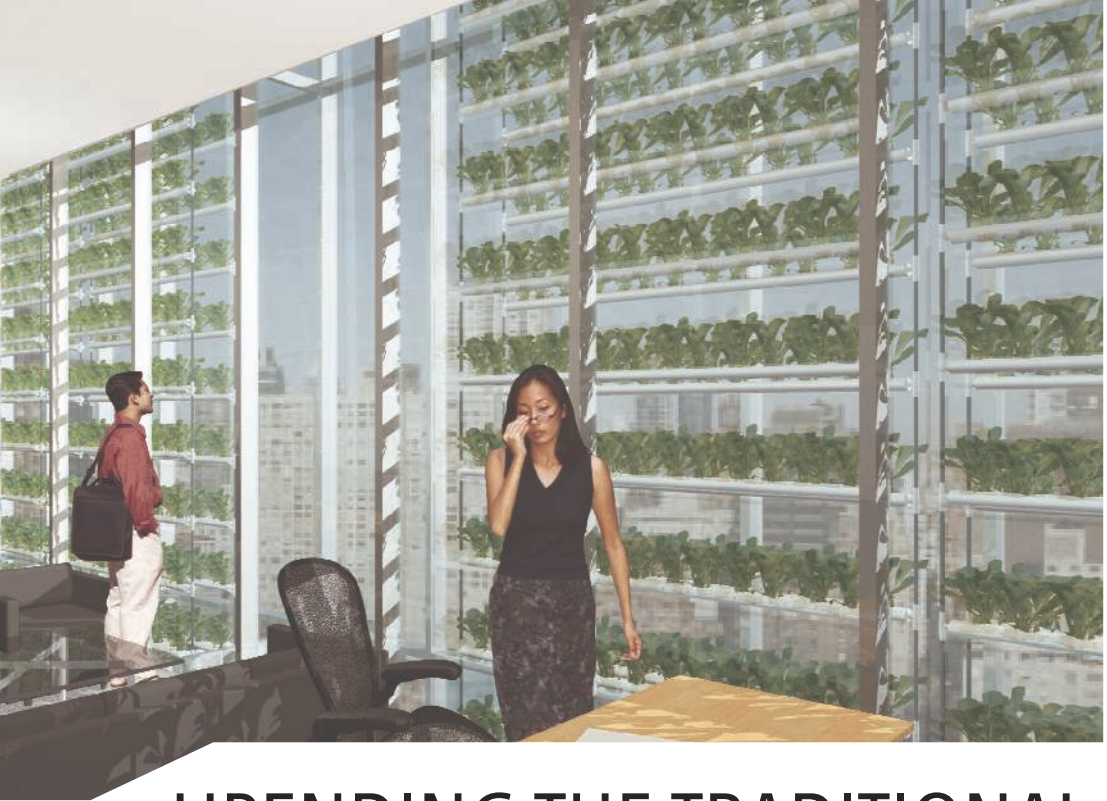

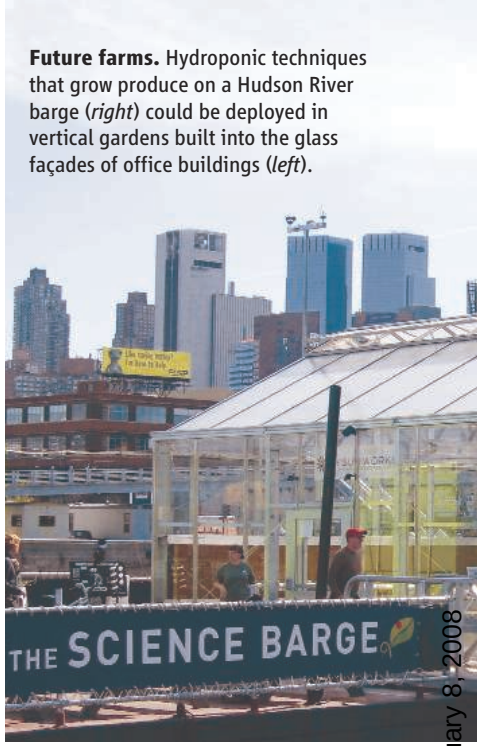

Future farms. Hydroponic techniques that grow produce on a Hudson River barge (*right*) could be deployed in vertical gardens built into the glass façades of office buildings (*left*).

UPENDING THE TRADITIONAL FARM

Cities are taking over farmland. Could they someday take over the job of farming, too?

IN A HIGH-TECH ANSWER TO THE "LOCAL food" movement, some experts want to transport the whole farm—shoots, roots, and all—to the city. They predict that future cities could grow most of their food inside city limits, in ultraefficient greenhouses.

"Vertical farms," proponents say, could produce more food using a fraction of the resources that traditional farms consume. The lives of millions of people may depend on it. Dickson Despommier, a parasitologist at Columbia University and an avid proponent of vertical farming, calculates that with projected population increases, the world will need 1 billion more hectares of arable land by 2050—roughly the area of Brazil and far more land than will be available.

Researchers are now putting prototypes of intensive urban farms to a real-world test. The basic concept is an evolution, not a revolution, of greenhouse technology. Greenhouses "can grow any crop anywhere at any time—at a cost," says Gene Giacomelli of the Controlled Environment Agriculture Center at the University of Arizona in Tucson, which has built a $450,000 greenhouse for researchers who winter at the South Pole. Well-designed greenhouses use as little as 10% of the water and 5% of the area required by farm fields, says Theodore "Ted" Caplow, executive director of the engineering company New York Sun Works in New York City, which designs energy-efficient urban greenhouses. "We are removing that footprint from the countryside," he says, and reducing pressure on habitats and depleted soils.

Urban indoor farms can't do it all. Growing grains such as wheat, corn, and rice indoors does not save as many resources as growing vegetables and fruits indoors, says Caplow, and most trees grow too slowly to make greenhouse orchards pay off. Some of the more ambitious concepts for vertical farms will require technological breakthroughs in lighting and energy consumption. And initially, at least, urban produce will likely be more expensive than that grown at conventional farms and shipped to a city.

But as oil prices rise, greenhouse economics look more favorable, Giacomelli says. "All our cheap food is based on cheap transportation, cheap water, and cheap energy for nitrogen-based fertilizer," he says.

One approach that could be implemented quickly is rooftop greenhouses. In a demonstration of what can be grown on New York City's roofs, Caplow's company last summer built and operated the Science Barge, a floating greenhouse on the Hudson River that used solar power and recycled water to grow fruits and vegetables. New Yorkers eat 100 kilograms of fresh vegetables on average per year, Caplow says, and the rooftops of New York City would provide roughly twice the needed space to supply the entire city. New York Sun Works is now installing a demonstration greenhouse on top of a New York City school that would serve as a teaching area and supply produce to its cafeteria.

A more ambitious concept is farming the facades of office buildings. Double-glass facades are already popular among architects as an energy-saver, allowing winter sun in while insulating against noise and heat loss. In the summer, most double facades have built-in shades to keep the interior cool. Hydroponic gardens could provide that shade, Caplow says. Vertical conveyor belts could cycle plants to the lower floors in time for harvest. "The systems we are designing are what we can actually do today," Caplow says.

Gazing further into the future, Despommier and his students are refining the idea of skyscraper farms. They estimate that a 30-story farm on one city block could feed 50,000 people with vegetables, fruit, eggs, and meat. Upper floors would grow hydroponic crops; lower floors would house chickens and fish that consume plant waste. Heat and lighting would be powered by geothermal, tidal, solar, or other renewable energy sources. Nitrogen and other nutrients would be sieved from animal waste and perhaps from the city sewage system. "That's where a significant fraction of your fruits and vegetables are going," into sewage, Despommier says. "You have to close the loop." Eventually, he says, hydroponic greenhouses could

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also be a boon for the developing world. In tropical regions, they could make use of ample sun, conserve water, and give worn-out soils a rest. Ideally, they would also provide a way to safely turn human waste into plant food, he says.

Such ideas are inspiring, says Jan Broeze, an agricultural scientist at the University of Wageningen, the Netherlands. But "you need large technological breakthroughs" in lighting and waste processing to realize them. In 2001, Broeze, Peter Smeets, and their colleagues proposed a six-story urban farm called Deltapark at Rotterdam harbor that would recycle water and nutrients and use excess heat from nearby buildings. The agricultural ministry supported Deltapark, but the project was abandoned after the press criticized it for being "too industrialized." Now Broeze is working on several projects that link greenhouses with livestock producers to recycle waste and reduce energy consumption. And he and other Dutch scientists are working with colleagues in India and China to design urban farms in several cities. The biggest project is part of Dongtan Eco-city, near Shanghai (see p. 740).

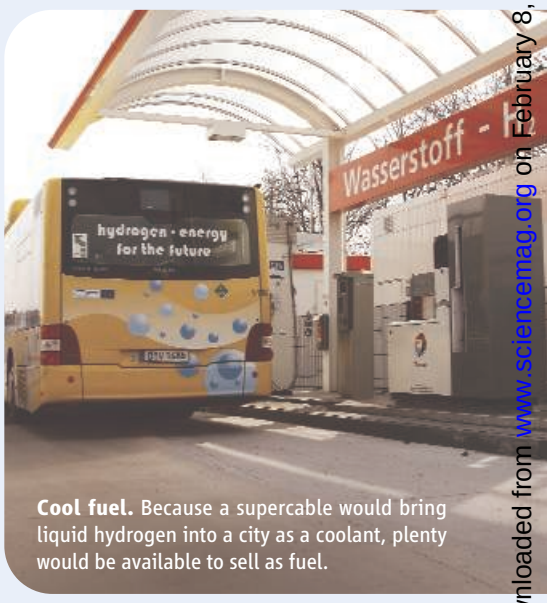
One goal of Dongtan is to grow enough food to replace lost productivity as farmland is urbanized, says Peter Head, director of Arup, a design company leading the project. "The big question is whether it is economically viable," he says. Head predicts that the lessons learned in China will propel a fundamental shift in the world's approach to agriculture. "It isn't a matter of whether we think it would be nice to do urban farming or not," he says. "It's a matter of whether we are going to survive."

–GRETCHEN VOGEL

Imagining a City Where (Electrical) Resistance Is Futile

IF YOU WERE BUILDING A CITY IN THE 21ST CENTURY, HOW WOULD YOU POWER AND FUEL IT? Pipe in electricity by copper cable and haul in gasoline by road, as is done today? Paul Grant thinks not. He envisions using superconducting electrical cables and liquid hydrogen to energize a metropolis while emitting little or no carbon.

Grant's "SuperCity" is popular with proponents of nuclear energy because it relies heavily on the next generation of nuclear plants. But the hard work of fleshing out the concept and developing the cables has only just begun. "The basic research still needs to be done. Can this thing really be built?" asks electrical engineer Thomas Overbye of the University of Illinois, Urbana-Champaign, who has organized a couple of workshops on the related idea of a SuperGrid to wire a whole continent. Not everyone is convinced. "We should sort out the problems with the energy system we have" before inventing new ones, says Robert Socolow of the Energy Group at Princeton Environmental Institute. Grant concedes that at the moment, SuperCity remains a utopian vision. "It's about the energy society we should be looking at 50 years from now," he says.



Cool fuel. Because a supercable would bring liquid hydrogen into a city as a coolant, plenty would be available to sell as fuel.

While working at IBM's Almaden Research Center in northern California during the 1980s, Grant pioneered the development of high-temperature superconductors, complex oxides that carry electricity with zero resistance at temperatures that are low but much higher than those for earlier materials. Unlike their predecessors, high-temperature superconductors can be cooled using easily obtained liquid nitrogen. In 1993, after more than 40 years with IBM, Grant moved down the freeway to the Electric Power Research Institute (EPRI) in Palo Alto, where he applies his skills to solving energy problems, such as improving transmission. In 1999, Grant was challenged to come up with a "wild idea" to present at a U.S. Department of Energy (DOE) meeting on superconductivity. His brainstorm was to combine superconducting cables with a hydrogen economy.

Today's electricity grids lose about 7% of power to resistance, so superconducting cables would boost efficiency—if the lines could be supercooled. Grant proposed pumping liquid hydrogen into a pipe in which the superconducting cable runs down the middle, creating a "supercable" that carries both electricity and hydrogen into a city. Fuel stations could tap into the coolant to power electric fuel-cell cars. Hydrogen could also be burned for domestic heating and cooking, circulated au naturel for air conditioning, or converted into electricity during peaks in demand.

The SuperCity requires nuclear power to generate electricity, Grant argues, because renewable energy sources such as biofuels and wind or solar farms take up valuable land and degrade the environment. "You cannot beat nuclear for its [small] footprint and [high] power density," he says. Upcoming nuclear reactor designs, known as generation IV, will operate at high temperatures and produce hydrogen as a byproduct of electricity generation. Grant's SuperCity doesn't dismiss other energy sources entirely, however. Every roof could be covered with solar cells, and waste could be burned to generate power. Such alternative sources could supply about 10% of a city's energy demand, he says.

Because of the huge investment sunk into conventional technology, it may take decades to realize the entire SuperCity vision. Supercables integrated into the electricity grid could happen sooner. "It would have immediate appeal," says Steven Eckroad of EPRI, which has carried out cable-design studies. Overbye adds: "The concept really needs a big funder [such as DOE] to step up and say, 'This is the way we're going to go.' But that hasn't occurred yet."

Grant, now retired from EPRI but still consulting, is undaunted. "If we were starting from scratch on another planet, this would be the way to do it," he says.

–DANIEL CLERY

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