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Conceptualizing Environmental Technologies in the Urban Sphere

This article reinterprets the existing literature on environmental technological systems with literature from contemporary urban environmental studies, primarily from the fields of urban geography and urban history. Urban environmental literature offers a historical and spatial understanding of environmental technological systems that emphasizes social, political, and economic structures. In using this literature to reinterpret architectural technological history and theory, three themes are examined—the urban and regional reach of environmental technological systems, the use of environmental technological systems to capture and control space, and the relationship between the beneficiaries of environmental technological systems and larger managerial and governmental spaces.

Powerful spatial relationships emerge with the heating, cooling, and ventilation of space that connect urban spaces and other social aggregates in a complex social, political, and economic network. Understanding the complexity of these relationships requires reinterpreting the literature on environmental technological systems with literature drawn from urban geography and urban environmental studies. Most contemporary and historical writing on environmental systems examines the invention and development of these systems in spatial isolation, within the confines of interiors or the systems of particular buildings. The best of these writings relate the desire for cooling or heating to the social constructions of the marketplace and key shifts in American and European society. Those writings that explore the relationship between environmental technologies and a larger material space primarily deal with the impact of these technologies on the natural world, the environment, and other ecological abstractions. These writings, mostly environmentalist and phenomenological in approach, have provided knowledge about the possible natural, biological, and sensorial effects of manufactured architectural environments. Environmentalist and phenomenological historians, critics, and architects dominate recent discussions of environmental technological systems. Rather than solely examining the relationship between environmental technologies and nature, the environment, or some notion of a purely natural region, environmental technologies can also relate to the complex conurbation of urban space. An exploration of the urbanization of environmental technology is important for theoretical, historical, and contemporary architectural reasons. By integrating the literature on environmental systems with literature from contemporary urban theorists, the study of heating, cooling, and ventilation potentially informs an important ongoing examination of the blurred lines between urbanism and nature. From a historical perspective, by relating environmental technologies to urban studies, the study of architectural environmental technologies potentially reframes an understanding of fundamental urban spatial issues based on the social categories of ethnicity, race, and class. Perhaps most important, the entanglement of urban environmental studies and architectural technological studies describes a large social site of action for those designers or theorists interested in using these technologies (or some variant of them) as part of a critical approach to the design of buildings and urban spaces.

The Geographic Reach of the Mechanical Environment

Historians of architectural environmental technologies cite the mechanical heating, ventilating, and cooling of space as producing a pronounced and new thermal disconnection between interior and exterior space that is significantly different from preindustrial forms of environmental control.[1] Before modern mechanical methods were invented, the ventilation and cooling of internal spaces was achieved passively, through windows and ventilators

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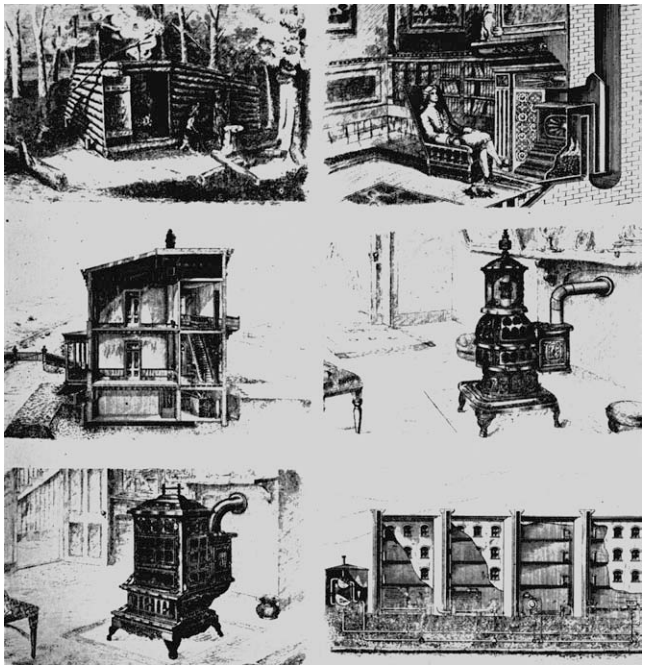
that simply brought exterior air into inhabited space, connecting interior space to a building's larger climatic territory (Figure 1). For heating, it involved connections to one's surroundings through a direct proximity to a fuel source and direct knowledge of how to transform that fuel source into heat through open hearths, fireplaces, and stoves.[2] In the major industrial period of the nineteenth and early twentieth centuries, heated and ventilated space was increasingly produced through mechanical means, initially in public buildings, but by the late-nineteenth century primarily within the spaces of upper-class apartment buildings and office buildings in large cities.[3] In this period, environmental effects were delivered by environmental control equipment—e.g., boilers and radiator systems—from remote locations within buildings. Numerous urban buildings were increasingly sealed from the exterior during heating months to increase the efficiency of mechanical heating equipment. During cooling months, ventilation equipment was used to help increase the exchange rate of air between interior and exterior, but in most buildings, operable windows retained a connection with exterior air, providing a simple option for passive air circulation. Nevertheless, the idea of fully manufactured interior thermal and ventilation standards becomes established in this period.[4] In the postindustrial period, the nature of this ''disconnected'' environment increases. With the ascendancy of cheaply-powered gas-fired heating systems and centralized cooling plants, interior thermal conditions become increasingly mitigated by machines year round. In many cases, especially in the United States, operable windows virtually disappear from public buildings and homes, thereby disconnecting the thermal aspects of interior space from their surroundings.[5]

The shift from preindustrial systems of environment management, where interiors maintained direct connections to their surroundings, to a mechanical environment, thermally separated from its surroundings, has been evaluated through

1. ''The history of heating'' evolves into ever-smaller equipment and devices; yet, it engages in a larger spatial geography

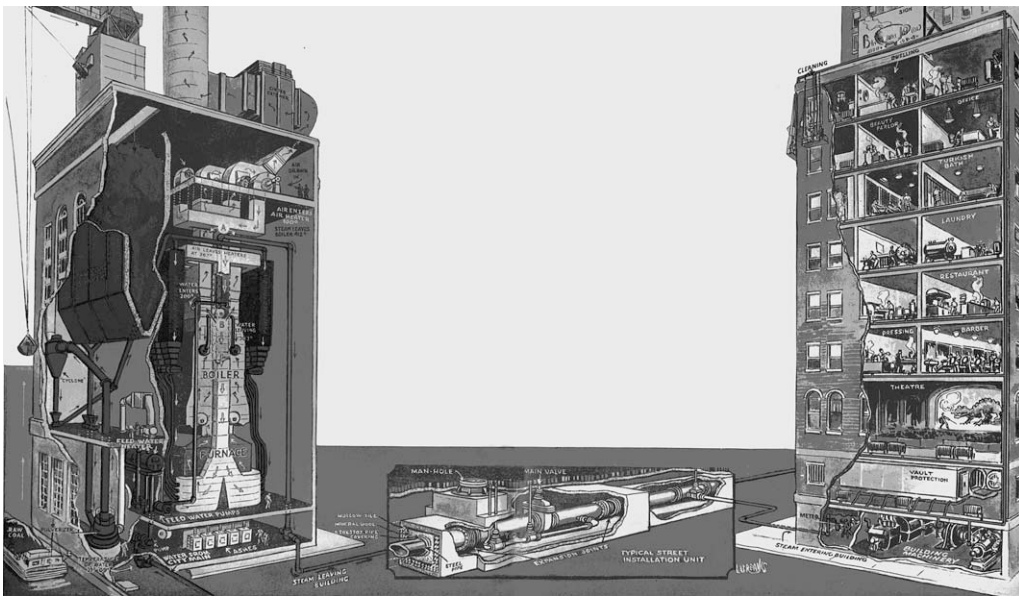


a variety of engineering, social, environmentalist, and phenomenological critiques and analysis. Engineering historians understand the development of the disconnected mechanical architectural environment as something that is continually evolving toward a more efficient functional and hygienic form, based on quantifiable data related to ideal transnational (and often transhistorical) averages of temperature and humidity. These historians, often writing for engineering organizations such as the American Society of Heating, Refrigerating and Air-conditioning Engineers (ASHRAE), laud the efforts of environmental control pioneers such as Rumford, Franklin, or Willis Carrier in achieving progressive levels of comfort with higher regularity and less dirt, dust, and fumes.[6] In contrast, recent sociotechnological historians such as Elisabeth Shove understand the development of a disconnected, isolated mechanical environment as an increasingly wasteful manifestation of the socially constructed values of comfort. In this writing, air-conditioning and heating machines appear as addictive luxuries that radically altered a set of idealized social relationships between individuals and their own self-sufficiency and/or cultural region.[7] Several historians within this literature category invert the rhetoric of early-twentieth-century environmental determinism, claiming that the experience of heat is a driving force in the production of authentic cultures. These historians blame air-conditioning for diminishing the cultural importance of experiencing heat.[8] Historical and theoretical analyses with an environmentalist bent, including Thomas Saunders' and James Wines' writings, build on the social critical approach, but they primarily criticize the mechanical achievement

of heating, cooling, and ventilating as an illustration of the way industrialized society has moved away from natural rhythms and energy sources. Many historians of the environment and architectural theorists bemoan the loss of more passive forms of environmental control or celebrate those cultures whose thermal comfort is achieved as a ritualized aspect of everyday life.[9] Simply by being within thirty feet of a window, they believe architects and engineers can connect the inhabitants of space to the exterior natural world. More phenomenological accounts, most famously Lisa Heschong's ''Thermal Delight in Architecture,'' see the separation of environmental control from exterior space in the nineteenth century as a form of thermal ''disembodiment'' mirroring the artifice and alienation within modernist space. This disembodied environment becomes one of the constituent factors in a loss of an individual's identification with his or her surroundings, self-sufficiency, and with a larger pretechnological sense of community.[10]

These historians, sociologists, and architectural writers employ different theoretical models to describe the evolution of environmental control; however, they all share a belief that the industrialized environment of modernity disconnects interior and exterior in startling ways. With the exception of engineering historians, this literature provides salient warnings about the parasitic aspects of this interior/exterior disconnection. While these writings provide important critical tools to analyze architectural technology, the ultimate problem of the mechanical environment may not be its disconnected character. In fact, its seemingly disconnected character may be hiding a more significant reality. The return to the outside called for in sociotechnical environmentalist and phenomenological literature is predicated on the belief that we occupy an environment disconnected from nature. What this literature discounts are the physical and social networks that emerged with mechanical forms of environmental control that modified but did not utterly displace the interior–exterior links in preindustrial environmental modification processes. The development of mechanical systems in the nineteenth century was dependent on physical systems—ducts, pipes, and gas tubes—that extended out of interior space and stretched into the bowels of buildings, the city, and its surrounding territories. Producing comfortable air required an urban environmental network that was local—connecting interiors with pipes and ducts linked to basement boilers and fans operated by building service workers—and regional—connecting the coal- and oil-fired boilers and generators to the labor-intensive centers of coal and oil production in rural regions[11] (Figure 2). In addition to these power networks, the urban mechanical environment was dependent on a network of air delivery that provided ventilation of domestic and work-related buildings. Throughout the nineteenth and twentieth centuries, a series of laws monitoring the emission of miasmas, exhalations, and odors kept this diffuse network of air as stable as possible, primarily based on the criteria of upper-class urbanites.[12] In the early twentieth century, laws governing building form ensured access to air and also that buildings did not impede other buildings' ability to receive air.[13] From the nineteenth to twentieth centuries, the entire city, its circuits and flows, in the form of street deliveries, rail lines, gas tubes, vents, and ducts, must be understood as part of the process that produced interior air. To say that the mechanical environment that emerged in the nineteenth century is the beginning of a form of mechanical control that disconnects interiors from their surroundings may be a fundamental misinterpretation of the real territorial relationships being established and a statement that reinforces ideological tendencies that keep these connections hidden. In other words, while being alienated from the myriad methods of producing thermally

2. New York City's steam heat network; this enormous diagram explains the labor and technology of heat production in 1930s New York City



modified space, consumers of heat and air in cities were entering into a relation with a larger system. And much of the critical literature on environmental control, while examining these systems within buildings, discounts the larger geography of this technology.

An alternative approach that would potentially shift the problem from a disconnected environment to a ''networked'' environment can be found in the recent writings of historians, geographers, and urban theorists.[14] These authors' works emerge from the fields of urban environmental and technical history and cultural and urban geography but can be characterized as part of a growing field of urban environmental studies. The authors of this literature have developed several themes that can begin to provide a critical framework for understanding the mechanical environment as part of a larger system and understanding what it may mean to study this hidden reality. Of this group, William Cronon is one of the earliest historians to address the importance of understanding networks as both a physical reality in the historical production of urban consumables and a force that reorganizes cities and distant territories. Examining the production of grain, pork, and lumber in nineteenth-century Chicago, Cronon demonstrates the way these consumables come into existence through urban networks such as rail lines and waterways that connect urban consumers with the distant territories where raw material is held. In connecting the city with a productive region, these networks were more than just a transit system; they were a device that enabled key historical agents to reorganize urban space based upon needs related to the consumable. The previously imagined boundary between urban and rural was blurred in these networked relationships as the desires surrounding capitalist production required the radical reconfiguring of rural regions and more local regions into productive territories.[15] In his explorations of water infrastructures, the geographer Erik Swyngedouw builds on Cronon's arguments by exploring urban networks as an interstitial process where environmental material transforms into consumables through the application of technology and human labor. In Swyngedouw's work, a network not only links a glass of water with a distant reservoir, it is a process that transforms ''H_2O'' into consumable water through filtration and treatment. By gathering and transforming material as it enters urban space, the network potentially optimizes the profitability of the consumable being conveyed. As a system filled with filtration and production machines, the network is a site of technological marvel; yet, as a site of human labor, the network is also fraught with social tensions and dispute.[16] In addition to exploring the above themes, the urban geographer Matthew Gandy describes how urban networks recode various forms of urban subjectivity. Being connected or disconnected to particular urban networks not only determines the ability to consume water and fuel but also signifies one's social and economic status. Being disconnected from these networks historically implies being de-urbanized; being connected implies partaking in a new order of class-based consumption.[17] Finally, historians and geographers of urban networks discuss the continuing absence of the network in urban consciousness. As the better world promised for all by a world of capitalist consumption never materializes, and as the productive labor involved in developing consumables becomes increasingly contentious, networks become increasingly obscured, shrouded in mystery. In a jointly authored article, Maria Kaika and Swyngedouw demonstrate how the disappearance of urban water networks in the early twentieth century reinforced larger ideological processes that naturalized the provision of water. Hiding the real labor involved in the production of water discounted the true life and death that went into the production of this key urban consumable. Nevertheless, these authors (and others) demonstrate that the continued attempts to hide the labor or physical reality of urban networks are undermined by the fact that networks are made by people and distributed by machines, and these processes can never be completely hidden. The appearance of the real productive forces occurs through the breakdown of equipment and through laborers' demands for better conditions, for example, higher wages and better workspaces.[18]

Concepts from urban environmental studies motivate a new historical and theoretical interpretation of the interaction between the use of mechanical environment systems and the effect of this use on surrounding cities and regions.[19] The literature of contemporary urban environmental studies promises an understanding of the way cities, regions, and interior spaces partially configure each other. Urban environmental literature also informs relations between technology and various forms of urban and regional subjectivity. The powerful human actors within particular networks, and the technologies themselves, configure the producers and consumers of mechanical environmental control. For example, the achievement of a warm interior in early twentieth century New York City was only possible due to the creation of a technological and labor-based system that delivered and maintained coal shipments. Simultaneously, the expansion of coal extraction technology and labor was partially accountable to increased demand for heat in the city. In the labor disputes of the early twentieth century, the laborers who extracted and delivered coal understood that a coal strike very often meant a ''heat strike,'' and they used this knowledge as a form of power against their managers. Although contemporary electrical and gas networks obscure the systems and labor that go into the production of heat and cold, they are still sites of social production and social strife. In sum, urban environmental literature provides theoretical tools to better understand the spatial reach of technological systems as well as the myriad technological actors who move through these different scales of space.

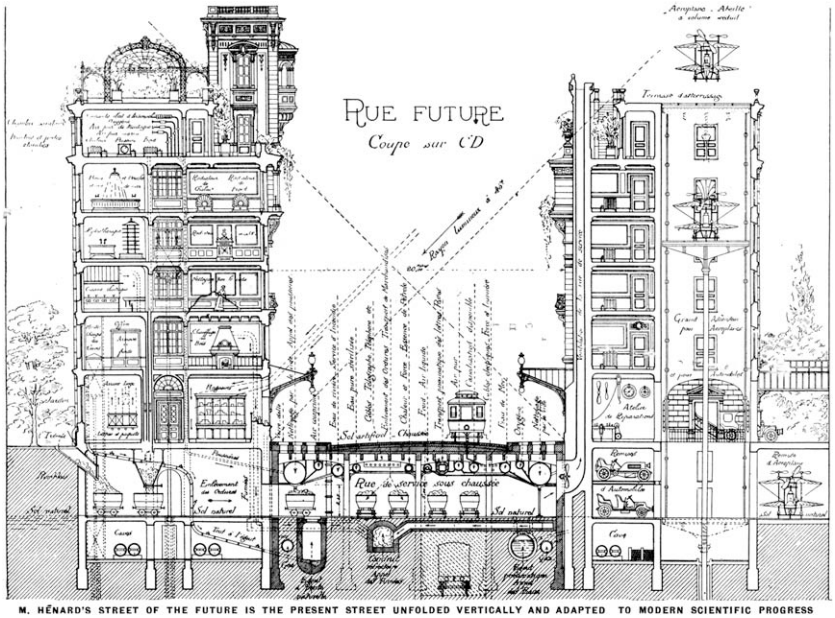
The Territorial Aspects of Mechanical Environmental Networks

In addition to illuminating the social reach of technological systems, the ideas within urban environmental literature can also inform the way we understand climate control to ''colonize'' space itself. Several contemporary historical examinations of climate control explore the way mechanical environmental equipment enables individuals to transform ''hostile'' climates into comfortable ones. The authors of this literature, such as technological historian Gail Cooper or social historian Marsha Ackermann, portray the efforts of architects and engineers to create postwar air-conditioned architectures and aggregations in previously inhospitable environments, such as the deserts of Arizona or Las Vegas. These authors demonstrate how air-conditioning systems were employed by developers to construct porchless houses and smooth-skinned, inoperable, glass-windowed skyscrapers in the desert or tropics. In this literature, mechanical environmental systems understood as a brute mechanical force that acts against a previously uninhabitable climatic frontier.[20] Technological critics, particularly from an environmentalist viewpoint, see these developments as indicative of a society that has lost touch with the relationship between building form and climatic structure; the erection of Western building forms in tropical or arid climates exemplifies the problems with universal globalization. In some of this literature, particularly the antitechnological writings of Egyptian architect Hassan Fathy, heavily air-conditioned buildings are imagined as creating a situation where cultural approaches to environmental control are forgotten. Fathy, committed to a low-tech approach, has called for the end to erecting technologically intense Western building types in tropical or arid climates. The more technoenvironmentalist theorist and practitioner Kenneth Yeang calls for a more mediated strategy. Yeang proposes Western building forms laced with hybrid technological systems that combine Western and regional climatic modification equipment.[21] Literature on climatic environmental displacement provides knowledge on the energy and cultural effects of climate control and the potential spaces that can exist within and beyond purely passive environmental relationships. Nevertheless, in examining the territorial implications of climate control, we might take a different approach, away from the dichotomies of nature and culture, inside and outside that entail an exploration of the way air-conditioned space transforms hot climates into cool interiors or the way environmental control enables a disconnected urban setting. Using the ideas explored in the previous section, we can begin to explore how ''environments'' are constructed within and *outside* the space of the interior and how these two constructed environments relate to each other.

It is clear that what is being transformed in buildings laced with mechanical environmental control equipment, such as suburban houses, urban skyscrapers, or apartment buildings, are the external climatic features of a building's particular precinct. With both passive and active systems, the heterogeneous features of the outside are continuously turned into a more homogenous and ''comfortable'' internal product. With contemporary year-round air-conditioning systems, this shift becomes more pronounced. However, in producing this valuable environment what is being processed in environmental control systems is not only the climatic features of an exterior nature—solar radiation, wind direction, and temperature—but also the additional features of the surroundings that are less concrete and more evaluative, such as ''pollutants'' and ''odors.'' The social content of air is not as well explored in the critical literature on climate control; yet, if climate-control heavy buildings participate in providing alternatives to their surroundings, surely this is one of their roles.

All the pathological and healthy contents of exterior air become the potential contents of the interior environment, where they are either processed into something less distinct or threaten to overcome environmental management systems. The entire city's ''exhalations''—the useful nineteenth-century term for the air emerging from urban neighborhoods—are the potential ''inhalations'' of an emerging, highly-controlled interior milieu. Thus, the mechanical environment emerges as something that negotiates with a much larger set of external factors than just climate. What is potentially erased in the name of maintaining the health of interior air is not just climatic uniqueness but a whole set of other urban environmental features and their causes, potentially anything that throws up undesirable, representative aspects of its processes into the urban air. This can include the real and imagined pollutants of industry or the real and imagined exhalations of historic and contemporary urban inhabitants. This erasure of these elements can occur by filtering them out through environmental technological systems, bypassing them via infrastructural systems, or more directly by relocating them away from areas of the urban air system as they become potentially harmful components of that system (Figure 3).

Literature within the field of urban environmental studies examines the tension implicit in efforts to monitor and control the undesirable outputs of urban spaces in the name of social reform, urban progressivism, and pre- and postwar environmentalism within an urban sphere modeled on industrial capitalist processes. The urban environmental historians David Stradling and Maria Rosen (building on the earlier work of Joel Tarr) explore the late-nineteenth-century and mid-twentieth-century efforts of wealthy urban American citizens to remove industry from cities primarily due to the smoke from the use of coal for industrial manufacture.[22] Stradling also concentrates on the rise of the municipal engineer, who was employed by cities to rethink the way smoke—among other pollutants—entered the urban air system and to understand and limit the ways it moved through the

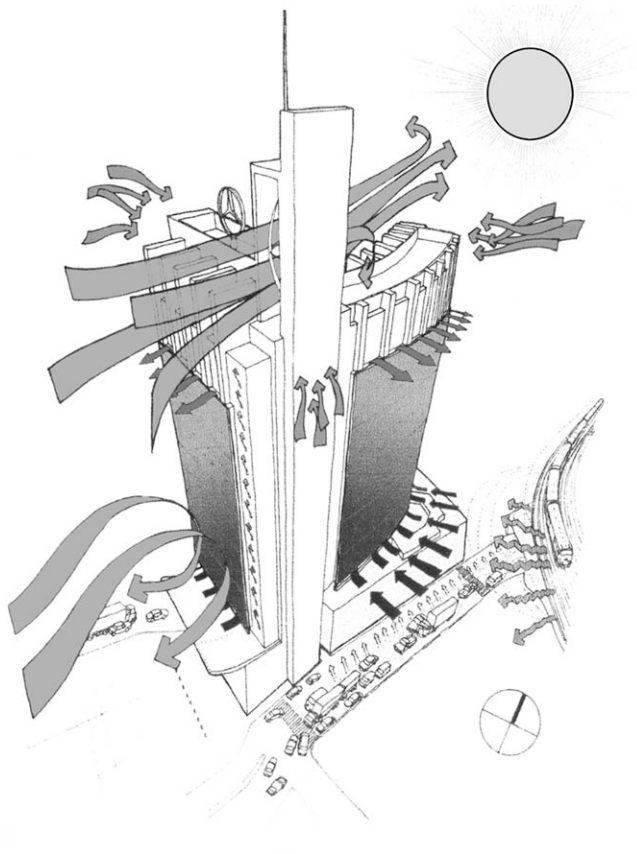


M. HÉNARD'S STREET OF THE FUTURE IS THE PRESENT STREET UNFOLDED VERTICALLY AND ADAPTED TO MODERN SCIENTIFIC PROGRESS

3. Urbanist Eugene Henard (1910) paid close attention to issues of air and pathology in his ''city of the future.'' Garbage and other urban waste are conveyed underground, industry is located to the city's periphery, and special urban ''air chambers'' are fed by an air infrastructure of underground tubes that bring country air into the city.

space of cities and into homes and workplaces.[23] Max Page is among a larger group of historians who demonstrate that the major industrial labor force of immigrants in American cities were often cast as ''urban polluters.'' In the late-nineteenth and early-twentieth century, immigrants became associated with exhalations and ''miasmas'' that moved from their tenement neighborhoods through the city producing sickness and epidemics, and they were also continual victims of redevelopment and removal efforts and various forms of social engineering efforts.[24] In his study of New York City, David Scobey interprets the call to disperse both industry and immigrants from the city as a manifestation of a nascent moral environmentalism that associated a clean homogenous city with a larger sense of urban morality. This ''negative environmentalism'' naturalized urban problems with their settings, paving the way for massive displacement and redevelopment efforts.[25] Although these American prewar urban environmental movements failed due to the inherent contradictions between capitalist forms of urbanization and progressive moralist visions of urbanization, many of these prewar themes continued, unresolved, in the postwar era. In his study of Gary, Indiana, Andrew Hurley explores how urban pollutants were understood as a threat to the emerging idyllic environment of wealthy and white urban suburbs. As middle-class and upper-class suburbanites moved to increasingly remote areas, they removed themselves from industrial and social problems that were closer to the urban core.[26] Analyzing the contemporary city, geographers and sociologists such as Robert Fitch, Christopher Mele, and Neil Smith explore the way neoreformist rhetoric informs the postwar gentrification of neighborhoods and the dispersal of poor neighborhoods and industry to the urban periphery of New York City.[27] Today, more populist environmental urban works examining biological terrorist threats and the proximity of cities to chemical industries and nuclear plants revive socioscientific debates regarding the future of urban form.

In order to connect this socioenvironmental history with the historical development of environmental systems, we would need to know how the technologically outfitted interior spaces of urban buildings such as apartments, hotels, and offices were seen as the recipients of these various environmental ''polluters.'' We would also need to know how this related to key urban environmental reform efforts. Very little in the historical literature on air pollution describes where environmental problems were perceived in the city. The perception of environmental problems with the rise of the industrial city may have been part of what architectural historian Meir Wigoder has described as an emerging nineteenth-century ''skyscraper consciousness.'' This was a new view of the city from above that became possible with tall office and apartment buildings.[28] This new visual consciousness gathered the exterior city into the urban elite's eyes, but it may also have gathered the city into their noses and lungs. How apartment and skyscraper dwellers understood their interiors and the environmental control equipment within them as inputting, at an unprecedented level, a dangerous external urban milieu is important. Numerous maps and cartoons from the mid- and late-nineteenth to the mid-twentieth century depict the city as a field of potentially harmful exhalations seeping out of the spaces of the poor and into the general field of urban air, infiltrating the spaces of the urban upper classes. In the near future, fears of biological agents entering buildings may lead to new calls to change buildings and the way buildings relate to the urban air and street system. The interpretation of urban air as containing representative aspects of undesirable urban phenomena or being completely benign may



4. Guy Battle's diagram of desirable and undesirable urban forces on a 1960s office building, which includes noise, and polluted and fresh air.

be an underexplored aspect of the process and rationale for specific urban actors to modify aspects of cities and buildings (Figure 4). Thus, rather than understanding the installers or users of mechanical environmental systems as colonizing their surroundings, we understand that in many instances, the external ''environment'' was (and is) every bit as constructed as the mechanical environment within buildings. By making connections between these spheres, we can potentially relate several complex historical and contemporary processes. This includes twentieth-century efforts to remove industry and immigrants from cities and contemporary efforts to barricade city streets leading to air intakes in contemporary office and apartment buildings.

The Urban Body in and Out of Environmental Control Networks

Historians of architectural technologies often view the development of universal ventilation and thermal standards as a key factor in the development of modern conceptions of physiological comfort and bodily efficiency. Scientists developed the first thermal and ventilation standards in the eighteenth and nineteenth centuries as part of the Enlightenment project of institutionalization. With the direct control over the thermal qualities of space out of the hands of inhabitants within institutional spaces, scientists and engineers promoted scientific standards for acceptable general levels of thermal comfort based upon the demands of particular programs.[29] The study of thermal standards continued into the late nineteenth and early twentieth century as part of emerging conceptions of individuality that banished the experience of heat or visible sweating from the interior spaces of the domestic and public spheres.[30] These individualist standards were projected by engineers as *the* standard. They were implemented within upper-class spaces and were encouraged in the poorest areas of the city as an aspect of urban tenement reform efforts. The early-twentieth-century engineers who created the first truly systematized ''comfort'' standards built on these earlier ideas, but their work reflected the rise of Fordist and Taylorist tendencies toward interior standardization and the body. The development of the ''comfort zone'' in 1923, prescribing a small range for the ideal heat and humidity within interiors, resolved disputes and enabled a nascent heating, ventilation, and cooling industry to work toward achieving a set of agreed standards within a competitive technological market.[31]

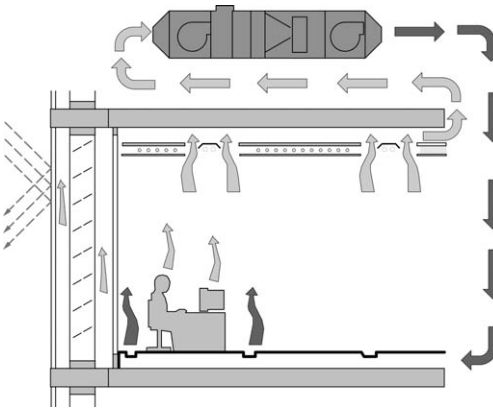
The development of physiological thermal standards from the eighteenth century to the twentieth century represents one of the myriad attempts to regulate bodies and to construct conceptions of bodily normality and averageness, a key theme of cultural modernity that has rightly come under criticism as part of the postmodern project. For example, sociologist Elisabeth Shove characterizes the increasing normalization of thermal standards as ''thermally alienating'' inhabitants who fall outside the scientifically developed

standards of comfort.[32] Historian Raymond Arsenault adds to this by demonstrating how these standards minimize the individual ways people cope with heat or cold, as well as the cultural uniqueness of thermal needs in tropical and arid zones. In his work, thermal standards are attributed to a loss of ''Southerness'' as people forget how to adjust to higher temperatures in postwar air-conditioned high-rise apartment and office buildings.[33]

In response to these problems, building engineers such as Guy Battle of the London-based firm Battle McCarthy have called for a differing set of thermal standards for air-conditioning equipment in arid and tropical zones, based on maintaining regional and national variants in comfort.[34] One of his specialties (in concert with the aforementioned Kenneth Yeang) is developing buildings that deliver the unique thermal experience of nontemperate climates in the massive spaces of high-rise apartment and office buildings. These buildings typically feature a variety of sun-shading devices and passive ventilation systems that bring largely unmodified exterior air into the space of the home or workplace.[35] Alternatively, several critics of thermal standards see the need for systems that recognize that comfort is an individual achievement that is based on personal physiological standards. The development of individualized comfort systems, such as the underfloor and desktop air register systems developed by the engineering firm Arup (Figure 5) and the company Johnson Controls, is one of the myriad solutions for developing individualized environments.[36]

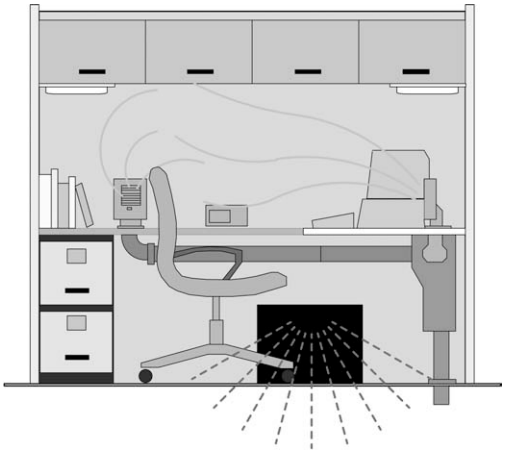
We can see these developments as a critique of the ''Fordist'' one-size-fits-all tendencies of modernity. In response to the universal environment of the comfort zone, critics of thermal standards call for buildings that provide a mass-customized environment, a physiological adjunct to the heterogeneity of the visual and economic postmodern project. However, to paraphrase David Harvey—a major critic of ''post-Fordism''—both the strict physiological standards of modernity and the mass-customized standards of postmodernity may merely be repeating the deep structure of body–city or body–state relations that lurk beneath almost all health management efforts. As is the case economically, the flexible climate controls of ''thermal'' postmodernity most likely obscure increasing levels of bodily management. One possible link between Enlightenment, Fordist, and mass-customized standards is what the historian Luis Fernandez-Galiano has identified as the ''panthermicon,'' the network of body–state relations established with the advent of heating systems. Fernandez-Galiano sees a high level of bodily management as an important aspect of the historical development of mechanical environmental systems. According to Fernandez-Galiano, environmental mechanical standards were developed in the spaces of nineteenth-century hospitals and prisons. The centralization of heating equipment and its movement into prison and hospital cells—carefully worked out in the famous scheme of Jeremy Bentham—was designed to thermally and acoustically isolate inmates. The monitoring of the thermal conditions of these spaces was yet another way to implement a regimented rationalist space onto the body itself.[37] Although Fernandez-Galiano did not explore the idea past the Enlightenment, it might be useful to see the panthermicon concept as a latent aspect of contemporary, highly sophisticated energy-efficient ventilation systems. The closed thermal loop diagrams of Arup engineers or the computerized building management systems (BMS) have emerged as an important component of recent energy-conscious office buildings. The Arup diagram describes the role of buildings in monitoring and using the heat flows from space, equipment, and inhabitants (Figure 5), while the BMS system is more literally a remote thermal ''eye'' that drives individualized air registers that provide custom levels of air-conditioning and heating. These BMS systems can be used to monitor the amount of energy used in a particular space and the air used by each inhabitant of a building.[38] BMS systems, which monitor air use from centralized computers, often hundreds of miles from the actual spaces they monitor, are a partial realization of the panthermicon concept that emerges with environmentalist conceptions of resource management in the city (Figure 6). Ultimately, the increased centralization and supervisory role of mechanical environmental systems is in contradiction to the apparent flexibility promised by individually tailored heating, ventilating, and cooling systems.

5. The ''green'' air system diagram of Arup services locates the worker's body as an integral aspect of a larger building system.



More problematic is that the development of these elite thermal networks that monitor office workers' and apartment dwellers' physiological comfort evolves in stark contrast to the historic and contemporary spaces of environmental disconnection in cities. These ''thermal ghettos'' are the dialectical opposite of intelligent environmental networks. These sites of thermal disconnection have been targeted by moral environmentalists at various times, via proposals for tenement air shafts, new law tenements, etc., but they ultimately exist outside the historical and contemporary view of the managers of various urban mechanical environmental networks. Although more commonly associated with the

6. Contemporary building management service companies manage comfort at enormous scales and from remote locations. Their work suggests new systems for bodily comfort at national and global scales.



nineteenth century, particularly in the context of urban tenement neighborhoods, thermal ghettos continue to exist as an aspect of ''uneven'' technological development. For example, Eric Klinenberg's study of the 1995 Chicago heat wave demonstrates the way thermal ghettos are particularly vulnerable to environmental problems. In addition to the lack of access to standardized air--conditioned space, inhabitants of poor and often dangerous neighborhoods shut themselves into a sealed, and therefore deadly, environment due to their fear of crime. Although Klinenberg cites the myriad strategies that once existed in Chicago to combat heat, in his study, access to fresh air and especially air-conditioned space by all citizens becomes an important aspect of the crafting of a more just city. In a study of the same heat wave, environmental historian Ted Steinberg claimed that energy subsidies for the poor would have made the type of air-conditioned space available in wealthy zones available in poorer neighborhoods whose urban layout and building types made them much more susceptible to heat-related deaths. In the United States, which lacks the level of environmental law in European cities, thermal ghettos are also ventilation ghettos, often lacking the sophisticated air filtration equipment that comes with centralized mechanical systems. They are sites of high pollution concentrations and airborne pathogens that lead to disproportionately high levels of respiratory ailments.[39] For example, in East Harlem, New York City, the Little Sisters of the Assumption Health Clinic has conclusively linked high levels of asthma to the interior mold spores of apartments in the Jefferson Houses and Metro Park Houses.[40] Their ability to rid these housing projects of mold is linked to their ability to access sophisticated abatement equipment and to building managers' ability to maintain the crumbling services in these building complexes (Figure 7). Although historic documentation of the idea of the thermal and ventilation ghetto is lacking, these and other examples of contemporary problems relate poverty and thermal exposure in convincing ways that can inform future historical work. Thermal ghettos are the true alternative reality of Fordist urban environments. The thermal ghetto becomes a thermal variant on the historically and technologically disenfranchised spaces of the modernist city. It is a customized environment for the American urban poor that continually reconstructs poverty and thermal deficiency in a dangerous realization of Elizabeth Grosz' famous conception of the mutually constituent relations between body and city.[41]

7. Activist ''engineer'' Ray Lopez leads asthma remediation efforts at numerous New York City housing projects.

Conclusions

Urban environmental literature provides sophisticated epistemological tools for the historians, theorists, and practitioners who reexamine the ''effects'' of architectural environmental technologies. Most historians and theorists of environmental technological systems explore the climatic appropriateness of a particular technological system, its low fuel use, or its cultural relevance. Urban environmental literature suggests that a larger set of social issues surrounds mechanical environmental technologies—labor, ghettoization, surveillance, and access—that extends throughout a complex envirotechnological space. Urban environmental literature does not discount that these technologies impact ''nature,'' but it reveals that the agents of these technologies impact the social sphere in radical ways. It remains to be seen how a sociourban

examination of environmental systems could produce new historical knowledge. With enough documentation, a more accurate description of the connection between interior, thermally controlled space, and surrounding regions could be attained. With more knowledge regarding the mechanical environmental network, the various human actors along its route, from key empowered agents to the more anonymous laborers, could be identified. With this knowledge, a more nuanced history of technological systems could be developed from above and ''from below'' (à la E. P. Thompson). With an increased understanding of the territoriality of mechanical environmental systems, the dispersal of urban ghettos and contemporary forms of gentrification might relate to seemingly innocuous desires for homogenous air and a ''cooler'' city. A study of the larger management structures of environmental systems might reveal new forms of historical agency that emerge with, and challenge, this form of biopower. Finally, it remains to be seen how a sociospatial examination of environmental systems could produce and/or inform alternative critical approaches to the design of environmental technological systems. As environmentalist technological strategies are increasingly incorporated into corporate management structures, the ''alternative'' provided by these systems becomes vague. The urban outside that the inhabitants of office and apartment buildings are ''returned'' to is an increasingly homogenous and deindustrialized milieu, an almost perverse manifestation of the progressive visions of the 1960s for cities within cities. Similarly, more humane, individualized environmental systems may ultimately provide the thermal disconnection that they were intended to thwart as individuals increasingly occupy distinct comfort spheres.

By employing concepts from urban environmental studies, the disconnected interior that characterizes recent studies of environmental technological systems was reconnected with a larger network of social, economic, and political relations. This network was charted to the farthest regions of urban space, revealing the potentially enormous social and political factors that produce comfort. One of this network's constituent elements—air—was charted back into the space of the city, revealing new forms of spatial reorganization. Returning to the primary ''subject'' of the history and theory of architectural environmental technology, the inhabitant of the interior, this individual is recast as either connected to a complex thermal management system or disconnected. We find ourselves back where we started but as part of a more complex reality. The network of relations between fuel and air networks and the space of the region and individual comfort will continue to be explored historically, building toward a set of arguments about a new understanding of environmental technologies and urban space.

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Notes

1. See, for example, Reyner Banham, *The Architecture of the Well-Tempered Environment* (Chicago: University of Chicago Press, 1969, 1984), pp. 171–94, 234–66; Robert Bruegmann, ''Central Heating and Forced Ventilation: Origins and Effects on Architectural Design,'' *Journal of the Society of Architectural Historians* 37 (1978): 143–60; and John Crowley, *The Invention of Comfort* (Baltimore: Johns Hopkins University Press, 2001), pp. 171–202.
2. John Crowley, *The Invention of Comfort*, pp. 8–14.
3. See, for example, Elizabeth Hawes, *New York, New York: How the Apartment House Transformed the Life of the City* (New York: Alfred A. Knopf, 1993), pp. 183–87; Carl Condit and Sarah Landau, *Rise of the New York City Skyscraper* (New Haven: The Yale University Press, 1995), pp. 30–33.
4. See Carol Willis, *Form Follows Finance: Skyscrapers and Skylines in New York and Chicago* (New York: Princeton Architectural Press, 1995), p. 8; and Richard Sennett, *Flesh and Stone* (New York: Faber, 1994), pp. 347–49.
5. David Arnold, ''The Evolution of Modern Office Buildings and Air Conditioning,'' *ASHRAE Journal* 41 (1999): 40–54; Willis, *Form Follows Finance*, pp. 132–43.
6. See, for example, John F. Fitchen, ''The Problem of Ventilation through the Ages,'' *Technology and Culture* 22 (1981): 485–511; Cecil D. Elliott, *Technics and Architecture: The Development of Materials and Systems for Buildings* (Cambridge, MA: MIT Press, 1992), pp. 271–326; Bernard Nagengast, ''Early Twentieth Century Air-Conditioning Engineering,'' *ASHRAE Journal* 41 (1999): 55–62.
7. See Marsha E. Ackermann, *Cool Comfort: America's Romance with Air-conditioning* (Washington, DC: Smithsonian Institution Press, 2002), p. 184; Elisabeth Shove, *Comfort, Cleanliness and Convenience: The Social Organization of Normality* (Oxford: Berg, 2003), pp. 53–57; Heather Chappells and Elisabeth Shove, ''Comfort: A Review of Philosophies and Paradigms'' (unpublished essay, 2004).
8. Examples include Raymond Arsenault, ''The End of the Long Hot Summer: Air Conditioning and Southern Culture,'' *The Journal of Southern History* 50 (1984): 597–68; and Gwyn Prins, ''On Condis and Coolth,'' *Energy and Buildings* 18 (1992): 251–58.
9. Of the numerous environmentalist critiques against the mechanization of building technology, see, for example, Hassan Fathy, ''Natural Energy and Vernacular Architecture: Principles and Examples with References to Hot and Arid Climates,'' in Charles Jencks and Karl Kropf, eds., *Theories and Manifestoes of Contemporary Architecture* (London: Academy Editions, 1975), p. 145; and for arguments for passive technologies, see, for example, William McDonough, *The Hannover Principles: Design for Sustainability* (New York: William McDonough Architects, 1992), pp. 14–15; and James Wines, *Green Architecture* (London: Taschen Books, 2000), pp. 132–45.
10. Within this growing literature category, see early examples such as Lisa Heschong, *Thermal Delight in Architecture* (Cambridge, MA: MIT Press, 1979), pp. 1–17; and the more nuanced Luis Fernandez-Galiano, *Fire and Memory: On Architecture and Energy* (Cambridge, MA: MIT Press, 2000), pp. 212–61.
11. On this, see David Stradling, *Smokestacks and Progressives: Environmentalists, Engineers and Air Quality in America, 1881–1951* (Baltimore: John Hopkins University Press, 1999), pp. 18–20.
12. See Joel Tarr, *The Search for the Ultimate Sink: Urban Pollution in Historical Perspective* (Akron, OH: University of Akron Press, 1996), pp. 227–61; and David Stradling, *Smokestacks and Progressives*, pp. 37–60.
13. Within the extensive literature on this subject, see Carol Willis, ''Zoning and 'Zeitgeist': The Skyscraper City in the 1920s,'' *The Journal of the Society of Architectural Historians* 45 (1986): 47–59; Gail Fenske and Deryck Holdsworth, ''Corporate Identity and the New York Office Building: 1895–1915,'' in David Ward and Oliver Zunz, eds., *The Landscape of Modernity: New York City, 1900–1940* (Baltimore: Johns Hopkins University Press, 1992), pp. 129–59; and Keith D. Revell,

''Regulating the Landscape: Real Estate Values, City Planning, and the 1916 Zoning Ordinance,'' in David Ward and Oliver Zunz, eds., *The Landscape of Modernity: New York City, 1900–1940* (Baltimore: Johns Hopkins University Press, 1992), pp. 19–45.

14. See Thomas Hughes, *Networks of Power* (Baltimore: Johns Hopkins University Press, 1983), pp. 1–17; Joel Tarr and Gabriel Dupuy, eds., *Technology and the Rise of the Networked City in Europe and North America* (Philadelphia: Temple University Press, 1988), p. xvii; William Cronon, *Nature's Metropolis: Chicago and the Great West* (New York: W. W. Norton and Company, 1991), pp. 55–86; Mark H. Rose, *Cities of Light and Heat: Domesticating Gas and Electricity in Urban America* (New York: The Pennsylvania State University Press, 1995), pp. 13–38; Wolfgand Schivelbusch, *Disenchanted Night: The Industrialization of Light in the Nineteenth Century* (London: University of California Press, 1996), pp. 25–33; Maria Kaika and Erik Swyngedouw, ''Fetishizing the Modern City: The Phantasmagoria of Urban Technological Networks,'' *International Journal of Urban and Regional Research* 24 (2000): 120–38; Martin V. Melosi, *The Sanitary City: Urban Infrastructure from Colonial Times to the Present* (Baltimore: Johns Hopkins University Press, 2000), pp. 73–173; Matthew Gandy, ''The Paris Sewers and the Rationalization of Urban Space,'' *Transactions of the Institute of British Geographers* 24 (1999): 23–44; Matthew Gandy, *Concrete and Clay: Reworking Nature in New York City* (Cambridge, MA and London: MIT Press, 2002), pp. 19–76; Stephen Harrison, Steve Pile, and Nigel Thrift, eds., *Patterned Ground: Entanglements of Nature and Culture* (London: Reaktion Books, 2004), pp. 34–40; and the theoretical works which inspire some of this recent literature: Donna Haraway, ''A Cyborg Manifesto: Science, Technology, and Socialist-Feminism in the Late-Twentieth Century,'' in Donna Haraway, ed., *Simians, Cyborgs and Women: The Reinvention of Nature* (New York: Routledge, 1991), pp. 149–81; Bruno Latour, *We Have Never Been Modern* (London: Harvester Wheatsheaf, 1993), pp. 51–55; and Gilles Deleuze, with Felix Guattari (trans. Brian Massumi), ''City/State,'' in Neal Leach, ed., *Rethinking Architecture: A Reader in Cultural Theory* (London: Routledge, 1997), pp. 313–18.

15. William Cronon, *Nature's Metropolis*.

16. Eric Swyngedouw, ''Modernity and Hybridity: Nature, Regeneracionismo, and the Production of the Spanish Waterscape, 1890–1930,'' *Annals of the Association of American Geographers* 89 (1999): 443–65; and Eric Swyngedouw, ''Circulating Waters, Circulating Moneys, Contested Natures,'' in Stephen Harrison, Steve Pile, and Nigel Thrift, eds., *Patterned Ground: Entanglements of Nature and Culture* (London: Reaktion Books, 2004), pp. 119–21.

17. Matthew Gandy, ''The Paris Sewers''; Matthew Gandy, *Concrete and Clay*; and Matthew Gandy, ''Cyborg Urbanisation: Complexity and Monstrosity in the Contemporary City'' (unpublished manuscript, 2004).

18. Kaika and Swyngedouw, ''Fetishizing the Modern City''; and Maria Kaika, ''Interrogating the Geographies of the Familiar: Domesticating Nature and Constructing the Autonomy of the Modern Home,'' *International Journal of Urban and Regional Research* 28 (2004): 265–86.

19. Understanding mechanical environmental systems as part of a network does not automatically distance the study of environmental systems from environmentalist thinking. An environmental mechanical network can be projected into sustainable discourses on ''ecological footprints,'' for example. Although this approach is avoided in this essay, see the very good work by William J. Mitchell, *Me++: The Cyborg Self and the Networked City* (Cambridge, MA: MIT Press, 2003), pp. 22, 43, for examples of this approach.

20. See Gail Cooper, *Air-Conditioning America* (Baltimore: Johns Hopkins University Press, 1998), p. 156; Marsha Ackermann, *Cool Comfort*; Elisabeth Shove, *Comfort, Cleanliness and Convenience,* p. 54; and Carol Willis, *Form Follows Finance*, pp. 132–34.

21. Hassan Fathy, ''Natural Energy and Vernacular Architecture: Principles and Examples with References to Hot and Arid Climates,'' in Charles Jencks and Karl Kropf, eds., *Theories and Manifestoes of Contemporary Architecture* (London: Academy Editions, 1975), pp. 145–47; and Kenneth Yeang, *Reinventing the Skyscraper* (London: Wiley-Academy, 2002), pp. 126–47.

22. Joel Tarr, ''Searching for a 'Sink' for an Industrial Waste: Iron-Making Fuels and the Environment,'' *Environmental History Review* 18 (1994): 9–34; Christine Meisner Rosen, ''Businessmen against Pollution in Late Nineteenth Century Chicago,'' *Business History Review* 69 (1995): 351–97; and David Stradling, *Smokestacks and Progressives: Environmentalists, Engineers and Air Quality in America, 1881–1951* (Baltimore: John Hopkins University Press, 1999), pp. 21–36.

23. David Stradling, *Smokestacks and Progressives*, pp. 85–107. Clay McShane and Stanley Schultz, ''To Engineer the Metropolis: Sewers, Sanitation, and City Planning in Late-Nineteenth Century America,'' *Journal of American History* 65 (1978): 389–411.

24. Max Page, *The Creative Destruction of Manhattan, 1900–1940* (Chicago: The University of Chicago Press, 1999), pp. 69–92. See also Richard Plunz, *A History of Housing in New York City* (New York: Columbia University Press, 1990), pp. 21–53; David Ward and Oliver Zunz, eds., *The Landscape of Modernity: New York City, 1900–1940* (Baltimore: The Johns Hopkins University Press, 1992), pp. 116–18; Alan M. Kraut, *Silent Travelers: Germs, Genes and the Immigrant Menace* (Baltimore: Johns Hopkins University Press, 1994), pp. 105–35; and Christopher Mele, *Selling the Lower East Side: Culture, Real Estate, and Resistance in New York City* (Minneapolis: University of Minnesota Press, 2000), pp. 78–119.

25. David M. Scobey, *Empire City: The Making and Meaning of the New York Landscape* (Philadelphia: Temple University Press, 2000), pp. 134–57; see also M. Christine Boyer, *Dreaming the Rational City: The Myth of American City Planning* (Cambridge, MA: MIT Press, 1983), pp. 9–32.

26. Andrew Hurley, *Environmental Inequalities: Class, Race, and Industrial Pollution in Gary, Indiana, 1945–1980* (Chapel Hill: University of North Carolina Press, 1995), pp. 111–35.

27. Robert Fitch, *The Assassination of New York* (New York: Verso, 1993), pp. 3–35; Neil Smith, *The New Urban Frontier: Gentrification and the Revanchist City* (London: Routledge, 1996), pp. 3–29; and Christopher Mele, *Selling the Lower East Side*.

28. Meir Wigoder, ''The ''Solar Eye'' of Vision: Emergence of the Skyscraper Viewer in the Discourse on Heights in New York City, 1890–1920,'' *Journal of the Society of Architectural Historians* 61 (2002): 152–69.

29. See John Thompson, *The Hospital: A Social and Architectural History* (New Haven: Yale University Press, 1975), pp. 118–69; and N. S. Billington, ''The Evolution of Environmental Temperature,'' *Building and Environment* 22 (1987): 241–49.

30. A concept explained well in Richard Sennett, *Flesh and Stone*, pp. 255–57; and Dell Upton, *Architecture in the United States* (New York: Oxford University Press, 1998), pp. 156–58.

31. See the development of the comfort zone in Gail Cooper, *Air-Conditioning America*; and Elisabeth Shove, *Cleanliness, Comfort and Convenience*.

32. An early phenomenological critique of the comfort zone can be found in Lisa Heschong, *Thermal Delight in Architecture*.

33. The most famous critique being that of Raymond Arsenault, ''The End of the Long Hot Summer.''

34. See his article in David Gissen, ed., *Big and Green: Towards Sustainable Architecture in the 21st Century* (New York: Princeton Architectural Press, 2002), pp. 36–54. Another good example of this approach is in Humphreys and Nicol, ''Understanding the Adaptive Approach to Thermal Comfort,'' *ASHRAE Transactions Symposia* 40 (1998): 991–1004.

35. An early example of these ''critical'' passive approaches oriented in a primarily domestic context is in Victor Olgyay, *Design with Climate: Bioclimatic Approach to Architectural Regionalism* (Princeton, NJ: Princeton University Press, 1963), and a more recent example oriented to more massive development is Kenneth Yeang, *Reinventing the Skyscraper*.

36. A good explanation of the critical social potential of these technologies is in David Serlin, ''Some Like it Cold: Engineering the Personal Environment,'' *Cabinet* 3 (2001): 13–17.

37. Luis Fernandez-Galiano, *Fire and Memory: On Architecture and Energy* (Cambridge, MA: MIT Press, 2000), pp. 229–31.

38. Interview with Paul von Paumgarten, Johnson Controls, November 2001.

39. On this issue, see Andrew Hurley, *Environmental Inequalities*, pp. 15–45; Matthew Gandy, *Concrete and Clay*, pp. 200–213.

40. This is from an extensive interview between Ray Lopez of the Little Sisters of the Assumption Health Organization and the author (July 2005) to be published in the forthcoming article ''Abject Atmosphere.''

41. Elizabeth Grosz, ''Bodies-Cities,'' in Beatriz Colomina, ed., *Sexuality and Space* (New York: Princeton Architectural Press, 1992), pp. 241–53.