AIR DESIGN

Maider Llaguno-Munitxa

As described by Sloterdijk in *Terror from the Air,* "the discovery of the 'environment' took place in the trenches of World War I." On 22 April 1915, a specially formed German gas regiment launched the first large-scale chemical attack against French-Canadian troops in northern Ypres Salient, using chlorine gas as their means of combat. Chlorine-filled cylinders were positioned facing prevailing north-northeast wind and released the liquefied chlorine into the air, producing a cloud nearly 6 kilometers wide and 600 to 900 m deep. It is estimated that 15,000 people were poisoned and 5,000 died in this terrorist act, which Sloterdijk describes as "'atmotechnic' innovation […] a sort of regional atmospheric design." Sloterdijk introduces the concept of "air-design" as "the technological response to the phenomenological insight that human being-in-the-world is always and without exception present as a modification of 'being-in-the-air.'" And he continues, "Since there is always something in the air, advances in atmosphere explication throw up the idea that, by way of precaution, we might put something in it ourselves."[1]

1. P. Sloterdijk, *Terror from the Air* (Cambridge, MA: MIT Press, 2009), 23 and 93.

Chai Jing's *Under the Dome*, documentary from 2015
Al Gore's *An Inconvenient Truth*, documentary from 2006

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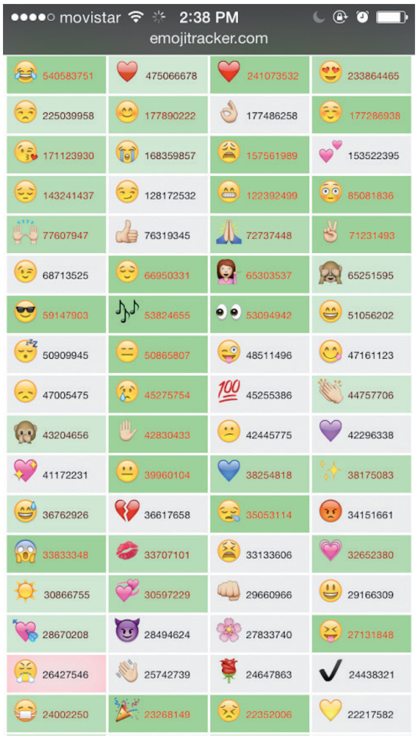

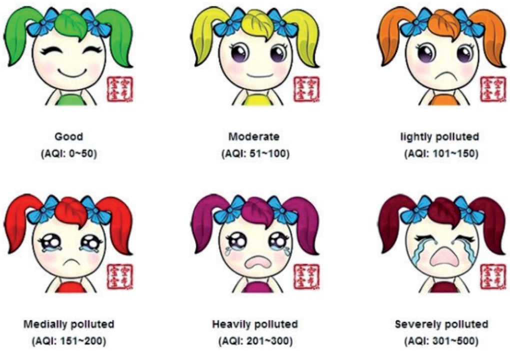

The atmosphere is progressively transformed through anthropogenic emissions as a form of "slow violence" that is dispersed across time and space.[2] Through vehicular, household, and tertiary activities, the chemical composition of our atmosphere is constantly under transformation, and in many cities around the world air quality is being severely compromised, seriously affecting urban health. A recent report from the WHO stated that "in 2012, around 7 million people died—one in eight of the total global deaths—as a result of air pollution."[3] Various newsletters and documentaries, such as *Under the Dome* by Chai Jing or *An Inconvenient Truth* by Al Gore, have reached large audiences that exceed the boundaries of scientific research, and thus air pollution has become a topic of general concern. Hence, regulatory bodies to improve the air quality conditions in our cities are becoming more in demand every day.

2. R. Nixon, *Slow Violence and the Environmentalism of the Poor* (Cambridge, MA: Harvard University Press, 2013).

3. WHO, *World Urbanization Prospects 2014* (United Nations, 2014).

The mask emoji is among the most popular emojis
Air Quality Index graphics by the Shanghai Environmental Monitoring Centre

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However, air phenomena has proven to be very hard to regulate. Airflow is an irregular medium and, as such, its regulation is conceptually problematic. The nonlinear characteristics of turbulent flows make a deterministic approach to resolve them analytically intractable; therefore, it is challenging to formulate simplified modelling approaches for urban flows. In addition, quantitative predictions about the influence of environmental policies on local air quality are hard to prove and difficult to argue for. Air is also a continuum with no physical boundaries, and thus geopolitical friction over regulatory policies is often unavoidable. Consequently, while the anthropogenic transformation of our atmosphere has been ongoing for over two centuries already, curating this "design process" through the implementation of regulatory strategies has proven challenging.

Not surprisingly, the governance bodies that handle environmental policies have also often proven unsuccessful or insufficient in addressing the problem at the required spatio-temporal scales, which account for the variability in the phenomena[4]. The phenomena in the atmosphere are classified according to temporal and spatial scales [5], which within the Urban Boundary Layer (UBL) range from the study of meso- to local and micro-scale climates.[5] And thus, in order to reflect upon the locally specific concentration levels, the governance bodies that implement environmental policies have to effectively address the spatial variability of air quality in cities.

As of today, the responsibility to draft atmospheric regulations generally falls in the hands of high-level regional or federal governance bodies, occasionally complemented by city-scale regulations. Not surprisingly, such high-level governance bodies fail to account for the atmospheric variability that characterizes local and microclimate scales. While "small-scale" atmospheric variability has been scientifically understood since the nineteenth century (refer, for example, to the pioneering work of meteorologist Luke Howard from 1838),[6] it remained within the realm of environmental sciences and was not discussed in public forums. However, especially in the last decade, with the spread of sensing technologies and the Internet of Things (IoT), the local variability in air quality concentrations is being acknowledged and the role of architecture in the design of the atmosphere is starting to be recognized.

In this context, the physical boundaries of architecture are to be revisited to consider the design of natural systems as part of the disciplinary domain. Since adverse air quality tends to be primarily an urban problem, incorporating the measures to guarantee good air quality in built areas is critical. And so through architectural design strategies, we have the opportunity to become active agents in the remediation of this common.

4. Kundu PK, Cohen IM. Fluid Mechanics. Burlington, MA: Elsevier; 2008. 904 p.

5. The urban boundary layer is a mesoscale phenomenon. Its characteristics are affected by the urban surface. Oke, T.R. 1987. Boundary Layer Climates. York, UK: Methuen & Co. Ltd.

6. L. Howard, *The Climate of London, Deduced from Meteorological Observations Made at Different Places in the Neighbourhood of the Metropolis* (London: C. Baldwin Printer, 1838).

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DIVERGING GLOBAL AIR POLICIES

Concerns about air quality have been present for centuries, as have regulations for emission controls. Since King Edward I's ban on burning sea coal in London in 1306, through the Glasgow smog in 1873, to the London smog in 1952, households were forced to reduce the use of coal, eventually leading to the formulation of the 1956 clean air act in the United Kingdom. Similarly in the United States, following the 1881 Chicago and Cincinnati smog, and the 1939 extreme smoke days in the city of St. Louis, among other events, the U.S. Congress passed the Air Pollution Control Act of 1955 to solve the problems associated with air quality.[7]

By the second half of the twentieth century, hand in hand with economic globalization, environmental policies acquired regional and global scales. Influenced by contemporary theories such as the ecosystem approach addressed in *Silent Spring* byRachel Carson,[8] the formation of environmental think tanks such as the Club of Rome (1968)[9], or the formulation of concepts such as "sustainable development" addressed in the Brundtland report (1987)[10], a global environmental consciousness was recognized and global environmental consensus on issues such as pollutant emission controls started to be sought. Thus, while the intensification of global economic activity contributed significantly to environmental deterioration, globalization also enabled increased public awareness of environmental issues around the world.

7. CCPS-AIChE, *Safe Design and Operation of Process Vents and Emission Control Systems* (Hoboken, NJ: John Wiley & Sons, 2006). 326 p.

8. R. Carson, *Silent Spring* (Boston, MA: Houghton Mifflin, 1962).

9. https://www.clubofrome.org/ In 1972 the The Limits to Growth(the first study to question the viability of continued growth in the human ecological footprint was published).

10. N documents url: http://www.un-documents.net/our-common-future.pdf.

U.S. President Richard Nixon signing the Clean Air Act in 1970

U.S. President George H.W. Bush signing the first climate change agreement in the UN conference on the Environment in Rio de Janeiro in 1992

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Global initiatives to stabilize greenhouse gas (GhG) concentrations were first introduced as an issue of global concern at the United Nations (UN) Conference on the Environment and Development held in Rio de Janeiro in 1992.[11] Since then, and as part of the Annual UN Framework Convention on Climate Change (UNFCCC), various international conferences have followed, with the Paris UN Conference of partiers (COP 21) held in 2014 and the last one (COP 22) being held in Marrakech in November 2016, committing its members by setting internationally binding GhG emission reduction targets. On the other hand, regional-scale pollutant release regulations such as the EU VI or the U.S. emission standards set by the EPA introduce limits for vehicle exhaust or industrial emissions.

In the table shown below, the concentration standards such as those established by the National Ambient Air Quality Standards (NAAQS) for the United States or the European Commission of Pollutant Standards are compared against the guidelines suggested by the World Health Organization (WHO). While these standards are not legally binding, they offer an outlook on the criteria followed in the different countries and reveal a missing coherent approach on the definition of air quality criteria. Similarly, the commitment of different stakeholders to global and regional pollutant emission regulations has historically proven to be challenging, and thus such policies become a recurrent domain for geopolitical confrontation.

Furthermore, neither the global nor regional regulations reflect the concentration peaks observed in urban environments for which municipal-scale emission controls are implemented. That is the case, for example, with the newly approved anticontamination protocol in the city of Madrid,

11. UNFCCC, Rio Convention 1992, http://unfccc.int/essential_background/convention/items/6036.php, accessed 28 March 2016.

U.S. EPA Director Scott Pruitt, on taking a "humble" approach to regulating the CO_2 emissions, 28 March 2017

U.S. President Donald Trump officially withdraws from the Paris climate accord during a speech at the White House Rose Garden on Thurs. June 1, 2017. Screenshot from White House video

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	WHO	EU	US	Canada	Australia	China
Ozone 8 hour, ppb	50	60	75	65	80	80
Fine Particulate 24 hour, µg/m³. PM2.5|10	25 | 50	25 | 50	35 | 150	30 | -	25 | -	75 | 150
Sulfur Dioxide 24 hour, ppb	8	48	140	115	80	60
Nitrogen Dioxide Annual, ppb	21	21	53	53	30	21
Carbon Monoxide 8 hour, ppm	9	9	9	13	9	-

or with the Low Emissions Zone (LEZ) regulation established in 2008 in London.[12] Similar policies are also being implemented in other cities around Europe, such as Paris or Zurich.

However, municipal regulations fail to reflect local concentration levels. Air quality is generally measured in idealized sites (often located in suburban contexts) where the concentration levels don't resemble those observed in urban street canyons.[13] Furthermore, recent findings have shown that the concentration levels of ultrafine particles are approximately six times higher in urban street canyons.[14] Since air quality is therefore not a homogeneous phenomenon, municipal regulatory bodies generally fail to address the concentration gradients present in urban environments, and prove unsuccessful in incorporating the necessary remediation strategies.

Thermal pollution and chemical pollutant concentrations peak in cities as opposed to the countryside, due not only to high and localized anthropogenic emissions, but also to the topographical and surface material properties of the urban fabric.[15] A building can affect its

12. Transport for London, "Low Emission Zone" (2015), https://tfl.gov.uk/modes/driving/low-emission-zone, accessed 15 June 2016.

13. T. R. Oke, "Siting and Exposure of Meteorological Instruments at Urban Sites," in C. Borrego and A. L. Norman, eds., *Air Pollution Modeling and Its Application XVII* (New York: Springer Science+Business Media, LLC, 2007), 615–31.

14. R. E. Britter and S. R. Hanna, "Flow and Dispersion in Urban Areas," *Annual Review of Fluid Mechanics* 35(1) (2003): 469–96.

15. Kumar P, Fennell PS, Hayhurst AN, Britter RE. Street Versus Rooftop Level Concentrations of Fine Particles in a Cambridge Street Canyon. Boundary-Layer Meteorology. 2008;131(1):3-18.

Comparison of Ambient Air Quality Standards and Guidelines local wind speed, wind direction, air pollution, driving rain, radiation, or daylight,[16] and so by adjusting its geometrical or material attributes, a reduction in the local concentration levels can be induced. Therefore, in order to achieve effective air-quality remediation strategies, not only must international, regional, and municipal policies be incorporated, but domestic scale (street and neighborhood scale) strategies must also be integrated where local urban structures (topography, architecture, etc.) play a crucial role.

CONVERGING LOCAL AIR POLICIES

The period of time between the second half of the nineteenth and the first half of the twentieth century was particularly interesting for the study and implementation of urban environmental initiatives which included air quality remediation strategies. At that time, the disciplinary boundaries of architecture, planning, and urban sanitation were not yet clearly drawn, and hence the architect had to think holistically about architectural, social, and environmental considerations. Architecture was therefore often designed to comprise its surrounding microclimate and air quality.

The role of passive architectural considerations such as building morphology and materiality in urban health were discussed in various climate forums and were incorporated at urban policy levels. To ensure solar access and fresh air to streets and communal areas as well as to building envelopes, many cities in Europe and in the United States introduced a variety of building codes between the 1850s and the 1930s. Interestingly, these codes, while pertaining to urban scale regulations, also introduced indications for architectural-scale geometrical aspects such as roof geometries.[17]

Ildefons Cerdà's masterplan codes also introduced environmental architectural parameters for the Eixample in Barcelona planned in the late 1850s. Besides including building height H to street width W ratio indications, Cerdà introduced regulations to constrain building frontage heights and set back distances for the terrace levels. This criterion was intended to promote a continuous urban frontage while limiting the massing to enable the access of direct sunlight to urban street canyons and building envelopes. His considerations in regard to urban ventilation were proposed in the form of block consolidation. That is, block permeability was encouraged to favour street ventilation, and the consolidation of more than two façade frontages was deemed undesirable for courtyard ventilation.[18] While the measures proposed by Cerdà to guarantee the access of direct

16. B. Blocken and J. Carmeliet, "Pedestrian Wind Environment around Buildings: Literature Review and Practical Examples," *Journal of Thermal Envelope and Building Science* 28(2) (2003):107–59.

17. W. Atkinson, *The Orientation of Buildings, or Planning for Sunlight* (New York: John Wiley and Sons, 1912).

18. A. Doerr, "Behind Four Walls: Barcelona's Lost Utopia" (2014), http://www.failedarchitecture.com/behind-four-walls-barcelonas-lost-utopia/, accessed 10 May 2016; A. Soria y Puig, *Cerdà: The Five Bases of the General Theory of Urbanization* (Madrid: Sociedad Editorial Electa Espana, 1999); J. Busquets, *Barcelona: The Urban Evolution of a Compact City* (Rovereto: Nicolodi; Cambridge, MA: Harvard University Graduate School of Design; distributed by Actar, 2006).

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sunlight to the building facades and streets were generally successfully adopted, his proposal for the limiting block consolidation to guarantee urban ventilation was less successful. As opposed to the open courtyards Cerdà had envisioned, urban blocks are mostly enclosed today.

The London Building Act of 1894, on the other hand, prescribed slanting roofs instead of flat or curved ones to maximize the access of natural light in urban street canyons.[19] Likewise, building codes established in 1902 for the city of Paris not only described the requirements for street width and building height, but also introduced indications to regulate roof geometry. With the same philosophy, William Atkinson, an advocate of passive solar design, in *The Orientation of Buildings, or Planning for Sunlight* from 1912,[20] criticized the limitations of most of the building codes that only constrained street *H/W* ratios. Atkinson instead proposed strategies to compute direct sun ray incidence and shadow casting on public areas or neighboring buildings, and suggested such measures should also be incorporated in planning policies. Among his considerations we can find studies on the effect of cornice details, the influence of roof designs on street daylight conditions, and neighbor shadow-casting studies.

The 1916 Standard Zoning Act in the United States also addressed the role of passive design strategies on sun incidence and ventilation. The building code aimed at stopping the erection of massive buildings such as the Equitable Building in New York which would prevent light and air from reaching the streets below.

The increasing concerns about urban sanitation, coupled with the ongoing aerodynamic investigations in early-twentieth-century Paris, awakened local architects' awareness of the interaction of buildings and airflow and, in particular, the role of building geometry in urban ventilation.

Little is known about the meteorological investigations performed by Gustave Eiffel, however. Fascinated by the interactions of land and airflow, Eiffel developed one of the first urban weather stations: the Eiffel Tower. From his *pied à terre* located 285m above the city in the Eiffel Tower, Gustave Eiffel monitored weather conditions in the city of Paris. Between 1903 and 1914, beginning with the drop test studies performed from the tower,[21] and culminating with the wind tunnel tests developed at the Champ-de-Mars laboratory located at the base of the tower, the Eiffel Tower became a platform where various meteorological and aeronautic experiments that

19. F. Banister, *The London Building Act, 1894: A Text-book for the Use of Architects, Surveyors, Builders, etc. Containing the act printed in extenso together with a full abstract, giving all the sections of the act which relate to buildings, set out in tabular form for easy reference and an introd. showing the leading alterations made by the act* (London: B. T. Batsford, 1896).

20. Atkinson, *The Orientation of Buildings*.

21. A. Angot, "Les Observations meteorologiques de la Tour Eiffel," *La Nature* (869) (1890): 117–8; G. Eiffel, *Nouvelles recherches sur la résistance de l'air et l'aviation, faites au Laboratoire d'Auteuil* (Paris: E. Chiron, 1919).

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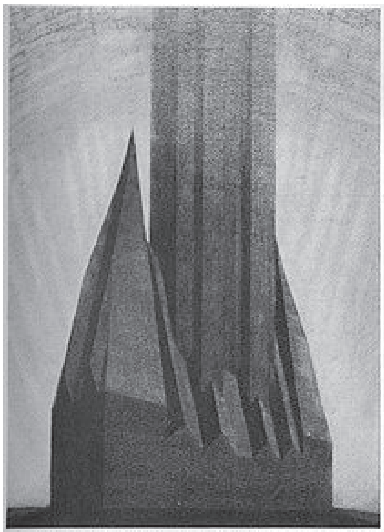
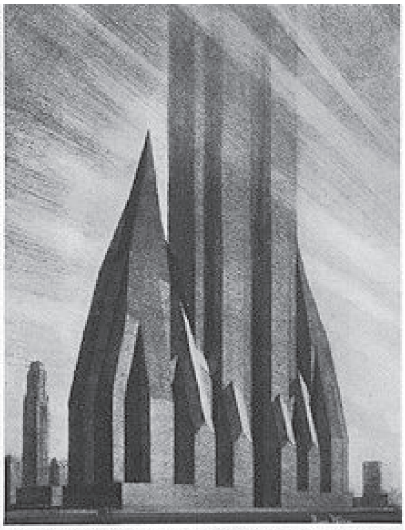
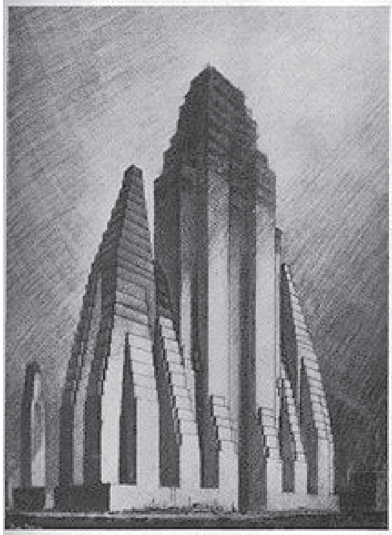


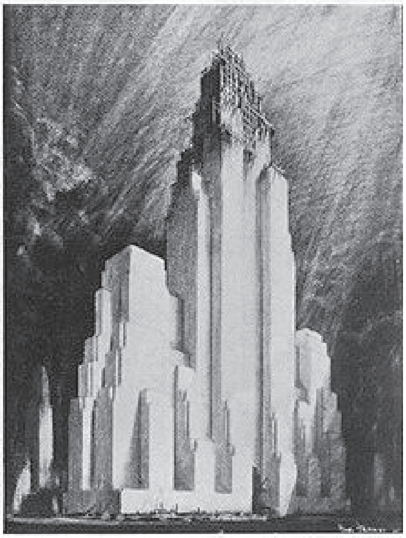
I. THE ENVELOPE AS DEFINED BY LAW.
Assumed a city block 200 x 800 feet. The number and position (but not the volume) of the Dormers, likewise the shape and position (but not the area) of the tower, are optional with the designer. Otherwise this perspective is simply a pictorial representation of the maximum mass allowed by the present laws.



II. THE ENVELOPE MODIFIED BY A PLAN.
Its appearance after having assumed a plan, and having passed this downward through the original envelope.



III. THE MODIFIED ENVELOPE FILLED WITH RECTILINEAR FORMS.
Its appearance after having substituted for the sloping planes, set-backs occurring at every second floor; tentative limitation being placed upon the tower.



IV. THE MASS MODIFIED BY THE STEEL CONSTRUCTION.
Its appearance after conforming the set-backs to the steel grillage and truncating the pinnacles to the highest floor level, which contains a practicable area. The mass is now ready for architectural articulation.

Drawings by Hugh Ferriss illustrating the impact of the 1916 New York City Zoning Code. Exhibited at the 37th Annual Exhibition of the Architectural League of New York, 1922

Voorhees Walker Smith & Smith,. *Zoning New York City: A Proposal for a Zoning Resoluition for the City of New York* (New York: The City of New York, 1958)

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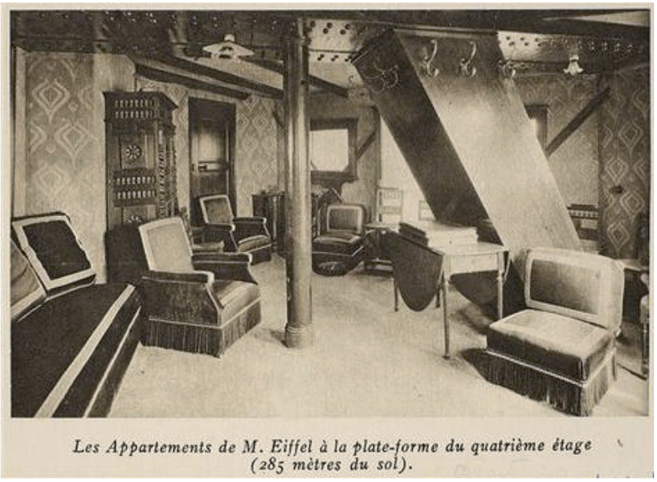
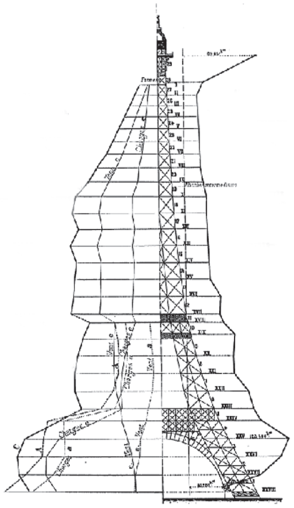
focused on the study of airflow were developed.[22] Such experiments enabled Eiffel to identify the urban boundary layer, which described the interaction between the rough urban surface and the incoming airflow, as well as the influence of building geometries on the surrounding pressure gradients. Such investigations inevitably echoed in the work of designers concerned with the contemporary problems of urban health and air quality in particular.





Soon after the recently adopted French law "L'hygiene des Habitations a Bon Marché (HBM)" of 1894,[23] Adolphe Augustin Rey designed the winning entry for the Rothschild housing competition located between the rue Charles Baudelaire and rue Teophile Roussel in Paris. In response to contemporary concerns about tuberculosis, the main goal of Rey's proposal was to introduce architectural strategies that would enhance urban ventilation, an ambition that is reflected in Rey's words: "L'air est devenu le premier élément dont vit l'habitat."[24] In his proposal, Rey refused to resort to the traditional closed courtyard massing strategy and instead proposed fragmented housing layouts designed to promote urban ventilation and access of fresh air to the communal areas as well as to all rooms in the residential units. Rey's entry for the Rothschild

22. G. Eiffel, *The Resistance of Air, and Aviation: Experiments Conducted at the Champ de Mars Laboratory* (London: Constable & Co., 1913).

23. The "Habitations à bon marché" from 1894 is the first French law on social housing, and is considered the first in the world.

24. C. Simonnet, *Breve histoire de l'air* (Versailles, France: Quae, 2014).

Gustave Eiffel's private apartment in the Eiffel Tower
Analysis of force of wind load on the Eiffel Tower

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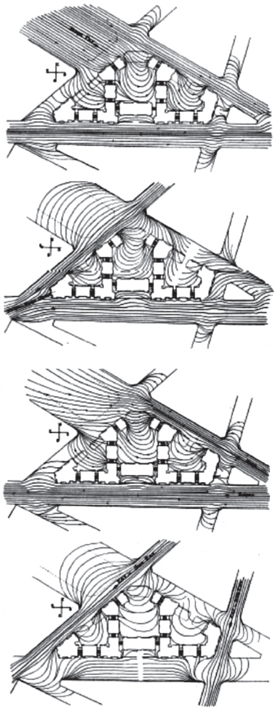

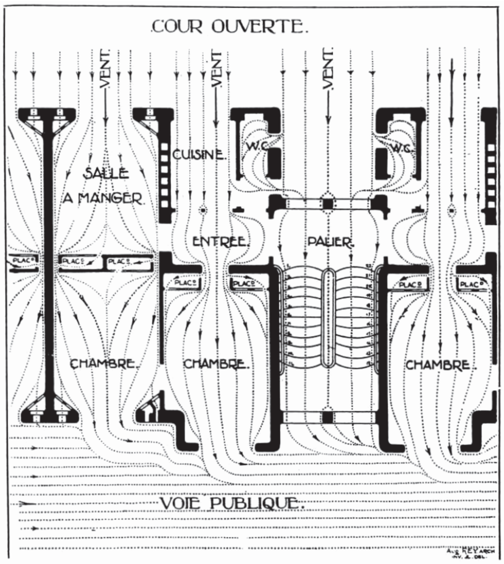

Foundation competition proposed an aerodynamic urban block design. In his diagrams, all overlaid with airflow streamlines and arrows, Rey describes the interaction of the proposed block layouts with variable angles of attack to argue that the proposal would enable a ventilated urban environment no matter what the predominant wind direction would be.

While the urban and household ventilation considerations of Augustin Rey's entry were welcomed by the jurors, the design that was ultimately constructed suffered many compromises and ended up resembling the traditional courtyard typology. Possibly, the lack of understanding of the phenomena of airflow and the impossibility of introducing an analytic strategy to quantify the influence of the building's geometry on neighboring air quality prohibited Rey from proposing a detailed argument. Once again, Rey's proposal resorted to a reduction of building units to enhance building permeability to airflow. Not surprisingly, this criterion produced friction with the speculative forces that urban areas were subject to, and compromised the suggested strategies to promote urban ventilation.

Augustin Rey's Rothschild competition entry. Airflow diagrams showing variable angles of attack
Augustin Rey's Rothschild competition entry. Interior space ventilation

From A. Rey, "Concours de la Fondation Rothschild: etudes preliminaries des plans—determination du parti adopte par la question de ventilation generale," *L'Architecture: journal hebdomadaire de la societe centrale des architectes francais* 18(36) (1905). Reprinted in E. Ramirez, *Airs of Modernity* (Princeton: Princeton University, 2013)

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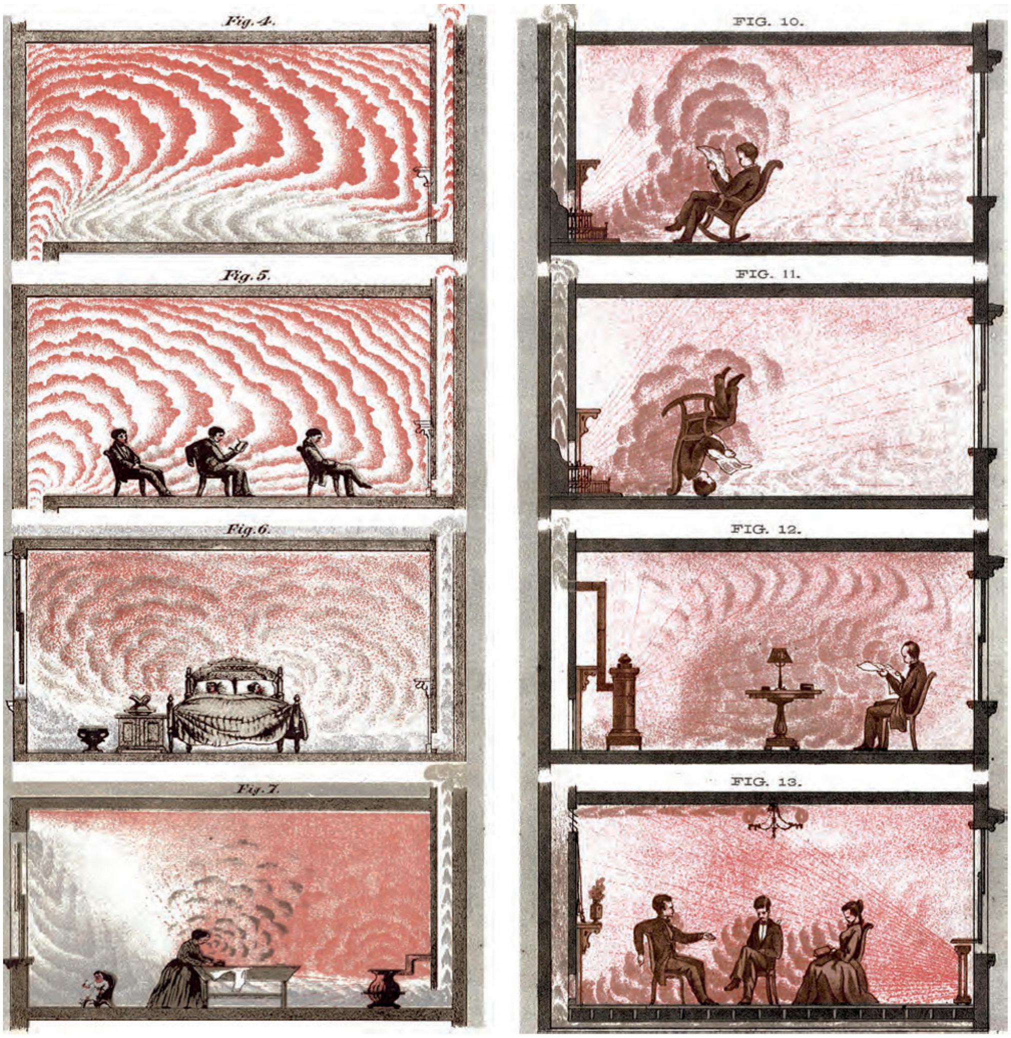
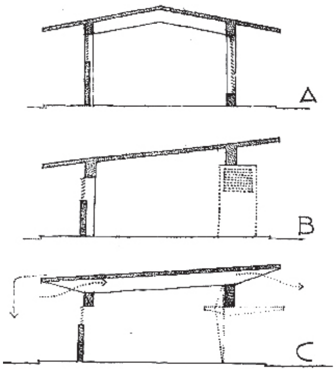


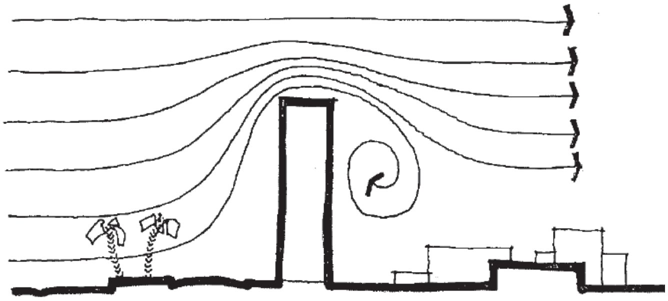
As opposed to airflow analysis, the geometrical representation of sun rays, as well as the physical understanding of the phenomena of sunlight from an architectural and urban design perspective, enabled sunlight considerations to be analytically studied and subsequently incorporated in architectural design processes as well as in the formulation of urban policies. The phenomena of airflow, on the other hand, cannot yet be resolved analytically. Therefore, airflow in architectural drawings has generally either been introduced as a qualitative atmospheric representation or through diagrammatic sketches.

Lewis Leeds, lithographs of a glass room showing the qualitative effects of stale air

001-440.indd 71 17-6-9 下午5:13

Thus, given the lack of analytic tools for airflow analysis in urban areas, the formulation of detailed architectural-scale measures to improve urban ventilation has been historically problematic. Instead, general strategies such as the reduction of F.A.R (Floor Area Ratio) or limitations to the block consolidation were suggested. While sun ray studies offered concrete guidelines that could be more easily implemented at an architectural level, urban ventilation proposals compromised building density, and so limited the chances to prevail over the social and economic pressures that were favoring dense cities. Therefore, although an intuitive understanding of the phenomenon has been present since ancient times, criteria to favor strategies such as street ventilation were generally ignored because the effect of such strategies couldn't be quantified.





13 unfortunate obstruction of breeze by high buildings in hot-wet climate

IN SEARCH OF EVIDENCE ON AIR QUALITY

The scientific search for evidence on the interaction between architecture and local air quality has been ongoing since the nineteenth century. Meteorologist Luke Howard's pioneering 1838 work *The Climate of London*, mentioned earlier, reflected upon urban pollution based on meteorological records. Albert Kratzer's seminal publication *Das Stadtklima* from 1937 also offered a comprehensive description of the relationship between urban characteristics and urban climatology.[25] His standpoint was shared by succeeding peers such as Helmut Landsberg, who emphasized the benefits of introducing microclimatic considerations in architectural design processes: "One of the surest ways of improving the performance of individual buildings and

25. A. Kratzer, *Das Stadtklima* (Braunschweig, Germany: Vieweg & Sohn, 1937).

Sketches from Richard Neutra on school room ventilation. From R. Neutra, *Architecture of Social Concern in Regions of Mild Climate* (Sao Paulo: Gerth Todtmann, 1948)
Maxwell Fry and Jane Drew described the disadvantageous conditions (lack of ventilation) produced behind large buildings

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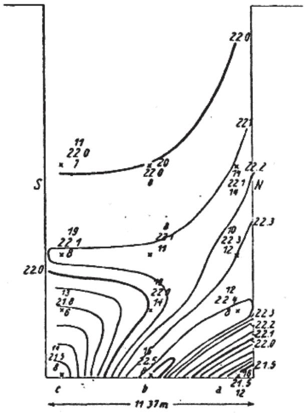
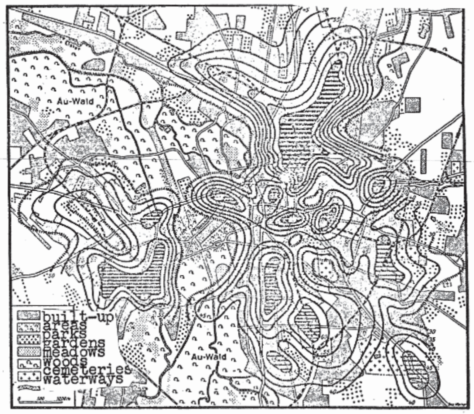


Temperature distribution in a courtyard in Berlin-Charlottenburg, July 27, 1931, 6 p.m.

The colder air at the lower left and right is outgoing cellar air, i.e., from the entrance to the courtyard. One can see very clearly the effect of the house wall which is in the sun (N) [3, 96].



whole cities, would be to incorporate microclimatic knowledge into their design […] buildings should blend harmoniously with the visible landscape but they should also recognize the invisible but important configuration of their microclimate."[26] That is, the role architecture plays in its surrounding microclimate must be acknowledged.

Today, investigations on the influence of urban structures on local pollution levels are confirming the strong dependence of local air quality on the neighboring architectural parameters.[27] However, given the uncertainties associated with numerical simulations and wind tunnel experiments, as well as the ongoing lack of a sufficiently extensive body of research on the topic, the results are yet to be validated against field experimental data. There is thus a growing need for urban meteorological data to support air pollution research and management. Nevertheless, urban weather stations are generally costly to implement and rarely provide sufficient information on neighborhood- and street-scale microclimate and air quality.[28] Therefore, while the number

26. H. E. Landsberg, "Microclimatology," *Architectural Forum* 86(3) (1947): 114–9.

27. Britter and Hanna, "Flow and Dispersion in Urban Areas."

28. Oke, "Siting and Exposure of Meteorological Instruments at Urban Sites."

Temperature distribution in a courtyard in Berlin, Charlottenburg, July 27, 6 p.m.
Dust distribution in Leipzig

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of weather stations for measuring urban air quality is growing, the space resolution obtained from these networks is generally insufficient to analyze the effect of architecture on urban microclimates and air quality. This means that when operating at the building and neighborhood scale, or when data is required for specific sites, weather stations generally provide the necessary temporal resolution to capture the steady and unsteady flow characteristics; however, the spatial resolution of the data obtained from weather stations generally proves insufficient.

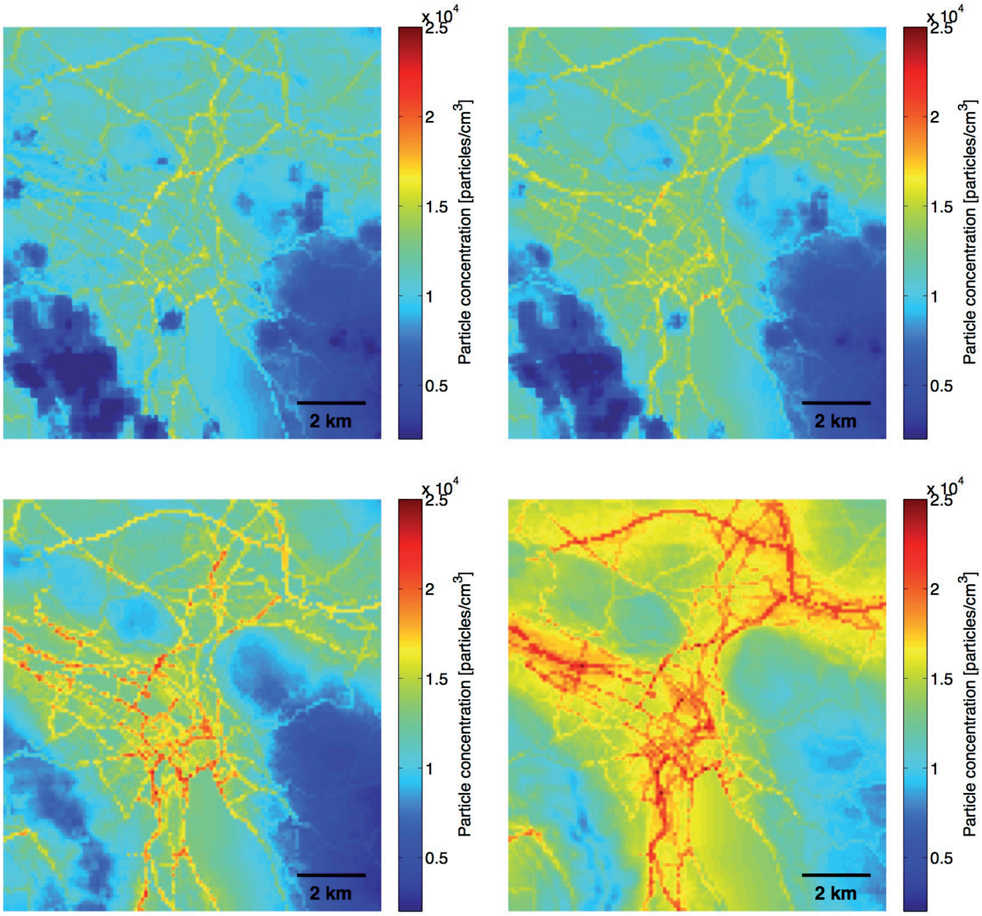
In recent years, with advancements in sensor technologies, it has become possible to acquire environmental data at fine spatial and temporal resolution. In upcoming years, it is expected that vast quantities of data will be gathered by autonomous sensors that will cover large spatial extents. That is, with the spread of the Internet of Things (IoT) and the availability of relatively cheap meteorological sensors, it will become increasingly possible to observe the spatial pattern of atmospheric variables with much more detail than in the past.

In this context, aiming for a higher acquisition of spatial air quality data, the use of sensor networks and remote sensing technologies is becoming more widespread. Furthermore, the increasing accessibility of easy-to-use and low-cost sensors is also motivating citizens to engage with urban

Map of the average smoke concentration over the City of London

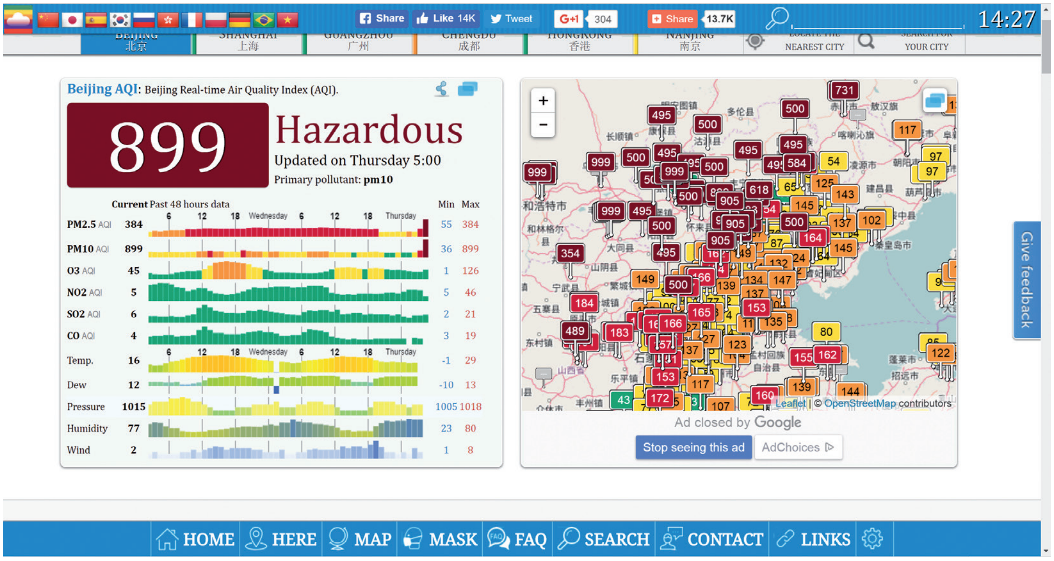
001-440.indd 74 17-6-9 下午5:13

sensing projects through citizen science initiatives, as well as promoting their incorporation in everyday objects. And thus our capacity to understand the phenomena of airflow to an increasingly higher spatio-temporal resolution is providing us with the necessary evidence to address the problem of air quality locally and quantitatively. Such data is starting to enable us to prove the effect of architecture and urban features on local microclimates and air quality, and thus to argue for urban- and architecture-scale strategies that can contribute to the remediation of local air quality.



Ultrafine particle concentrations in Zurich, based on the OpenSense measurements of one year (from left to right: spring, summer, fall, winter)

001-440.indd 75 17-6-9 下午5:13



LOCAL RESISTANCE IN THE FACE OF ENVIRONMENTAL DEREGULATION

In the current political situation, where global environmental agendas are often neglected by questioning the validity of international goals, and governmentally funded environmental research is often not made available to the public, it seems critical to empower local urban environmental remediation strategies.

In this context, initiatives such as ICLEI – Local Governments for Sustainability (the global cities network) focus on exploring the possibilities of establishing local governance structures to enable sustainable water, air quality, or urban soil management.

While still rare, air quality assessment regulations that pertain to urban planning and architectural design considerations are also starting to be implemented in some cities, such as Hong Kong.[29] Instead of incorporating top-down and generalized building restrictions, these regulations capitalize on local environmental studies to design architecture and its immediate microclimate

29. E. Ng, "Policies and Technical Guidelines for Urban Planning of High-density Cities: Air Ventilation Assessment (AVA) of Hong Kong," *Building and Environment* 44(7) (2009):1478–88; and E. Ng, "Towards Planning and Practical Understanding of the Need for Meteorological and Climatic Information in the Design of High-density Cities: A Case-based Study of Hong Kong," *International Journal of Climatology* 32(4) (2012): 582–98.

Aqicn.org sensed air quality data for the city of Beijing

001-440.indd 76 17-6-9 下午5:13

cohesively. Further strategies to improve the thermal environment and pollutant concentration in cities via cool roofs and green roofs are also being researched and deployed.[30]

Strategies at the building scale are also starting to be revisited. Today buildings are subject to local-scale environmental assessment proposals. That is, in order to obtain building permit or planning approval, environmental assessment processes that involve the fulfilment of a building certification system such as LEED also must be undertaken. Once again, given the complexity of airflow phenomena, such international certification processes often fail to incorporate airflow considerations in their rating processes. And thus, the need to complement such global assessment structures with locally informed microclimate strategies is starting to be discussed.

Citizen science initiatives are also beginning to reframe the role of citizens in environmental policy making. Especially in city- and neighborhood-scale initiatives, citizen science and participatory democracy mechanisms are enabling the empowerment of communities by involving them in research as well as in local political debate.[31]

While the results obtained from locally driven air quality policies are still to be seen, in times when high-level governance bodies are failing to undertake the steps required to heal the insalubrious air quality conditions present in many cities around the world, local action becomes critical. And thus, local power relationships must be established in the air common.

30. T. Susca, S. R. Gaffin, and G. R. Dell'Osso, "Positive Effects of Vegetation: Urban Heat Island and Green Roofs," *Environmental Pollution* 159(8–9) (2011): 2119–26.

31. K. Rowland, "Citizen Science Goes 'Extreme,'" *Nature* (2012).

001-440.indd 77 17-6-9 下午5:13