Harvard HouseZero

Cambridge, Massachusetts

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UNDER EMBARGO UNTIL DECEMBER 3, 2018 Cambridge, Mass.

Harvard Center for Green Buildings and Cities Unveils First-of-its-Kind HouseZero Lab and Prototype

HouseZero's advanced data-driven infrastructure will enable cutting edge research, aims to shift the design and operation of buildings

The Harvard Center for Green Buildings and Cities (CGBC) at the Harvard Graduate School of Design (GSD) announced today the completion of HouseZero, the retrofitting of its headquarters in a pre-1940s building in Cambridge into an ambitious living-laboratory and an energy-positive prototype for ultra-efficiency that will help us to understand buildings in new ways. The design of HouseZero has been driven by radically ambitious performance targets from the outset, including nearly zero energy for heating and cooling, zero electric lighting during the day, operating with 100 percent natural ventilation, and producing zero carbon emissions. The building is intended to produce more energy over its lifetime than was used to renovate it and throughout its subsequent operation. Snøhetta was the project's lead architect and Skanska Teknikk Norway was the lead energy engineer.

Leveraging HouseZero as both a workspace and a research tool, the CGBC will use millions of data points from hundreds of sensors embedded within each component of HouseZero to continually monitor its performance. This sensory data will also provide Harvard's researchers with an unprecedented understanding of complex building behavior. This data will in turn, fuel research involving computational simulation, helping the CGBC develop new systems and data-driven learning algorithms that promote energy-efficiency, health, and sustainability.

"HouseZero's flexible, data-driven infrastructure will allow us to further research that demystifies building behavior, and design the next generation of ultra-efficient structures," said Ali Malkawi, founding director of the Harvard Center for Green Buildings and Cities and the creator and leader of the HouseZero project. "By creating both a prototype and an infrastructure for long-term research, we hope to raise interest in ultra-efficient retrofits and inspire substantial shifts in the design and operation of buildings."

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"Harvard HouseZero is an extraordinary physical example of efficiency and transformative design," said Mohsen Mostafavi, Dean of Harvard GSD and the Alexander and Victoria Wiley Professor of Design. "As a living laboratory, it equips Harvard students and researchers with an unparalleled, innovative infrastructure for exploration and research as they design the next generation of sustainable buildings and cities around the world."

As a prototype, HouseZero works to address one of the biggest energy problems in the world today—inefficient existing buildings. The U.S. building stock is responsible for around 40 percent of energy consumption, with housing nearly a quarter of that use. Property owners spend more than $230 billion annually heating, cooling and powering its 113.6 million homes. [AL9] Addressing the energy-inefficiencies locked into this problematic building stock offers tremendous opportunity for curbing its impact on climate change. Paving the way through ultra-efficient retrofit strategies, HouseZero creates a blueprint for reducing energy demands and increasing cost savings for property owners.

"HouseZero demonstrates how to solve that problem by optimizing current technologies to achieve unprecedented building performance," said Malkawi. "HouseZero challenged us to rethink the conventions of building design and operation to enhance lifelong efficiency and quality of life for occupants." The ultra-efficiency of HouseZero lies at the intersection of cutting-edge technologies and applications of established, low-tech architectural design solutions. An example is natural ventilation, which is controlled by a window actuation system, which employs sophisticated software and sensors arrays to automatically open and close windows to maintain a quality internal environment throughout the year. The building itself will strive for best possible comfort; however a window can always be opened manually to ensure individual comfort still remains firmly tethered to human instinct.

HouseZero will be used to research how to fundamentally redefine how a structure can connect with and respond to its natural environment to promote efficiency and health. Rather than approaching the building as a "sealed box," the building envelope and materials of HouseZero were designed to interact with the

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seasons and the exterior environment in a more natural way. The building will adjust itself constantly—sometimes by the minute— to reach thermal comfort for its occupants.

As a living lab, the Center's researchers are afforded inspiring surroundings that they themselves will be able to control and adapt. With time, the CGBC's research has the potential to greatly diminish the environmental impact of the building industry through widespread sharing and implementation of HouseZero's findings and data-driven building research across new construction and future building renovations worldwide.

About the Harvard Center for Green Buildings & Cities

The Harvard Center for Green Buildings and Cities aims to transform the building industry through a commitment to design-centric and computationally-driven strategies that directly link research outcomes to the development of new processes, systems, and products. By strongly emphasizing innovation and multidisciplinary collaboration, the Center will work to promote holistic change within the built environment, namely the creation and continued improvement of sustainable, efficient, high performance buildings and cities. The CGBC was established at the Harvard Graduate School of Design in 2014.

Team Credits

Client: Harvard Center for Green Buildings and Cities
Lead Architect, Landscape Architect and Interior Designer: Snøhetta
Energy/Climate Engineer: Skanska Teknikk (Norway)
Structural Engineering: Silman Associates
MEP/FP Engineering, Lighting: BR+A
Civil Engineering: Bristol Engineering
BAS/Controls/Natural Ventilation System: WindowMaster
Acoustics: Brekke & Strand Akustikk
Code & Accessibility: Jensen Hughes

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Geotechnical Engineering: Haley & Aldrich

Vertical Transportation: Syska Hennesy

Specficiations: Kalin Associates

BAS/Controls/Security Systems: Siemens Building Technologies

Photovoltaic System: Solect Energy

Landscape Architect, rear yard and surrounding properties: Reed Hilderbrand

Project Management: Harvard Planning & Project Management & CSL Consulting

Operations Support: Harvard Graduate School of Design Staff

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Why Focus on Existing Buildings?

Even before the 2015 Paris agreement to curb global warming by 2050, it was understood that the building industry alone accounted for 40% of all worldwide energy use and thereby 40% of all global greenhouse gas emissions from the production of that energy. In developed countries, roughly 65% of the total expected building stock in 2060 has already been constructed. (Source: UN Environment and International Energy Agency, Global Status Report 2017).

This demonstration project attempts to address the urgency issue by focusing on one of the most challenging building types—inefficient *existing* structures—which account for vast amounts of energy use and carbon pollution worldwide. While numerous *new* buildings have achieved net-zero or positive-energy performance goals, the retrofit potential of the current U.S. building stock has not been thoroughly explored.

As such, the CGBC intends to demonstrate that by coupling current technologies with better design, deep energy retrofits of our existing building stock can, indeed, achieve rigorous energy efficiency goals. By retrofitting the current building stock in the United States to achieve even some of HouseZero's radical efficiency standards, we can achieve significant energy savings, which will translate into billions of dollars in savings per year.

By creating both a prototype and an infrastructure for long-term research, the CGBC hopes to raise interest in ultra-efficient retrofits and inspire substantial shifts in the design and operations of buildings.

Targeting the most rigorous efficiency standards ever achieved by a building retrofit, HouseZero has the following performance goals:

1. Almost zero energy required for heating and cooling (No HVAC system)
2. 100% natural ventilation
3. 100% daylight autonomy (No daytime electric light)
4. Zero carbon emissions, including embodied energy in materials


Before Retrofit

Zero Carbon Emissions

In order to address proposed emission cuts of the Paris agreement, HouseZero goes further by offsetting the hidden emissions generated throughout the building's life cycle: from the fabrication and transport of building materials and construction processes, to maintenance and decommissioning. The production surplus is dimensioned to completely offset carbon emissions from the equivalent energy used throughout the intended lifespan of the house including embodied energy for construction materials, building operations, and equipment plug-loads for over a 60-year life-span. This surplus clean energy is to be fed back into the grid.

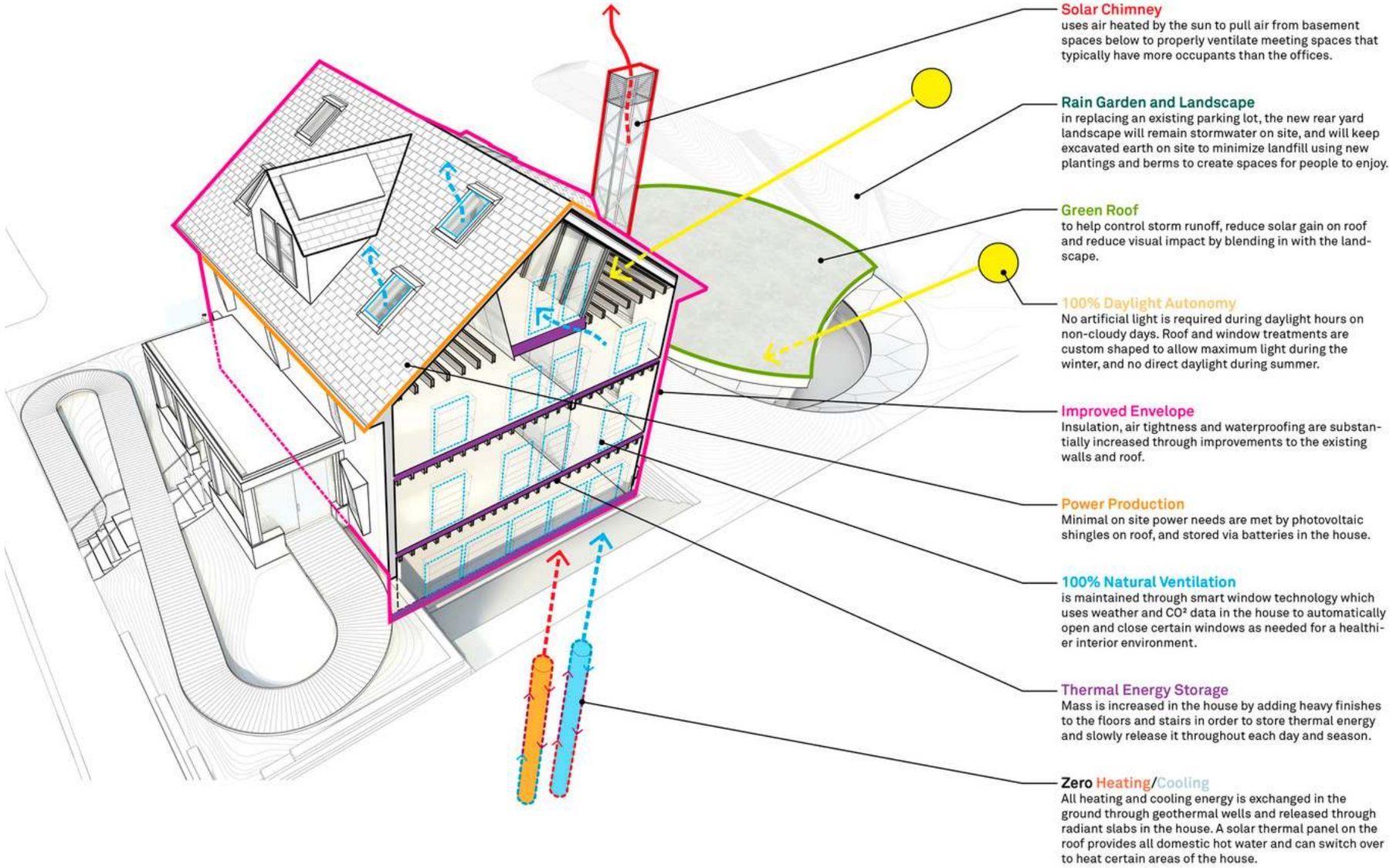
Beyond the retained existing materials, we used locally-sourced white cedar shingles, ash and birch interior finishes, ultra high-slag concrete, natural clay plaster, and reclaimed brick and granite, all of which are high performance and locally available. Treatment and finishing are to be kept to a minimum. All materials were chosen for non-emitting purposes to preserve air quality , and for a balanced indoor climate.

Zero Energy Required for Heating and Cooling

The CGBC believes that the green buildings of the future should embrace an ecological approach rather than an engineering dominated approach. If we allow our solutions to be inspired by ecosystems, buildings might be treated as living organisms that can breathe and adjust themselves relative to their surroundings. This represents a fundamental paradigm shift that could have enormous implications for the environment and the human condition.

As such, HouseZero works to fundamentally redefine how a structure can connect with and respond to its natural environment to promote efficiency and health. Rather than approaching the house as a "sealed box," the building envelope and materials of HouseZero were designed to interact with the seasons and the exterior environment in a more natural way.

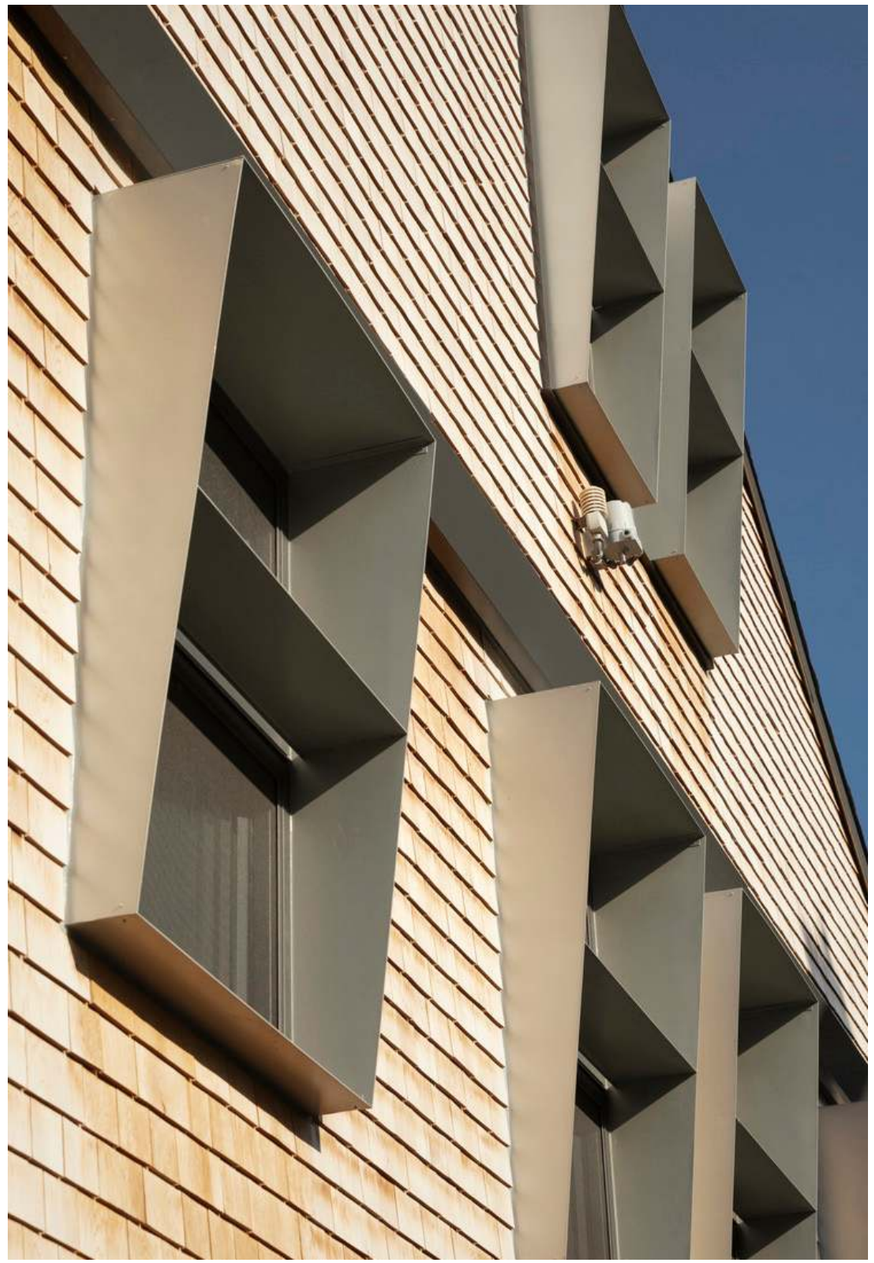
The building will adjust itself seasonally, and even daily, to reach thermal comfort targets for its occupants. 285 sensors embedded within the building collect almost 17 million data points each day. This data infrastructure enables the building to immediately self-adjust in response to both internal and external variables such as outdoor air temperature or rain, and indoor CO2 levels and air temperature.



100% Daylight Autonomy

Artificial lighting isn't used during daylight hours because the design of the building is optimized to maximize daylight use and passive solar practices in each space.

An open floor plan and careful selection of lighter-colored materials enhance the sense of openness in the space.



Sculpted window shrouds protect the interior spaces of HouseZero from direct sun during summer months to reduce required cooling, yet allow winter sun into the space to reduce seasonal heat demand.

100% Natural Ventilation

Natural ventilation is controlled by a window actuation system, which employs sophisticated software and sensors arrays to automatically open and close windows to maintain a quality internal environment throughout the year. The building itself will strive for best possible comfort; however a window can always be opened manually to ensure individual comfort still remains firmly tethered to human instinct.

A solar vent is used to instigate buoyancy-driven natural ventilation. A prominent feature at the east façade; the glazed enclosure is oriented to the sun and charges an integral thermal element of recycled brick to aid ventilation in the basement event space (at left) at certain occupancy conditions as well as a future extension. Glazed sections in the solar vent allow natural light to enter the stairwell.

Human-centric design for a data-centric building

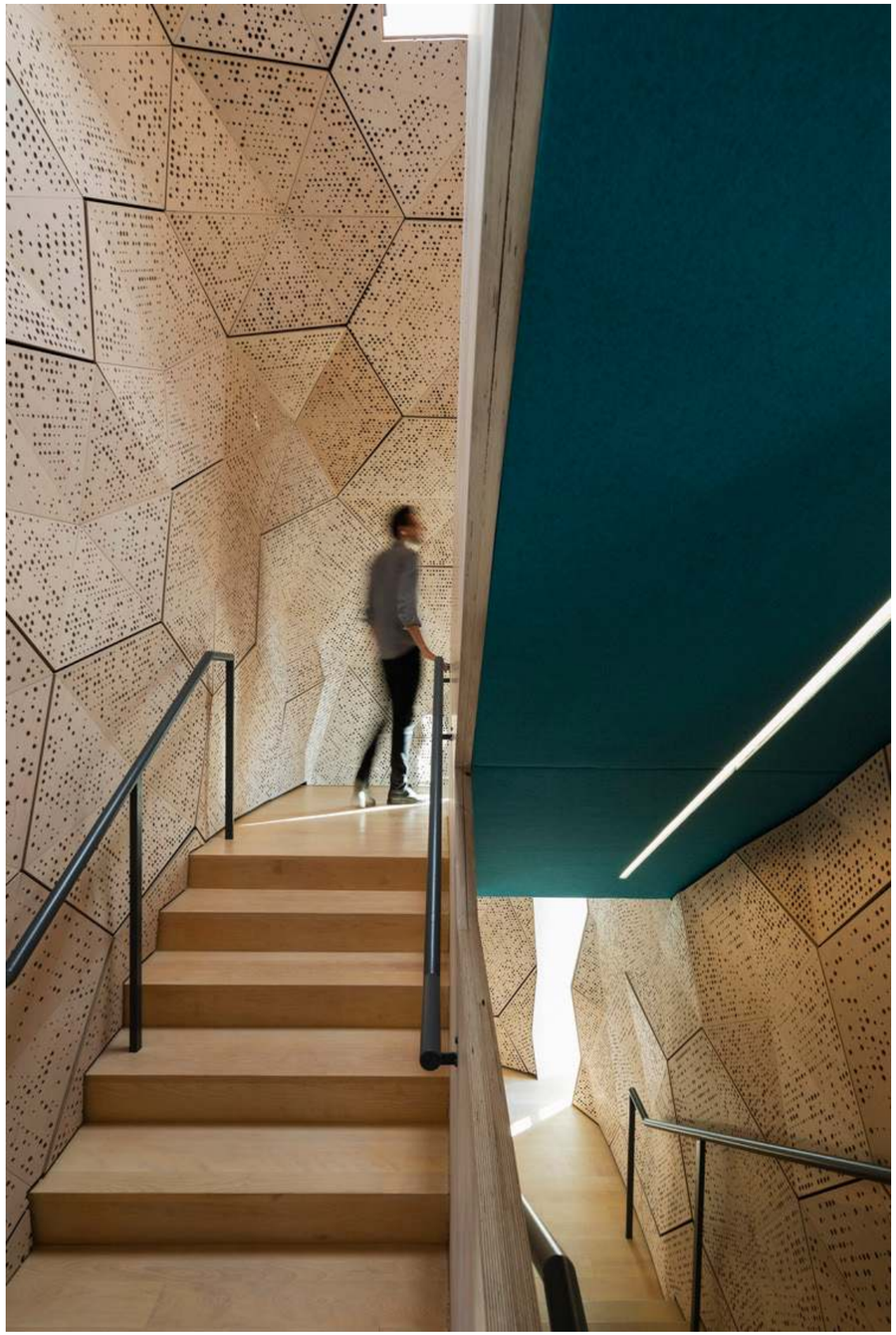
While the performance and research at HouseZero targets the building industry's impact on climate change at large, it does so without sacrificing the day-to-day needs of its users.

The design takes care to elevate the spatial experience and occupant comfort through ample daylighting and acoustic privacy.

The team prioritized acoustic quality as a key criteria for a spatial experience. Ultimately, HouseZero must be a productive and pleasant work environment. All rooms are designed to feature acoustic damping, reduce noise transmittance, and enable clarity of speech. Treatment of the existing structure, from exposure of the existing beams to creation of double height spaces, has positive effects on both volume and acoustics.

Ultimately, the ultra-efficiency – and potential industry-wide replicability – of HouseZero lies at the intersection of cutting-edge technologies and innovative applications of established, low-tech, human-centric sustainable architectural design solutions.

With education as a core tenet of its mission, the CGBC will be able to use the building as an pedagogical tool, communicating its work to students and the public through tours and live demonstrations of its technology.



At the center of the building, a faceted stairwell that spirals up through all four floors of the building, and is designed to reduce disturbance from circulation throughout the building.

As part of a unique digital exchange, the hexagonal panels of the stairwell have been robot-milled and finished by students at the Harvard Graduate School of Design.