City, Climate, and Architecture

A Theory of Collective Practice

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KLIMA POLIS Vol. 1

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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 from 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.

Certain parts of the present publication have already been published as articles for journals; full details of these can be found in the References section. In addition to lectures and publications, lecture manuscripts that served as preparation for seminars at the Academy of Architecture in Mendrisio and at ETH Zurich held in 2016, 2018 and 2020 formed the preliminary stages of this first volume.

Sascha Roesler, March 2022

European Developments before 1945: The Field of Knowledge

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Thermal Geographies of the European City
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An Introduction

The primary aim of this publication is to *urbanize* the thinking on climate in architecture. For this, an understanding of the practice of climate control is to be developed in light of an architectural history and theory of urban climates. My central thesis is that certain discourses and built projects of the 20th century contain the elements for a new urban theory of climate control. The reconstruction of urban climatological knowledge in 20th-century architecture results in a different understanding of climate than that which was brought to fruition by the research guided by a notion of *comfort*. Most importantly: the practice of climate control is understood as being a collective practice—rather than a practice of the individual.

Today, the American lines of thought on comfort must be subjected to a radical revision through the perspective of urban environments. What is commonly understood by *climate control* did not emerge by considering such environments: there is a prevailing suburban context in the theory of climate control, and in sustainability at large. Even the so-called passive solar movement remained steeped in the comfort thinking of *air conditioning*, and thus focused on a practical methodology that was entirely committed to the individual building and individualism.[1] Today, there is an urgent need to relate the theory of climate control to the particular conditions of cities and to identify the relevant urban agencies of climate control. The consideration of groups of buildings, rather than isolated individual buildings, as being the fundamental "climatic unit"[2] also challenges basic assumptions of current architectural theory.[3]

The Notion of Man-made Climate

The notion of *man-made climate* forms the theoretical pivot of this publication. It is the starting point for the elaboration of an urban theory of climate control. By referring to groups of buildings and to *thermal difference* (rather than to climatic stabilization), the concept of man-made climate opens up new ways of thinking about climate control in, through and of cities. This notion (in German: *künstliches Klima*) was widely used in Europe—in particular, in Germany and Austria—in the interwar period. It was equally applied to outdoor and indoor environmental conditions and not just to mechanically conditioned interiors.[4] Beyond this, the examination of urban climates—one could say *the urban studies of man-made climates*—promoted a new modern sensitivity for the interdependence of the scale of the building and the scale of the city.[5] In the urban climatological thinking of the interwar period, the topological interconnection of interior and exterior perspectives—of the apartment and the city—was particularly present. As such, the imperative of *integrating indoors and outdoors* in order to reduce environmental and thermal loads in cities is the critical legacy of interwar urban climatology. By promoting a systemic and multi-scalar understanding of heat management throughout the city, the notion of man-made climate can be viewed as being proto-ecological.

Historically, the notion of man-made climate has been the decisive theoretical interface along which the mutual appropriation of modern urban climatology and modern architecture and urban planning has taken place. Berlin and Vienna in particular were laboratories and intellectual centers of urban climatology in the 1920s and 30s, which can be explained not least by the political conditions in both cities at the time—German social democracy and Austro-Marxism. The interest in the living conditions of the many and not—as in the case of the American ecology movement—of the individual may go some way to explaining why urban climatology originally developed under politically left-wing conditions. From its inception, urban climate research appeared to be both an applied and interdisciplinary endeavor aimed at improving the built environment of broad segments of the population. The interdisciplinary project of applied urban climatology, as I will show, was equally driven by climatologists, physicians, architects and urban planners; it developed in the wake of a discourse on urban hygiene that increasingly took into account the urban climate.

Interwar urban climatology had a twofold interest: on the one hand, it posed the comprehensive question of society's dependency on the climate ("the great role climate plays in people's health and in their economic and cultural achievements"[6]); on the other, however, it also raised the considerably novel question of the influence of the city—as a human artifact—on the climate ("the manner in which these great concentrations of human beings influence their climate"[7]). This approach gave architects and urban planners a completely new scope for thinking about the relationship between architecture and climate. The urban climate was now no longer merely a driving force of building design but, just the other way around, rather the *result* of it. Climate in cities thus came to be seen not only as a naturally given influencing factor but also as a result of urban configurations.

This publication aims to make this important intellectual heritage visible and to present its relevance for today's architecture and urban design. With the growing awareness of the Anthropocene and the Earth as a whole as a "world ecology",[8] the notion of the man-made climate has become more relevant still. An enlightened political ecology provides the further theoretical framework for this. Referring to Karl Marx, Maria Kaika and Erik Swyngedouw proposed the metaphor of "metabolism"[9] to do justice to the mutual correspondences between nature and society, in which "non-human 'actants' play an active role in mobilizing socio-natural circulatory and metabolic processes".[10] This publication relies on this tradition of political ecology to build bridges within a highly relevant epistemic field.[11] Seen from the perspective of man-made climate, urban microclimates appear as man-made artifacts and thus as the result of consciously designed buildings.

The central intuitions and insights of the German-language urban climatology of the interwar period have still not yet been properly received in architectural history and theory.[12] The reasons for this are primarily linguistic: the majority of source texts have not yet been translated from German into English. As such, the insights into urban climate made by meteorologists and architects are made accessible to a global readership probably for the first time through this publication. In addition, there might be a certain subconscious aversion (in the Anglo-Saxon world) to research that was published only after the National Socialists came to power in 1933: basic writings of modern urban climatology, such as Albert Kratzer's *Das Stadtklima* and Brezina and Schmidt's *Das Künstliche Klima*, were both published in 1937. This makes it all the more difficult for today's readers to separate the (bio)political echo chambers of this research from the findings that continue to be relevant (today).

Even more importantly, the urban climate, by being reduced to a phenomenon of outdoor space—without any relation to indoor space—has stood in the slipstream of the controlled indoor environment, as it spread with air conditioning, central heating and insulation in the West and beyond. Part of this one-sided fixation on outdoor space is revealed by the fact that the notion of "urban heat island" was elevated to the central paradigm of urban climatology in the late 20th century. By focusing on the relationship between "meteorology and urban design", a one-sided focus on urban outdoor spaces was established—one that threatened to make the central epistemological implications of urban climatology obsolete.[13] The narrowing of the notion of "man-made climate" to mechanical air conditioning inside buildings gave urban climate the status of a niche topic in the discipline of architecture and exorcised a deeper sense for climate control in urban environments. It is precisely the mutual reaction between the exterior and the interior that has not yet been adequately taken into account by the historiography of urban climatology. Such an integration forms, in essence, the intellectual program of an urban theory of climate control.[14]

The rhetoric of "light, air and sun," as promoted by members of the Bauhaus and CIAM reveals another meaning in the context of urban climatology: It also appeared as part of a scientific, ultimately empirical, evidence-based project to which the Bauhaus, for one, was committed. Its directors, Walter Gropius and Hannes Meyer, were particularly convinced of the interdisciplinary character of their school. However, this rhetoric—widespread among modern architects of the interwar period— has so far hardly been seen in the context of the emerging urban climate discourse of the interwar period.[15] Although the Modern Movement widely addressed air and sun, "the evidence basis remained sketchy, since designers had little empirical understanding of the complex nature of urban microclimates".[16] The predominant helio-therapeutic meaning given to complex climatic phenomena by early CIAM members obscured the scope of architectural reflection on the man-made climate in the 1920s and 30s. This is exemplified by the schematic and ideological debates about the proper orientation of buildings and streets in the big city.[17]

Architectural historiography followed the intellectual guidelines of modern architects without examining the scientific contexts more closely. In the context of this publication, historiographical corrections will be made, illuminating the knowledge of urban climate in the context of wind- and sun-oriented modern architecture. Beyond that, however, the work of those modern architects will be discussed for whom an interest in urban climate research was made *expressis verbis*—such as Gustav Hassenpflug, who was trained at the Bauhaus, and Ludwig Hilberseimer, who taught there. Hilberseimer was the protagonist of the modern architectural movement who most comprehensively attempted to translate the new findings of urban climatology into new principles of planning and design; accordingly, he is the secret hero of this publication, whose far-reaching considerations repeatedly appear throughout the book.[18] While the first part provides a systematic overview of urban climatological knowledge of architecture and urban design, as it emerged in the interwar period in Germany and Austria, the second part follows developments as they took place after 1945 under globalized conditions. In both the first and the second part, Berlin plays a central role in this publication. With its buildings and landscapes, forests and lakes, it is a critical agency and enabler for a new kind of discourse that connects human with non-human actors. Berlin shows the possibilities and the limits of a design-driven appropriation of urban climatological knowledge through architecture and urban design.

The Translation of Science into Design

Today, the vast quantity of scientific studies on urban climate stands in sharp contrast to the lack of architectural methodologies to apply the insights of these studies. The rudimentary awareness of the *translation* needed between urban climatological knowledge and architectural practice manifests itself in a fundamental lack of design methodologies. This is also revealed by the fact that Baruch Givoni is still considered the central representative of a transfer of urban climatology into architecture, although his work is exemplary for its disregard of the *agency* of design.[19] In his case, urban climatology appears as a field of applied natural laws, with marginal reference to architectural history and theory—and thus to design and culture. Accordingly, the actual aim of this study is to provide theoretical and historical foundations for a *methodological* transfer between urban climatology and architecture. The direction taken by this publication is towards the fragmentary appropriation of urban climatology by 20th-century architecture and the ideas and methods developed along the way. Two remarks on the main approach of this book:

Discourses

This publication reconstructs discursive links between hygienists, climatologists and architects in order to highlight architectural dimensions of urban climate. The emergence of the new science of urban climatology is described as being parallel to that of modern architecture and urban planning, which at the time was also in its nascent stages. In this publication, urban climatological texts are examined for their references to models of urban design and, vice versa, urban projects by architects for their climatological implications. Discourses played a unifying role: linking the practices of architects with those of scientists; civil engineering and meteorology came together in the discourse on hygiene.[20] Thus, following

→ fig. 1

Michel Foucault, the aim of this study is to find the common denominator of *les mots et les choses*, as developed in his "archaeology of the human sciences", pursuing an archaeology that examines the epistemological transformations of a scientific object—the urban climate—into a design artifact. The book presents manifold transformations of the concept of the urban climate through architecture in the 20th century. Transmission and sublimation play an important role in the incorporation of scientific knowledge by design disciplines; the theoretical focus is accordingly on processes of exchange, appropriation and transformation. This publication insists on an asymmetrical relationship between urban climatology and architecture and it reveals fluid transitions and hybrids consisting of architecture and landscape architecture, architectural projects and research interests.

Buildings

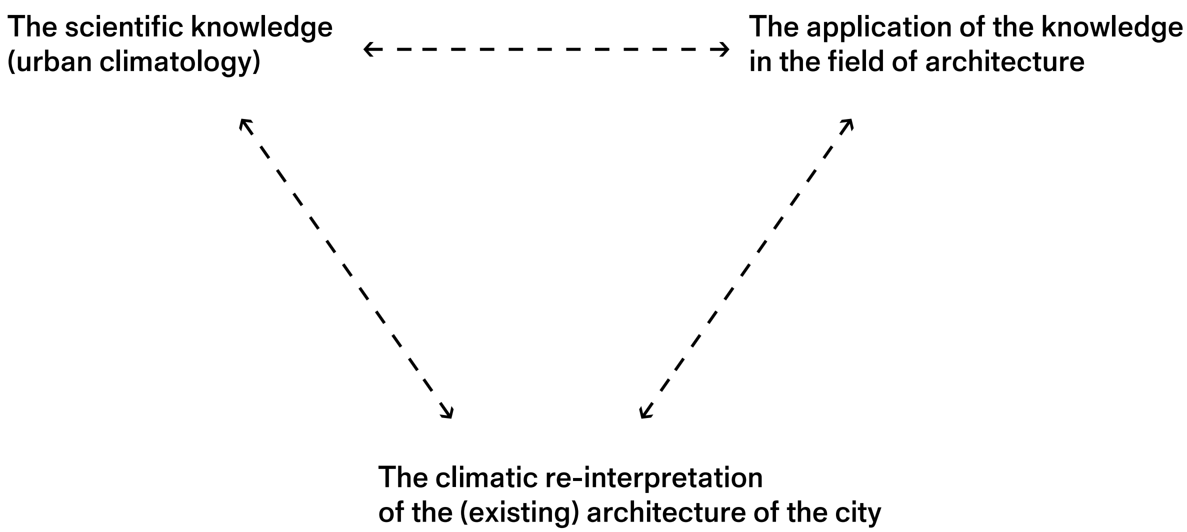
By combining a history of science with a history of architecture, the publication brings together the "imaginary and the real".[21] In this context, one can speak of a "discrepancy between the many new urban planning ideas and proposals and their actual realization";[22] many urban climate-related-ideas failed due to prevailing social and spatial conditions. However, the aim of this study is to highlight an architectural knowledge of urban-climatology insights as components of a new theory of practice. Such a theory of collective practice combines a "history of ideas" with a "practical science" of architecture.[23] Crucial to this is a discourse history that negotiates interior and exterior conditions as thermally interdependent and conceives the control of climate as a collective endeavor. This is the reason why buildings—as the interface between inside and outside—remain epistemologically at the center. The building at the center of this book is not a self-sufficient entity but one that is closely interconnected with its urban environment and embedded in its city quarter. Urban buildings are found in a cultural, social, and ecological exchange with their surroundings. Accordingly, these investigations are located in the transitional area between architecture and urban design. The main focus is on the question of how a building is thermally influenced by adjoining buildings, streets, parks and winds.

Climatic Determinism, Revisited

Unsurprisingly, the debates on global warming and the Anthropocene have promoted a new architectural interest in concepts of *climatic determinism*.[24] In the history of the architecture–environment relationship, the city is the exemplary artifact where subordination gradually turns into a "progressive ability to control nature".[25] Clarence J. Glacken's classic 1967 study *Traces on the Rhodian Shore* demonstrates the importance of ancient and early modern theorists of architecture, such as Vitruvius and Leon Battista Alberti, in theorizing the complex relationship between nature and culture, and, more specifically, between climate and urbanization. Urban climate is a prominent field of application of an intellectual interaction that Glacken sees as being at work in Europe since antiquity. He points to the constancy of a certain way of thinking, which underwent a fundamental transformation only in the 19th century. "Buffon, Kant, or Montesquieu, I think, would have found the classical world strange, but the gulf between their times and classical times would have been less than that between 1800 and 1900."[26] The empirical approach to urban climate—which forms the center of my study—has experienced a strong developmental push, especially since the early 20th century, which can be described as the *scientification* of urban climates. In this process, the atmospheres of the evolving modern city were subjected to investigations based on the methods of meteorology and thermodynamics.

Urban climatology as a science emerged at the beginning of the 20th century with the development of the modern European city. In the future, however, its integration into architecture and urban design will have to draw increasingly upon the manifold manifestations of planetary urbanization.[27] A future architectural theory of urban climate must further elaborate the modes of thought in terms of three forms of appropriation: 1. As a *transnational metabolism* between West and East, North and South. Here, the focus is on urban landscapes as cross-cultural phenomena and under reciprocal transcontinental influences; 2. As a *scientific metabolism* between meteorology and the building sector; this is applied research in architecture and urban design; and 3. As a *political–regulatory metabolism* between law and architecture. In the context of the latter, the approaches strive for a regulation of urban climates; they aim at a new kind of thermal governance that exceeds (if not replaces) the concept of climate control. For the kind of architectural theory of the urban climate aimed at here, the inclusion of these three lines of thought plays an important role, in which they are brought together as urban studies of man-made climate.

1
Urban climates from the perspective of the architect.



1 Thermal Geographies of the European City

Urban Hygiene and the Heat Economy

The urbanization that emerged in parallel with the industrialization of Europe, was characterized by an ambivalence that encompassed both control and chaos, social integration and the dissolution of relations. The "factory city of the 19th century"[1] developed from the dialectic of new workplaces and new settlements; one entailed the other.[2] The factory city formed "a spectrum that ranged architecturally from sprawling slums to the hallmarks of industrial prosperity, the new train stations and crystal palaces".[3]

From the early 19th century onwards, "industrialisation, urbanisation and eruptive modernisation"[4] had an enormous impact on the evolution of European cities, not just in terms of their urban structures but also their urban microclimates. Industrialization and urbanization altered both the indoor and outdoor atmospheres found in the cities. The anonymous architecture of industrialization created a new thermal geography of the city, with innumerable urban climatic focal points and consequent attempts at conscious human adaptation. Air pollution from the new factories, overheating in homes and unhealthy thermal conditions in workplaces provoked thorough investigations by architects, scientists and social reformers.[5] Decades before the advent of the comfort paradigm, large cities and new industrial landscapes stood for largely uncontrolled thermal conditions and experiences—a new diversity beyond moral judgment.

1.1 Schinkel in England

For the early historiographers of modern architecture, above all Sigfried Giedion, the anonymous functional buildings of industrialization in Europe were harbingers of a dawning new age of architecture. According to the argumentation of this historiography, the functionality and economy of industrial production promoted a new kind of structurally and constructively conceived architecture, which decisively contributed to the overcoming of the historicizing schools of style with their tendency towards decoration.[6] Within the framework of this historical argumentation, however, the microclimatic aspects that went hand in hand with industrial production and its architecture were omitted.

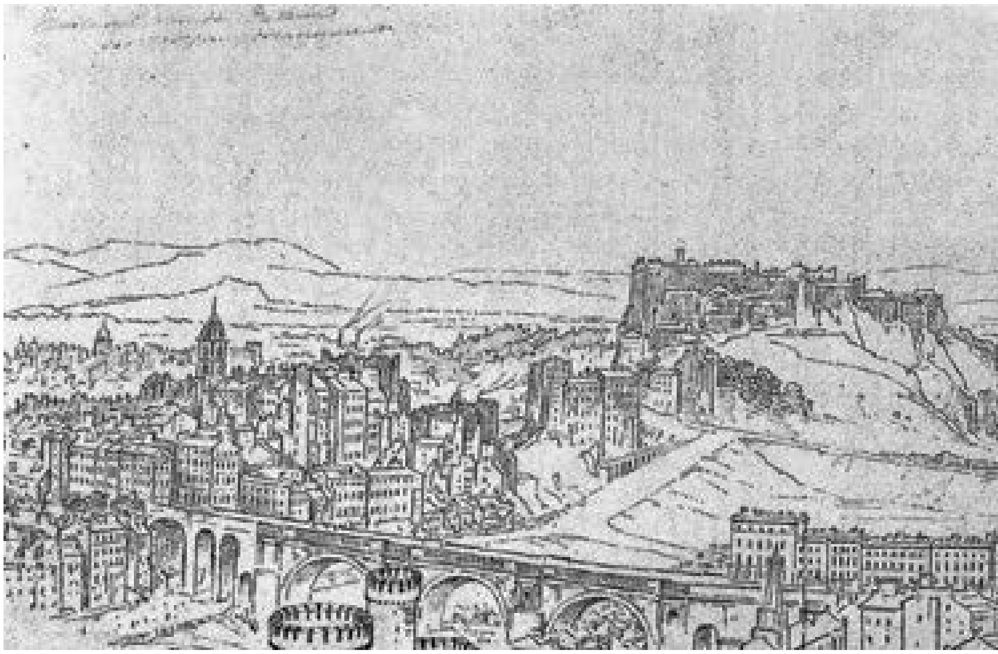
Karl Friedrich Schinkel's diary documenting the time he spent in Great Britain in 1826 not only includes a comprehensive analysis of the new building materials iron and glass; it also provides something generally overlooked—many keen observations concerning the associated microclimates both outside and inside of Britain's novel industrial buildings. The main fields of application of the building material iron, meticulously described by Schinkel, was in infrastructure (such as bridges) but also factory and warehouse buildings. These large buildings that characterized the new industrial landscapes also produced specific microclimates. Schinkel's journal registered the atmospheres of the emerging industrial landscapes and the associated capacity to influence them via building envelopes and the nascent technologies of building services. Schinkel's journal reveals how deeply he, as an architect, was impressed by new thermal conditions he experienced, and it provides an account of the new phenomena of urban climates and their associated social conditions.

As the art historian Gottfried Riemann emphasized, Schinkel's observations formed the "decisive starting point for the new tendencies that his late work exhibits"—first and foremost the Bauakademie in Berlin.[7] This late work, sublimating his observations of the new industrial landscapes of Great Britain, anticipated and pioneered the modern architectural culture of the 20th century.

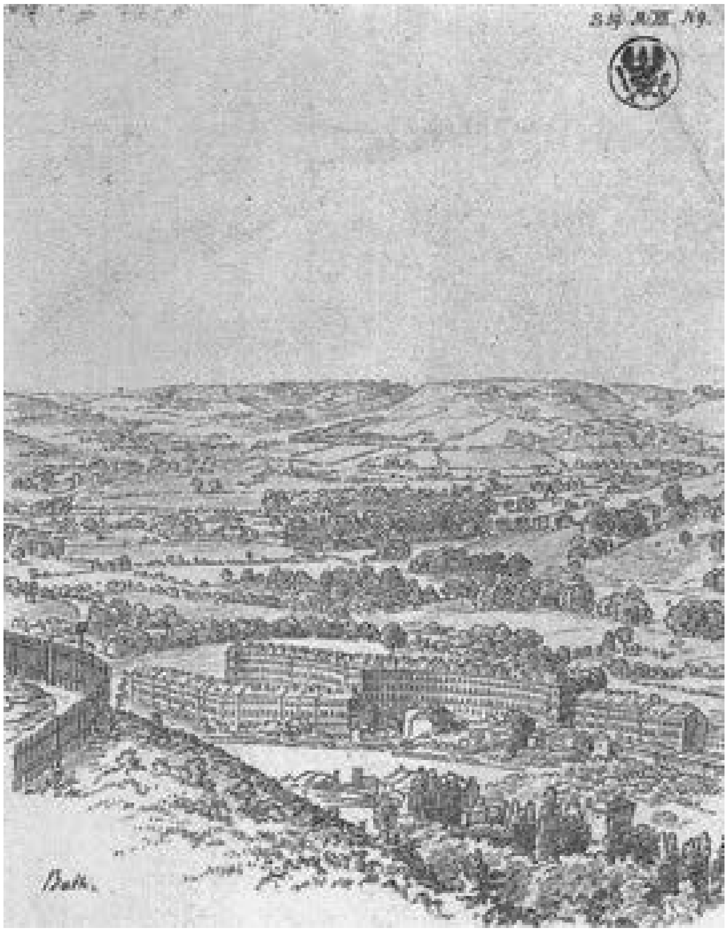
1.1.1 Greenhouse Effects

Schinkel registered the enormous disparities of wealth that were also manifested in different urban microclimatic conditions. The extreme poverty of the new industrial workforce became visible in the hygienic conditions of their neighborhoods and dwellings. Whether in London, Birmingham, Edinburgh or Manchester, Schinkel made note of the thermal differences that would later so thoroughly preoccupy the European architects and urban designers of the 20th century. In one of his journal's entries, he describes walking to the Natural History Museum in Edinburgh: "We walked down one of the old streets to the Museum: no greater contrast can be imagined than between the filthy cramped conditions of the coarse black dwellings and the poverty of their occupants,

→ fig. 2



2
Karl Friedrich Schinkel, view of Edinburgh (UK), 1826.



3
Karl Friedrich Schinkel, view of Bath (UK), 1826.

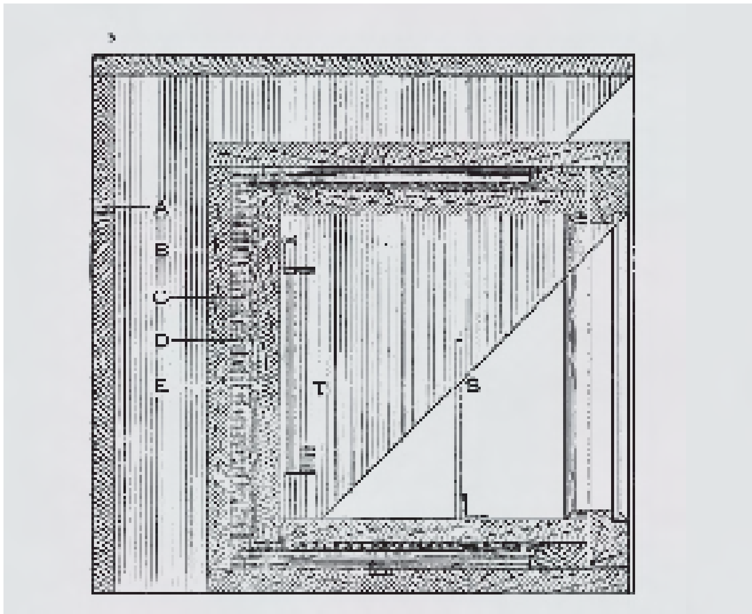
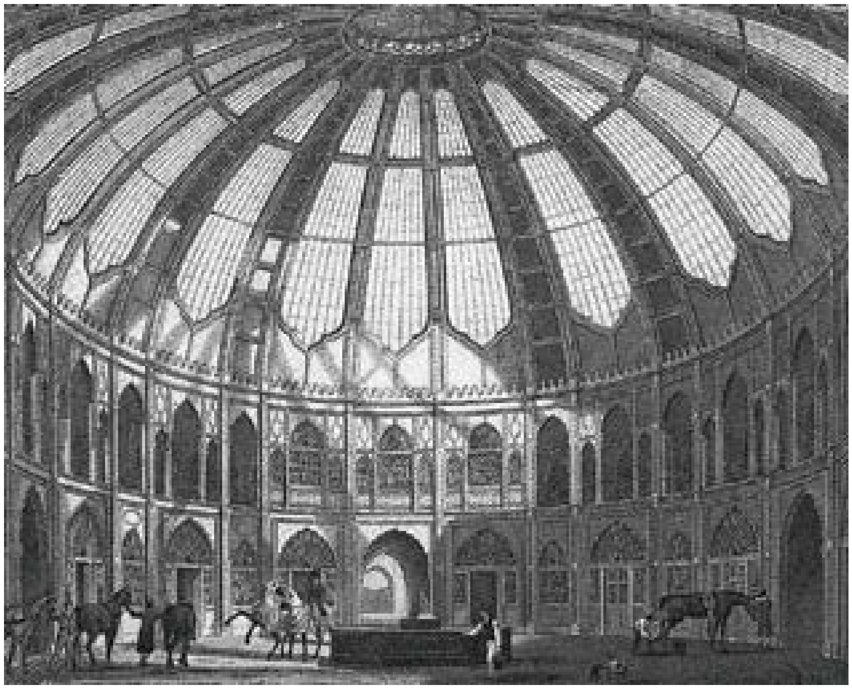


Fig. 45.—Cross-section of sun box. A. Hood or cover. B. Outer box. C. Air space. D. Lino-felt. E. Inner box. T. Thermometer. S. Shield.

4
William Atkinson, sun box, 1912.



5
Riding school, Brighton (UK). Schinkel's comment on June 10, 1826: "Too hot inside, really crazy: it was designed to be a greenhouse."

6
Joseph Paxton, Conservatory (84m long, 37m wide and 19m high) in Chatsworth (UK), 1840.

and the magnificence, elegance and airiness of the new streets. Several fine wide streets have also been built through the old town, so that a visitor is usually unaware of such pockets of squalor."[8]

Technologies of Climate Control

As a guest of the British nobility and factory owners, Schinkel had the opportunity to become acquainted with various technical innovations in building services that concerned the microclimatic conditioning of the interiors of buildings. William Strutt, for example, owner of a cotton mill, is an example of such a technically developed imagination. As the operator of one of the largest spinning mills of his time, in 1806–1810 Strutt with the help of a local architect built a new type of hospital in Derby, which inspired Schinkel with its technical and architectural details.[9] In this hospital, the control of climate already has been put entirely at the service of a new kind of hygienic self-image. The comprehensive mechanical control of the interior microclimates and the mechanization of the washing of laundry single out this hospital as a significant pioneer of new climate-control technologies. In Schinkel's brief description, the program for the building services of the 20th century already appears; the building services, and not just the construction, are described here as a field of innovation in architecture: "Visited the famous Infirmary with Mr. Strutt, fine, pleasant building in every way. Magnificent staircase. The steps faced with lead plates. The famous hot-air heating, water-closet with shutters, movement of air in and out of the rooms, the stale air is drawn off by a rotating ventilator on the roof. Very practical cooking equipment. Magnificent baths, a whole room, the anteroom through a canvas curtain, warmed by air wafted in from the bath. The doors made of slate, so that the steam does no damage, everything thought out to the last detail. […] Fairly large area in the Infirmary for drying clothes, steam washing-machines, hot and cold water is used (a continuously turning wheel with compartments.). Mangles, the washing is pressed after being placed in a square linen bag."[10]

In the case of the Lancaster School that Schinkel visited, again in Derby, a new kind of central heating, which circulated hot air in a closed system of pipes, was applied; Schinkel also encountered such closed systems in factories, for example to guide liquids in a system of tubes as in the case of a tannery. The uniformity of central heating was in clear contrast to the practice of heating zones of the room or parts of the body at that time. "Lancaster school, circulation heating, the floors on an inclined plane, lavatories visible from the teacher's chair through a glass door. Heating with warm air to save wood, only moderately heated, but continuously. The flow of cold air always originates a long distance away underground from clean, healthy locations, gas light."[11]

It was not only in hospitals and schools but also in other institutions of bourgeois society that the new cultural technique of active air conditioning was used. The beginnings of central heating can be also found in courthouses, penal institutions and archives as well as the buildings of the new bourgeois public such as museums, theaters and cinemas, with heat generation outside the buildings. One advantage was the reduced risk of fire. These places were focal points of a new understanding of regulating the climate of urban societies.[12]

Heat Traps

Temporary buildings such as wide-span tents and the early glass architecture of southern England provided insights into novel thermal interior qualities. Schinkel visited, for instance, the round stable building in Brighton, which became later known as the "Dome". The building was built between 1804 and 1808 by the architect William Porden. It was one of the early glass-and-iron structures in England that Schinkel clearly recognized as a greenhouse: "The stables built around a large glass-domed building 85 ft in diameter. Each individual stable with 3–5 horses has its own ventilation. Too hot inside, really crazy: it was designed to be a greenhouse."[13] The description of this riding school made Schinkel aware of the thermal possibilities of such a building. In particular, however, its surprising function (as a riding school) prompted Schinkel to think beyond botanical uses that were common at the time. The size of the riding hall gave rise to the idea of an artificially created climate under a unifying cover (made of glass). The greenhouse effect represented, in a sense, a physical phenomenon with still open potential for social interpretation. Microclimatic experiences like those of the Dome have been conceived as experimental fields for new programs and functions that will change the character of architecture. The deliberate combination of solar heat and glass architecture equally founded and reinforced new architectural imaginations of the nobility of the rising bourgeoisie; imaginations that were based on the so-called "heat trap".[14]

As early as 1767, Horace de Saussure had simulated the greenhouse effect of glass buildings with the glass "hot box"[15] he had developed, thus initiating the systematic study of glass architecture in the field of building physics. In his empirical studies, the sun—in

→ figs. 4, 5, 6

combination with glass and the insulating layer—was recognized as a powerful source of heat. This could be desirable in winter, but could lead to overheating in summer. At the beginning of the 20th century, the American architect William Atkinson empirically deepened[16] this experimental approach in a specially manufactured arrangement, which he called "sun boxes", thus establishing a tradition that in the 20th century understood buildings as receivers and amplifiers of thermal conditions (see chapter 3). Atkinson summed up an insight that Schinkel might already have sensed during his visits to English greenhouses, that architecture itself can be seen as an experimental arrangement—a kind of *sun box*: "That the sun's rays are not of indifferent value in the heating of our houses in winter is shown by the last experiment (December 22), in which the air within the sun box reached a temperature of 115° F with the air outside at 25° F. Every dwelling may be converted into a sun box by properly insulating the outside walls."[17]

1.1.2 Black Fog

The new industrial landscapes were accompanied by new kinds of urban climatic phenomena. Schinkel made emblematic drawings of these that demonstrate his dual talent as an architect and a draftsman. The ability to penetrate industrial landscapes with technical expertise and aesthetic capacity gives these drawings a futurological dimension, in how they accurately anticipated the later atmospheres of European cities.

In his diary, Schinkel documented the "comprehensive change" from which the English countryside had suffered as a result of rapid industrialization, in which the "appearance of landscape and towns" underwent a profound transformation. "New industrial buildings, usually hastily and haphazardly erected, as in this case the ironworks with their smelting furnaces and workshops, form a strong contrast to the park-like landscape with a few villa buildings."[18] Schinkel captured one of these contrasting landscapes in his drawings of Dudley (*View of the industrial scene around Dudley*), which incidentally was also prominently depicted in a painting by William Turner in 1832 (*View of Dudley*). The dense atmosphere and peculiar colors in Turner's painting were due in equal measure to heavy air pollution and novel manufacturing techniques; the coal dust in the air made for colorful sunsets. In a diary entry, Schinkel speaks of the "overwhelming sight of thousands of smoking obelisks. Coal, iron and lime are mostly brought up from the mines by winding engines."[19]

Buildings Without Architecture

In other architectural drawings, the novel industrial architecture of Dudley's industrial landscape was subjected to a drawing-based examination. One of the drawings shows the just completed Wednesbury Oaks ironworks near Dudley, depicting two parallel hall buildings with large chimneys as well as a prominent walled enclosure with arches. The smoke-billowing structures must have fascinated Schinkel in their articulation and sheer size, which he could only compare to major works of architecture built by the nobility. Schinkel acknowledges the funnels as new representative signs of his epoch. His perception of the chimneys as "smoking obelisks" connects the new man-made atmospheres to the picturesque taste of his time. The confrontation with a new type of architecture inspired the use of a metaphorical vocabulary. Referring simultaneously to the past and the future, Schinkel placed the new industrial architecture in a historical context, in which it was conceived as being part of ancient Egyptian, Roman and Classicist traditions of ruling. Further north, near Newcastle, in "a wider valley which contains as many potteries as Dudley has ironworks", Schinkel found "wonderfully Egyptian-oriental forms of the towns because of their factory buildings".[20] In Manchester, on the other hand, huge cotton mills are described in the context of social conditions and drawn as a kind of non-architecture due to the brute cubic appearance of the buildings. "Since the war 400 factories have been built in Lancastershire; one sees buildings standing where three years ago there were still fields, but these buildings appear as blackened with smoke as if they had been in use for a hundred years.—It makes a dreadful and dismal impression: monstrous shapeless buildings put up only by foreman without architecture, only the least that was necessary and out of red brick." Schinkel harshly judges these objects that so fascinated him as being "buildings without architecture".[21] But he would later take inspiration from the radicalism of the factory buildings he saw in Manchester and elsewhere in his magnum opus, the building for the Bauakademie in Berlin.

The smoke of factory chimneys is one of the recurring landscape-defining phenomena one finds in Schinkel's diary. More broadly, he saw the new signs of industrialization not only in the cities themselves but also in the open landscape. Urbanization was accompanied by a new kind of atmosphere, which gave the romantic view of the landscape a man-made

→ figs. 3, 7, 8, 9, 10

touch. “Canal in Birmingham [...]. Pleasant location, in the distance you can see the smoke of ironworks, which stretch for miles.”[22] Natural fog and man-made smoke were to be often found together and often mixed-up phenomena, which indicated the growing anthropogenic character of the climate of industrial landscapes.

London’s Haze

When Schinkel visited England in 1826, its cities appeared as if shrouded in veils. London, capital of the world at that time, was subject to a man-made climate in a particularly dramatic way. Schinkel’s notes on the city accordingly contain several remarks on the subject. The inversion of the weather caused by human activity led to severe air pollution.[23] At the beginning of June, Schinkel writes, “Although the weather was fine London was wrapped in fog and smoke; you could not see to the edge of the city, the towers were invisible in the haze.”[24] Two days later he writes, “From everywhere one has a view over the Thames valley and London, which is however never visible owing to the smoke from the chimneys.”[25]

Since the end of the 18th century, London had been infamous, not least among foreign visitors, for its “black rain”, as the architectural historian Nikolaus Pevsner pointed out.[26] Schinkel anticipates Pevsner’s observation in his diary by bringing *urbanization and climatization* to bear on their interactions. The atmospheric conditions in the outdoor spaces of the great cities become apparent as the result of industry and heating practices of the inhabitants. The atmospheres of London are *hybrids* or even *artifacts*, subject to human behavior and imagination. The industrial landscape of England literally enters the viewer’s field of vision in Schinkel’s descriptions. In London, Schinkel visited the Covent Garden Theatre where he was confronted with an “unbearable vapor and stench from the gas light”.[27] The new urban microclimates had first and foremost an olfactory dimension, which was later also incorporated into literature by authors such as Emil Zola and Charles Dickens. In Dickens’s story *Our Mutual Friend* (1864), “an atmosphere of mist, darkness, filth, and death spreads over the great city” of London.[28] An image of London emerges as a mixture of “amorphously growing urban masses, urban climatic disadvantages [and] the effects of urban working conditions on the inhabitants”.[29]

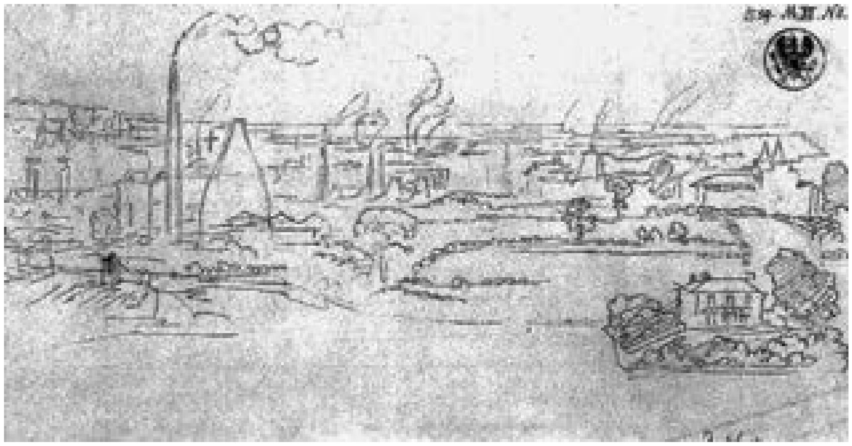
In his essay *The Geography of Art,* Nikolaus Pevsner therefore questions the immutability of “climate” and, following on from this, the rigid cultural-theoretical argumentation that proclaims “the dependence of character and history on climate”.[30] In times of industrialization the climate increasingly becomes a man-made phenomenon—the formula “black fog is moisture plus soot,” launched by Pevsner, powerfully incorporates the anthropogenic character of this phenomenon, inversing the assumed deterministic relationship between mentality and climate. The climate was no longer a stable quantity. As Pevsner writes, “A moist climate may be the natural climate of England and as such be permanent. It will always be conducive to mists and fogs. [...] But black fog is moisture plus soot, and so what one complains of as climate is the combination of climate with such things as the exploitation of coal, a development of industry that calls for vast masses of coal, and, in the house, a system of heating evolved for wood fires and not yet universally adjusted to the use of coal. [...] Perhaps the early and ruthless development of mining and industry is English?”[31] The mixture of *fog* and *smoke* from the chimneys indicated a growing anthropogenization of the climate, which would still have the same problematic character in the middle of the 20th century.[32] In 1949, for instance, Charles Ernest Brooks addressed the necessary exchange between the meteorologist and the architect in order to reduce the environmental pollution in English cities. “Smoke is one of the most important climatological factors in this country. When you consider that nine-tenths of the dirt and dust and soot deposited in London comes from burning coal you realize what a very great problem that is. With a south-west wind, the smoke of London can be traced as far as Norwich. That is a problem which meteorologists can point to, but it is for the architects to solve it by getting rid of the smoke.”[33]

The heavy air pollution[34] that industrialization created in European cities affected not just the lower classes but all strata of society, as Lewis Mumford pointed out in *The City in History* (1961). Accordingly, Gert Kähler speaks of the “megalopolis, which became the clearest sign of a dissolution of ties to the natural environment” and the “first large-scale ‘destroyer of the environment’”.[35] The technologies for burning; the shape and the sizes of the chimneys; and, above all, the siting of the factories remained of greatest concern throughout industrialization.[36]

→ fig. 11

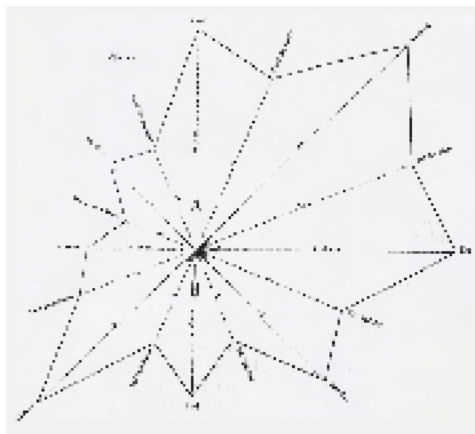
7
Karl Friedrich Schinkel, view of cotton mills with “smoking obelisks”, Manchester (UK), 1826.

8
William Turner, view of Dudley, Worcestershire (UK), 1832.



9
Karl Friedrich Schinkel, view of the industrial scene around Dudley (UK), 1826.

10
Karl Friedrich Schinkel, Bauakademie (Building Academy), Berlin, 1832–36.



11
Jean-Pierre-Joseph d’Arcet: on the correlation of pollutant exposure and wind direction, 1843.

1.2 Private Urban Development and the Heat Economy

The logic of manufacturing underwent a fundamental reorganization in the course of the Industrial Revolution. Home work was increasingly replaced by new factories, whereby two forms of development can be distinguished. On the one hand, workshops that were "still quite dispersedly embedded into neighborhood structures",[37] such as the Luisenstadt in Berlin (from the late 1840s), were located relatively close to the center of cities. There was a prevailing conviction that "small and medium-sized industries" should not have separate areas—i.e. that "special industrial and working-class neighborhoods [should be] avoided", which strongly exacerbated the problem of air pollution.[38] As late as 1927, Ludwig Hilberseimer stated, "Residential districts are interspersed with noisy and smoking factories."[39]

And on the other hand, new, "land-demanding large-scale enterprises"[40] emerged in the countryside and on the outskirts of the city, which depended on large numbers of both unskilled and skilled workers as well as transportation and energy infrastructures such as railroads and waterways. In Berlin, large-scale production plants were established along the "entire ¾ ring of workers' residential areas".[41] The shortest possible distance between the workplace and the home was of central importance for the working classes, due to the lack of means of transportation.[42]

With industrialization, the "heat economy" became a factor of both economic and hygienic dimensions.[43] On the one hand, the heat economy provided the energy resources for new industry and the housing sector; at the same time, however, as we have already seen, it caused the first serious man-made environmental problem in history—the result of air pollution caused by the insufficient combustion of heating fuels. It was not until the beginning of the 20th century that considerations about the efficient utilization of energy resources would transform into the discourse on energy efficiency. "Only the conditions of the war economy after 1914 as well as the coal emergency of the immediate post-war period created a broad awareness of the value of efficient coal utilization, so that heat management advanced from a marginal subject area to a key discipline within a very short time. [...] From a purely technical point of view, this development certainly accommodated the concerns of air pollution control. A movement dedicated to using fossil fuels as efficiently as possible was bound to be interested in reducing smoke and soot as the classic products of incomplete combustion."[44]

1.2.1 Factories: The Advantage of Location

Climate knowledge, as it matured in the context of the industrial production of a new a globalized economy, evolved as trade-off between inside and outside conditions. In this context, the aforementioned basic contradiction of economic rationality becomes apparent: it simultaneously promoted microclimatic conditions that were harmful to health and the planning of measures to overcome them. In many cases, the increase of industrial production was accompanied by both a neglect of urban climatic conditions and an ever more precise control of the indoor climate. Economic development also relied on the controllability of the indoor climate. In this sense, the factories of the 19th and early 20th centuries must be conceived in two ways: as part of an atmospheric plague of European cities on the one hand, and on the other as a scientific–technical field for innovation. In the *Dialectic of Enlightenment,* Horkheimer and Adorno speak of the "hygienic factory space" as a reform strategy of capitalism, which was based on a gradual reformation of living conditions—shown, for example, by the way in which the microclimates of factory spaces were dealt with.[45]

Outdoor and Indoor Climates

In addition to local coal deposits, humid climatic conditions were of decisive importance for the establishment of the cotton industry in areas of England from the beginning of the 19th century. The humidity in these regions had made possible a quality of textile products that was unparalleled anywhere in the world—something that even Schinkel noted.[46] The cotton industry required rather humid conditions with constant, moderate temperatures. Areas such as Lancashire, Yorkshire and the city of Liverpool particularly benefited from these specific climatic conditions.[47] The bioclimatic conditions favored the establishment of certain industries. Indoor conditions, which were highly dependent on external conditions, had to be considered with site-specific solutions. The location-dependency of industries meant that they were "often sited along riverbanks, lakes, or narrow valleys, and often equipped with thick exterior walls" to allow for uniform temperature and humidity in the work spaces.[48] This crucial location factor led to the migration of industry from Manchester to neighboring Oldham within a few decades, as Gerhard von Schulze-Gävernitz noted as early as 1892. "This humidity was later to make it possible to spin cotton to a fineness which, on the other hand, would be impossible to achieve elsewhere, or only at great extra cost. How much this climatic advantage comes into consid-

→ figs. 13, 15

eration is shown by the fact that spinning increasingly was located in the shadow of those hills where the precipitation was strongest, so for instance, in Oldham rather than Manchester."[49]

This "natural climatic favor" discussed in the technical literature had a central influence on the choice of location for industries—and thus also for urbanization—in the 19th century. Their purpose was twofold: to provide "cost advantages for individual companies" and to protect "society from various kinds of damage".[50] Exemplary industries in which the advantage of location was taken into account were the textile industry (including yarn-making and bleaching processes); the food industry; and, later, the paper and film industries. In addition to the basic climatic advantages of a location, seasonal fluctuations also influenced the production and manufacturing processes. In the case of beer brewing, the tobacco industry and the confectionery industry, one can speak of truly *seasonal* work, as decisive steps in the production process were only carried out at specific times of the year. They might require entirely opposing conditions; very hot and humid in the case of the tobacco industry and cool and dry in the case of the confectionery industry. The importance of the season for certain technical processes in industrial production and their success was a huge consideration for certain industries until the middle of the 20th century.

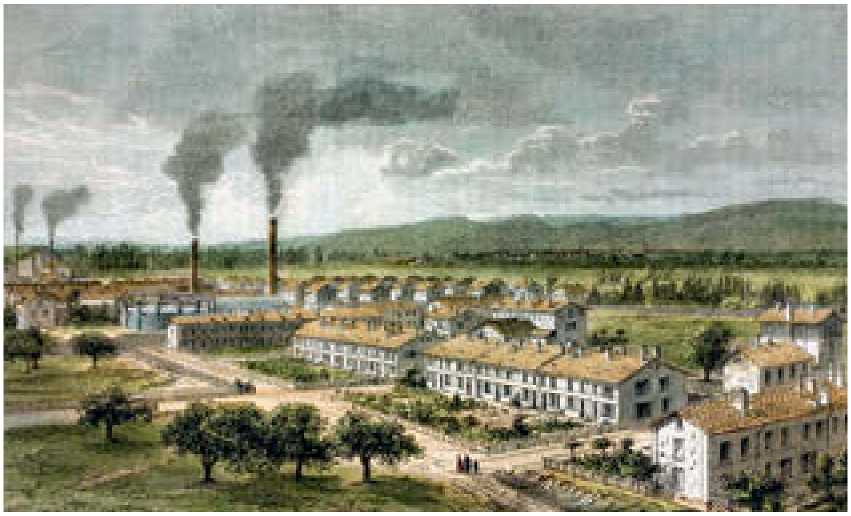
The influence of climate on industrial production subsequently led to the study of microclimatic conditions in factories.[51] The "importance of climate for the industrial location", the "optimum climates of industrial production processes" and the "study of artificial climates and air-conditioning technology" were still closely linked.[52] In particular, the "air temperature, humidity, air movement and air purity"[53] formed key parameters that were incorporated into science. Proper climatic conditions in the factory and the warehouse were of great importance for industrial production in Europe and its colonies.[54] This involved the advantage of certain local microclimates for manufacturing processes of raw materials, semi-finished products and goods, as well as their persistence. In reference to Gabriel Guévrekian's "Batiments Industriels" of 1931, we can mention grain silos, sugar refineries, docks, dry fodder silos, cement silos, water storage facilities, wholesale market halls, benzene refineries and storage buildings for financial instruments (in paper form). Storage buildings in particular evolved at the intersection of microclimatic and structural requirements; in the center were the microclimatic strategies used to preserve things and to store goods. Storage buildings, where raw materials and semi-finished products were temporarily stored or kept for a longer period of time have to be distinguished from the production facilities themselves.

In contrast to the planning of human dwellings, as Hilberseimer notes, in the case of industrial factory farming, for example, careful attention was paid to the correct solar orientation (insolation) of the buildings. "It is only in our times that builders have flagrantly disregarded it in their construction for human dwelling, though, oddly enough, they seem to remember well the value of insolation when they build shelter for domestic animals. Poultry breeders, for instance, almost invariably take care to locate chicken houses toward the sun. It is good business for them to do so and they know it."[55]

Goods versus Workers

Goods and workers in factories have different needs. Even in the middle of the 20th century, the so-called field of *industrial climatology* still had to organize the adequate mediation of indoor and outdoor conditions. "Climates affects industry in two ways: by raising or lowering the general efficiency of the workers, and by the effect on the actual processes of manufacture."[56] The productive power of the workforce also appears as a function of the microclimates inside the factories. Charles Brooks points to the textile industry in England, where the basic microclimatic contradiction between labor and goods was particularly visible: "the high humidity required for good products is very unfavorable to the welfare of the workers. Strict control is necessary and the conditioned air must be evenly distributed through the factory by proper circulation."[57] Just as the raw materials required an adequate microclimatic environment, the workers—especially in the hot European colonies of the tropics—demanded an adequate physical rhythm. The imperative for comfort still appeared to be characterized by the real danger of heat stroke—a kind of total bodily exhaustion. The impairment of the "efficiency" of the workers was in contradiction with the things to be worked: "The theoretically best conditions for the product may not be conductive to sustained output by the workers. In such cases a compromise is necessary. Generally speaking, a suitable outdoor climate and surroundings, with their good effect on the energy and efficiency of the workers, are more important than the requirements of the process rooms, since conditions in the latter can, within limits, be adjusted by air conditioning."[58]

→ fig. 14



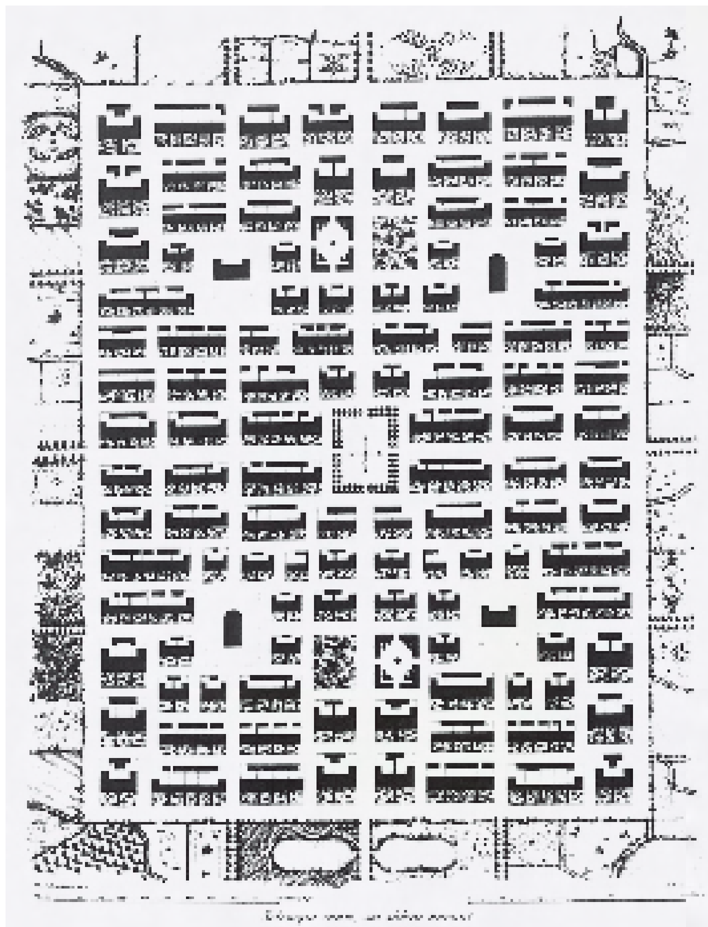
12
Cités Ouvrières de Mulhouse, around 1855.

13
Siemensstadt, Berlin, 1907.

14
Adolph Menzel, *Eisenwalzwerk* (Iron Rolling Mill), 1875.

15
Siemensstadt, Berlin, 1931.

16
Bernhard Christoph Faust, view of the Sun City, 1829.



17
Bernhard Christoph Faust, layout of the Sun City, 1829.

The microclimates of factories, which emerge as important components of urban development in European cities, provide a novel field of activity for engineers and physiologists. Statistical data, such as those collected on occupational injuries and mortality rates in the European and American industrial workforces, bear eloquent witness to microclimatic conditions in factories. Extreme forms of heat, prolonged humidity and rapid temperature changes were the cause of severe illness and premature death. The factories were not only built with new construction methods and building materials such as iron and reinforced concrete; they were also equipped with new microclimatic conditions, in which people often had to spend hours on end. The engineer André Missenard reports, "The disastrous consequences of the artificial, too warm and humid climates have since been confirmed by the English investigations on mortality to be due to simple pneumonia and tuberculosis among the weavers and the cotton spinners. Thus, mortality due to diseases of the respiratory tract has been compared among workers employed in the warm and humid environments required by cotton work and among woolen mill workers working under normal conditions. The mortality due to bronchitis is two or three times higher among cotton workers than among wool workers. The baleful influence of humidity is confirmed by the fact that in the same factory there is three times as high a mortality from bronchitis and pneumonia among the workers who work in the damp halls as among those who spend their days in the dry halls."[59] This problem of proper microclimate anticipated an issue that would later be given the name of "Sick Building Syndrome" in air-conditioned office buildings. This phenomenon, from the second half of the 20th century, was also an expression of a dilemma or "closure paradox". The growing need for airtight building envelopes—in the name of high employee productivity as well as energy efficiency—led to a gradual reduction of air exchange rates, resulting in health problems of the occupants of these buildings.[60]

Air-improvement Systems

The industrial production that accompanied the rapid industrialization of Europe led to the formation of two perspectives on the control of climates: one devoted to labor and the other devoted to things (raw materials and goods). Factories formed the venues of a new kind of climatic knowledge in which trade-offs were made between people and things. Which of the two aspects was prioritized depended on the priorities of the manufacturers. However, industrial production made necessary new thermal regimes, in which economic, biological and social factors were combined. Until the middle of the 20th century, natural ventilation and mechanical air conditioning were equally important means of combating sometimes extreme microclimatic conditions: "In offices and factories the effect of high temperature and humidity is accentuated by the heat and moisture produced by the workers themselves. Ventilation is only a partial remedy, for under extreme conditions the current of air required to give sufficient cooling would be so strong that it could raise dust and cause other inconveniences. The cooling power of the air increases only as the square root of the air speed, whereas the lifting of dust increases as the square of the speed. Air currents exceeding 500 feet per minute are impracticable for this reason. Under such conditions the only remedy is air conditioning."[61]

Since the beginning of the 20th century, different technical apparatuses and procedures that influenced microclimates in factories and warehouses began to appear, which variously comprised "heating systems, air improvement systems, ventilation, deaeration, dedusting and demisting".[62] In practice, such mechanical air-conditioning systems either compensated retroactively for buildings that were designed to be climatically inadequate or they provided a degree of control over indoor conditions that would be impossible to achieve by passive architectural means alone. "Engineering seeks to put the knowledge gained from climatology and medicine into practice. After all, we cannot demolish entire blocks of houses, factory buildings, etc. because the 'microclimate' found in them is unfavorable. On the other hand, we all know how uncomfortable we often feel in smoky restaurants or cramped work spaces, and how unpleasant it can be to stay in a cinema or theater in midsummer, despite all the ventilation. This is where technology steps in: it creates an artificial climate in place of the natural one."[63]

Industrialization, as a driver of urban development, contributed to the increasingly artificial character of urban indoor climates against the background of existing climatic conditions. The growing technical influence on the control of indoor conditions led to natural climatic advantage becoming less important. Locational advantage was overridden and eclipsed by other economic considerations. "Modern manufacturing processes are so complex that from start to finish a wide range of conditions is generally called for, and these can only be provided artificially."[64] The thermal continuum between inside and outside appeared increasingly as the enemy of productivity and economic efficiency. Colonial production geared to the global