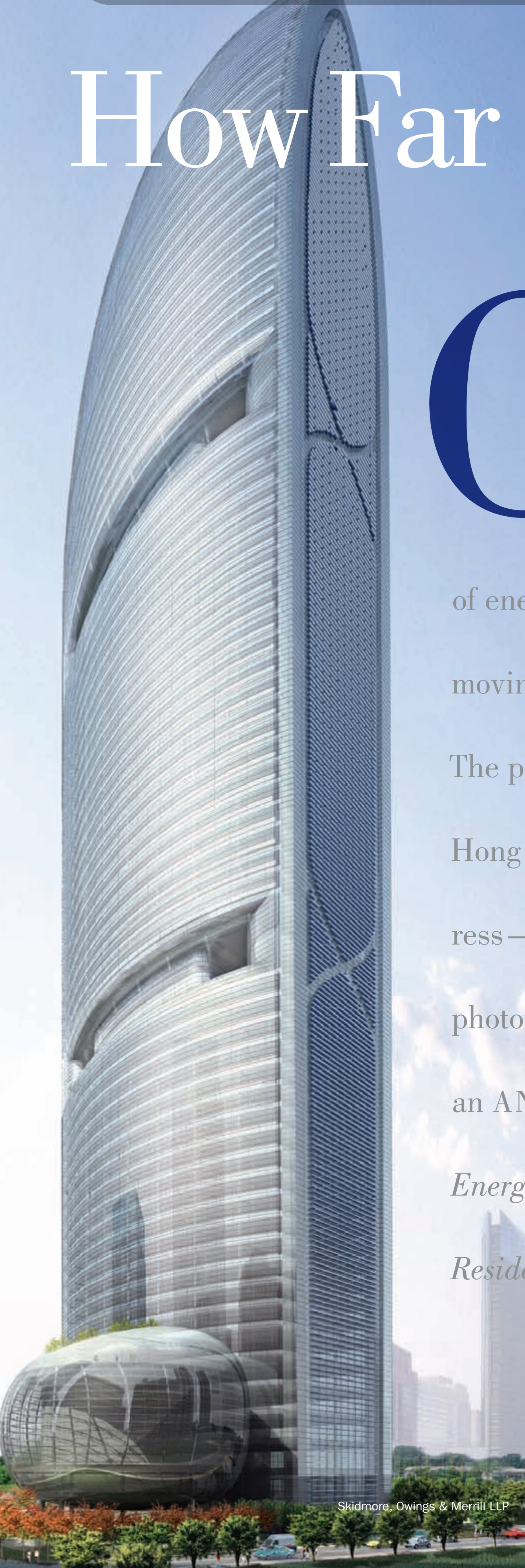
How Far Can You Go?

BY KYRA EPSTEIN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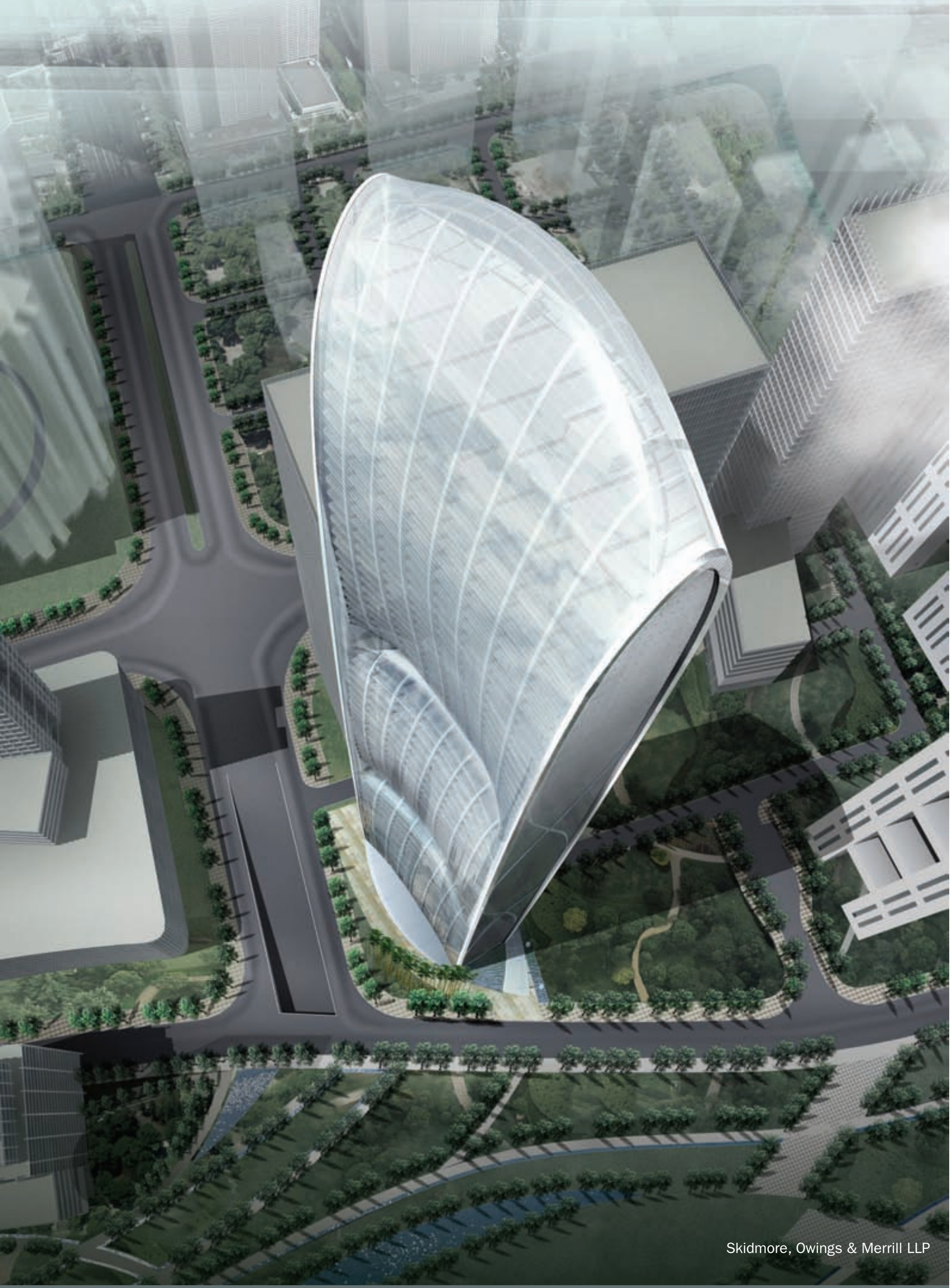
Guangzhou, China, has leaped the hurdle of energy-efficient buildings with a single bound, moving into a new era of efficient super-tall towers. The port city of 6.6 million, about 100 miles from Hong Kong, will soon have a new symbol of progress—a 71-floor office tower using wind turbines, photovoltaics and about 60% less energy than an ANSI/ASHRAE/IESNA Standard 90.1-2004, *Energy Standard for Buildings Except Low-Rise Residential Buildings* base case.

Left Depiction of Pearl River Tower



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Pearl River Tower is designed to be the most energy-efficient super-tall tower in the world.

The Pearl River Tower, which will be the corporate headquarters for the CNTC Guangdong Tobacco Company, was first designed as a carbon-neutral tower. But permitting (a lack of net-metering laws for commercial buildings) and cost issues whittled the efficiency predictions to a not-unimpressive 58% less than Chinese building code, which in the last few years has become, in some cases, more stringent than Standard 90.1.

It still is expected to be the most energy-efficient super-tall tower in the world, according to project engineer Roger Frechette, director of sustainable engineering at Skidmore, Owings & Merrill LLP (SOM).

BUILDING AT A GLANCE

Building Name Pearl River Tower

Location Guangzhou, China

Size 2.3 million ft²

Started 2006

Completed Estimated 2009

Use Office Building

Cost
Estimated $12 million more than a building designed to meet the minimum requirements of Standard 90.1

Distinctions
Designed to be the most energy-efficient super-tall tower in the world

BUILDING TEAM

Owner
CNTC Guangdong Tobacco Company

Architect
Skidmore, Owings & Merrill LLP (SOM)

SOM Project Team
MEP Roger Frechette, P.E., project engineer, SOM's director of sustainable engineering

Architecture Russell Gilchrist, project architect, SOM's director of technical architecture

Structural William Baker, P.E., FASCE, SOM's structural engineering partner

Management Tom Kerwin, FAIA, SOM's managing partner

Wind Engineering Consultant
Rowan Williams Davies & Irwin Inc. (RWDI)

RWDI Project Team
Ray Sinclair, Ph.D; Duncan Phillips, Ph.D.; Glenn Schuyler, Ph.D.

Other Key Players
Guangzhou Design Institute

All of this, Frechette said, can be done cost effectively. The project, as currently designed, costs $12 million more than a building designed to meet the minimum requirements of Standard 90.1—all of which can be recovered in about five years due to reduced energy costs and the increased retail and office space that smaller HVAC equipment freed up.

"We wanted to know: how far can we go? Is it really possible to create a carbon-neutral tower building?" said Frechette. "Even though the current design is not carbon neutral, we've set a very high bar and we're doing something that hasn't been done before. We hope that we, and others, can learn something from this process and maybe someone can beat that mark."

The bar is high, and many of the building features are creating a stir even now, two years before the tower is scheduled to begin operations.

Building-Integrated Power Generation

Wind power—integrated into the design of the building—is one of the tower's distinct features. The building has four large openings in the envelope, two on each of the two mechanical floors, which house four small wind turbines.

Guangzhou's typical wind speed is usually a fairly mild 9 mph at that elevation, but the air is literally pulled

COOLING FROM ABOVE, AIR FROM BELOW

Of all the elements in the Pearl River Tower's energy-efficient design, the radiant cooling system is the biggest energy saver. In this system, water flows through ceiling panels and provides cooling from there.

Frechette says that the team looked to Germany for this technology—it is rarely used in North America and is unusual in China. Another record-breaker, the system will be the largest radiant cooling system in the world.

Because cooling is delivered by water instead of air (and no heating is necessary in the tropical climate), the system does not need to move air to cool the building. This saves the energy needed to run that equipment and the money to buy and maintain it.

A ventilation system is still necessary to bring in air for breathing; the system designed will deliver necessary ventilation underneath floors that are already raised to provide room for cable. In this design, swirled diffusers bring a supply of fresh outside-only air into the space and help to mix the air. This "once through" approach to ventilation improves the health of the building by reducing the risk of occupant exposure to airborne viruses and odors.

"We have a building that takes outside air, filters it, puts it into the building and then vents it from the building," said Frechette. "Conventional buildings use recirculation to cool or heat air because the air has already been cooled, and it saves energy. We aren't using air for cooling, so the small quantity of air we bring in from the outside, for breathing, is not that expensive or difficult to cool."

Because there is no need for large volumes of air and minimal fans, the shafts that run vertically through the building are smaller, saving space that can be used for office and/or retail space.

These systems also are quieter than the conventional design. A typical office floor in a United States building would be designed to have noise levels around 30 to 40 NC (noise criteria scale)—it's difficult to get levels lower than that due to VAV boxes, fan coil units and mechanical room fan and/or compressor noise. Modeling shows that Pearl River Tower occupants will enjoy spaces that are a quiet 25 NC.

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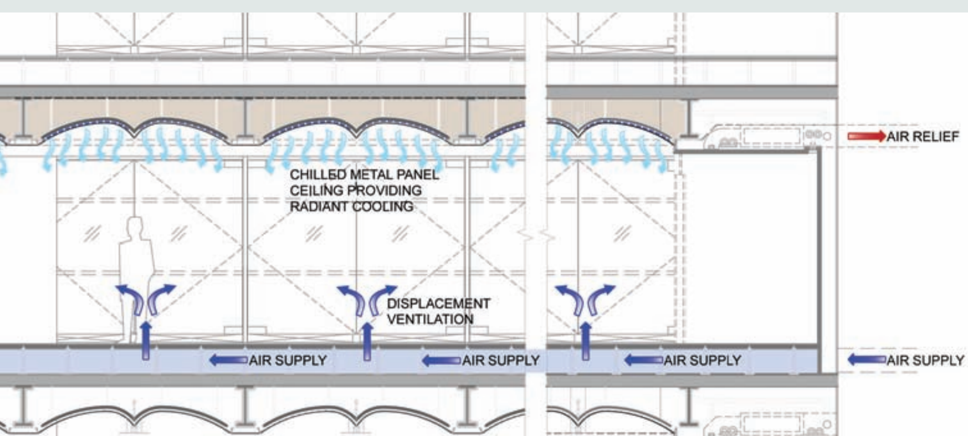
Radiant cooling panels in the ceiling provide cooling; ventilation air is delivered from below the floor.



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Air space between the two layers of the façade traps heat, which is vented out of each floor before it can radiate into the space.

The Pearl River Tower's wind design is based on a small turbine (almost 10 ft or 3 m in diameter) by English manufacturer Quiet Revolution. Each of the design's four turbines has a rated performance of 10,000 kWh per year.

SOM pulled in the largest wind engineering and consultancy in the world to help them with testing and modeling for the wind design—Canadian firm Rowan Williams Davies & Irwin Inc. (RWDI).

RWDI's models helped to size and place the turbines and provided suggestions to SOM for selecting turbines—considering maintainability issues, noise, and vibration issues.

One of RWDI's tasks was to model wind potential. Power potential for wind is a cubed relationship, Frechette said. Air is pulled through the building, accelerating the speed of the wind by more than two times—and increasing its power potential by a factor of eight.

For this site, models showed that average wind speeds of 9 mph (4 m/s) will speed up to as fast as 18 mph (8 m/s) when they are sucked through the building openings.

"In essence, one wind turbine located in one of the openings could theoretically produce the energy of eight turbines somewhere else," said Frechette. "So, this building has power comparable to 32 turbines."

The turbines are estimated to provide 1% of the building's energy needs.

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Pearl River Tower design was based on a turbine by Quiet Revolution.

through the holes in the envelope by the negative pressure on the leeward south side, accelerating winds to speeds of about 18 mph.

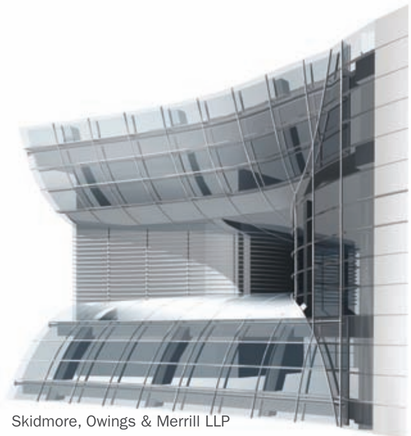
Modeling and wind tunnel testing show this design has a power potential capacity of nearly 15 times more than a typical stand-alone wind generator—in this case about 1% of the tower's power needs.

The design was based on using four small wind turbines manufactured by Quiet Revolution, which have a capacity of 10,000 kWh per year.

SOM also is taking advantage of the tropical sun, using two kinds of solar electric panels on the east and west façades. At the crown of the tower, the design calls for photovoltaic (PV) technology integrated into more than 16,000 ft^2 (1500 m^2) of the façade glass itself. Another 16,000 ft^2 (1500 m^2) of PV will be mounted onto the fixed solar shading feature on the west façade.

In all, the tower's PV technology will have a 300,000 kWh capacity (about 2% of the building's needs).

The wind and photovoltaic systems not only reduce the amount of electricity needed from the power grid to operate the building, but also create a more efficient system altogether. SOM's initial design also included the capability of producing power on-site using microturbine technology. Conventionally, power generation starts at the power plant, sends electricity along lines to a transformer, and finally to the building's wall receptacles. Energy is lost along every step of the way, making that energy pathway about 30% efficient.



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Four openings in the façade house the wind turbines and reduce pressure on the tower structure.

Generating electricity at the site where it will be used reduces the losses that come from handling and distributing it. According to Frechette, the Pearl River Tower systems, with heat recovery, would be able to use about 80% of the energy that is produced, much more efficient than "importing" electricity from the utility.

Multipurpose Double Wall Façade

With 71 floors of glass exposed to tropical sun, one key element to reducing cooling load and the energy associated with it is the façade itself. SOM and their Canadian subcontractor Rowan Williams Davies & Irwin Inc. (RWDI) used modeling and wind tunnel testing to find the façade that would fit the structure and design intent.

LESSONS LEARNED

With more likely still to come, Frechette and Sinclair already have a list of lessons learned.

Early Involvement First, said Frechette, to create a truly high performance building it is critical to assemble all of the primary stakeholders of the project at the very beginning of the design process to obtain full buy-in before proceeding. He lists the stakeholders as the design team, consultants, contractors, city officials, local utilities, as well as the owner.

As an example, one major stumbling block during the design process was the fact that the local electric utility would not allow, or did not have the policies in place, to allow the owners to sell power to the grid (net metering). This problem was not discovered until well into the design process and was one of the major factors in not meeting the carbon neutral goal.

Design Team Balance Another lesson is the importance of the makeup of the design team. The proper balance of individuals is important to achieve what Frechette calls "pragmatic innovation."

"We have all seen intriguing design concepts that are never seen through to fruition due to the impracticality of the detail," he said. "For innovation to be fully realized on a major project, the design team must be made up of individuals who can dream of what might be possible, working in concert with individuals who are grounded with years of practical no-nonsense experience. This pairing of personalities leads to fully attainable, realizable innovations."

Double Façade Sinclair points out that the double façade design is not for every building. The systems require a significant amount of engineering and particular conditions—they are not an automatic silver bullet for high performance buildings, though the Pearl River Tower design is a good application of the technology.

CFD Modeling He also emphasizes that high performance can sometimes mean "highly complicated": "As buildings become more sustainable and use less energy to move more air, the air tends to migrate in natural ways with less velocity," he said. "That means flows are weak and will slosh around. Higher levels of CFD modeling are required. We found that was an important consideration."


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At the crown, PV technology is integrated into the façade glass.

Most buildings have a single exterior façade, but the Pearl River design has an insulated exterior layer (two pieces of glass sealed together) and an inside layer—with air space sandwiched in between the two layers. When heat from the sun warms the air in the space between the layers, it is vented out of the building, before it can radiate into the space, by fans drawing air from a slot at the bottom of the glass on each floor.

The air is drawn into the mechanical room where it can be released from the building if it's hot air, or used to draw humidity out of the space with a heat exchanger. In essence, it's a solar-powered dehumidification system. RWDI's modeling helped optimize the airflow needed to size the dehumidification system and airflow, and found that an estimated few hours of running the system after a shut down will remove moisture from the space and prevent condensation on the radiant ceiling panels.

Automated shading devices, integrated into the façade on the north and south exposures, will be integrated in the active double-wall enclosure. These devices will be operated by a daylight-responsive control tied into an energy management system and will optimize the amount of daylight and heat being delivered to the space.

RWDI project manager Ray Sinclair, Ph.D., helped model the flow of air from the façade through the building. With automatic shading and the façade's airflow design, modeling shows that the inside of the façade will never get hotter than about 80°F, and that glare will not impair the comfort of the occupants.

"We modeled all of the factors that affect heat transfer and heat moving through the cavities," said Sinclair. "Then, we optimized the amount of air moving through the cavity, and we showed that you could achieve comfort at the perimeter of the space even in worst-case solar times of the day — while still maintaining views and daylight."

Operations and Maintenance: Is It Easy to Work?

A high performance building requires attention even after the design is implemented and the building is operational. The SOM team partnered with the local Guangzhou Design Institute to take the lead on the assembly of training manuals, and the owner plans to hire an experienced firm to operate the building.

But, according to Frechette, the unique systems being implemented actually should decrease the amount of operation and maintenance effort required, compared to a conventionally designed building. For example, the radiant ceiling systems, serving the office floors, eliminate the need for VAV boxes and fan coil units, minimizing maintenance and operations tasks such as changing filters, cleaning coils, repairing damper actuators, and responding to complaints about fan and air noise — not to mention the frequent requirement of balancing and rebalancing air systems as tenants move in and out of the building.

Looking to the Future

Though the project has been a challenge, Frechette said he has found it to be exciting and very rewarding. He hopes that the technologies included in the tower design will become more mainstream, and that the project will encourage other designers to consider high performance technologies.

"We're in the middle of an environmental crisis that largely has to do with carbon emissions," Frechette said. "Even architects and engineers need to be reminded that buildings produce more emissions than industry or transportation. We need to challenge ourselves to take this on, and we hope this project is a baby step in the right direction."

Or maybe a giant, 71-story leap in a single bound. ●

Wind and photovoltaic systems reduce the amount of electricy needed from the power grid to operate the building.

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ABOUT THE AUTHOR

Kyra Epstein is a technical writer who has worked with the National Renewable Energy Laboratory (NREL), Architectural Energy Corporation, and LOHAS (Lifestyles of Health and Sustainability).