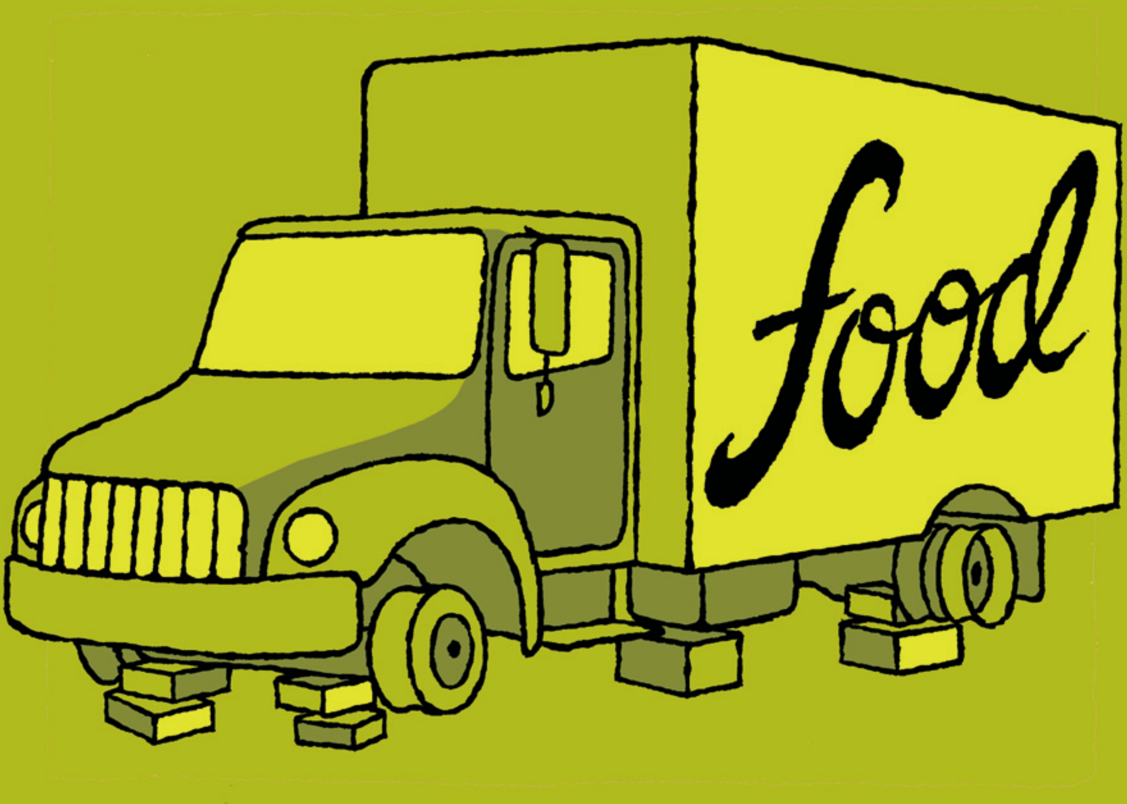
The Post Carbon Reader Series: Food

Getting Fossil Fuels Off the Plate

By Michael Bomford



About the Author

Michael Bomford is a research scientist and extension specialist at Kentucky State University and an adjunct faculty member in the University of Kentucky Department of Horticulture. His work focuses on organic and sustainable agriculture systems suitable for adoption by small farms operating with limited resources. His projects examine practical ways to reduce food-system energy use and meet farm energy needs using renewable resources produced on the farm. Bomford is a Fellow of Post Carbon Institute.

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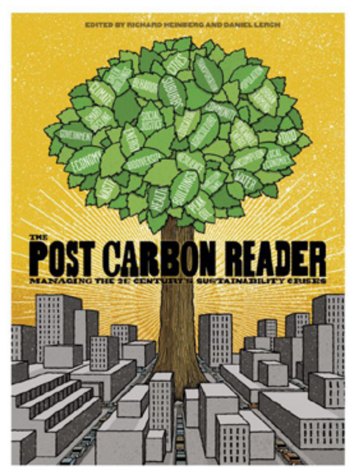

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Suddenly I lived in a magical world filled with plants using energy from the sun to assemble themselves out of thin air.

I learned about photosynthesis early in grade school, but its implications didn't sink in for some time. When they finally did, I got excited.

Suddenly I lived in a magical world filled with plants using energy from the sun to assemble themselves out of thin air. I was among the innumerable living beings interacting with one another on a solar-powered planet shaped by life itself. I could breathe because billions of years of photosynthesis had enriched my planet's atmosphere with oxygen stripped from carbon dioxide molecules. The carbon from those molecules had been reassembled into energy-rich chains that made up the bulk of living things and could be rendered to fuel my body. With every breath I took, my body released a little energy that had once been stored by a plant, reuniting carbon with oxygen to make carbon dioxide. Eating and breathing were photosynthesis in reverse. Without plants, I could do neither.

My grade school years were mostly spent in northern British Columbia, where the growing season is short, but good land is cheap, soils are fertile, and summer days are long. Each spring farmers rushed to plant vast fields of grains and oilseeds as soon as the snow melted. The summer fields turned brilliant yellow with canola flowers and lush green with fast-growing wheat, oats, flax, and barley. By fall the plants were spent, stalks were dry and golden brown, and farmers rushed to collect the energy-rich seeds before the snow returned. The short summer's sunshine could be stored as grain for the long winter ahead. It would feed our animals, so we could have fresh meat, eggs, and milk in the depth of winter. It would feed us, as my dad reminded me with his bumper sticker: "Don't complain about farmers with your mouth full."

My parents gardened. Half of our giant backyard was filled with vegetables every summer. The garden filled our plates with fresh produce, and there was plenty left over to fill our freezer and root cellar for the winter ahead. Before we said grace, Mom often proclaimed with delight, "Everything in this meal is from the garden." It all came from photosynthesis.

Agriculture is an important part of the economy in northern British Columbia, but oil is even more so. My grubby little town was full of young men in big trucks and muscle cars who had come north to make their fortunes in the oil fields. During oil booms they kept the bars hopping and the hookers busy, dropping hundred-dollar bills like candy. They didn't have gardens—they seemed to live in a realm separate from sunlight—but somehow they managed to eat and breathe. When the wells ran dry the young men disappeared, shops shuttered their windows, and the town shrank. New oil discoveries brought them back, with all of the gold-rush excitement and disarray that accompanied them. In the seven years I lived there, I saw two cycles of boom and bust.

I left home for university, brimming with idealism and determined to serve humanity. I took a degree in plant science: What could be more fundamental to human existence than plants? There I studied farm management, greenhouse management, weed management, and pest management; fruit production, vegetable production, agronomy, and agro-forestry. I learned about the wonders of the green revolution and the promise of genetic engineering. I learned about innovations that allowed fewer farmers to grow more food on less land, to meet the ever-expanding appetite of a growing human population. It all came from photosynthesis.

Or so I thought. I remember the sunny day—well into my Ph.D. work—when I first read that each calorie of energy I got from food required seven to ten calories from fossil fuels to get to my plate. I was stunned. Surely this couldn't be true. I, like other living organisms, got my energy from plants, which got it from the sun. Of course I knew it took some petroleum to farm, process, package, haul, and market food, but I still considered food a renewable resource.

I checked other sources, and found that anybody who took a serious look at the energy balance of an industrialized food system reached a similar conclusion: My food was much more nonrenewable than renewable. The young men in the oil patch were doing more to feed me than the farmers.

I knew how fickle those young men were. The sun would keep shining, but the oil would run out, and they would be gone. I didn't want my food supply to depend on them, and I knew it didn't have to.

For most of human history we, like other animals, got by on renewable energy. We used muscle power for farm tools and food hauling. We ate fresh food when it was available, keeping what we could in root cellars or storing it longer by pickling, salting, fermenting, and drying. We cooked and heated with wood fires. We packaged our food in ceramic jars, wooden boxes, leaves, and paper. Our diets were shaped by where we lived, and changed with the seasons. We lost a lot of food to spoilage.

Only in the past century and a half did we start to invest a lot of fossil energy in our food system. The 1840s brought a diverse array of new factory-made farm machines that made farming easier but demanded that farmers raise enough cash crops to pay for them. The wheel-blade can opener was patented in 1870. A glass-bottle blowing machine made mass production of jars possible in 1903. By 1910 we were beginning to make synthetic nitrogen fertilizer and use gasoline-powered tractors. Frozen foods, fridges, freezers, and refrigerated trucks showed up in the early 1930s and 1940s.

Each ingenious new invention made it easier to get food to the plate—at an energy cost. In 1840 the U.S. food system depended almost entirely on renewable energy sources, including labor from 70 percent (12 million) of the 17 million Americans of the day, more than 2 million of whom were enslaved.[1] By 1900 the population had grown to 76 million, less than 40 percent (30 million) farmed, slavery had finally been abolished, and the food system consumed about 3 quadrillion Btu of fossil fuel.[2]

Today less than 1 percent of the population farms, and those 2 million farmers feed more than 300 million of their fellow citizens. The entire U.S. food system consumes about 10 quadrillion Btu from fossil

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fuel every year: 1 quadrillion Btu to make farm inputs like fuel, fertilizer, and machinery; 1 quadrillion to farm; 1 quadrillion to haul; 4 quadrillion to process, package, and sell food; and 3 quadrillion to run the fridges, freezers, stoves, and the other appliances that fill our home kitchens.[3] The vast majority of energy used to get food to our plates is used after the food leaves the farm. Our kitchens consume far more energy than our farms.

The past century in America was characterized by rising crop yields that more than kept pace with a growing population, despite a dramatic decline in the number of farms and farmers. It isn't easy to determine how essential fossil-fuel energy inputs were in achieving this remarkable feat. Although the energy used by the American food system increased over the course of the century, the energy used to feed each American declined. Energy consumption by U.S. farms peaked in 1978 and has fallen almost 30 percent since, while yields continue to rise.

There are some obvious ways to further reduce farm energy use. Making nitrogen fertilizer is an energy-intensive process, accounting for most of the indirect energy consumption of U.S. farms. Some give synthetic nitrogen fertilizer the lion's share of the credit for increasing crop yields over the past century, but even without it organic farms today achieve yields comparable to those of conventional farms. Studies that show organic farming to be more energy efficient than conventional often find that most of the difference comes from eschewing synthetic nitrogen.

In places like Kentucky, where I live now, it is possible to grow cold-tolerant winter cover crops that build soil health, protect soil from erosion, and convert atmospheric nitrogen to plant-available forms using energy from photosynthesis. These soil-building crops can be killed in the spring to release plenty of nitrogen for a summer cash crop, eliminating the need for synthetic nitrogen applications. Very few farmers use this energy- and soil-saving strategy in Kentucky today because applying synthetic nitrogen is cheaper and easier than managing a nitrogen-fixing winter cover crop. That changed when the price of nitrogen fertilizer spiked along with energy prices in 2008, giving the economic advantage to those who had planted a nitrogen-fixing winter cover crop. I fully expect that less nitrogen fertilizer will be applied to U.S. farms as energy prices climb, with conventional farmers adopting techniques used mainly by organic growers today.

In northern British Columbia, the growing season is too short, and the winter too cold, to allow nitrogen-fixing winter cover crops. There, the organic farms have to plant nitrogen-fixing cover crops that grow through the summer, like alfalfa. This precludes production of a grain or oilseed crop on the same land that year, but still generates income for the farmer, who can cut alfalfa hay for sale while the plant's roots add nitrogen to the soil.

Some types of agriculture are much more energy efficient than others. The typical meat-centered diet is an energy-intensive luxury. By the time it reaches the plate, a serving of beef consumes about twenty times more energy than an equivalent serving of bread.[4] Grain farming accounts for most of the energy used for beef but only 10 percent of the energy that goes into bread (the rest is mostly for milling and baking). In fact, very little of the grain grown in the United States is destined for bread, or other human food: It's far more likely to be fed to animals.[5]

This is wasteful. The digestive system of cattle evolved to process grass, not grain. Cattle allowed to graze on grass use less energy than cattle fed on grain. Grass-based cattle operations use more land than grain-based systems, but they are often on marginal land planted to sustainable perennial mixtures. In contrast, confinement-based animal agriculture systems relying on grain are not just energy intensive and cruel, they compete directly and unnecessarily for grain harvests that could feed people. Meat and dairy products from pasture-raised animals tend to be healthier, too: They are leaner and richer in the omega-3 fatty acids often lacking in our diets.[6]

A grain- and vegetable-based diet almost always consumes less energy than a meat-based diet, yet vegetables can be energy hogs too. North America's big vegetable greenhouses—marvels of Dutch technology—are a case in point. Tomato, pepper, cucumber, and lettuce plants flourish in the nearly ideal environments the greenhouses maintain: never too hot or too cold; roots bathed in scientifically perfected nutrient solutions; no wind or rain; air enriched with carbon dioxide; human-reared beneficial insects released constantly to devour pests. It's plant heaven, but it comes at a hellish energy cost. The energy used to get one serving of greenhouse-grown tomatoes to the plate is about the same as for a serving of chicken, or twelve servings of field-grown tomatoes.[7] A local vegetable grown out of

season in a heated greenhouse usually uses considerably more energy than its imported field-grown equivalent, trucked or shipped from afar.

It doesn't have to be this way. Innovative farmers around the world are developing low-energy alternatives to the Dutch greenhouse system. Perhaps the simplest is the high tunnel—a low-tech, unheated, plastic-covered structure that extends the growing season for soil-based fruit and vegetable systems. Plants grown in high tunnels lead a more stressful existence than those grown in Dutch-style greenhouses, and they don't yield as well, but the energy savings compensates for the yield reduction many times over. High-tunnel-grown vegetables offer health benefits, too: Beneficial phytochemicals are often more concentrated in plants that have experienced stress than in plants that are pampered.[8]

High tunnels extend the growing season, but do not allow winter production of warm-season crops, like tomato, in most of North America. Vegetable farmers in China may have a low-energy solution. Rejecting the Dutch model, Chinese farmers are increasingly constructing low-input solar-heated greenhouses with thick walls of concrete or brick on the north face to absorb solar radiation by day and warm the growing area at night. Before the sun goes down the farmer lowers an insulating blanket of rice straw over the clear plastic cladding to trap daytime heat, then returns at

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sunrise to roll the blanket up. Using this passive solar system, Chinese farmers keep tomatoes and other warm-season crops growing through winters similar to those in much of North America, without burning fuel for heat.[9]

The Chinese-style greenhouse is probably superior to the Dutch-style greenhouse from an energy efficiency perspective, but paying somebody to roll an insulating blanket up and down every day may be more expensive than paying for heating fuel. Organic farmers may use energy more efficiently than conventional farmers, but they also use more labor—a trade-off that is often justified by premium prices available for organic products. Labor has been one of the most expensive inputs in North American agriculture over the past fifty years, and farmers have responded by developing labor-optimizing systems, capable of producing more and more food with fewer and fewer people. Such systems will stop making sense as energy prices continue their inevitable long-term climb in response to declining fossil-fuel supplies.

I am concerned about the increasing fossil-fuel dependence of American farms that characterized most of the twentieth century, but impressed by the marked reduction in farm energy use that followed the energy price shocks of the 1970s—and confident that many more opportunities exist to reduce farm energy use. Elimination of fossil-fuel consumption by U.S. farms, and replacement with renewable energy sources, appears to be a realistic and achievable goal in the near term.

But farms are just a small part of our industrialized food system. Animal feedlots and heated greenhouses are exceptional examples of farming systems that account for most of the energy used to get food to our plates. Weaning our food system of fossil fuels demands a hard look at the journey food takes after it leaves the farm. Too often, this analysis is limited to an attempt to measure the distance that food travels between farm and fork. The "food mile" has caught the popular imagination as a simple indicator of food-system sustainability. But it is not a very useful one.

How food travels is much more important, from an energy perspective, than how far it travels. Oceangoing freighters are more efficient than trains, which are more efficient than semi-trucks, which are more efficient than small trucks. Air freight would be the worst way to move food, if it weren't for individuals driving big cars to carry small quantities of food. Far less energy is needed to import bananas by boat than to fly fresh fish from the same tropical starting point. A quick jaunt in the SUV to fetch a few of those bananas at the grocery store two miles down the road uses more fuel per banana than the journey of thousands of miles over water that brought them from their tropical home.[10] Taking fewer trips to the grocery store, or getting there by foot, bike, transit, or carpool, has far more impact on food-system energy use than obsessing over paper versus plastic bags. (We should be reusing cloth bags, anyway.)

Food often takes a convoluted route to get from farm to fork, traveling twice as far as the direct distance between the two points.[11] Even so, transporting food accounts for just 10 percent of our food-system energy use. We need to find ways to reduce this energy cost—and we can—but doing so will not wean our food system of fossil-fuel dependency.

Recognizing the relatively small and tremendously variable impact of food miles on food-system energy use is important to avoid fetishizing the "local" instead of conducting rigorous analyses of food-system energy use. It is easy to find gee-whiz renderings of urban skyscrapers filled with plants, increasingly billed as the answer to our food energy woes.[12] These fantastical vertical farms would be obscenely expensive structures, dependent on synthetic fertilizers, heating fuel, electric grow lights, pumps, water purifiers, and computers. Like Dutch-style heated greenhouses, they appear to ignore the energy cost usually incurred when we attempt to replace free ecosystem services with human ingenuity. Although vertical farms can almost certainly produce high yields of hyper-local food, their ecological footprint would far exceed that of field-grown products transported to urban centers from land-based farms that depend on sun, rain, soil, and other gifts of nature.

Food processing, packaging, storage, and preparation account for most of the energy cost of most of our food.[13] If local food economies can reduce the need for these elements of the food system they will succeed in reducing our fossil-fuel dependence dramatically. Whole, unprocessed foods—often promoted for their health benefits—offer tremendous energy benefits too. If we're concerned about food-system energy, it's hard to beat whole grains, protein-rich beans (stored dry), and fresh produce, prepared simply. Yum!

In a society where less than 1 percent of the population grows most of the food for the other 99 percent, it's easy to feel removed from the food system,

or disempowered by decisions that appear to be in the hands of others. The reality is that most of the power to wean the food system from fossil fuels rests with eaters, not farmers. The choices that we make in our homes and kitchens matter.

I work with many rural residents of Kentucky who have clear memories of getting their first fridge. Today almost everybody I know has a fridge (or two), and, chances are, it's a lot bigger than the one they had ten years ago. They probably also have a freezer, a microwave, a dishwasher, a food processor, a toaster, a coffee maker, a slow cooker, an electric kettle, a blender, and other electric kitchen appliances. Over the past thirty years our farms have reduced their energy consumption, but our kitchens demand ever more.

All of this kitchen technology should offer energy advantages. Microwaves are much more efficient than ovens; dishwashers can be more efficient than hand-washing; slow cookers and electric kettles can be more efficient than stove-tops. Advances in fridge, freezer, and stove technology generally make newer appliances more efficient than similarly sized older appliances. The problem is that we expect our new high-tech kitchens to do much more than replace the functionality of our old kitchens. Using the fridge as an example, we might replace a small, low-efficiency fridge with a bigger high-efficiency fridge, ultimately using more energy

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despite the efficiency gain. The unexpected result of efficiency gains leading to greater resource consumption is so common it has a name: the Jevons paradox.[14]

Weaning the food system off fossil fuels demands that we simplify our diets and kitchens instead of demanding an endless parade of bigger, better, and faster. It will be a difficult lesson.

Simplification does not mean an end to technological advances. On the contrary, it offers many opportunities for creative problem solving and new ideas. I think back to the freezer in my parents' basement in northern British Columbia. Why were we using energy to keep our food frozen in a heated basement when it was minus 40 degrees outside? Couldn't the freezer be outside of the house, with just an insulated door opening in? As we face the reality of higher energy prices, eaters—like farmers—will invent creative solutions that might have existed all along, but only become obvious when the bills come due.

We need only look to our own backyards—or apartment balconies, or community plots—to find one of the easiest, cheapest, and most enjoyable solutions: the garden. Stepping outside to harvest the evening meal is not only deeply satisfying, it eliminates most of the energy-intensive steps between farm and fork that contribute to our food system's dependence on fossil fuels. Provided that we can avoid the temptation to indulge in synthetic fertilizers, plastics, and pesticides, our gardens allow us to approach the ideal that most other animals realize as a matter of survival. We again become organisms fueled by photosynthesis.

Endnotes

1 Karl Finison, *Energy Flow on a Nineteenth Century Farm,* Anthropology Research Report 18 (Amherst: University of Massachusetts, 1979).

2 Between 1845 and 1905 primary energy consumption in the United States increased from 1.8 quadrillion to 13 quadrillion Btu, and the nonrenewable proportion of this energy increased from zero to 83 percent. Energy Information Administration, table E1, "Estimated Primary Energy Consumption in the United States, 1635–1945," *Annual Energy Review 2008*. Machines first outworked animals in 1870; by 1900 machines were doing 3.4 times as much useful work as animals. See R. U. Ayres, L. W. Ayres, and B. Warr, "Exergy, Power and Work in the US Economy, 1900–1998," *Energy* 2 (March 2003), 219–273.

3 Martin C. Heller and Gregory A. Keoleian, *Life Cycle-Based Sustainability Indicators for Assessment of the U.S. Food System,* Center for Sustainable Systems Report CSS00-04 (Ann Arbor: University of Michigan, 2000).

4 Annika Carlsson-Kanyama, Marianne Pipping Ekstrom, and Helena Shanahan, "Food and Life Cycle Energy Inputs: Consequences of Diet and Ways to Increase Efficiency," *Ecological Economics* 44, no. 2 (March 2003), 293–307.

5 Heller and Keoleian, *Life Cycle-Based Sustainability Indicators for Assessment of the U.S. Food System*.

6 J. D. Wood et al., "Effects of Fatty Acids on Meat Quality: A Review," *Meat Science* 66, no. 1 (January 2004), 21–32.

7 Carlsson-Kanyama et al., "Food and Life Cycle Energy Inputs."

8 H. Kim, D. Y. Kwon, and S. H. Yoon, "Induction of Phenolics and Terpenoids in Edible Plants Using Plant Stress Responses," in *Biocatalysis and Agricultural Biotechnology*, Ching T. Hou and Jei-Fu Shaw, eds. (Boca Raton, FL: CRC Press, 2009).

9 G. Tong, D. M. Christopher, and B. Li, "Numerical Modeling of Temperature Variations in a Chinese Solar Greenhouse," *Computers and Electronics in Agriculture* 68, no. 1 (August 2009), 129–139.

10 A Ford Explorer uses almost a third of a gallon of gasoline to drive four miles in the city (see U.S. Department of Energy/ Environmental Protection Agency, www.fueleconomy.gov), consuming about 36 megajoules of fossil energy—enough to carry two pounds of bananas around the world eight times on a full container ship. International Maritime Organization, "International Shipping: Carrier of World Trade," 2005, http://www.imo.org/includes/blastDataOnly.asp/data_id%3D13168/backgroundpaper%28E%29.pdf. A Toyota Prius can make the four-mile trip using 0.08 gallon of gasoline, which still contains enough energy for those bananas to circle the world twice.

11 Christopher L. Weber and H. Scott Matthews, "Food-Miles and the Relative Climate Impacts of Food Choices in the United States," *Environmental Science and Technology* 42, no. 10 (2008), 3508–3513.

12 "Designs," Vertical Farm Project, 2009, http://www.verticalfarm.com/designs.html.

13 Heller and Keoleian, *Life Cycle-Based Sustainability Indicators for Assessment of the U.S. Food System*.

14 Horace Herring and Richard York, "Jevons Paradox," Encyclopedia of Earth, October 8, 2006, http://www.eoearth.org/article/Jevons_paradox.

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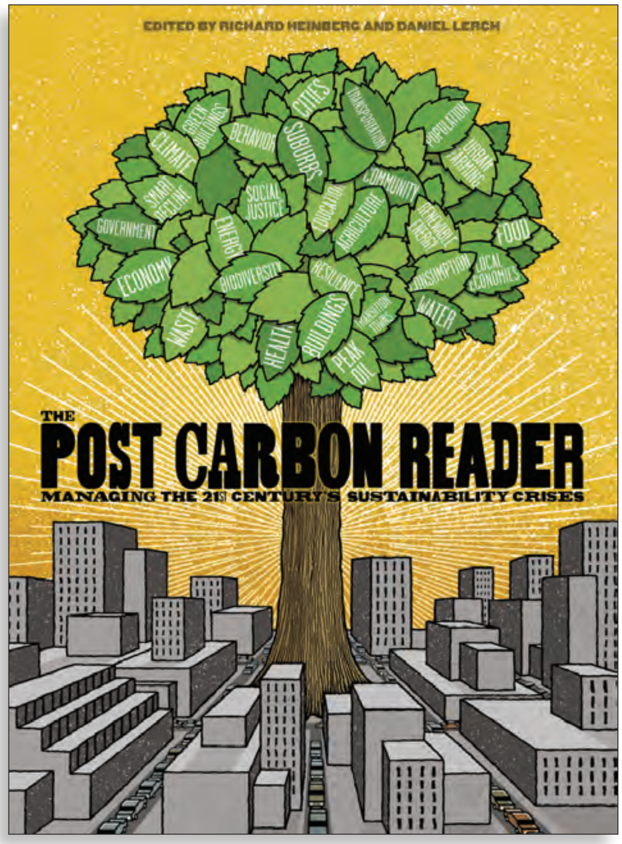

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The Post Carbon Reader

Managing the 21st Century's Sustainability Crises

Edited by RICHARD HEINBERG and DANIEL LERCH

In the 20th century, cheap and abundant energy brought previously unimaginable advances in health, wealth, and technology, and fed an explosion in population and consumption. But this growth came at an incredible cost. Climate change, peak oil, freshwater depletion, species extinction, and a host of economic and social problems now challenge us as never before. *The Post Carbon Reader* features articles by some of the world's most provocative thinkers on the key drivers shaping this new century, from renewable energy and urban agriculture to social justice and systems resilience. This unprecedented collection takes a hard-nosed look at the interconnected threats of our global sustainability quandary—as well as the most promising responses. *The Post Carbon Reader* is a valuable resource for policymakers, college classrooms, and concerned citizens.

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