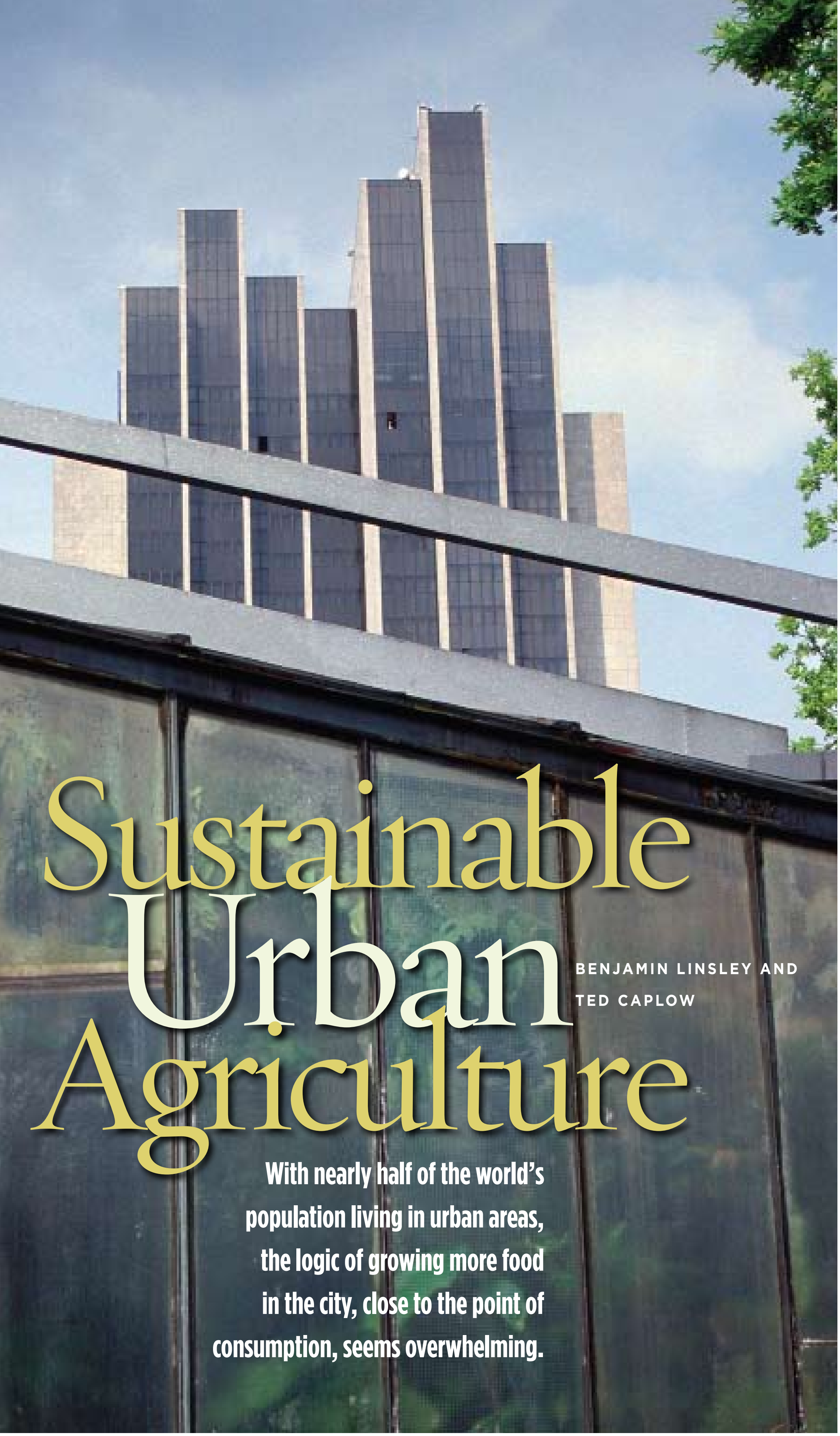

# Sustainable Urban Agriculture

BENJAMIN LINSLEY AND TED CAPLOW

**With nearly half of the world's population living in urban areas, the logic of growing more food in the city, close to the point of consumption, seems overwhelming.**

Many of the most effective inventions of an era actually are not entirely new when they break ground. More often than not, they are reapplications of existing technologies to a new or different problem. This process of adapting an extant technology to a different problem is at the heart of a new approach to sustainable food production. As ever more attention is directed at the environmental flaws in today's agricultural industry, and as global climate change and its implications place additional constraints on available resources of land, water, and energy, the need for creative and adaptive methods of food production has become clear. This article proposes a new, effective, and pragmatic approach to urban agriculture. The two questions it seeks to address are *how* and *where* food is produced.

## The Challenge

Modern farming, which feeds billions every day, is the world's largest consumer of both land and water, is the primary source of water pollution, and accounts for 15 percent of global greenhouse gas emissions. The production of a single kilogram (2.2 pounds) of tomatoes grown today under average conventional practices in the United States requires 170 milliliters (5.74 liquid ounces) of diesel fuel, 1.3 milligrams (0.00004 ounce) of pesticide, and 140 liters (37 gallons) of water. During this process, according to a New York Sun Works analysis, about half a kilogram (1.1 pounds) of carbon dioxide gas is released into the atmosphere.

Global competition for limited agricultural land, domestic dependence on imported food, and shifting commodity prices have made food insecurity a major concern across the world. Last December, *The Economist* reported that its global food-price index had reached its highest level since records began in 1845. According to the United Kingdom's Office for National Statistics, wholesale food prices rose 7.4 percent during 2007, three times the headline (Retail Price Index) rate of inflation. The higher wholesale prices drove the average cost of groceries up 12 percent in that one year, according to an article published on January 16 in *The Daily Telegraph*.

Fresh produce typically travels thousands of kilometers to reach urban consumers, adding to traffic congestion, air pollution, and carbon emissions. In the United States, for example, food items on average travel 2,400 kilometers (1,491 miles) before arriving at consumers' tables, according to R. Pirog and A. Benjamin in a 2003 report published by the University of Iowa. In the United Kingdom, food transport accounted for an estimated 30 billion vehicle kilometers (18.6 billion miles) in 2002 and produced 19 million tons of carbon dioxide, of which 10 million tons were emitted in the U.K., according to the Department for Environment, Food, and Rural Affairs. Concurrently, city dwellers and policy makers are fast falling out of love with our food transport habits. Carbon labeling of food already exists in some European Union countries and may soon become mandatory in many more.

With nearly half of the world's population living in urban areas, the logic of growing more food in the city, close to the point of consumption, seems overwhelming. Indeed, urban farming has enjoyed steady growth in popularity in recent years: the city farms such as Added Value, which started in 2001 in New York City, and Growing Power, which opened in 1982 in Chicago, have been real success stories. And the methods employed by these urban farms, which tend to be rooted in the organic farming movement and allied closely with the community-supported agriculture movement, are comparatively sustainable. The problems such city farmers face, however, is a lack of land. The controversial bulldozing of Los Angeles's South Central Organic Farm in 2007 illustrates most city farmers' worst nightmare: even the best run and most popular farms can be priced out of business by rising ground rent values. Furthermore, city farms are usually small, with only modest output—a problem exacerbated by low-yield organic methods. They lack enough land at ground level to be highly effective feeders of large urban populations.

Fortunately, this lack of land does not constrain all forms of agriculture. While soil-based farming systems may be limited to ground-level applications, modern hydroponic techniques most certainly are not. By adapting hydroponics, the high-yield farming technique used in the commercial greenhouses of the controlled environment agriculture (CEA) sector, the industry has a real opportunity to produce—in an efficient, cost-effective, and environmentally sustainable fashion—significant quantities of food on and in buildings within the heart of the city.

## The Science Barge

**In 2007, New York Sun Works built the Science Barge as a prototype for a sustainable urban farm. Constructed on a 4,305-square-foot (400-sq-m), steel deck barge moored in midtown Manhattan, the Science Barge is the only fully functioning demonstration of renewable energy supporting sustainable food production in New York City.**

**The purpose of the facility is to demonstrate a selection of technologies that, when brought together, can enable commercial yields of premium-grade vegetables to be grown in the middle of a large urban area. Vegetables from the Science Barge are grown within a stone's throw of the point of consumption, and with a fraction of the environmental impact of conventional agriculture. The facility grows tomatoes, cucumbers, squash, bell peppers, and high-value herbs, as well as many varieties of lettuce, with zero net carbon emissions, zero chemical pesticides, and zero runoff.**

**The principal feature of the Science Barge is a 1,291-square-foot (120-sq-m) greenhouse using state-of-the-art recirculating hydroponic farming techniques. The greenhouse electrical systems are powered by solar, wind, and biodiesel. A rainwater catchment system provides all the water needed to cultivate the plants.—B.L. AND T.C.**

NEW YORK SUN WORKS


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**Unlike most conventional farms today, the Science Barge (above), a hydroponic demonstration facility moored in midtown Manhattan, grows a variety of vegetables (top) in its greenhouse without emitting additional carbon or generating any runoff.**

### A Promising Alternative

Hydroponics refers to the growing of plants, especially vegetables, in water rather than soil. The water contains the essential mineral nutrients needed by plants. Recirculating hydroponics, the most modern and environmentally robust version, can yield premium-quality vegetables and fruits using ten to 20 times less land and five to ten times less water than conventional agriculture. Producing food using these modern greenhouse techniques also eliminates chemical pesticide use, fertilizer runoff, and most of the carbon emissions from farm machinery.

Hydroponics, which is practiced in most regions of the world, is a technically sophisticated commercial practice, but it is practiced on the most industrial scales in the Netherlands, Israel, Spain, the United Kingdom, Mexico, Canada, and the United States. Commercial greenhouses in Almeria, Spain, for example, where much of the salad crops eaten in the United Kingdom are grown, cover an area of around 20,000 hectares (49,400 acres). Today, there are over 1,200 hectares (2,964 acres) of hydroponic vegetables produced in the United States, Canada, and Mexico. In 2007, British grower Fresca Group Ltd. announced plans to develop a new 91-hectare (224-acre), high-tech greenhouse complex on the Isle of Thanet in Kent. The controlled environment agriculture industry is booming.

By maintaining a constant temperature throughout the year, these hydroponic greenhouses are able to cultivate premium-grade

## BrightFarm

The BrightFarm system transfers the sustainable urban farming techniques demonstrated on the Science Barge onto a rooftop. Making use of waste-heat capture from the host building or an adjacent structure, and with fully integrated renewable power sources, this system allows for year-round, sustainable urban food production. New York Sun Works is currently working on two versions for two different scales: BrightFarm Schools and BrightFarm Commercial.

BrightFarm for Schools delivers environmental education through sustainable urban food production. The system uses hydroponic greenhouse technology, powered by renewable energy, to grow food for consumption in the school cafeteria. The rooftop learning laboratory provides a unique facility for teaching science concepts, including plant biology, energy, food production, nutrition, and environmental sustainability.

A four-bay facility to be built on the roof of the Eleanor Roosevelt School in the Washington Heights neighborhood on the upper west side of Manhattan is the first of three systems currently in design. Two of its four bays will be dedicated to hydroponic crop production, and a third bay will provide dedicated year-round classroom space for the teaching of environmental science. The fourth bay will serve as storage space for engineering and teaching equipment.

Meanwhile, the BrightFarm concept is being applied at a much larger, commercial scale as well. New York Sun Works is working with an emerging urban farmer to design and construct BrightFarm Commercial 10011, a fully automated, climate-controlled greenhouse for fresh vegetable production on the roof of a ten-story warehouse building in the heart of New York City. Once construction is complete in summer 2008, the greenhouse will ensure secure, healthy, and cost-effective year-round production of premium-quality vegetables, leafy greens, and herbs. These crops will be marketed to local restaurants and retail outlets. According to New York Sun Works' calculations, the rooftop needs to be at least 32,291 to 53,819 square feet (3,000 to 5,000 sq m) for a BrightFarm system to operate as a profitable commercial venture.—B.L. AND T.C.

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**A Brightfarm system for the roof of a supermarket, the primary distribution point for produce, is currently in development.**

KISS + CATHCART, ARCHITECTS

**The first BrightFarm for Schools system, which will include hydroponic crop production and year-round space for environmental science classes, is being designed for the Eleanor Roosevelt School in New York City.**

produce in all four seasons. But heating the greenhouse is the principal challenge for the CEA industry from both an environmental and a financial perspective. Traditional heating methods are extremely costly, are subject to energy insecurity, and, of course, result in heavy carbon dioxide emissions.

### Building Integrated Agriculture

Locating the hydroponic greenhouse not only in cities but actually on buildings—an approach referred to as building-integrated agriculture—offers a solution to the two principal challenges introduced above: the need to reduce the environmental impact of growing produce and the need to decrease the distance that food travels before arriving on the plates of urban consumers.

Situating environmentally low-impact hydroponic greenhouses on underutilized flat roofs in the city would provide an urban farm with more space than would have been available at ground level at any price. And, equally important, the building itself also can provide a cheap source of heat for the greenhouse. Most urban structures, due to their size, dense occupancy, and internal power consumption, discharge substantial amounts of heat through the building envelope all year round, whether deliberately or otherwise. This heat is often difficult and expensive to recapture for building use, but could be easily used as a source of heat for plants. In addition, plants welcome the high levels of carbon dioxide—the product of human respiration—in the air exhausted from building ventilation systems.

Hydroponic greenhouses are relatively light and thus installation on rooftops does not normally require significant structural reinforcement to the host building. Advanced systems also capture rainwater for use in the greenhouse, thereby helping reduce stormwater runoff in the highly impermeable urban landscape.

Moving the farm into the city and onto the rooftops of buildings not only addresses the challenge of food transportation and agriculture sustainability, but also assists with the efficiency of the host structure. A fully integrated system should use solar panels, integrated into the greenhouse or sited next to it, to provide a renewable source of power for the greenhouse and, when excess sunlight is collected, to deliver surplus electricity to the building itself or to the city's power grid. Furthermore, a rooftop covered with vegetation will significantly reduce solar heat gain through the roof and will help mitigate the urban heat island effect.

It goes without saying that many roofs are simply not appropriate for this kind of use. Small residential buildings or structures with pitched roofs are less likely to be worth the capital outlay that these systems require. But on your next journey through the urban landscape, look around and consider how many supermarkets, warehouses, schools, hospitals, and shopping centers have flat roofs on relatively low-rise buildings. The roof of a supermarket, for example, represents a large piece of unused land; and where better to farm vegetables than on the roof of the primary distribution point?

## A Healthy Harvest

The approach outlined here does not address the production of every kind of agricultural product. Hydroponic techniques are best suited economically and logistically to a range of vegetables that include primarily leaf crops (such as lettuce, spinach, and basil) and vine crops (such as tomato, cucumber, beans, and zucchini). These crops travel far and travel regularly from conventional sources, and need to be kept cold and fresh on route; thus, their transportation places a particularly heavy burden on the environment. Furthermore, fresh, perishable vegetables tend to suffer the most, in terms of taste and vitamin content, from being transported long distances or harvested before they are ready in order to allow enough time for transportation.

Cultivation of crops on buildings within the built environment will reduce our environmental footprint, cut transportation costs, enhance food security, save energy, and enrich the physical surroundings of building occupants. Simple and pragmatic, the approach requires no new technology. The environmental benefits are significant: each hectare (2.47 acres) of rooftop vegetable farm, if built in the United States, would on average free up ten hectares (24.7 acres) of rural land, save 75,000 tons of fresh water each year, and, if fully integrated with building heating systems and on-site solar power, eliminate 1,000 tons of $CO_2$ emissions per year compared to a conventional greenhouse that lacks these alternative energy sources. The CEA sector already makes healthy profits; a well-designed system adapted to work in the heart of the city in order to reduce both transport and heating costs should also make very good business sense. ULG

## Vertically Integrated Farm

**The vertically integrated greenhouse (VIG) combines a double-skin building facade with a hydroponic greenhouse. The concept was jointly developed by New York Sun Works, Kiss + Cathcart Architects, and international engineering firm Arup.**

**The vertically integrated greenhouse uses the space between the two sheets of glass on a conventional double-skin facade wall to grow plants using a series of hydroponic troughs that move up and down the facade wall. The plants are ultimately harvested from the ground floor. The airspace and plants help insulate the building, keeping out the heat of the sun during summer and retaining warmth during winter, thereby lowering the structure's energy consumption and operational costs. They also help reduce noise from the outdoors. In addition, the harvest generates significant income for the building owner. The VIG provides increased production in winter, when produce prices peak. The VIG is able to accomplish this by adjusting the vertical spacing between trays on the cable, so rows become more tightly spaced in winter, when the sun is lower. This results in steady yields year-round, compared with lower winter yields for conventional greenhouses.**

**Research conducted on existing buildings in Europe indicates that a double-skin facade (DSF) adds approximately 5 percent to the cost of a new high rise; the additional components to make the DSF into a VIG add only slightly to this cost, which would likely be reaped in short order from the financial return of the greenhouse crops.—B.L. AND T.C.**

KISS + CATHCART, ARCHITECTS

**A vertically integrated greenhouse, conceived by New York Sun Works, Kiss + Cathcart, and Arup Engineers, would consist of hydroponic troughs that would move up and down within the airspace of a double-skin facade. In addition to growing vegetables for sale, the system would contribute to the thermal and acoustical insulation of the building.**

**BENJAMIN LINSLEY** is public affairs director at New York Sun Works (www.nysunworks.org). **TED CAPLOW** is executive director and founder of New York Sun Works, and designer of the Science Barge.