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Transparency in Urban Environment

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Abstract

A generation of tall buildings has been dominated by International Style with full height glazing that is often vision glass. Large glass was intended to bring the outside in, to allow a connection to the natural environment, and to promote daylighting. Yet the glass box model of architecture is now under criticism due to expense to build, thermal and visual comfort issues for occupants, large carbon footprints, danger for birds, and aesthetic concerns with lack of transparency. This paper will take a fresh look at glass, transparency, energy consumption, and human health before offering alternative paths forward.

Keywords: Comfort, Energy, Façade, Healthy, Sustainable

1. Reconsidering Full Height Glass

Glass buildings with current technology are undergoing reconsiderations. From the "Death Ray" in Las Vegas that heated up guests, the concaved "Walkie Talkie" that melted Jaguar car parts, the stringent glazing reflectance codes from Shanghai to Dallas, and energy consuming "nightmares," to the blinding glare on Sheikh Zayed Road, there are room for improvements. Selected cities, for example Toronto, regulate glass reflectance to avoid killing of birds near ground; others, like Chicago, have "lights out" programs for migratory birds. While full height glass is perceived as a connection between inside with outside, this connection often stops at visuals in tall buildings. When it comes to energy consumption, almost without exceptions, full height glass buildings perform worse than more opaque ones. The best performers in New York City, accordingly to the city's benchmarking, are the pre-1930 buildings. This suggests that we might have moved the building energy needle in the wrong direction in the last 100 years. Recent research suggests a healthier environment is not only an environment that connects visually to the outside, but also one that connects all senses. Are current all-glass tall buildings, often hermetically sealed, the best way forward? This essay will evaluate glass in light of performance and health to determine ways forward.

2. What is Glass For?

Glass can provide daylighting, solar energy (performance), and visuals to outside (health). Windows can provide fresh air, free cooling, sound transfer, and better resiliency. Do the basic functions of glazing (daylighting, solar energy, and visual connection), require full-height glazing?

3. Performance

Energy: For most buildings, full height glass does not save energy. It is consistent in all climate zones. See Fig. 1 for a study of a typical office building at 50 M (164.0') × 50 M (164.0') with 8 M (26.2') perimeter zone (Fig. 1). As hermetically sealed boxes, glass curtain walls have higher infiltration rates than opaque wall construction (7.3 M^3/Hr; 0.4 CFM/sf for infiltration in glass vs. 2.2 M^3/Hr; 0.12 CFM/sf for opaque wall per DOE-K Gowri, 2009) and worse thermal resistance. Conventional glass has a significantly lower (more than 5 times) thermal performance compared to insulated walls (prescriptive requirement of fenestration maximum: U-0.35 Btu/Hr.ft^2.°F, U-1.99 W/M^2.°C, nonmetal framing; wall maximum: U-0.064 Btu/Hr.ft^2.°F; U-0.365 W/M^2.°C, Steel Building, Climate Zone 4, per ASHRAE 90.1, 2013). As a result, the ASHRAE (American Society of Heating, Refrigeration and Air Conditioning Engineers) prescriptive standard limits glazing to 40% (ASHRAE 90.1, 2013). See Fig. 2 on performance when percentage of glazing is different than the 40% baseline within the same office building (Fig. 2). In its 2013 issue, the prescriptive requirements also limited east and west façades to have less than 25% window wall ratio (WWR, low angles create glare). IECC 2012 specifies the window wall ratio at 30%, though the way it calculates walls is slightly different. In cooling-dominated environments, heat gain through windows from solar radiation and conductance are much more than opaque walls. In heating climates, since direct solar heat gain is dynamic and moves from east to west throughout the day, while conductance heat lost is continuous throughout 24 hours, the net effect is usually an increase in glazing percentage

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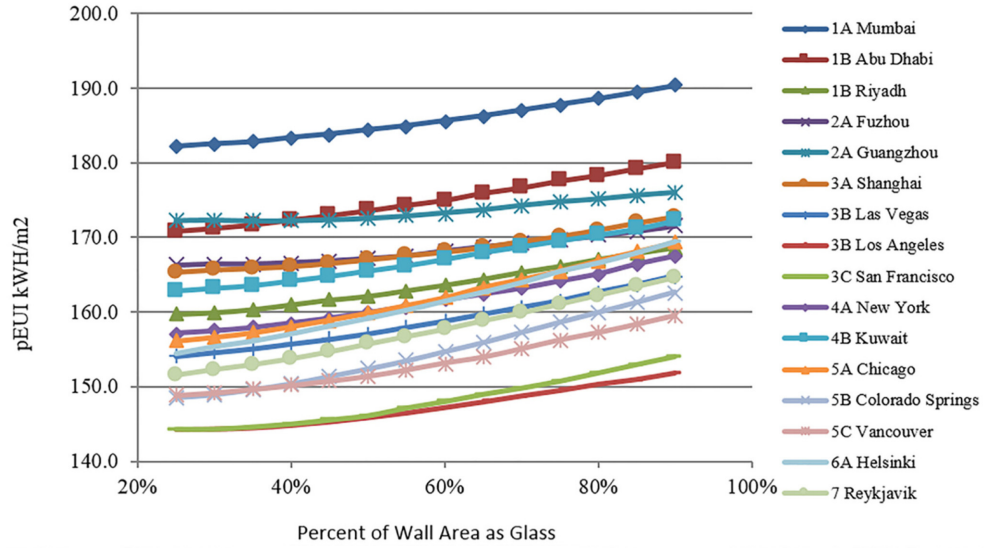


Figure 1. Predicted energy use intensity of an office building in all climate zones (Source: SOM).

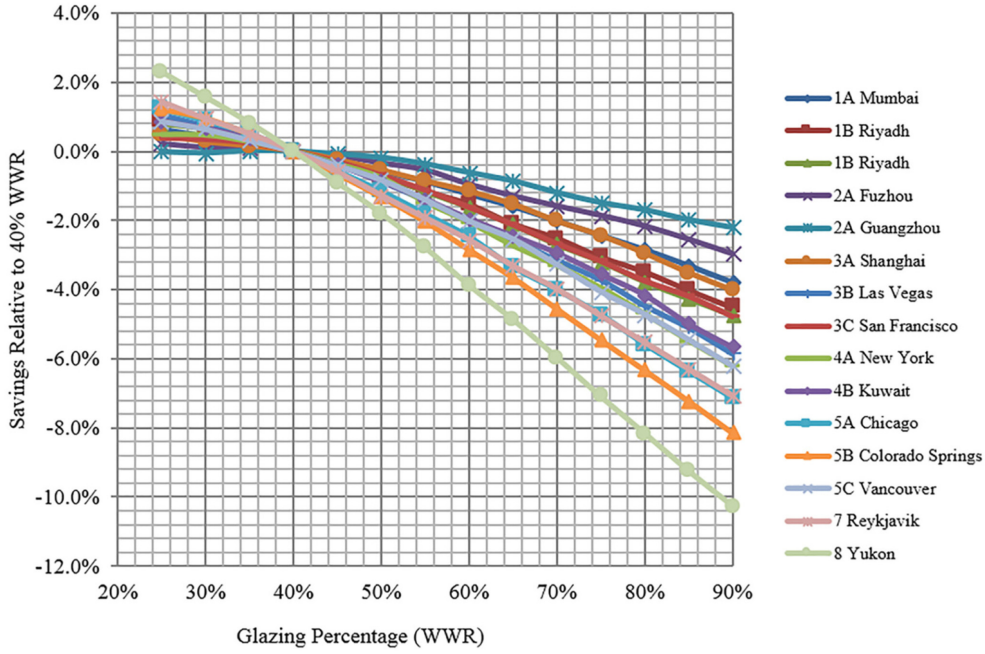


Figure 2. Energy use difference in percentage of an office building in all climate zones (Source: SOM).

worsens energy performance.

3.1. Daylighting

From our study regarding a conventional office building, full height glass buildings provide more daylight to a space. The Advanced Building Daylighting Pattern Guide suggests that a space with a 9' ceiling, a 100% interior wall glazed façade can get 95% of the space day lit with 300 Lux at 7.92 m (26') lease span. However, this daylighting comes at the expense of higher total energy consumption (Fig. 3). In Fig. 4, using the same office building in Shanghai as an example, while increasing window wall ratio has benefits in daylighting and reduction in the "interior lights" category, the "heating" and "cooling" energy change is much more significant, and as result, overall energy consumption is increased. The change in slope with window to wall ratio in Fig. 4 illustrates the same point (Fig. 4).

Besides daylighting, another benefit of full height glass can be improving the day time circadian rhythm. People in urban areas often spend much of the time indoor and

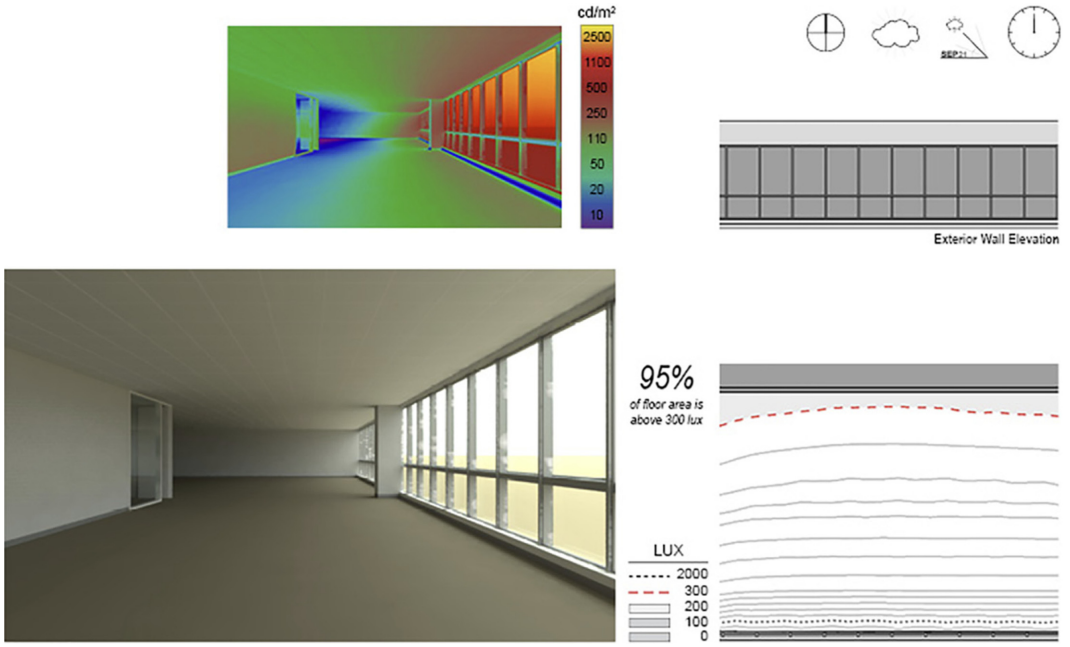


Figure 3. Daylighting with 100% interior windows at 2750 mm (9') ceiling (Source: Advanced Buildings Institute).

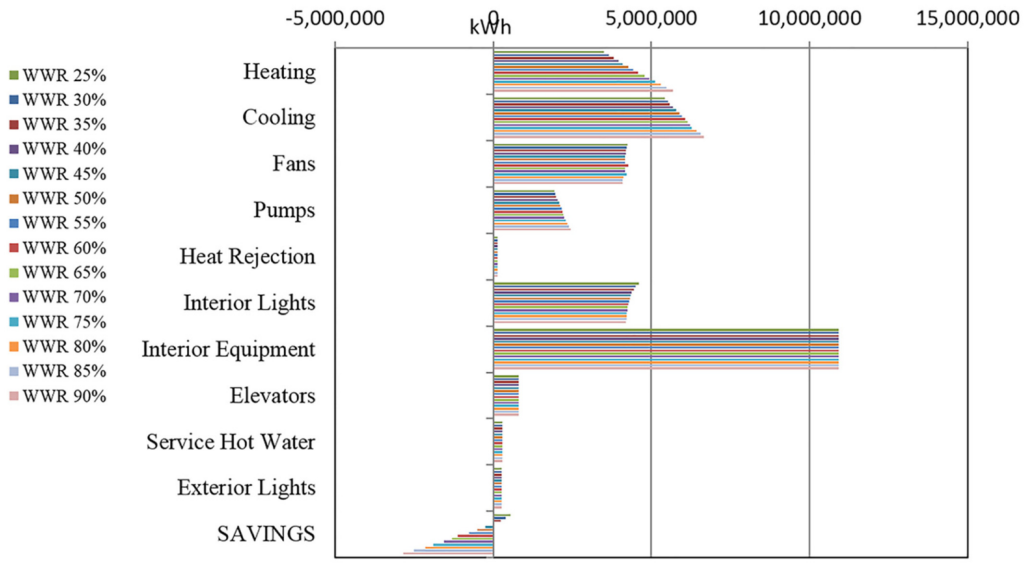


Figure 4. Window Wall Ratio impact on energy consumption for an office building in Shanghai (Source: SOM).

suffer from "light deficiency" during the day. Increased window wall ratios can bring more daylight indoors to improve the situation, especially for people that are unable to go outside, e.g., sick patients in intensive care. At night, the situation is reversed. Without closing the window curtains, bright light from surrounding buildings through glass can potentially disturb the circadian rhythm with too much light available while the body is trying to rest. This is especially true with blue lights from neon signs or from exterior lighting of other buildings. A rational solution can be walking outside during noon time, especially sunny days, roughly getting 80% of the anchoring (First 30~60 minutes) effect required in the daytime circadian rhythm, followed by dimmed lights in the evening.

Thermal Comfort: Achieving thermal comfort with full height conventional glazing is more difficult than a building with a lower window to wall ratio. Thermal comfort, in terms of operative temperature, is an average of air temperature and mean radian temperature. Since glass has lower thermal resistance compared to a solid wall, a full

height glazed space will be hotter in the summer and colder in the winter in mean radian temperature. It is more difficult in extreme climates (hot or cold) to achieve comfort close to the exterior wall area. As a result, some occupants in the exterior zones of the office buildings may have to dial up the air heat in the winter or dial down the cool air in the summer to "offset" the mean radiant temperature. This can be part of the reason why we are seeing overheating and overcooling of the air temperature in many offices which have a glass exterior.

3.2. Glare

Full height glazing will create more glare. Part of the issue is the nature of the sun's path from east to west creates many hours of low angled sunshine that is hard to shade. This can partially explain Urban Green's "Seduced by the View" report that 59% window area was covered by blinds and shade at all time. Over 75% of buildings had more than half their windows covered by blinds. Dynamic glazing that can change opacity can help, though people with very sensitive eyes still can have glare issues.

3.3. Resiliency

Sealed, full height glazing reduces the resiliency of buildings, particularly tall buildings. In the event of a power outage or failure of a mechanical system, building occupants need a certain level of indoor comfort maintained. In cooling-dominated buildings – most offices – sealed full height glazing increases solar gains and indoor temperatures. Lower window-to-wall ratios help reduce solar gains to maintain more comfortable indoor conditions. Operable windows can further improve the resilience of a building by providing ventilation and cooling even when mechanical systems or power may have failed. The United States Green Building Council (USGBC) offers a LEED pilot credit for Resilient Design, and particularly for Thermal Resilience, which describes how well a building can passively maintain livable indoor conditions in the event of an emergency. Tall buildings can exacerbate this resiliency concern for all glass buildings because they are less often mutually shaded by surrounding buildings, which exposes them to even more solar radiation.

In summary regarding performance, while full height glazing can bring about better daylighting and daytime lighting for circadian cycle, it is not as beneficial to energy, thermal, comfort, glare, resilience, and potential night time circadian rhythm performance.

4. Health

The urban environment, especially in hermetically sealed tall buildings, has decoupled humans with nature. Humans and animals have important roles in the ecology of life, both in contributing and receiving the benefits from the ecology system. Isolation of a species can have unintended consequences. Urban populations spend 90% of

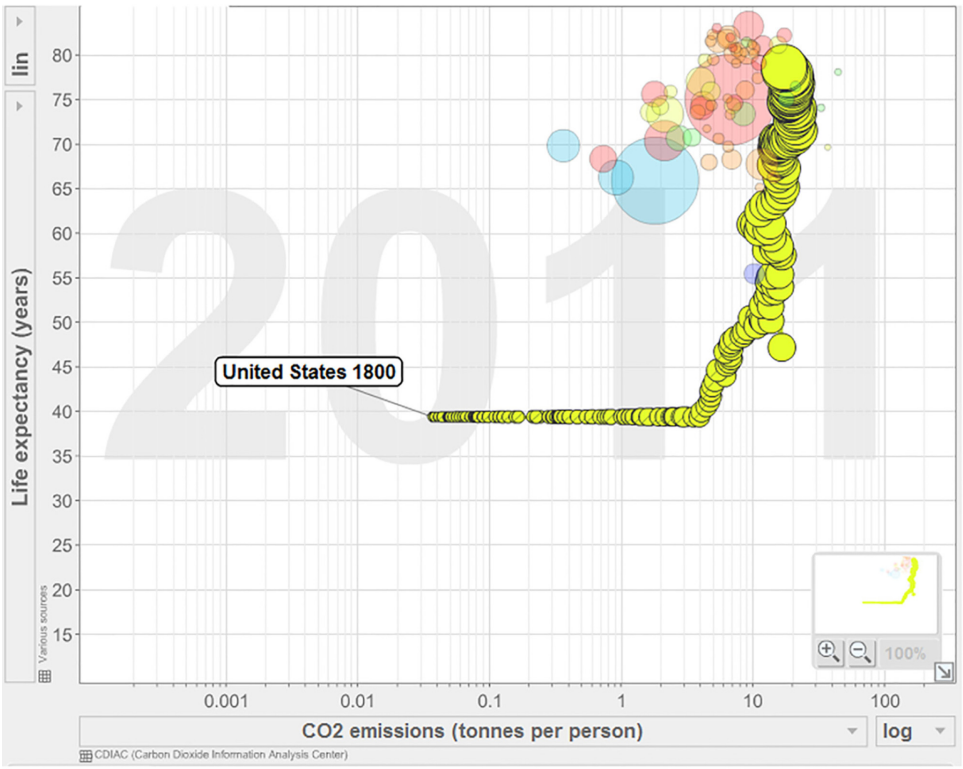


Figure 5. Life expectancy and carbon emission growth in the US, from 1800 (Source: Gapminder).

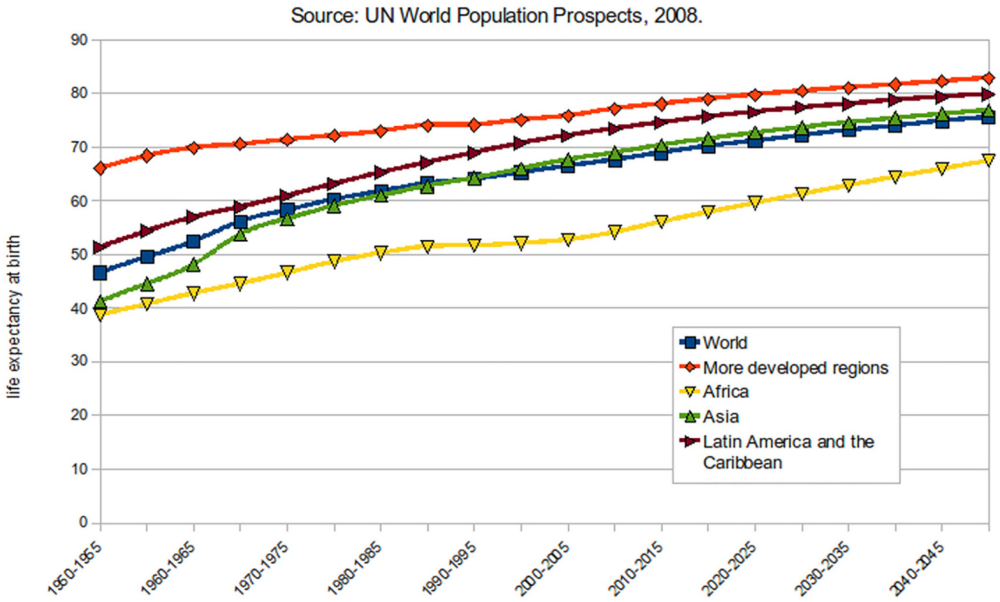


Figure 6. Life expectancy and birth by region, 1950~2050 (Source: United Nations).

their time indoor in relatively sterile environment. Life expectancy in the US during much of the 1800s was about 40 years, though infant and childhood mortaility were important factors to consider. Starting around 1890, life expectancy in US started to climb (yellow bubbles in Fig. 5 below), coinciding with a switch to a more fossil fuel based economoy and also with acceleration of urbanization (Fig. 5). In 2015, US estimated life expectancy was 79.68.

We almost doubled our life expectany in the last century. The US is not alone, as many countries have also increased their life expectancy with urbanization. Life exptancy is expected to climb further in the near future in most countries (see Fig. 6). As we live longer, several trends suggest the human race is becoming more fragile, and decoupling with nature is at least part of the reason (Fig. 6).

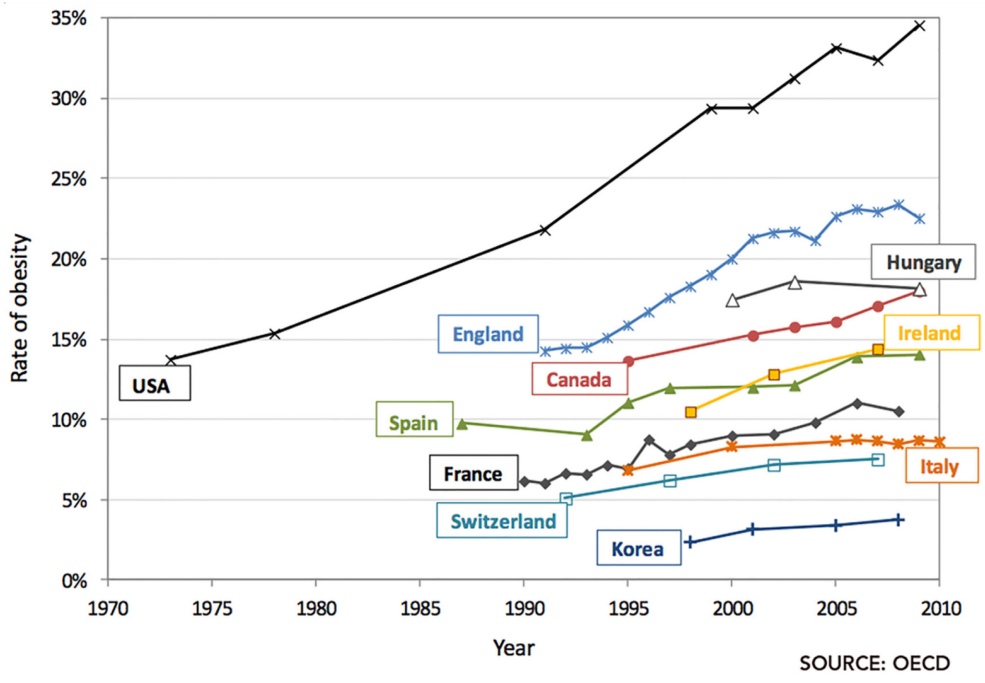


Figure 7. Obesity rate in developed countries from OCED data (Source: OCED).

Humans become more obese: Obesity in the US accelerated around the early-mid 20th century, around the time when air conditioning was introduced and popularized. Today, obesity has become an epidemic in selected developed countries. Obesity is projected to become an even larger problem in the future by the Organization for Economic, Cooperation and Development (Fig. 7). While diet, exercise, and genetics are often blamed as causes, living in conditioned, indoor environments can be a cause of obesity. Recent studies also indicate obesity can be caused by our hermetically sealed buildings that isolate the microbial biome from the outdoors and interrupt the natural circadian cycle.

4.1. Chronic Diseases

Asthma has been identified as a developed world disease. Allergies are on the rise with increasing urbanization. While the causes of asthma and allergies can be varied, they are also linked to the disturbances of the microbial biome through hermetically sealed buildings. Interruption of the circadian cycle, potentially from bright and blue light from surrounding the urban environment through all glass buildings, was related to causing different types of cancer. Further scientific research is still required to confirm these findings.

4.2. Mental Health Disorder

According to Richard Louv, US author and journalist, our generation suffers from "Nature Deficit." Without proper interaction with nature, our children suffer from a wide range of disorders, which are not documented in the medical manual as a disorder, e.g., ICD-10, DSM-5. A study from Stanford University also indicated that the urban environment is associated with more mental disease, and a 90 minute walk in nature can reduce activities in the area of the brain where it is known to cause depression, which is vital in the urban environment. The same study concluded city dwellers have a 20% higher risk of anxiety disorder and 40% higher risk of mood disorder.

5. Moving Forward

5.1. Energy

Due to higher infiltration and lower thermal resistance, all glass buildings consume more energy. To mitigate the impact, either glass percentage has to be lowered, full height glazing impact must be minimized by integrated building elements, or advance façade designs must be developed. Current SOM projects have a wide range of window wall ratio, including buildings with 34% (Fig. 8). While the building does not exceed 40% window wall ratio overall, full height glass was strategically place in



Figure 8. China State Construction Engineering Corporation Headquarters, Beijing: less than 40% window wall ratio (Source: SOM).



Figure 9. Guiyang Tower, Guiyang, China, integrated façade shading to minimize WWR and glazing impacts (Source: SOM).

area of highest potential for view and transparency. There are websites that have exemplary buildings that are below 40% glazing, e.g., "40 under 40" – forty exemplary buildings under 40% window wall ratio. Other buildings have integrated shading devices that use non-reflective material to minimize glare and shade the window (Fig. 9). The use of ceramic elements to reduce WWR and help shade the glazing is another option.

Regarding advance façades, a fan assisted double wall can be integrated with an atrium to provide inside-out ventilation for the Bank of Beijing. Rather than bring outside air in for natural ventilation, this building will use the atrium to bring the outside air into the base of the building, then use stack effect of the ventilated double wall windows, with fan assist, to pull the atrium air to work spaces (Fig. 10).

Much research needs to be done to make windows as energy efficient as opaque walls. Future developments need glazing that can dynamically react to solar, which can be done with electrochromatic glazing, and has similar thermal performance (R value and infiltration) compared to an opaque wall. It should be noted that many window technologies, including R-20 window, are available already, although they need to be mass produced to lower cost production cost.



Figure 10. Bank of Beijing ventilated double wall (Source: SOM).

5.2. Health

Rather than just visual connection in our hermetically sealed all glass tall buildings, a holistic spectrum of senses, visual, olfactory, and tactile can create a healthier and more positive experience. Recent studies indicated women (also applicable to men) that live among the greenest areas have 41% lower death rate for kidney disease, 34% lower death rate for respiratory disease, and 13% lower death rate for cancer. Another study on trees lost due to the Emerald Ash Borer concluded human mortality related to cardiovascular and lower-respiratory-tract illness increased as a result. Though the study cautioned that they explored correlation and not causation, these findings add to a growing knowledge that nature provides major public health benefits.

5.3. Visual

Full height glass views can have positive health benefits if the view is perceived as an open view of nature. The aesthetic of a full height glazing view to the outside can be fantastic, but the perceived openness and what occupants see through the window also matter. Recent research suggests the positive visual effect of having windows may be more about the perceived openness, which tall buildings can offer. Also, seeing green landscape has the most benefit regarding visual impacts. Seeing water is also better than seeing the urban built environment. Visuals of nature can improve cognitive abilities and help us to relax. Research in Toronto by Professor Marc Berman from The University of Chicago suggested having 10 trees on a city block can make a person feels $10,000 richer and 7 years younger. Also, disconnected nature, similar to potted plants inside a building, are less likely to thrive than plants integrated with nature outdoors. Taller buildings in urban environments can provide greater access to open views of nature given the increased view range from higher elevations. While a low-rise building may not provide views of the nearby ocean or park, a high-rise building is more likely to provide such a view.

Olfactory and beyond: Connection to air from nature does not require full height glass, and can bring about both physical and mental benefits through microbials, Phytoncides, and negative ions. A University of Oregon study indicated indoor air with mechanical ventilation has less diversity of microbials and more pathogens, while outdoor air tends to have a larger diversity of micro bacteria and less pathogens. A building with operable windows has more diversity of micro bacteria than a sealed building. This suggests a building should be opened to outside where possible given the outdoor ambient reflects a higher diversity of microbials. The immune system of humans can be enhanced by breathing in Phytoncides from the forest according to the New York State Department of Environmental Conservation. Phytoncides are an antifungal and antibacterial chemical that is produced by trees. When breathed into human bodies, they increase the white blood cell count to boost our immune system. In urban areas, the Phytoncides level is lowered than in a forest with trees. Additionally, the effect of having a hermetically sealed building with only visuals to the outside can be compared to humans feeling lethargic during cloudy days. This is because of the impact of indoor positive ions (carbon dioxide with a positive charge) can make us feel lethargic and tired. On the contrary, negative ions (oxygen molecule with a negative charge) are a mood enhancer. The ocean shore, mountains, trees, and waterfalls are all great sources of negative ions. Compared to country air, an average of 2000~4000 of negative ions per cubic centimeter, indoor "acceptable" environments only have 200~400 negative ions per cubic centimeter. The net effect is humans can feel more tired indoors in hermetically sealed buildings with minimal ventilation.

5.4. Tactile

Touching nature can be beneficial. Researchers from New York University, after studying the microbial biome in different indoor surfaces in the City of Manaus in Brazil and the Village of Checherta in Peru, concluded, "The remarkable changes in home microbial content across differing levels of urbanization raise the possibility that the reduced microbial exposure to environmental bacteria seen in modern homes contributes to immune and metabolic disorders, from asthma to obesity, which have become the new disease paradigm in the industrialized world" (J. F. Ruiz-Calderon, 2016). Researchers also found that the touching of other microbes outdoors can have positive impacts. For example, Mycobacterium Vaccae, a bacteria often found in soil that people will touch through gardening, may stimulate serotonin production, which mirrors the effect on neurons similar to drugs like Prozac.

More research suggests a healthier environment is one that humans can holistically integrate with nature through all our senses rather than hermetically sealed buildings that decouple humans from the natural environment. However, this points to a larger issue of how much nature we are getting in our cities. Given the environment in many cities, even when the buildings are opened to the outside, we may be getting more of the byproducts from urban environment in terms of noise, air quality, visual, and tactile than nature. Some suggest bringing nature into our buildings, but this has to be a very thoughtful process, since not all plants are necessarily healthy indoor. Selected plants, e.g., Caladium, are poisonous to humans, others plants like the Peace Lily, and associated micro bacteria in the soil, can generate potential harmful volatile organic compounds. The other solution is to design outdoor spaces that have more nature and can be used through extended periods of time through half climate conditioning (shading, spot heating, spot cooling etc.), so people can spend more time outdoors. SOM has developed an experimental housing scheme that stacks suburban homes to form a tall building with potential gardens for each home (Fig. 11). The idea

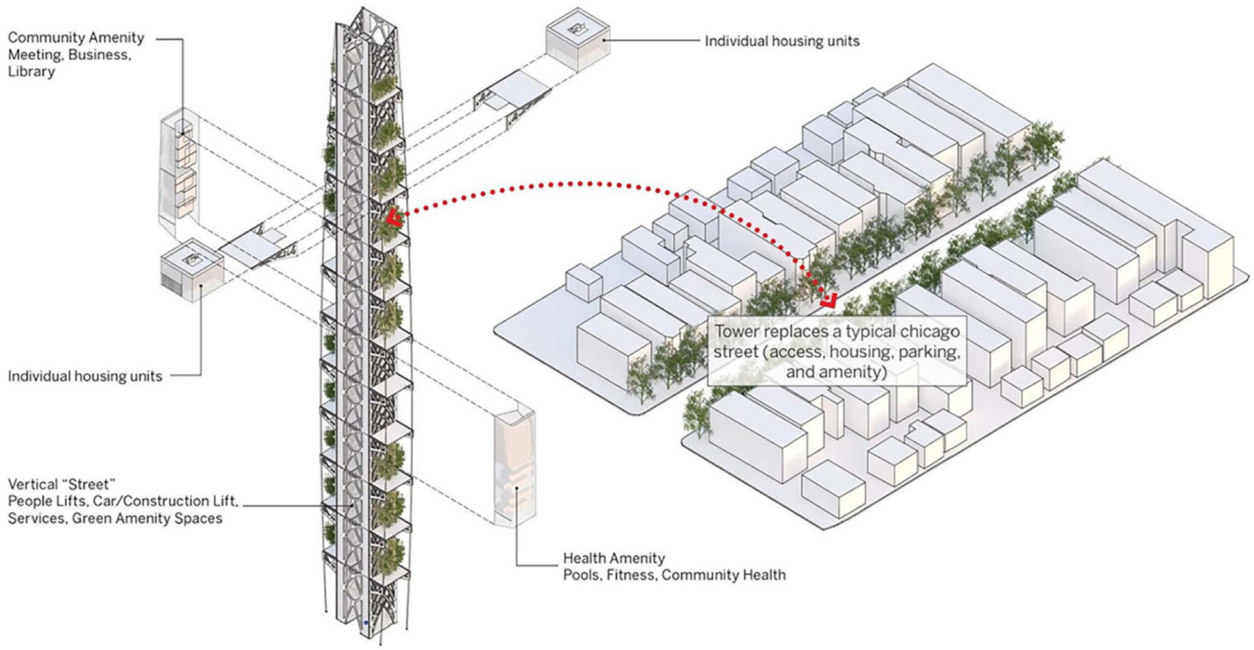


Figure 11. Experimental Home of the Future (Source: SOM).

allows each dwelling to have its own access to nature. There are still many issues we do not understand when decoupling people with nature in our tall buildings. More research will need to be done.

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