ECO-PIONEERS

Practical Visionaries Solving
Today's Environmental Problems

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foreword by Jonathan Lash

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Urban Rooftop Agriculture

Statistics about the number of people moving into cities around the world are enough to make your jaw drop. Consider the following disturbing projections:

- By the year 2005, the number of people living in cities is expected to outnumber those in the countryside for the first time in human history.
- Fifteen years later, in 2020, the number of urban residents will increase to 3.6 billion, more than twice the 1.4 billion who lived in cities in 1990.[1] By another calculation, the number of people who live in cities will reach 5 billion people by 2025.
- The number of "megacities" with populations over 8 million is also mushrooming. In 1950 New York and London were the only two megacities on the planet, but by 1990 there were 21 of them; by 2015, there will be 33 megacities, 27 of them in the developing world.[2]

With this phenomenal increase in the urban population on the horizon, many of the most farsighted eco-pioneers are working on ways to make the cities of tomorrow more ecologically efficient. And while some of their visions may sound far-fetched today, in the future these practices may be considered quite ordinary.

Two of those who have been looking for ways to turn urban waste products into resources are Paul and Julie Mankiewicz, co-directors of the Gaia Institute in New York. Paul Mankiewicz, a biologist, is developing new on-site systems for composting urban and suburban food waste in order to turn it into a rich nutrient base for growing food on the rooftops of city buildings and suburban supermarkets. Julie Mankiewicz, who received her Ph.D. on the biochemistry of plant cell wall components, is testing these innovative compost systems and the qualities of the compost they produce.

By turning urban food waste into compost for agriculture, Paul Mankiewicz hopes to simultaneously reduce the urban waste stream and provide farmers with a substitute for chemical fertilizers. To make this possible, he developed a system for collecting and composting 5 to 25 tons a day of food waste in both urban and suburban settings. Under a grant from the Environmental Protection Agency and in conjunction with the New York City Department of Sanitation, Bureau of Reuse, Recycling, and Waste Reduction, Mankiewicz looked at a variety of existing composting systems, including the agitated bay, tunnel system, silo system, and rotating drum. He concluded they were all too expensive or were not designed to "provide optimal conditions for biological performance."

In the course of doing research to determine what conditions would cause decomposition to take place most efficiently, Mankiewicz found that when food waste is chopped into pieces about 1 centimeter square, it provides the best surface area and air pockets for bacteria to thrive. He also

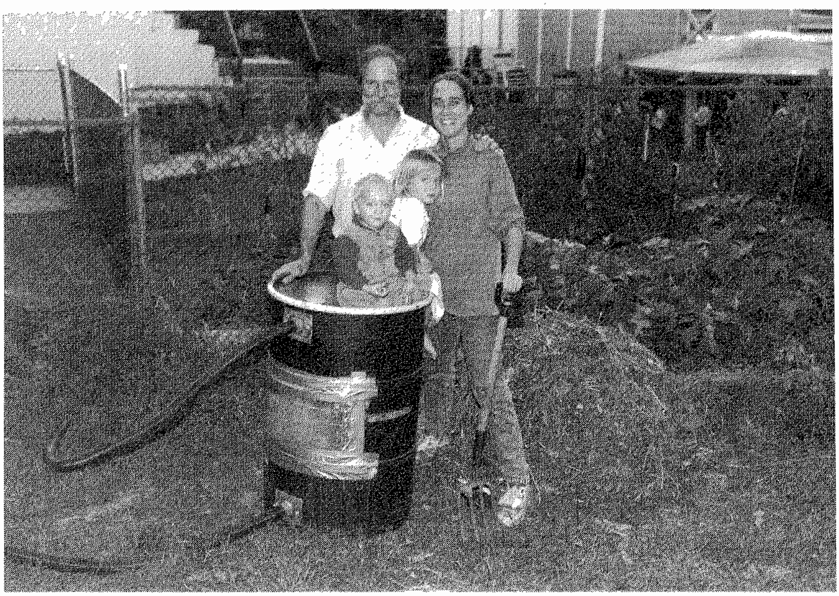

Figure 11.1
Julie and Paul Mankiewicz, director of the Gaia Institute at the Cathedral of Saint John the Divine with their children, Phoebe and Tighe, sitting atop an old prototype of the proprietary composting technology they developed with funding from the EPA and the New York Department of Sanitation. Photograph by Richard DeWitt.

discovered that decomposition took place most rapidly if the compost was not agitated or turned, as long as there was enough air being pumped through the pile to keep an anaerobic state from developing.

With these lessons in mind he set about building his own prototype, a 5-ton-per-day composting vessel that would be odorless and efficient enough to be accepted as a "good neighbor." What he came up with was a large container made of reinforced polyvinyl chloride (PVC) plastic with two air vents, one near the top and the other near the bottom. He cut the PVC in a cylindrical pattern on the floor, as one would cut a clothing pattern, and then sealed it with an adhesive which he found to be stronger than heat-welded seams. Into the bottom of the composter he installed a coiled, perforated hose covered by some screening material. The hose was then attached to a one-eighth horsepower blower so that air could be introduced into the bottom of the composter to control temperatures and keep an anaerobic state from occurring.

Into this vessel he placed shredded food waste along with some leaf mold as a bulking agent. On top of these organic materials he spread 8 inches of finished compost to suppress odors. In eight to twelve hours the whole system ran at 130° F. In four days he was able to achieve a 50 percent mass reduction and within two weeks the compost was ready to use. "Basically, all we did was figure out how to treat microbes well," Mankiewicz says modestly. "It is just more efficient than most people's compost."

In effect, Mankiewicz found a way to reduce by half the volume of New York City's food waste in four days. This is a significant achievement considering that organic, compostable material comprises anywhere from 12 percent to 30 percent of the municipal waste stream, depending on whether or not yard waste and some compostable paper are collected along with the food waste. Using Mankiewicz's on-site, in-vessel composting system, by the end of two weeks the compost could be sold to farmers as a substitute for chemical fertilizers instead of being hauled to the dump.

Not only had Mankiewicz come up with a workable way to compost municipal organic matter, it also made sense economically. The cost of the composting vessels was relatively cheap: $650 to $800 for a 1- to 5-ton-per-day vessel. A further advantage of these collapsible composters was that a dozen of them could be rolled up, transported in a small van, set up at the compost site, and connected to the air delivery system by two people in a morning.

While some inventors would have stopped there and claimed victory, Mankiewicz realized that unless he designed a start-to-finish, practical system that would save the Department of Sanitation money, the project had little chance of being adopted. To this end he began to look at what a 10-ton-per-day modular system for collecting, shredding, composting, and disposing of food waste would look like.

In scouting for space to compost food waste in Manhattan, Mankiewicz targeted the basements of large commercial and residential buildings. He calculated that if each household generated 1.5 pounds of compostable solid waste per day and captured 60 percent of it, in order to collect 10 tons per day he would have to service a three-by-five-square-block area, encompassing a little more than one quarter of a mile square, in which an average of 800 households per block were located.

By dividing the city into these one-quarter square mile zones, each generating 10 tons per day of compostable waste, Mankiewicz was able to avoid the use of the city's standard, large, noisy, garbage trucks, which cost about $110,000 each. As a substitute, Mankiewicz adopted the suggestion of William Kinsinger, an industrial engineer, who recommended the use of an $18,000 electric cart that could quietly and efficiently pick up the food waste at night when there was little traffic to interfere with collection. Mankiewicz figures that the electric collection vehicles' capital cost is between one-sixth and one-half that of the large garbage trucks on a tons-per-day basis. The annual cost of running these electric carts a couple of hours a day would be about $50 to $100. And the average distance from the composting facility in their zone would be about a two-minute drive.

These little electric carts would zip around the neighborhood sidewalks late at night and early in the morning collecting food waste. When they had a full load they would dump it into a chute that emptied into a shredding bin located in a 5000 square foot area of basement in a commercial building. There, the food waste would be shredded, weighed, mixed with leaf mold, and loaded onto pallet trucks for delivery to a "material placement gantry" equipped with a spreader. The material placement gantry, which would run on a set of elevated tracks, would spread the shredded food waste into one of twelve composting vessels. Subsequently, 8 inches of finished compost would be spread onto the food waste to suppress odors. Then the container would be sealed for a two-week composting period dur-

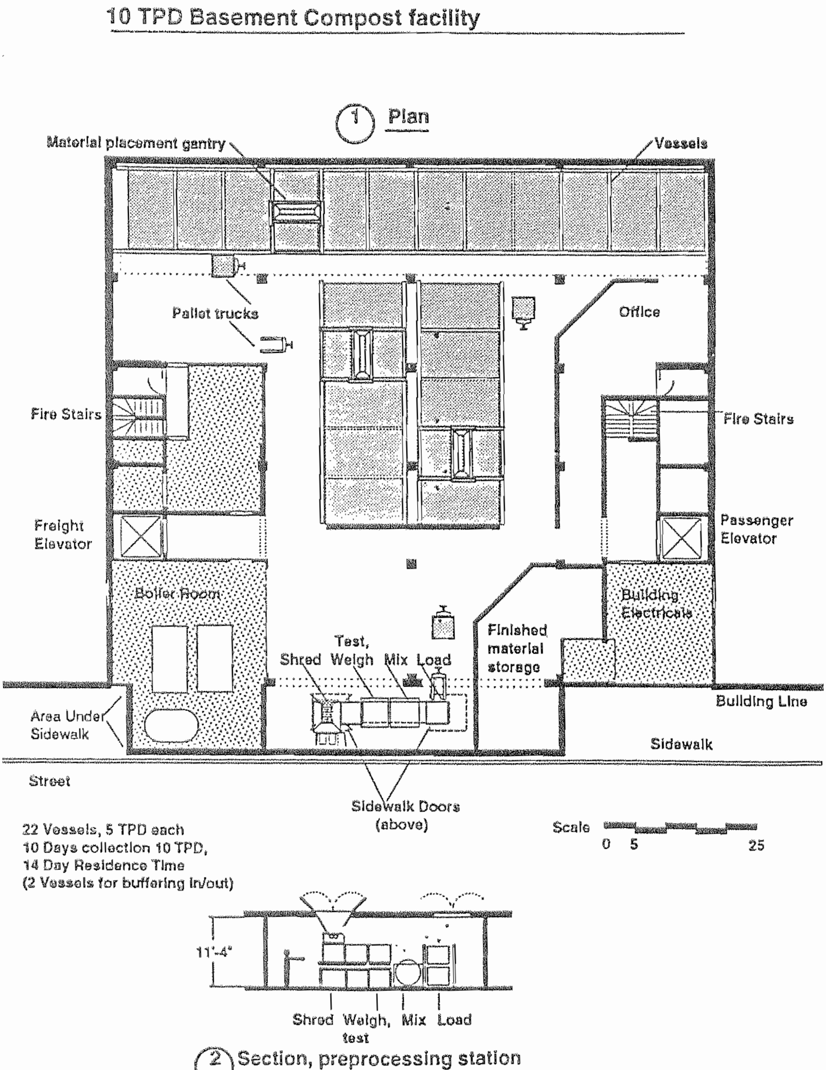

Figure 11.2
Schematic of 10-tons-per-day basement compost facility. Courtesy the Gaia Institute.

ing which air would be pumped through the compost to speed decomposition. At the end of the process the compost would be loaded into 44-cubic yard roll-on–roll-off containers that would be picked up every week.

But what would the city do with all this nutrient-rich compost? One solution would be to sell it to farmers at a cheap price as a substitute for chemical fertilizers. This would certainly beat dumping it in a landfill. But significant transportation costs are involved in trucking it out of the city. Instead, Mankiewicz has a vision of using this material to create urban farms.

In the past, urban agriculture has been restricted because it was prohibitively expensive to grow food on valuable city real estate. But recently planners have begun to look at city rooftops as a potential large expanse of sunlit territory on which to grow food. "Once you look around, you realize that the only open space in the city that is available for agriculture is roof space," Mankiewicz observes.

The vision of a city covered by vegetable gardens is seductive. Think what it would be like if everywhere you looked buildings had greenhouses on top of them where vegetables, fruits, and flowers were growing in profusion. Not just a few potted geraniums here and there, but rather full-fledged urban farms. It would add a whole new green layer to the urban landscape. In their book *Bioshelters, Ocean Arks, City Farming: Ecology as the Basis of Design*, Nancy Jack Todd and John Todd have written about the potential of rooftops to be "a combination greenhouse and hotwater collector." Their vision went further to suggest that solar collectors could be mounted on rooftops to power grow-lights for the floors below. "Old warehouses could be converted into ecologically inspired agricultural enterprises floor by floor where fish, poultry, mushrooms, greens, vegetables, and flowers could be grown in linked, integrated cycles."[3]

A pipe dream you say? But why couldn't it work? What are the constraints that prevent us from turning the vast unused rooftop acreage in Manhattan and other cities into productive agricultural plots?

Mankiewicz asked himself these questions and came up with answers. There was no way that you could pile tons of soil on top of Manhattan buildings because the additional weight would cause the roofs to cave in and crush the residents below. Most city apartment building rooftops are designed to hold 30 to 40 pounds per square foot while soil that has been watered weighs more than 100 pounds per cubic foot. To support this additional weight would require major retrofits, making an investment in an urban greenhouse unprofitable.

Rather than reinforce rooftops at great expense, Mankiewicz decided that the only way around this problem was to invent a superlightweight soil. The solution was improbable enough. He found that by shredding post-consumer expanded polystyrene (a.k.a. EPS or Styrofoam) he could make a soil substitute that weighs only 20 pounds per square foot, a mere fifth as much as dirt. When watered with diluted compost, this shredded Styrofoam acts like a sponge and holds nutrients until plant roots can make use of them.

Critics argue that mixing soil and Styrofoam is not a good idea because it will be difficult at a later date to separate them into organic and technological loops for composting and recycling. But Mankiewicz says that separating the Styrofoam out of the compost is not a problem. The Styrofoam can be blown into a bag placed on a screen over a low-powered blower. Or, if water is cycled through the mixture in a container, the Styrofoam floats to the top and can be skimmed off.

Growing food in the cities not only provides a local source of nutritious sustenance, it also reduces energy use and pollution by radically decreasing the distance over which food must be transported. It is estimated that the average unit of food now travels 1300 miles from field to table.[4] By reducing transportation and middleman costs, locally grown, rooftop food can also be sold below prevailing prices. Urban rooftop farming also holds out the possibility of providing some jobs for underemployed people with minimal education precisely in the inner-city areas where this population is concentrated.

Mankiewicz made urban farming even more attractive by inventing specialized equipment that eliminates many of the back-breaking, stoop-labor aspects of farming. This further opens the work up to both the elderly and handicapped population. In order to make urban gardens efficient and profitable, Mankiewicz and colleagues designed a "pulsed nutrient system" that calls for an array of perforated tubes to be laid out under the superlightweight soil. The perforated tubes can deliver measured doses of "water, nutrients in solution, microbes, carbon dioxide, and high concentrations of oxygen to enhance plant growth, control predators, and regulate soil temperatures," he argues.[5]

For large-scale operations, Gaia Institute colleague William Kinsinger designed a motorized gantry system that permits crops to be planted, tended, and harvested from above. The advantage of this device is that precious growing space is not taken up with footpaths, allowing large uninterrupted beds to be intensively sown with crops. The gantry itself is a moving steel platform that spans the width of the roof and rolls along tracks set on the parapet walls. It is designed so that urban agricultural workers can lie on their stomachs with their hands reaching down into the soil (like someone floating on an air mattress in a swimming pool) to tend the plants. For those who want to invest in more high-tech equipment, Kinsinger also designed an automated harvesting and planting mechanism (using existing technology), which can be fitted onto the gantry, further reducing the need for manual labor and increasing the profit margin.

Stretching over these urban gardens would be greenhouse structures made of materials much lighter and less expensive than conventional glass greenhouses. Mankiewicz favors a greenhouse built by Advanced Greenhouse Systems of Burlington, Vermont, which is constructed out of lightweight steel framing and a film-glazing technology. Working with Mankiewicz, structural engineers William Kinsinger Associates and Peter J. Galdi Associates have modified these greenhouses to make them adaptable to a number of building types.

Mankiewicz calculates that an 8000 square foot rooftop greenhouse garden would cost $360,000 to build and about $100,000 a year to operate. He figures that annual profits would be in the range of $100,000 to $180,000, permitting the operator to recoup the initial capital investment in two to five years. But these estimates are conservative: "Winter season prices for tomatoes and specialty crops could make it possible to recover the entire cost in one to two years," he claims.

While it is impossible to say whether these calculations will hold up in the real world, the exercise does suggest that some kind of reasonable profit can be realized with rooftop gardening. But beyond the direct profits involved in growing food and flowers on urban rooftops, there are other substantial advantages to Mankiewicz's plan. For one thing he projects that an 8000 square foot garden on a rooftop could supply fresh vegetables for some 2000 people for a year.

A garden on the roof of a building also adds a significant insulating factor, which keeps the building from heating up in the summer and losing heat in the winter, thus providing real energy savings. Furthermore, rooftop gardens will help moderate temperature extremes in the city and purify the air, as well as reduce the amount of waste that must be hauled to landfills by providing decentralized locations for composting organic wastes.

For suburban areas the collection of food wastes and the growing of suburban crops would be configured in a somewhat different fashion, Mankiewicz's colleague William Kinsinger suggests. Unlike the high-density urban area with a quarter square mile collection area and 3 miles of street on the collection route, the low-density suburban area with only sixteen households per block would comprise 5 square miles in order to be able to collect enough food waste to supply a 10-ton-per-day composting facility. The collection route in the suburban area would be an estimated 120 miles of street compared with a route of only 3 miles of street in the city. This longer street route might justify the use of large garbage trucks, Mankiewicz allows.

But where would composting facilities and gardening space be found in the suburbs? In most suburban areas there are shopping malls covered with huge, unused rooftops where composting food waste facilities and rooftop gardens could be sited, Mankiewicz points out. He envisions drawing a circle 2 miles in diameter around a typical shopping mall and establishing this as the collection zone. Food waste would be picked up in this area and delivered to a composting building that would be erected adjacent to one of the walls of a supermarket located within the mall. Within this structure, composting of the food waste would proceed in a fashion similar to that described above for the urban basement facility.

The only difference would be that instead of shipping the finished compost out to urban rooftops, the suburban compost would be taken to a greenhouse built on the roof of the supermarket where it would be used to grow produce. Once the compost is taken up to the roof by elevator it would be mixed with shredded post-consumer Styrofoam collected in the mall or on the shopping strip close to it. The Styrofoam would be shredded to make superlightweight soil. To maximize the growing surface, Mankiewicz would transplant seedlings into crop trays and place them in three-tiered hammocks suspended from the steel trusses that support the greenhouse roof. Supplemental, high-intensity, discharge lighting would be used to increase plant growth rates at off-peak hours when electricity could be purchased at reduced rates. Once the produce had grown to maturity, the trays could be taken down by elevator to the produce section of the supermarket where customers could literally pick their own produce, insuring its freshness and avoiding spoilage and refrigeration costs.

Growing fresh produce on the roof of a supermarket makes a lot of sense financially. Since much of the fresh produce sold in eastern cities in the United States comes from Florida, California, or Central America, significant savings can be realized on transportation costs alone. By growing food on the roof of a supermarket one eliminates interstate hauling charges, crating at the farm, local wholesale distribution facilities, sorting for spoilage, loading on trucks for local delivery, uncrating at the retail store, and a host of other expenses, Mankiewicz points out. Further savings are realized because intermediate profits are taken at each stage of this process. At the end of the chain Mankiewicz calculates that there is a 70 percent cost reduction on food that is grown on the roof compared with that shipped in over long distances. In addition, it is undeniably fresher when sold.

Although no one has yet attempted to implement this urban/suburban food waste to food production system on a large scale, it remains one of the more practical and well-thought-out options for making cities more ecologically sustainable. To prove that his composters will perform as advertised, Mankiewicz is starting small by installing a Department of Sanitation–funded, superefficient composting system for food wastes at the Brooklyn Botanic Gardens (BBG), the fourth most visited cultural institution in New York City. Food waste from BBG's palm house and cafeteria is shredded and then composted in one of Mankiewicz's composters. The composter, located in one of the BBG greenhouses, permits the 100,000 schoolchildren who visit the greenhouses every year to become familiar with this sophisticated composting process.

The in-vessel system at BBG, which reduces the volume of food waste by half within three or four days, has attracted the interest of restaurant owners and hospital food service operators who can see that virtually all the processing steps in food waste composting can be mechanized. Negotiations are underway with officials at one hospital who are interested in a combination food waste composting system and rooftop greenhouse, Mankiewicz reports.

In addition to providing highly nutritious food, grown without the use of pesticides or chemical fertilizers, Mankiewicz's urban rooftop gardens also provide urban dwellers with a whole new green environment within the city that they can visit and use as a refuge from the harsh reality of the streets below.

Imagine living or working in a building that has a farm on the top floor! The rooftop farm would be a pleasant place to visit where one could relax in a green open space. It would enable residents to show their children how food is grown. Some residents might even want to volunteer to work in the garden a few hours a week. Having a productive agricultural plot on a rooftop might also prove to be an excellent selling point for owners.