

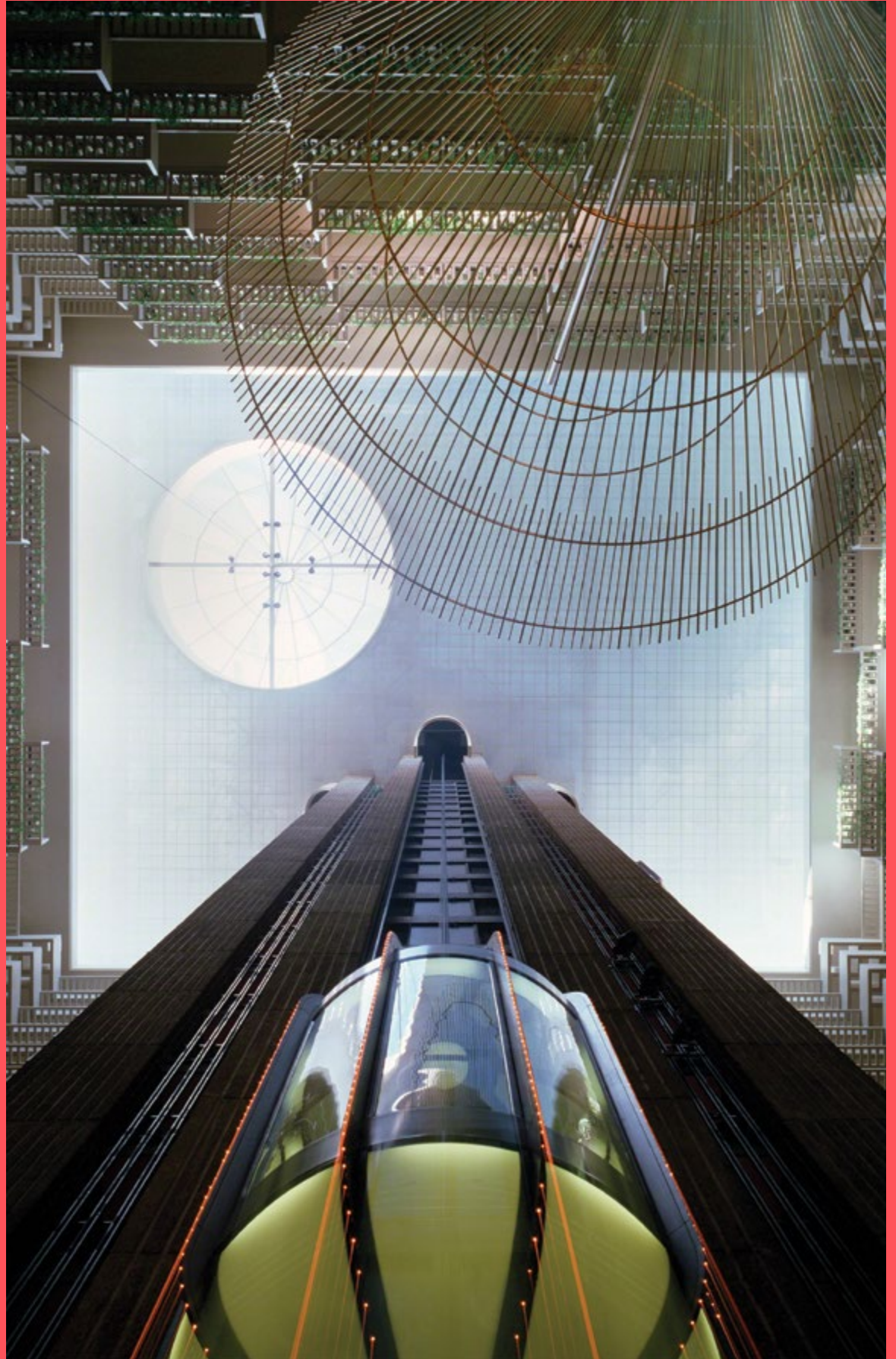
VERTICAL URBANISM

ISSUE TWO
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THE MAGAZINE
OF CTBUH

TOUR BOSTON
UNIVERSITY'S
AWARD-WINNING
VERTICAL CAMPUS

CITY ADVOCACY:
EIGHT CITYMAKERS,
FROM PARIS TO
ISTANBUL, ON DENSITY

PATRIK SCHUMACHER
PRAISES THE LATE
JOHN PORTMAN'S
PIONEERING TOWERS





LIVING LATTICE



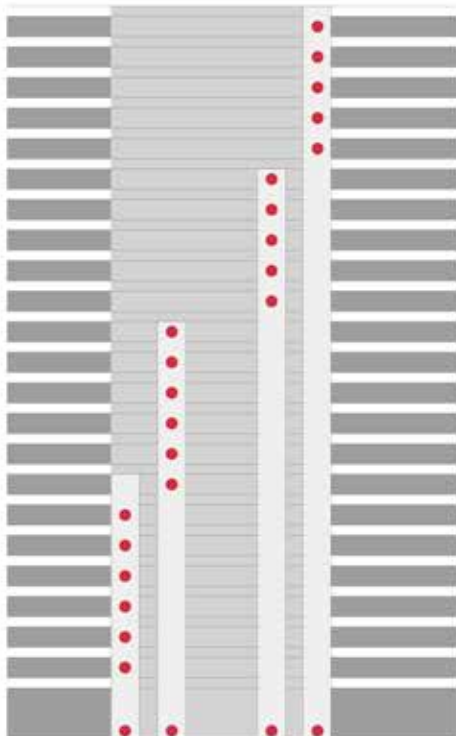
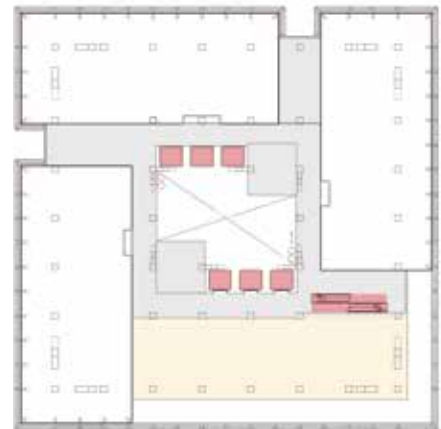
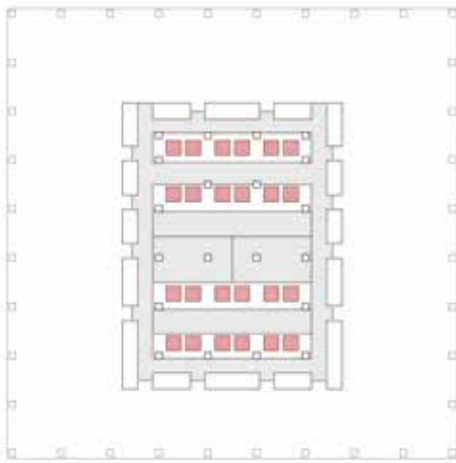
Regenerative Tree, a skyscraper prototype by Japanese firm *Nikken Sekkei*, blends timber engineering, biomimicry, and adaptability to reduce carbon emissions by 40 percent.

With the average global temperature expected to rise by 1.5 degrees by the early 2030s,¹ efforts to significantly reduce greenhouse gases are underway in countries around the world. Under Japan's "2050 Carbon Neutral Declaration," the Japanese government has been tightening regulations, including raising energy-efficiency standards for large non-residential buildings in April 2024.

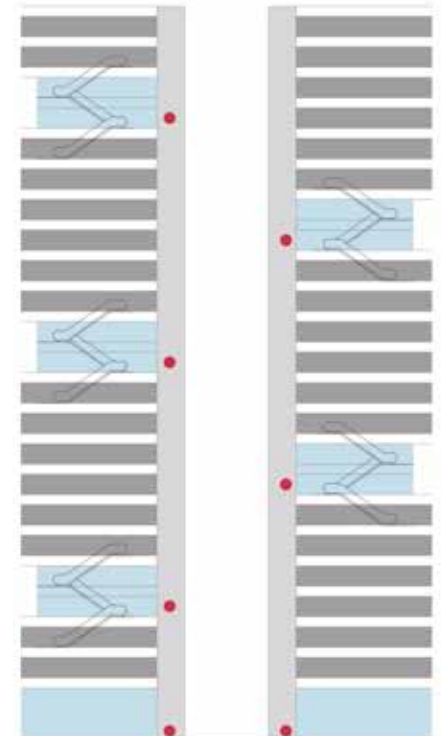
The industry is currently focused on CO₂ emissions associated with building operation—known as operational carbon—but the importance of reducing CO₂ emitted during the construction, refurbishment, and demolition phases—called embodied carbon—is garnering attention worldwide. Some countries have already enacted regulations regarding embodied carbon.



Previous page and left—
The Regenerative Tree is a prototype skyscraper designed for flexibility and adaptability, making use of low-carbon building materials.



Left—
Section diagram and floor plan of a standard building, with separate banks of local and express elevators.



Right—
Section diagram and floor plan of the Regenerative Tree prototype, which substitutes escalators for local elevators at key locations, reducing power, material, and floor-space consumption.

“Forty-percent reductions in CO₂ emitted over the building life cycle can be achieved by designing for diverse work styles, future conversions, and high environmental performance.”

Furthermore, there is a growing need for offices that offer employees the freedom to choose the location and environment in which they perform work, that encourage communication with others, and that promote wellness by connecting with nature, as well as offer flexible plans that enable refurbishments and changes in building use.

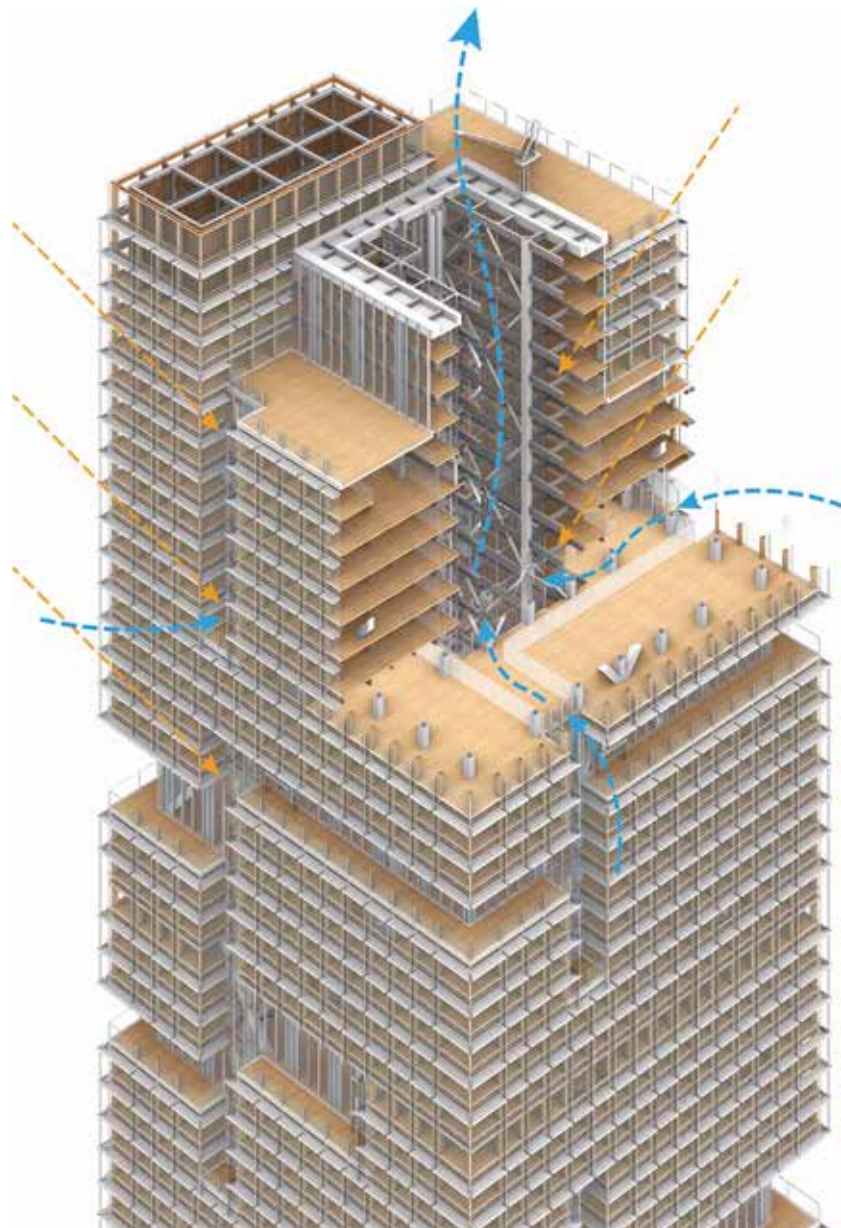
Our prototype of a next-generation skyscraper is 160 m high, with a total floor area of 100,000 m² and a projected life span of 100 years. It incorporates various strategies to reduce CO₂ emitted over the building life cycle, i.e., whole-life carbon. Reductions up to 40% over the building’s lifespan can be achieved by designing for diverse work styles, future conversions, and high environmental performance.

To substantiate the 40% carbon reduction figure, we established a baseline case, calculating material quantities for the structural frame and exterior of a simplified building of the same size (floor area) offering standard environmental performance. For the interior, actual values of similar-sized buildings were used. For mechanical equipment, standard values issued by the Architectural Institute of Japan (average values from past properties) were used.

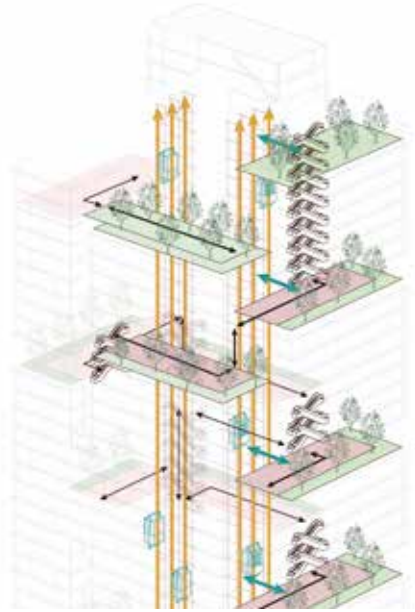
The expected embodied carbon of the proposed building is 1,778 kgCO₂/m², compared to 2,677 kgCO₂/m² for a standard building.

To minimize the CO₂ footprint of this new prototype, we reconsidered various common practices for large-scale offices, identified the truly essential functions,

Right—
The building’s environmental plan is inspired by phyllotaxis, the arrangement of leaves on a plant stem, promoting natural ventilation and light penetration.



“Columns are placed in structurally rational positions and the perimeter is made of timber to reduce the use of steel, better accommodate changes in use, and cut CO₂ emissions during construction.”



Above and top—
The provision of shared spaces, connected by escalators, affords occupants more choices about where and how they work.



Left—
Alternate view of a shared workspace.

Right—
Timber perimeter: Surrounded by wood, the texture-rich window areas create a new workplace that enjoys natural light and wind.



and thoroughly rationalized its structural and mechanical design. Specifically, the following elements contribute to the decarbonization of the scheme:

Structural Design

Conventional offices with wide, column-free spaces require large amounts of steel, due to long-span structures and the concentration of earthquake-resisting members around the core. In this prototype, columns and other elements are placed in structurally rational positions and the perimeter is made of timber. This reduces the use of steel, better accommodates changes in building use, and significantly cuts CO₂ emissions during construction.

The floor plan features “stepped floors,” workspaces segmented by slits and connected with the upper and lower floors by atriums and stairs. Compared to vast, single-floor spaces of conventional offices, this design incorporates natural elements and brings employees closer together, promoting communication.

By using wood flooring consisting of cross-laminated timber (CLT), the placement of atriums and stairs within rentable areas can be facilitated, and the overall building weight is reduced, leading to less steel and concrete usage and lower CO₂ emissions during construction. This also helps CO₂ reduction during the building’s operation phase by making refurbishments easier.

It is estimated that, by following this design, steel usage can be reduced by approximately 20% compared to

skyscrapers of a similar height in Japan. The timber elements are structural members that are meant to last the building’s entire life span (100 years, assuming routine maintenance). Since they are located within the building envelope, degradation due to external factors is not expected.

The CLT floor is 210 mm thick and directly joined to the steel beams. The plan is to use bolted joints, embedding lag screws into the timber elements, but this can change if a better method emerges. The main frame has been designed so that large-scale steel bracing on the inner side of the timber perimeter, combined with bracing in the core, bears most of the lateral force. Since the timber perimeter does not bear seismic forces, it can flexibly accommodate openings for stairs and atriums.

The stepped floor design is characterized by slits to let in natural light and wind, and openings such as stairs and atriums to connect the upper and lower floors. Since these components are installed in the timber perimeter, which sits outside the main frame, it does not affect the distribution of lateral forces.

Mechanical Design

As an approach to mechanical design, we have applied biomimicry, drawing inspiration from the mechanisms of living organisms. One example is the “Wonder Net,” a heat recovery system mimicking the human body, in which interwoven arteries and veins exchange heat to prevent drops in body temperature. The

system will be implemented as a three-pipe heat pump system capable of heat recovery for cooling and heating. When the cooling load and heating load are approximately equal, the operating efficiency will be doubled.

Another approach is to combine a high sensible heat operation and water spray system for air conditioners, similar to the process of perspiration for body temperature regulation. When a heat pump’s outdoor unit dissipates heat using only convection and radiation, without using water spray, it is called “high sensible heat operation”—similar to how humans regulate temperature through the body’s surface.

Water spray operation is a method of improving cooling efficiency by spraying water on the outdoor unit and dissipating heat through evaporation. This is similar to how the human body controls temperature by sweating, combining heat dissipation through latent heat. The control parameters are the refrigerant pressure of the outdoor unit (load state) and the outside air temperature.

With these energy efficiency measures a Building Energy Index (BEI)² value of 0.23 was achieved. Furthermore, inspired by the arrangement of leaves on a plant stem (phyllotaxis), slits on all sides and a central void were created to allow light and air to permeate the space. To manage stack effect in the vertical void, windows are installed along the exterior wall and central void, which can be opened and closed to balance between indoor and outdoor environments.

Right—
A large atrium at the center of the building brings light and ventilation to interior floor plates and carries utility lines.



Right—
Overview of whole-life carbon reduction measures used in the Regenerative Tree prototype.

Innovating Circulation

Conventional skyscrapers typically contain a balance of express elevators and local elevators, the latter of which stops at every floor, to transport workers during peak times. However, as workplace movement patterns change, peak time optimization becomes less critical. Therefore, we have fundamentally re-evaluated this transportation system, replacing the local elevators with a combination of express elevators and escalators.

Express elevators, suitable for long-distance transport, stop every four floors, and the escalators, ideal for mass transport, connect floors above and below, thus maintaining transportation capacity while significantly reducing power consumption (from 5,650 kWh/day to 1,750 kWh/day).³

To calculate expected circulation use, we assumed an 80% office attendance rate and a five-minute handling capacity of 10% during peak hours, six express elevators and 44 escalators are calculated to achieve the same performance as 24 local elevators.

By removing the local elevators, a large void (atrium) is created in the center of the building. This void can contain the main utility lines, improving

office space efficiency and serving as a natural ventilation path. It also makes maintenance, equipment replacements, and refurbishments easier, thereby reducing CO₂ emissions during operation and contributing to sustaining the building's value and longevity according to contemporary requirements.

Shared spaces, connected by escalators, are placed throughout the building in a spiral pattern to the rooftop. These spaces can serve as express elevator lobbies, can be combined with terraces and used as common refreshment areas, and include a variety of office support functions such as meeting rooms, cafes, bookstores, and coworking spaces. Building users can choose their preferred work environment among a diverse array of workspaces.

How does this new circulation system impact on net-to-gross floor area ratio? As the shaft area can be excluded from the FAR calculation, the net-to-gross floor area ratio can become higher than usual.

For maintenance, the central void can be used to install the main equipment lines, improving maintainability compared to the conventional core shafts. Equipment renewal work can also be carried out easily by using the void.

To allow for future adaptability, when in need of renovation work or changes in use type, the central void can serve as a transport route, so that work can be carried out while the building is in use. Technology infrastructure can be freely branched and connected to each floor plate from the main equipment line

in the central void. In addition, extra space for outdoor units is secured outside the shared spaces.

Primary elevators and escalators are not used during evacuation. As with a standard building, emergency elevators and evacuation stairs are installed.

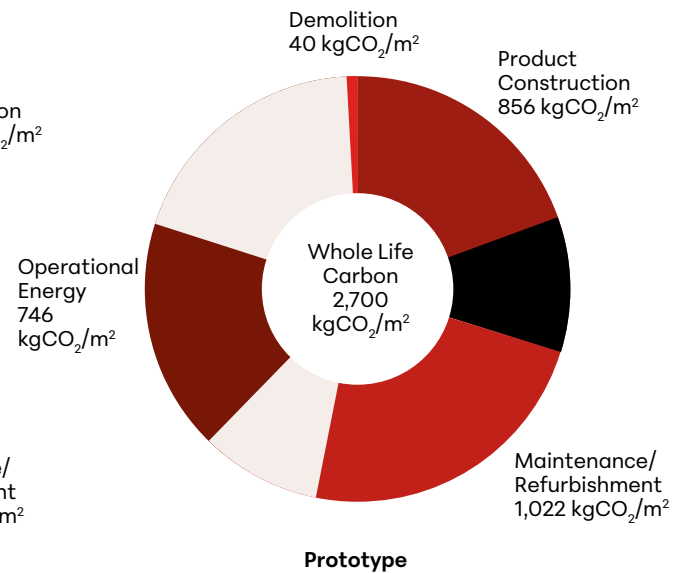
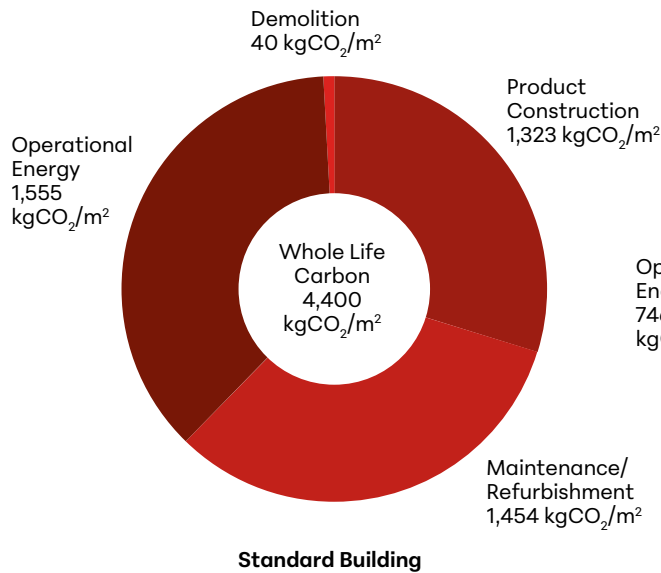
Future Outlook

Many elements of this prototype can be applied not only to the construction of new large-scale buildings, but also to the renovation of small- and medium-sized buildings, which make up the majority of existing stock.

Some elements, however, fall outside the scope of current evaluation systems or involve technologies still under development. Moving forward, we aim to implement the components of this prototype in individual projects through co-creation with our clients. We also intend to utilize this prototype to advocate for regulatory improvements and to continuously update its contents in response to technological advancements. It is anticipated the construction sequence will not differ greatly from the conventional procedure. The construction cost is estimated to be about 10% higher.

In 2021, Nikken Sekkei committed to realize a carbon-neutral society by 2050. This prototype is part of a plan to propose models to achieve carbon neutrality in terms of work styles and architectural design, and simultaneously share them with our clients and society to encourage all to join these efforts.

“By removing the local elevators, a large atrium is created in the center of the building.”



REDUCTION OF EMBODIED CARBON

Product/Construction		Maintenance/Refurbishment	
Interior columns	0.4%	Refrigerant pipe reduction	2.0%
Brace layout optimization	3.1%	Timely equipment replacement	5.5%
CLT		Mechanical system capacity optimization	1.7%
Timber perimeter		Void utilization	0.7%
Seismic isolation			
Access floor removal	0.9%		
Exposed ceiling	0.3%		
Facade rationalization	1.1%		
Green materials	4.2%		
Mechanical system capacity optimization	0.7%		

REDUCTION OF OPERATIONAL CARBON

Operational Energy	
Wonder net	3.2%
Perspiration	2.0%
Respiratory circulatory response	3.6%
Ventilation drive	1.0%
Phyllotaxis	2.3%
Ant colony	1.3%
Other (general technologies)	5.2%

NOTES

- 1 Based on the March 2023 report by the United Nations Intergovernmental Panel on Climate Change (IPCC).
- 2 Abbreviation for Building Energy Index. Calculated as the ratio of primary energy consumption of the designed building to the reference building, it is an indicator of the building's energy efficiency. A BEI value of 1.0 or less complies with current standards, with lower values indicating higher energy performance.
- 3 Comparison of daily power consumption between 24 local elevators and six shuttle elevators combined with 44 escalators.