TOWARDS A PASSIVE HOUSE CURTAINWALL

ALESSANDRO RONFINI, LEED AP [BD+C], CPHD

Passive House is a voluntary, performance-based building standard developed in Germany in the early '90s that encompasses a series of design principles used to obtain a quantifiable and rigid level of energy efficiency together with a specific and measurable comfort level. Originally a construction concept for small residential buildings, it can be applied to almost any kind of construction, nearly anywhere in the world. Passive House buildings can achieve up to 90% reduction of heating and cooling energy and 75% reduction of primary energy usage compared to the average existing building energy consumption. Furthermore, the comfort level for inhabitants is unrivaled: superb indoor air quality, consistent and comfortable mean radiant temperatures, improved acoustic insulation and extreme resiliency are qualities that can be found in all Passive House certified buildings.

DESIGN PRINCIPLES

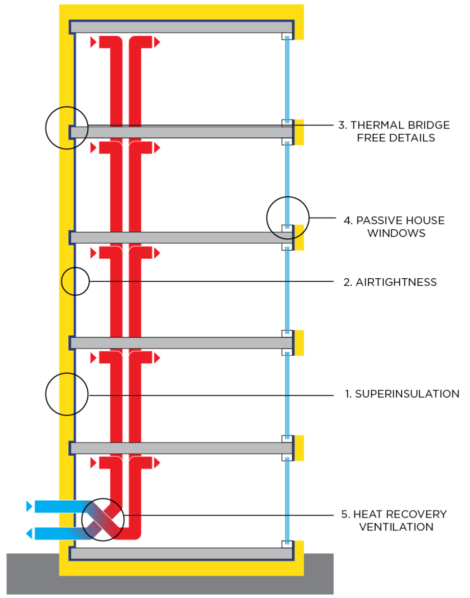


FIGURE 1
Design Principles.

1. SUPERINSULATION
The building has to have continuous superinsulation (usually R-35 and more per opaque walls) throughout the entire envelope.

2. AIRTIGHTNESS
A Passive House envelope is extremely airtight compared to typical construction. The maximum number of Air Changes per Hour (ACH) is 0.6 ACH at 50 Pascals pressure, more stringent than the 3.0 ACH50 required by the latest energy codes in cities like New York and Los Angeles.

3. THERMAL BRIDGE FREE DETAILS
Most of the details in a passive house building have to contribute to the energy performance, therefore all the heat losses per conduction have to be avoided as much as possible.

4. PASSIVE HOUSE WINDOWS
Passive House windows have to be engineered with extremely low U values, usually in the range of 0.15 BTU/hr•°F•ft^2 (for the entire window, frame included).

5. HEAT RECOVERY VENTILATION
Mechanical ventilation with a heat recovery rate of at least 75% is necessary to maintain the interior air quality while limiting the heat losses to the bare minimum.

To verify that these basic design principles and other best practices are implemented correctly, the Passive House Institute defined the following performance requirements as mandatory:

- *Space Heating Demand* should be no more than 4.75 kBTU/ft^2•yr or, if designed based on the peak load, no more than 3.17 BTU/hr•ft^2.
- *Cooling Energy Demand* should be no more than 4.75 kBTU/ft^2 with an adjustment for dehumidification.
- The total *Primary Energy Demand* (considering all energy consumptions) should be less than 38 BTU/ ft^2•yr
- Maximum of 0.6 ACH50, tested at building completion.

Meeting these tight requirements demands a strict and efficient teamwork that evaluates a complex model including every aspect of the design: function, orientation, insulation, illumination, shading, mechanical systems, appliances and more. However, what also appears clear from the five design principles listed above is that one of the most important and essential parts of a Passive House building is a high performing envelope.

THE IMPORTANCE OF THE ENVELOPE

While most of the examples of Passive House buildings completed around the world are small residential projects, usually single-family houses, this standard is suitable and theoretically easier to achieve for high-rise buildings.

Multi-story buildings can have a compactness ratio, calculated as the relationship between the envelope surface area and the internal volume, as low as 0.2 ft^2/ft^3, while single-family houses rarely fall below the Passive House recommended ratio of 0.7 ft^2/ft^3 and can have a very unfavorable factor as high as 2.0 ft^2/ft^3. A low compactness ratio is very helpful, especially in terms of air tightness: the limited surface area makes the 0.6 ACH50 requirement easier to achieve.

The higher the compactness ratio, the thicker the insulation layer required to protect that building: a multi-story building's skin can save inches on insulation compared to a small building achieving the same thermal performance per ft^3 of occupied space.

On the other hand, a large building envelope has demanding challenges compared to a small one: both its large scale and the technology used for construction. In fact, curtainwalls have in their most valuable quality—modularity—the biggest potential for failure and leakage. Unlike stick built systems, where a continuous building envelope is constructed layer after layer from the inside out, reducing the chances of leakage, in curtainwalls there is little material continuity and each panel uses clips and gaskets to create a weatherproof connection to the adjacent module.

For these reasons, creating a Passive House curtainwall is a challenge: not only does engineering demand extra studies and resources to evaluate the expected performances of each detail, but the installation work in the field requires consistent and meticulous quality control procedures to ensure that the potential for thermal bridges and air leakage is kept to a minimum.

Engineering work alone though can hardly bring a building's performance up to the Passive House standards; an intelligent and climate-driven design approach is necessary.

When we think of curtainwall we often think of shining glass surfaces, windows spanning from floor to ceiling around the entire perimeter of each floor guaranteeing abundant daylight and expansive views, but this transparency comes with a cost. Even the best insulated glass unit on the market will never rival a properly designed opaque surface, especially in the summer when

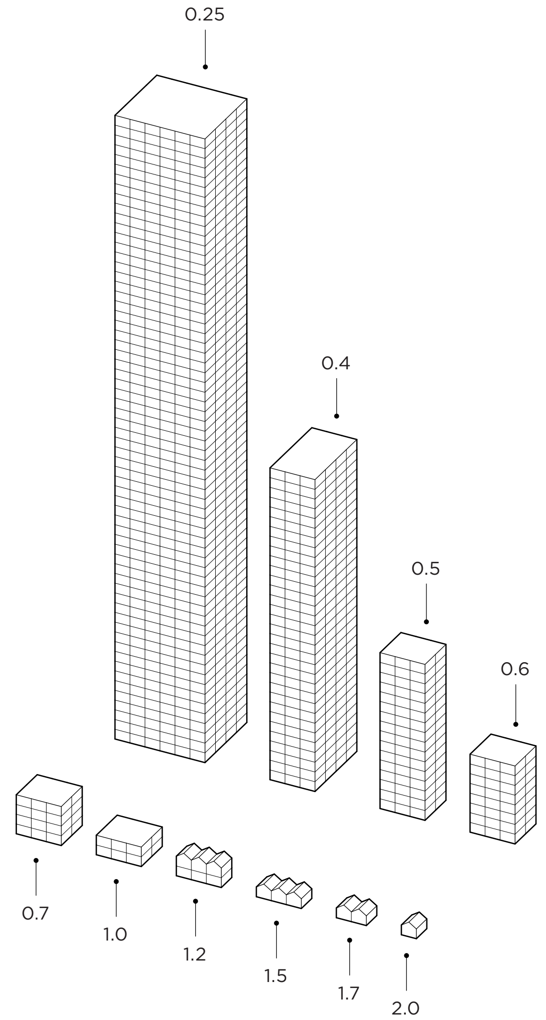


FIGURE 2
Diagram demonstrating compactness ratio.

the performance of an envelope is tested at the worst conditions and when solar heat gain increases the interior temperatures and therefore the cost of cooling. In New York City the 2016 Energy Code is already trying to reduce the amount of glass on highrise buildings, recommending a fenestration area of less than 40%. However, a more careful design can maintain a higher transparency while cutting down the energy costs it usually implies: the correct positioning of louvers and other shading devices can reduce the solar heat gain during the summer and help it in the winter decreasing both cooling and heating loads. Similarly, a facade design more aware of orientation can help the performance of a building tremendously.

COMPLETED PROJECTS

The number of Passive House certified buildings in the US is growing exponentially each year. In New York City alone more than 28 projects were under construction in 2016. While the majority are brownstone retrofit, some are much larger buildings, like Dattner Architect's 425 Grand Concourse, a 241 unit affordable housing project in the Bronx, or Bluestone Group's 101 unit apartment complex in Queens.

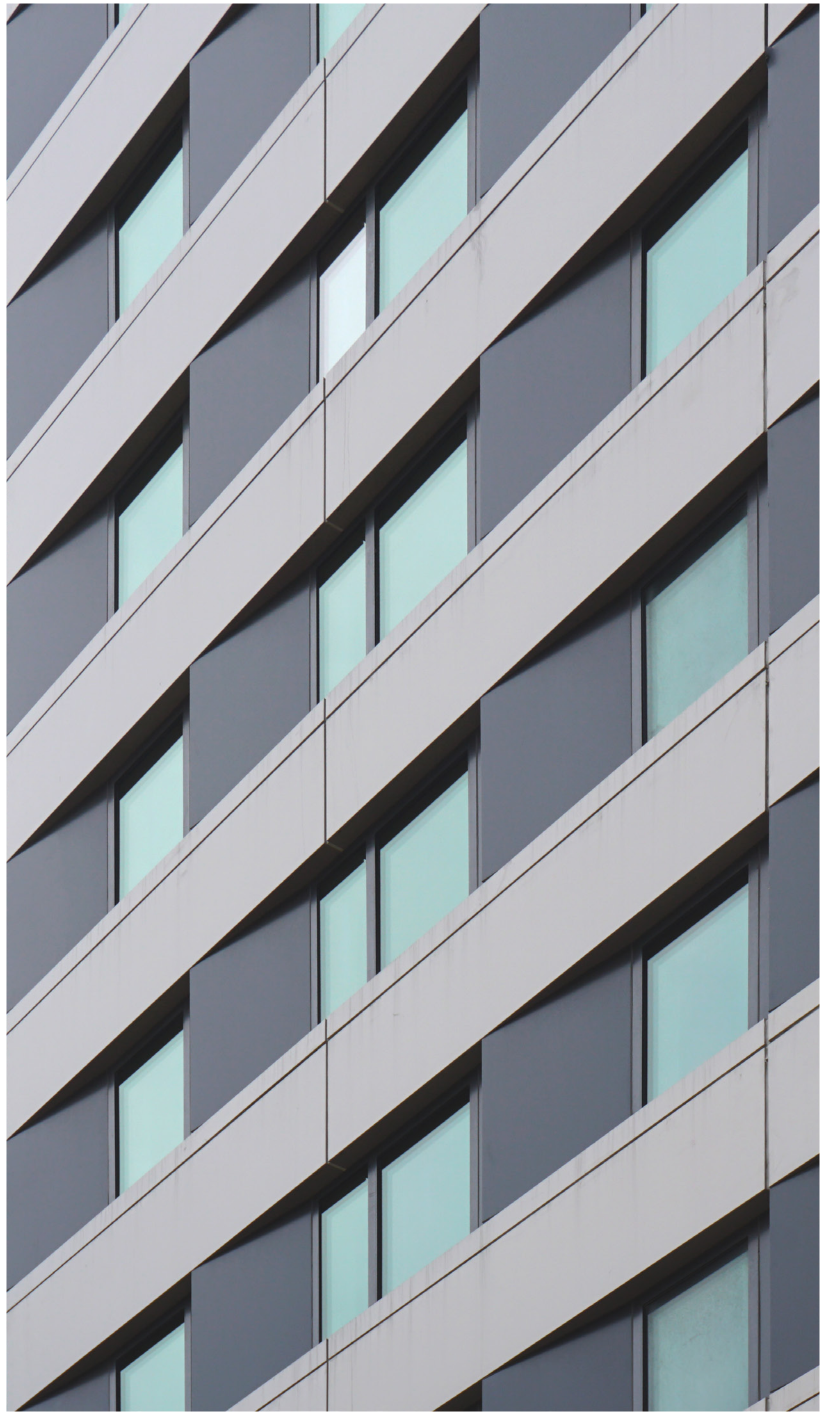
Most notably, Cornell Tech Residential is a break-through project for New York and the Passive House standard. Designed by Handel Architects, this 270-foot tall student housing project will soon be the most energy efficient highrise in the world and the largest and tallest building to achieve Passive House certification.

This building is expected to achieve 77.5% in energy reduction compared to similar projects and will offer an unparalleled interior comfort.

The facade of this building consists of 36' long prefabricated panels hung from the slabs and sealed together in the field to guarantee

FIGURE 3
Completed in 2017, Cornell Tech will soon become the tallest Passive House Certified building in the world.

FIGURE 4
The facade is made of prefabricated mega-panels 36' wide and 10' tall installed and sealed in the field.



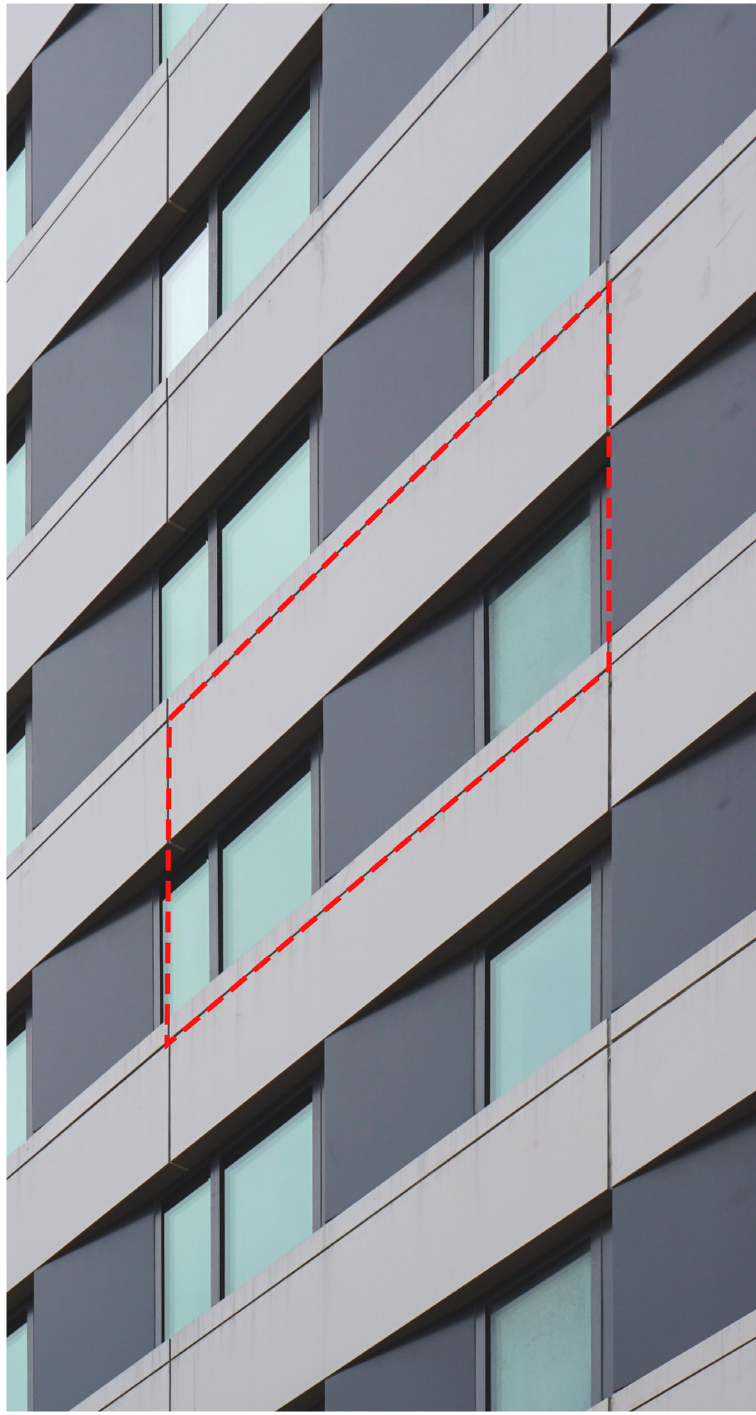


FIGURE 5
RHW.2 tower in Vienna, Austria by Atelier Hayde Architekten.

FIGURE 6
U.S. Building benchmarking policies.

an uninterrupted air and water barrier. This offers the opportunity for factory-controlled installation of windows and to assure their air tightness. At the same time, the expansive length of the panels reduces the number and length of joints that need to be sealed and verified in the field.

To ensure an airtight connection at every joint, two layers of silicon close each gap from the outside and an airtight membrane is installed on the interior surface, creating a continuous uninterrupted barrier that protects the building. The high comfort and high performances of the facade finally are assured by triple–glazed windows, a necessary requirement in the northeastern climate to guarantee the absence of drafts and maintain a comfortable mean radiant temperature on all the surfaces.

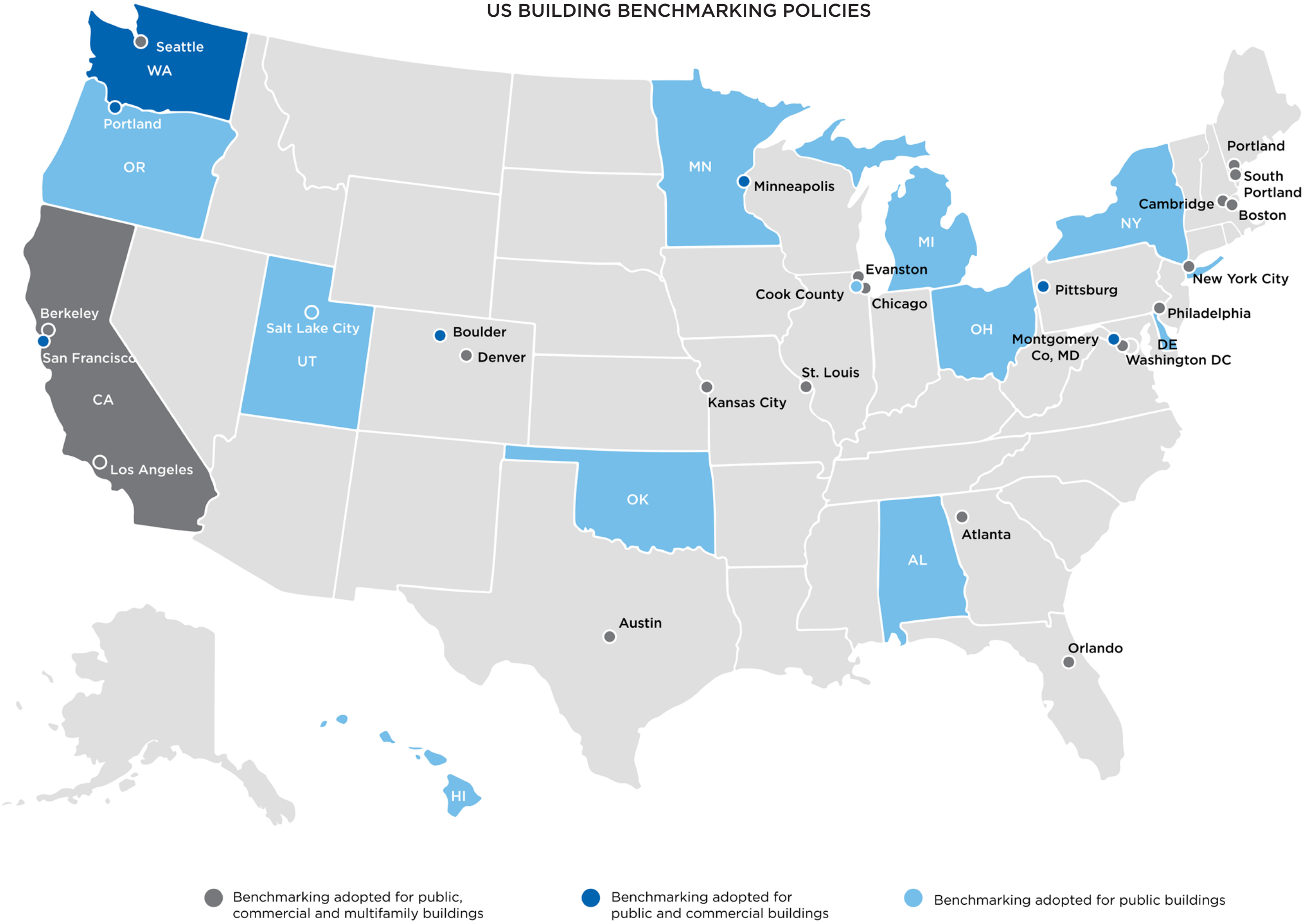
Completed in 2012, the RHW.2 tower in Vienna, Austria is another example of Passive House highrise pushing technology forward to create a comfortable and extremely energy efficient building. This 260' tall tower on the bank of the Danube is entirely covered in a highly engineered double-skin curtainwall. The cavity between the single glazed exterior and the triple–glazed interior walls work as a ventilation and sun shading zone that keeps the building warmer in the winter and protects it from overheating during the summer, all while maintaining unobstructed views of the surrounding for the people working in the tower.

Of course, the engineering of these buildings goes well past the sole facade: every building is an organism able to function properly only if all its organs work properly and in unison. Climate, function, mechanical systems, context and human activity are all factors that, together with the envelope of a building, contribute to its functioning and to the achievement of the performances required by the Passive House standard.

A STEP FORWARD

According to the Environmental and Energy Study Institute in Washington DC, in 2004 the emission of CO^2 from residential and commercial building contributed to 39% of the total US emissions. In major cities this percentage grows dramatically: in New York alone buildings are estimated to create more than 73% of the entire city production of greenhouse gas emissions. [1]

Most of the existing commercial and residential buildings do not offer protection from these pollutants, air drafts and poor construction often does not create enough of a barrier and high level of pollutants can be found outside as well as inside the spaces we live. Creating better, more efficient spaces is not only something we owe to the world but to ourselves too. And the real estate market has already noticed the importance of this added value: a 2010 study by



McGraw Hill Construction (*Green Outlook 2011: Green Trends Driving Growth*) demonstrated how the lease-up rates in "green buildings" ranges from market average to 20% above, with more and more clients considering indoor environmental quality as a crucial factor in the decision to sign a lease or buy a property.

As of 2013 the "green building" market represented 20% of the new constructions in the US, a market worth more than $260 billion according to a 2014 study by Lux Research Inc. Large coastal cities like New York, Los Angeles and San Francisco are leading this change. In the past years they have issued more stringent energy codes aiming to reduce the impact of buildings to the environment and increase the quality of the air we breathe, inside and outside of the spaces we live and work in.

At the same time, more and more cities and states have implemented benchmarking, a public energy report often required for both existing and new buildings. Disclosing the effective energy use can have a dramatic impact on the market: not only can it affect the value of a building but it can also reveal the real efficiency of other green standards based on checklists rather than an effective control of performances.

For these reasons, the implementation of Passive House has increased dramatically both in Europe and in the US in recent years. A standard based on the actual energy utilized by a building is a more credible metric of quality and something that both municipalities and developer are considering as a fundamental value in new constructions.

ENVIRONMENTAL

FROM BILLET TO BUILDING

EVALUATING INTERIOR NIGHT LIGHT EXFILTRATION THROUGH COMMERCIAL BUILDING FACADES

[1] Boyce, P. R. (2014). Human Factors in Lighting. Third edition. Boca Raton: CRC Press/Taylor and Francis

[2] Parkins, K. L., Elbin, S. B., & Barnes, E. (2015). Light, Glass, and Bird—Building Collisions in an Urban Park. Northeastern Naturalist 22 (1): 84–94.

[3] Machtans, C., Wedeles, C., & Bayne, E. (2013). A First Estimate for Canada of the Number of Birds Killed by Colliding with Building Windows. Avian Conservation and Ecology 8 (2): 6.

[4] Schiler, M. (1992). Simplified Design of Building Lighting. Parker-Ambrose Series of Simplified Design Guides.

[5] Kumaragurubaran, V. (2012). High Dynamic Range Image Processing Toolkit for Lighting Simulations and Analysis. Retrieved April 25, 2016, from http://search.proquest.com/docview/1034738463

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[1] City of New York Inventory of New York City's Greenhouse Emissions, April 2016, by Cventure LLC, Cathy Pasion, Mikael Amar, and Yun Zhou, Mayor's Office of Sustainability, New York, 2016

MATERIAL

ARCHITECTURALLY EXPOSED STRUCTURAL STEEL FACADES

EMERGING MATERIAL APPLICATIONS