with its physical location, and missing data can be properly identified.

365 The data on surface temperatures is mostly drawn from Landsat images; the material visualizes either surface or built-surface temperatures. An exception is the map of Santiago; it shows medium temperature differences between winter and summer (*amplitude térmica*).

366 For the income variable, we relied on the following data: for Chongqing, we show the average monthly salary gathered from job advertisements in 2018. For Geneva, we used the average annual salary of married couples, according to communes in 2015. For Santiago, we relied on non-specified income groups divided into five stages between poor and high income in 2012. For Cairo, we included the per capita income of districts.

367 For the real-estate variable, we relied on the following data: for Chongqing, we used the average monthly rent in 2018, ranging between 0 and 50,000 RMB. For Geneva, we took the average rent per square meter (ranging between 18 and 24 CHF [Swiss Francs] of free apartments of three to five rooms from May 2019. For Santiago, we relied on land prices from 2014 (ranging between 0 and 26 Unidad de Fomento). For Cairo, we used the average residential property prices per square meter in each district in the first quarter of 2019.

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Sascha Roesler

Prof. Dr. Sascha Roesler is an architect and architectural theorist, working at the intersection of architecture, ethnography, and science and technology studies. He is the Associate Professor for Theory of Urbanization and Urban Environments at the Academy of Architecture in Mendrisio, Switzerland (*Università della Svizzera Italiana*) and a visiting professor at the Institute of Technology in Architecture (ITA) at ETH Zurich. Between 2013 and 2015, Roesler was a senior researcher at the Future Cities Laboratory (Singapore-ETH Centre for Global Environmental Sustainability), and between 2015 and 2021, he held the position of Swiss National Science Foundation Professor for Architecture and Theory at the Academy of Architecture in Mendrisio, leading a research project on "Architecture and Urban Climates." Roesler has published widely on issues of global architecture, sustainability, and environmental technologies. His books include *Weltkonstruktion* (Gebr. Mann, 2013), a global history of architectural ethnography, and *Habitat Marocain Documents* (Park Books, 2015), a volume on the transformation of a colonial settlement in Casablanca.

Madlen Kobi

Prof. Dr. Madlen Kobi is a social anthropologist and an assistant professor at the University of Fribourg (Switzerland). Her primary research and teaching interests include architectural anthropology, urbanization, infrastructure, and the anthropology of waste, with a regional focus on China. Kobi obtained her PhD from the Institute of Social Anthropology at the University of Bern in 2014. From 2016 to 2021, she worked as a postdoctoral researcher on the Swiss National Science Foundation (SNSF) funded research project, "Architecture and Urban Climates," at the Academy of Architecture in Mendrisio, Switzerland (*Università della Svizzera Italiana*). Currently, she is leading the project "Urban Bricolage. Mining, Designing and Constructing with Reused Building Materials," which is funded by the SNSF and examines the practical challenges of reuse practices in Europe. Her articles have been published in a number of journals that include *The International Journal of Urban and Regional Research*, *Social Anthropology*, *TSANTSA (the journal of the Swiss Anthropological Association), Inner Asia*, *Eurasian Geography and Economics*, the *ABE Journal – Architecture Beyond Europe* and *Central Asian Survey*.

Lorenzo Stieger

Dr. Lorenzo Stieger is an architect whose research focuses on urban planning, architectural theory and history. Stieger is particularly interested in the physical nature of the environment, its constitutive forces and cultural implications, as well as the conceptual reinterpretation of existing conditions. From 2019 to 2021, he worked as a postdoctoral researcher on the SNSF-funded research project, "Architecture and Urban Climates" at the Academy of Architecture in Mendrisio, Switzerland (*Università della Svizzera Italiana*). He completed both his diploma in architecture (2009) and his PhD, entitled "Vom Hang zur Schräge: Das Terrassenhaus in der Schweiz – Aufstieg und Fall einer gefeierten Wohnbautypologie 1958–1973" (2018), at ETH Zurich. He worked for several years as an architectural practitioner in various offices in Los Angeles and Zürich before becoming a researcher and teacher at the Chair of Architecture and Urban Design (Alex Lehnerer) at the Future City Laboratory in Singapore, and at ETH Zurich. He also co–authored *The Western Town: A Theory of Aggregation* (Hatje Cantz, 2013), which took the DAM Architectural Book Award in 2013.

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Dr. Dalila Ghodbane is an architect and urban planner (École nationale supérieure d'architecture [ENSA] Paris la Villette and the French Institute of Urbanism). From 2015 to 2019, she worked on the SNSF-funded research project "Architecture and Urban Climates" led by Sascha Roesler at the Academy of Architecture in Mendrisio, Switzerland (*Università della Svizzera Italiana*). In 2021, she concluded her PhD, her thesis entitled "Without a Plan? An Ethnography of Architecture, Domestic Microclimates, and Building Practices in Contemporary Cairo." Ghodbane was an associate researcher at CEDEJ (Centre d'études et de documentation économiques, juridiques et sociales) in Cairo (2017–18), and an SNSF Doc-Mobility visiting doctoral fellow at the University of Oxford Brookes (2020). Her key research interest lies at the intersection of architecture and the social sciences, study that enables her to address urban development from the perspective of the lived experience.

Lionel Epiney

Dr. Lionel Epiney is an architect who holds a Master of Sciences ETH in Architecture. His studies and practice have included work in Switzerland and Chile. From 2016 to 2021, he worked on the SNSF-funded research project "Architecture and Urban Climates" led by Sascha Roesler at the Academy of Architecture in Mendrisio, Switzerland (*Università della Svizzera Italiana*). In 2021, he concluded his PhD on the merits of his thesis, "Thermal Standards in Santiago de Chile – To Design or Regulate Thermal Environments." His interest in analyzing the dynamics between city climate, socio-economic conditions and regulation in the housing production of Santiago de Chile emerged partially from his experience working for Alejandro Aravena (Elemental).

Chandrasekhar Ramakrishnan

Chandrasekhar Ramakrishnan is a software developer, data scientist and media artist. He has degrees in Mathematics from the University of California, Berkeley (BA 1997) and Media Arts and Technology from the University of California, Santa Barbara (MA 2003), where he studied signal processing and electronic music with Curtis Roads and Stephen T. Pope, as well as data visualization with George Legrady. Since 2008, he has been at ETH Zurich, currently working as a software developer in the Swiss Data Science Center. In addition, he has, since 2008, worked as a freelance data scientist under illposed.com, and, in this capacity, has realized projects applying data-science tools and approaches—often in domains where data is difficult to acquire and possibly of questionable quality.

Adrian Ehrat

Adrian Ehrat is an independent graphic designer and photographer based in Zürich. Ehrat has worked as an art director for Studio Achermann and for the men's magazine *Vogue Homme International*. In addition to his visual work, Ehrat is an initiator of art spaces such as Perla Mode and Corner College, and also a host at the artists' association *Zampano*. In 2015, and for author Sascha Roesler, Adrian Ehrat designed *Habitat Marocain Documents* (Park Books), which was later awarded the DAM Architectural Book Award as one of the year's ten most outstanding architectural publications.

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Sascha Roesler, Madlen Kobi, Lorenzo Stieger
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