*productive architecture*

# Kiss + Cathcart, Architects

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# *the 2020 tower*

The 2020 Tower is a mixed-use, 150 story, **productive** building, that produces all its own energy, treats and reuses its water and waste.

In 2001, the National Building Museum commissioned Kiss + Cathcart to design a speculative building for “Big + Green,” an exhibition originally shown at the National Building Museum in Washington DC. In collaboration with Arup Engineers, we targeted new ecological, urbanistic, and quality of life standards for tall buildings. While technologically advanced, this design is not a utopian vision but a building that has been carefully engineered to be practical and economical by the year 2020.

The 2020 Tower inspired two research programs funded by the National Science Foundation from 2005 to 2014. The research, entitled *Self-Sustaining Urban Buildings*, was carried out by an international, multidisciplinary team headed by Rutgers University. As part of the conclusion of the study, Kiss + Cathcart and Arup updated the technical and performance parameters of the 2020 Tower to the year 2050 - The 2050 Tower.

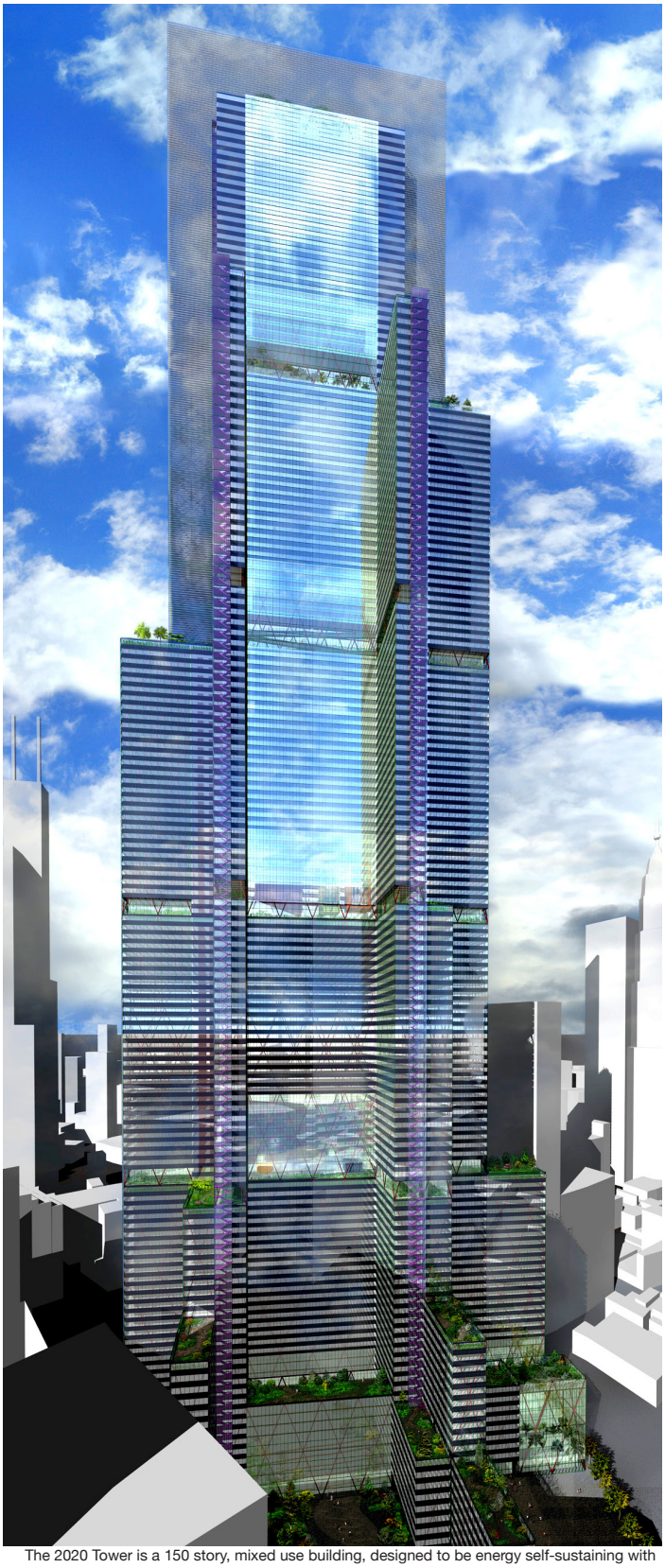
**The Client:**
The National Building Museum
National Science Foundation

**The Team:**
Kiss + Cathcart, Architects
Ove Arup + Partners

**Project Details:**
6,690,000 sf
Ongoing research

**National Building Museum, 1/03**
**Yale University Art Gallery, 6/03**
**Museum of the City of NY, 1/04**
**National Science Foundation**
**Grants 2005, 2007–2014**

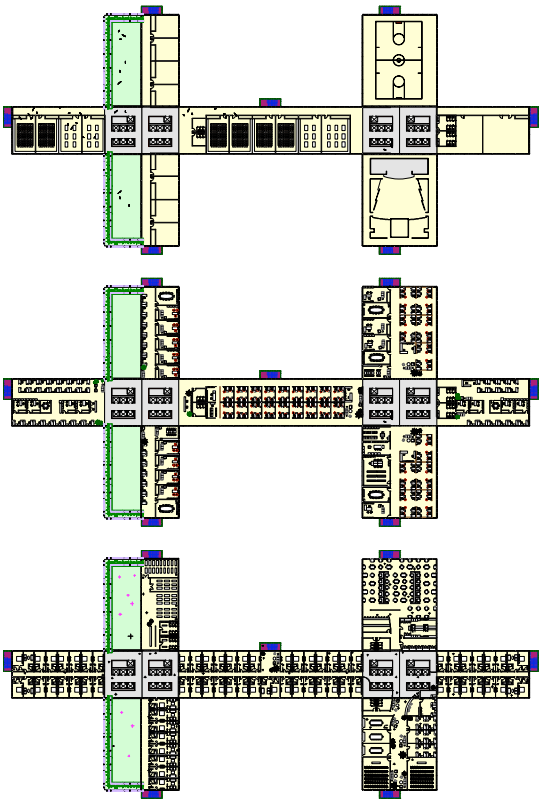
Originally commissioned by the National Building Museum for Big & Green, 2001


The 2020 Tower is a 150 story, mixed use building, designed to be energy self-sustaining with technology available by the year 2020

## The 2020 Tower

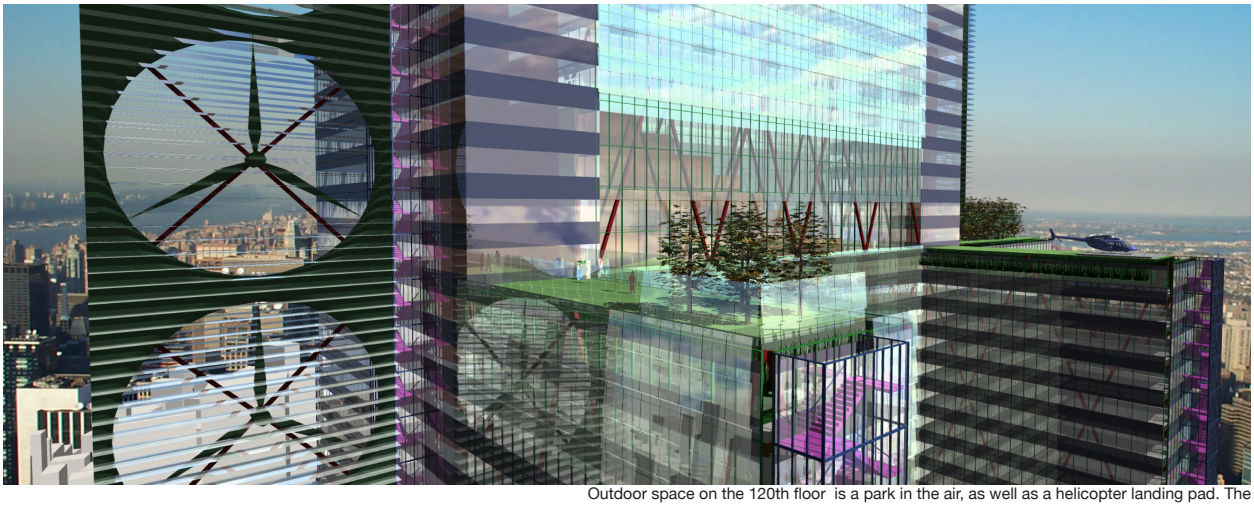
The 2020 Tower is conceived as a vertical city, with the same mix of residential, commercial and cultural activities as the city around it. With a peak population of 20,000, this building is the size of a small town. Compared to a single-use office or residential building,  it will function more efficiently in human terms - with a variety of round-the-clock activities - and in terms of building services - energy, water, and waste - by spreading peak demands throughout the day. Solar and wind power meet 100% of this building's energy needs.

The project was designed for New York City conditions, but the design is adaptable to a range of climates. For locations other than New York, we have assumed a large urban center, with sufficient public transportation available to serve it. There is a subway transit hub integrated into the base of the building.



The building plan is thin - typically no deeper than 15 meters - which is and is adaptable to many functions.: top, a school, middle, an office, bottom, a hotel.

The  skin of the building is a mixture of photovoltaics, rainwater capture, biological screens, and even integrated food production.



Outdoor space on the 120th floor  is a park in the air, as well as a helicopter landing pad. The solar skin generates a third of the building's energy; wind turbines generate the remaining third.

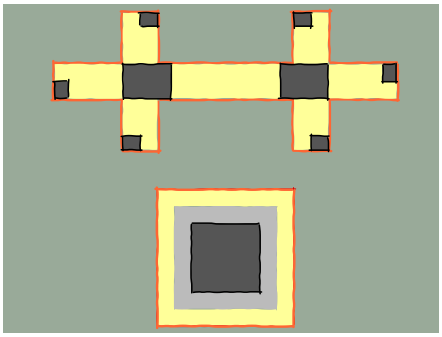
# *the 2020 tower*

## Planning the Vertical City

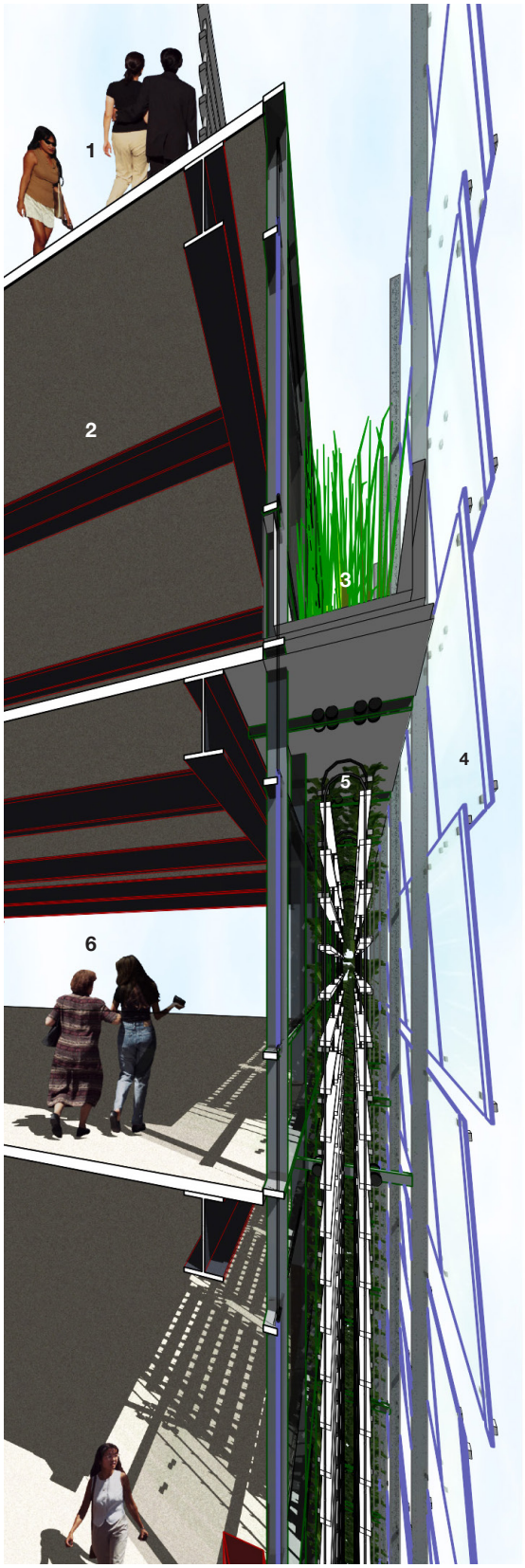
The building is divided into 30 story vertical units. Every 30 floors, the building has a major public level including commercial and cultural activities, and outdoor space. Below each public level is a service floor ringed with greenhouses serving the biological waste treatment system, which allows reuse of more than 90% of the building's water. These greenhouses are visible from outside, and form a green strip around each public level.

There is a major special use on each public floor - a hotel, theater complex, a university, and a botanical garden - with smaller scale shopping, restaurants, and service business adjacent. Outdoor space at each public floor serves as parks in the sky, and also as landing sites for helicopters - in the event of a serious problem, one is never more than 15 floors away from rescue.

In plan, the shape of the building is determined by our requirement that the building have thin floor plates, to provide good natural light, views, and the possibility of natural ventilation. The resulting plan form is similar to most buildings built before the age of deep floor plate air conditioned buildings. The thin plan increases the ratio of energy-generating solar facade to energy-using floor space. Compared with a conventional plan with a single core and a minimum perimeter, this plan provides higher-quality space, with the added amenity and safety of multiple cores.

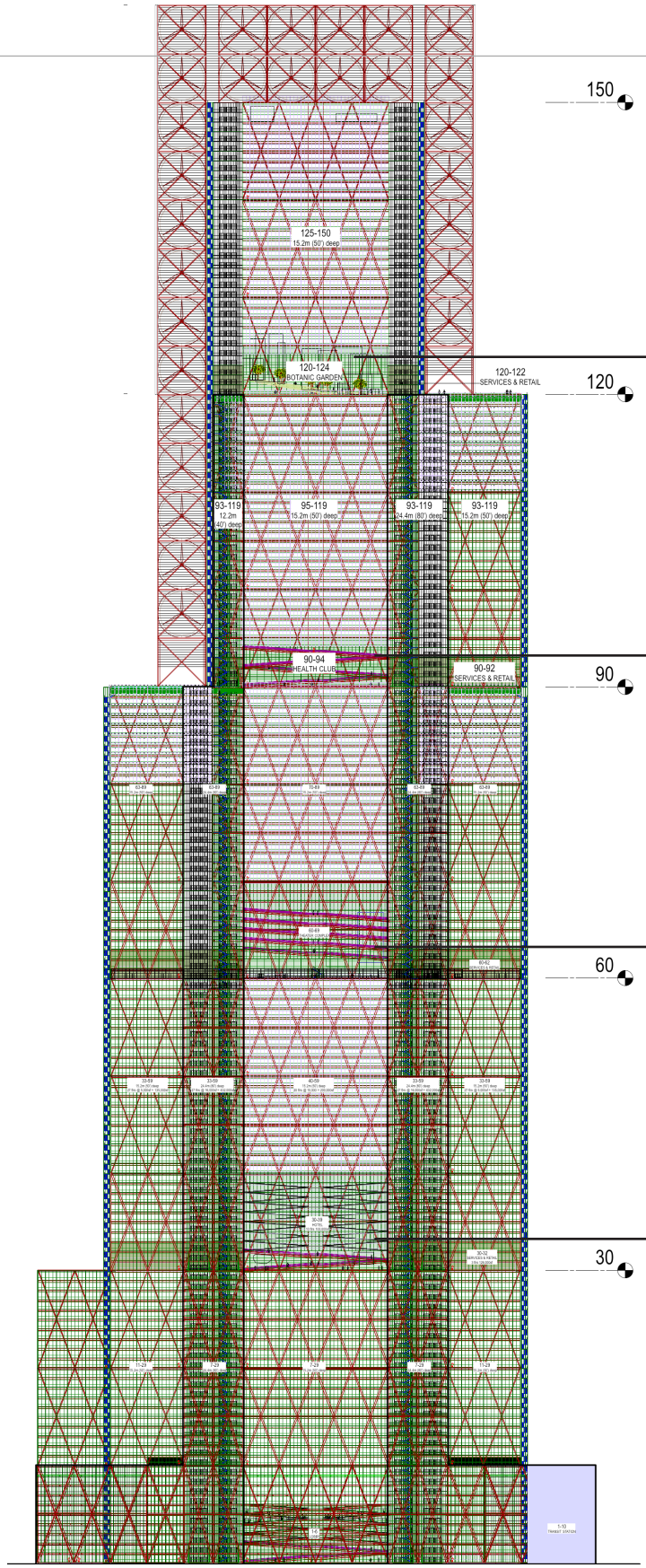


A comparison of a traditional skyscraper floor plate (bottom), to the 2020 tower-style plan, with thin floor plates, maximum perimeter, and multiple cores.

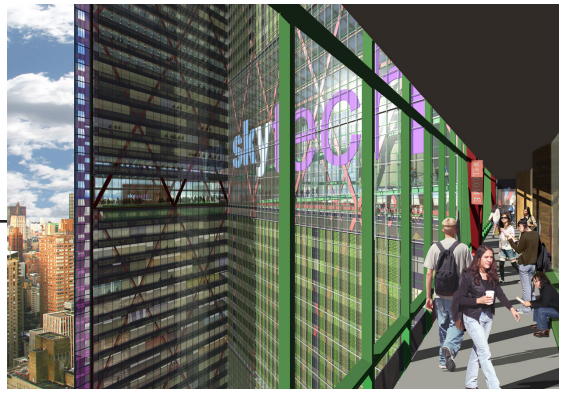



Upper deck - park in the sky - **1**
Service floor - **2**
Greenhouse for biological waste treatment system - **3**
Outer layer - rain screen/wind screen - **4**
Vertical hydroponic growing system - **5**
Residential or commercial floors - **6**

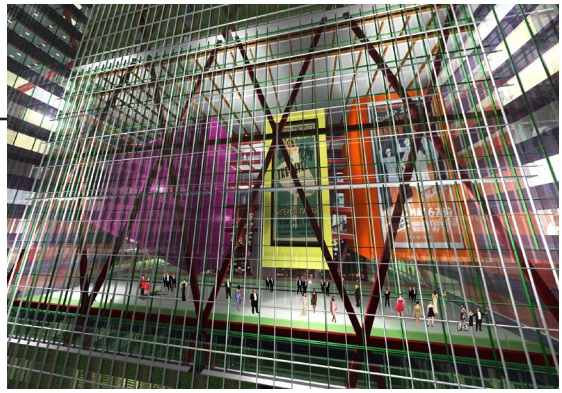
Partial section. The 2020 Tower has a multilayer facade system, accommodating office/commercial uses, residential with or without balconies. The cladding system includes PV glazing, integrated vegetation, or integrated food production via vertical hydroponic systems.



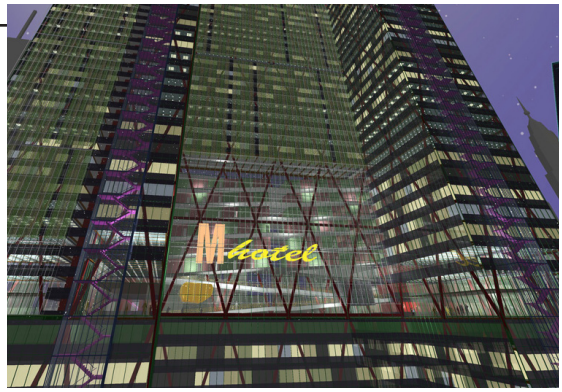

120th floor botanical garden



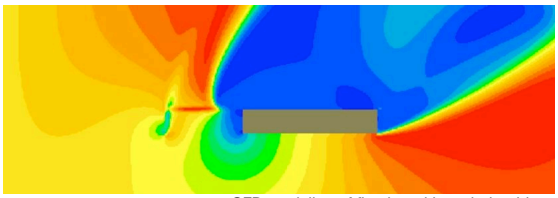
90th floor University



60th floor theater complex

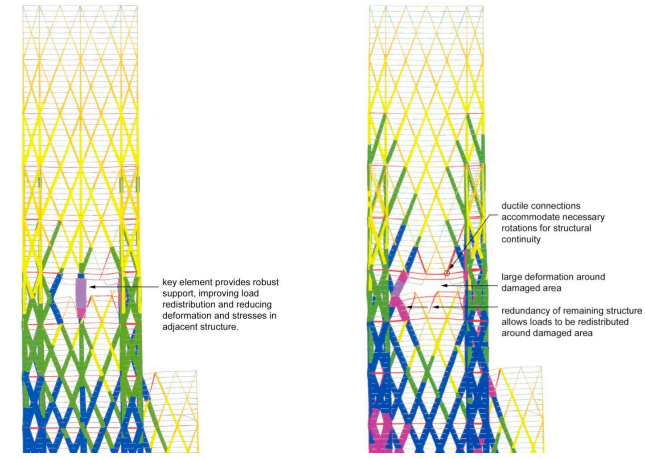



30th floor hotel



CFD modeling of fixed-position wind turbines

Prototype vertical hydroponic system (BrightFarm Systems)




Structure showing redundant, ductile systems surviving a major aircraft impact.

## Water/Waste

A greenhouse band encircles the building below each of these public floors, containing the biological waste treatment systems that clean and recirculate the building's water. Over 80% of building water will be reusable.

## Energy

The 2020 Tower has an average energy consumption of between 50 and 60 kWh/square meter per year, about one quarter the consumption of a standard building in 2001. The Building Integrated Photovoltaic skin of the building uses advanced thin-film modules, over 15% efficient and similar in cost to coated, laminated glass. The output from the opaque BIPV spandrels, and transparent BIPV windows (about one third the efficiency of the opaque units), provide 2/3 of all the energy consumed in the building. Given that we assumed the building is surrounded by 50 story structures, and that it also shades itself to some degree, wind turbines were needed to provide the remaining 1/3 of the building's energy.

## Vegetation and Food

The building skin is a multilayer system that can accommodate vines or other plants, or hydroponic growing systems. Vegetation provides seasonal shading, evaporative cooling, thermal mass, air filtration and oxygenation, as well as psychological benefits for people far above ground and the reach of natural vegetation. Growing food - primarily fresh produce like greens, fruits such as strawberries, and - provides all these benefits and more.

## Structure/Safety

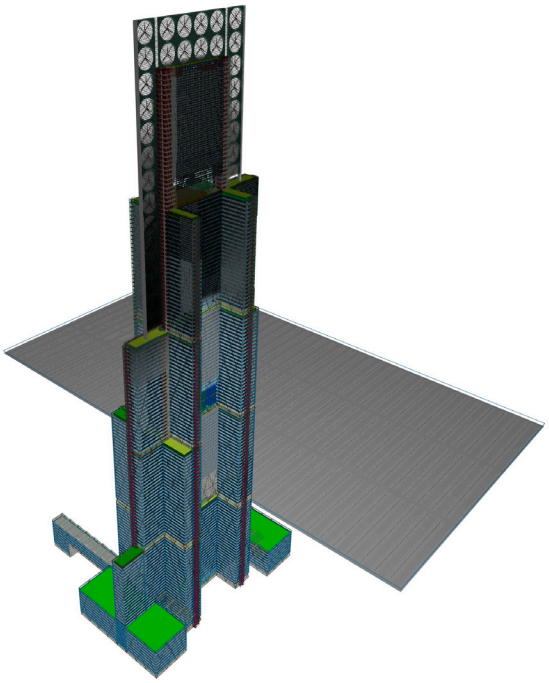
A diagonal grid of steel tubes defines a series of supertube elements, which create a self-bracing beam in elevation. The structure is designed with a high degree of redundancy, so that a large part of the structure could be destroyed without compromising overall building integrity. The thin plan requires that core elements (elevators, services) be divided into multiple sections, which is an amenity for people, promotes efficiency via multiple routes for services, and is a safety feature, providing more than one way out of the building.

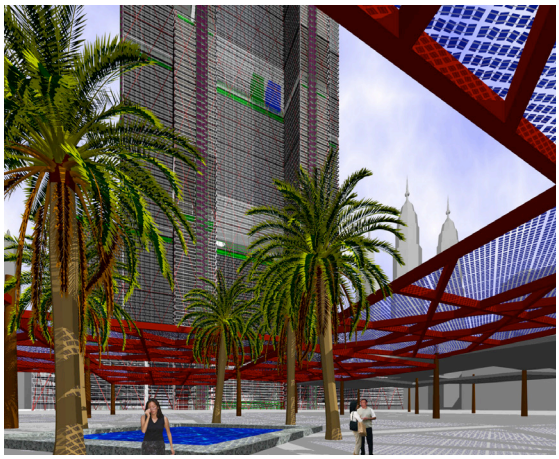
## Economics

Compared to a traditional building with a more compact footprint (less perimeter), the 2020 Tower would cost about 19% more to construct. The economic benefits of greater quality space (for example, higher rents for window offices vs interior space), plus lower operating costs, and greater human productivity and health, should provide a quick return on investment.

## 2020 Tower in 2016

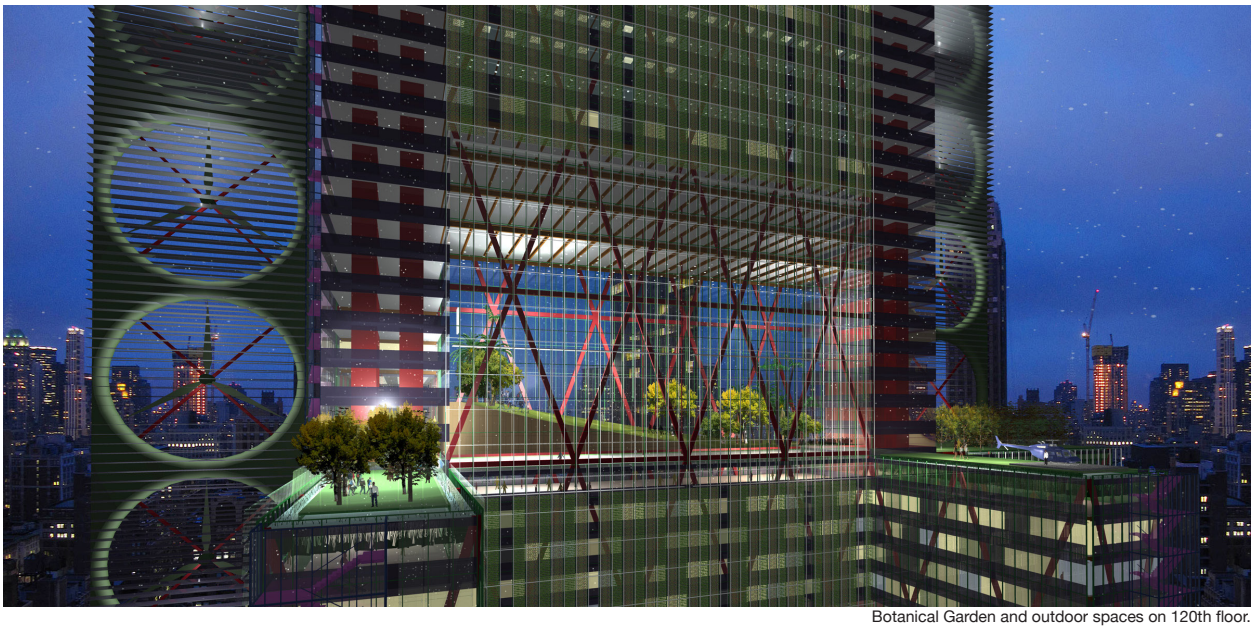
Adjusting our assumptions about the technology of 2020 to include 2010 technology, the majority of the performance criteria of the 2020 are attainable today. Technologies, costs, and configurations of systems will change to some degree, but the project is feasible today. We believe the benefits of self-sustaining infrastructure are real today and will become more evident as time passes.





To accomplish the zero energy goals of the 2020 tower with 2016 technology, additional PV generating area will be needed. This area can be integrated into sheltered or shaded site features, shading parking and/or public space.

Rendering of the 2020 Tower in Pudong, Shanghai



Botanical Garden and outdoor spaces on 120th floor.


The Rutgers/NSF project website

Rendering of the 2050 Tower. Note the wind turbines have been replaced with floor space.

## The 2050 Tower

Since more than ten years had based since the original 2020 Tower design, in 2014 the team updated the project to 2050 technologies, and also updated the performance criteria to reflect the greater ambitions we developed in the intervening years.

While the 2020 Tower was designed to be self-sufficient in terms of operating energy only (the energy required to heat, cool, light and power accessories within the building on a daily basis), the 2050 Tower was designed to provide additional energy to pay back the embodied energy of construction and maintenance over a 75 year lifespan. We also included waste to energy systems in the building. This reflects a more realistic assessment of the energy-related environmental impact of the project.

We also provided vertical greenhouse space to grow specifically the amount of fresh produce consumed on site by the building's inhabitants (i.e., meals consumed at home by residents, and lunches on work days by commercial occupants).

To summarize the changes from 2020 to 2050:

- Projections for technological improvement were updated to 2050 from 2020
- Energy demand increased to include operating plus embodied energy
- Waste to energy systems added based on site organic waste streams
- The wind turbines were removed based on the belief that they would not function reliably
- Integrated agriculture systems revised

**ENERGY SUMMARY SHEET**

-Operating Energy Consumed:

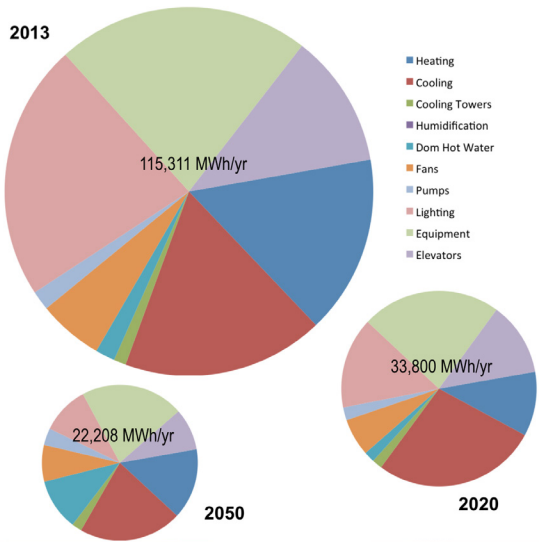
- 2013: -189.0 kWh/m2
- 2020: -55.4 kWh/m2/year
- 2050: -36.4 kWh/m2/year

-Energy Production Achieved:

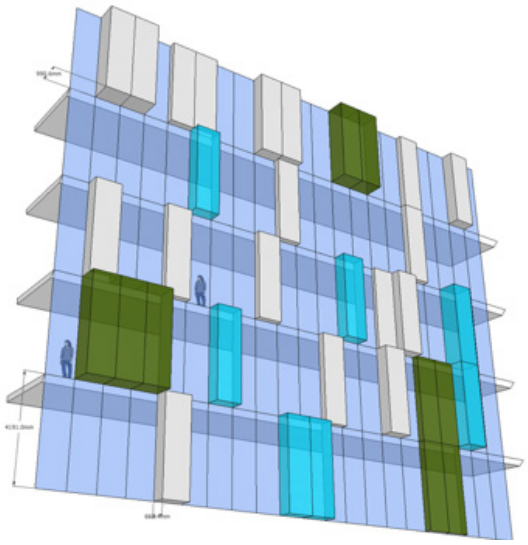
- 2020: +41.2 kWh/m2/year
- 2050: +60.5 kWh/m2/year

-Energy Balance

- 2020: -14.10 kWh/m2/year
- **2050: +24.1 kWh/m2/year**

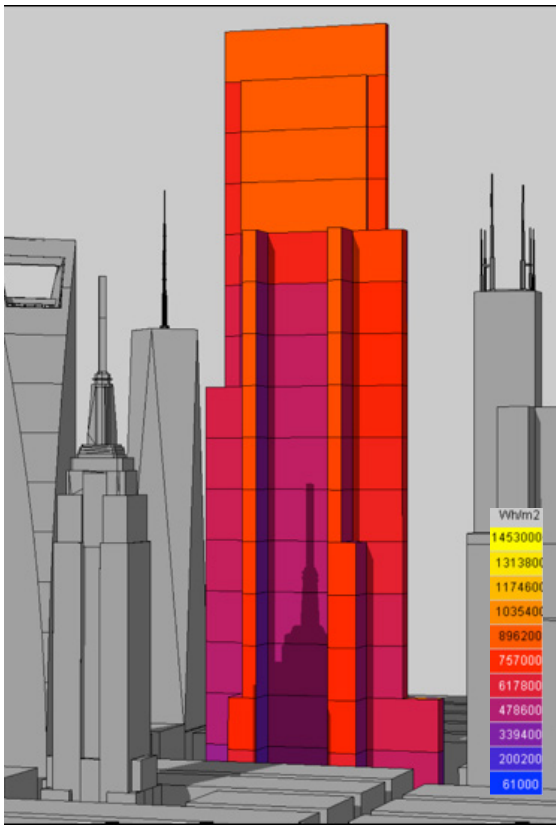



Energy consumption in 2013, 2020 and 2050



Modular facade components including individual vertical greenhouse units.

| BREAKDOWN | 2020 | 2050 | |
|---|---|---|---|
| **Energy production** | | | |
| % PV | 60.0% | *60.0%* | |
| System efficiency | 20.0% | 30.0% | |
| Unshaded context | 25,876 | 38,813 | MWh/year |
| Urban context | 23,546 | 35,319 | MWh/year |
| Urban context + greenhouses | 20,906 | 31,359 | MWh/year |
| Waste to energy | 3,661 | 5,491 | MWh/year |
| Total energy production | **24,567** | **36,850** | MWh/year |
| **Operating Energy** | | | |
| Basic operating | 55.4 | 36.4 | kWh/m2/year |
| | 33,800 | 22,208 | MWh/year |
| Water-desalination | 1,264 | 326 | MWh/year |
| Greenhouses | 5,041 | 1,260 | MWh/year |
| Other | | | |
| Total operating energy | **40,105** | **23,794** | MWh/year |
| **Embodied energy** | 4,521,593 | 834,156 | MWh |
| Life span | 75 | *75* | |
| Embodied energy/year | **60,288** | **11,122** | MWh/year |
| Operating + embodied | **100,393** | **34,916** | MWh/year |
| **Energy production/consumption** | | | |
| Operating only | **61.3%** | **154.9%** | |
| Operating + embodied | **24.5%** | **105.5%** | |




Insolation model in NYC climate conditions, hypothetical site.