NEW YORK TIMES BESTSELLER

DRAWDOWN

THE MOST COMPREHENSIVE PLAN EVER PROPOSED TO REVERSE GLOBAL WARMING

EDITED BY PAUL HAWKEN

FOOD

PLANT-RICH DIET

RANKING AND RESULTS BY 2050

#4

66.11 GIGATONS REDUCED CO2

GLOBAL COST AND SAVINGS DATA TOO VARIABLE TO BE DETERMINED

The Buddha, Confucius, and Pythagoras. Leonardo da Vinci and Leo Tolstoy. Gandhi and Gaudí. Percy Bysshe Shelley and George Bernard Shaw. Plant-based diets have had no shortage of notable champions, long before omnivore Michael Pollan famously simplified the conundrum of eating: "Eat food. Not too much. Mostly plants." "Mostly plants" is the key, although some argue all. Shifting to a diet rich in plants is a demand-side solution to global warming that runs counter to the meat-centric, highly processed, often-excessive Western diet broadly on the rise today.

That Western diet comes with a steep climate price tag. The most conservative estimates suggest that raising livestock accounts for nearly 15 percent of global greenhouse gases emitted each year; the most comprehensive assessments of direct and indirect emissions say more than 50 percent. Outside of the innovative, carbon-sequestering managed grazing practices described in this book, the production of meat and dairy contributes many more emissions than growing their sprouted counterparts—vegetables, fruits, grains, and legumes. Ruminants such as cows are the most prolific offenders, generating the potent greenhouse gas methane as they digest their food. In addition, agricultural land use and associated energy consumption to grow livestock feed produce carbon dioxide emissions, while manure and fertilizer emit nitrous oxide. If cattle were their own nation, they would be the world's third-largest emitter of greenhouse gases.

Overconsumption of animal protein also comes at a steep cost to human health. In many places around the world, the protein eaten daily goes well beyond dietary requirements. On average, adults require 50 grams of protein each day, but in 2009, the average per capita consumption was 68 grams per day—36 percent higher than necessary. In the United States and Canada, the average adult consumes more than 90 grams of protein per day. Where plant-based protein is abundant, human beings do not need animal protein for its nutrients (aside from vitamin B12 in strict vegan diets), and eating too much of it can lead to certain cancers, strokes, and heart disease. Increased morbidity and health-care costs go hand in hand.

With billions of people dining multiple times a day, imagine how many opportunities exist to turn the tables. It is possible to eat well, in terms of both nutrition and pleasure, while eating lower on the food chain and thereby lowering emissions. According to the World Health Organization, only 10 to 15 percent of one's daily calories need to come from protein, and a diet primarily of plants can easily meet that threshold.

Vertumnus by the painter Giuseppe Arcimboldo, created 1590–91, symbolizing the Roman god of metamorphoses.

A groundbreaking 2016 study from the University of Oxford modeled the climate, health, and economic benefits of a worldwide transition to plant-based diets between now and 2050. Business-as-usual emissions could be reduced by as much as 70 percent through adopting a vegan diet and 63 percent for a vegetarian diet (which includes cheese, milk, and eggs). The model also calculates a reduction in global mortality of 6 to 10 percent. The potential health impact on millions of lives translates into trillions of dollars in savings: $1 trillion in annual health-care costs and lost productivity, and upwards of $30 trillion when accounting for the value of lives lost. In other words, dietary shifts could be worth as much as 13 percent of worldwide gross domestic product in 2050. And that does not begin to include avoided impacts of global warming.

Similarly, a 2016 World Resources Institute report analyzes a variety of possible dietary modifications and finds that "ambitious animal protein reduction"—focused on reducing overconsumption of animal-based foods in regions where people devour more than 60 grams of protein and 2,500 calories per day—holds the greatest promise for ensuring a sustainable future for global food supply and the planet. "In a world that is on a course to demand more than 70 percent more food, nearly 80 percent more animal-based foods, and 95 percent more beef between 2006 and 2050," its authors argue, altering meat consumption patterns is critical to achieving a host of global goals related to hunger, healthy lives, water management, terrestrial ecosystems, and, of course, climate change.

The case for a plant-rich diet is robust. That said, bringing about profound dietary change is not simple because eating is profoundly personal and cultural. Meat is laden with meaning, blended into customs, and appealing to taste buds. The complex and ingrained nature of people's relationship with eating animal protein necessitates artful strategies for shifting demand. For individuals to give up meat in favor of options lower on the food chain, those options should be available, visible, and tempting. Meat substitutes made from plants are a key way to minimize disruption of established ways of cooking and eating, mimicking the flavor, texture, and aroma of animal protein and even replicating its amino acids, fats, carbohydrates, and trace minerals. With nutritious alternatives that appeal to meat-centric palates and practices, companies such as Beyond Meat and Impossible Foods are actively leading that charge, proving that it is possible to swap out proteins in painless or pleasurable ways. Select plant-based alternatives are now making their way into grocery store meat cases, a market evolution that can interrupt habitual behaviors around food. Between rapidly improving products, research at top universities, venture capital investment, and mounting consumer interest, experts expect markets for nonmeats to grow rapidly.

In addition to meat imitation, the celebration of vegetables, grains, and pulses in their natural form can update norms around these foods, elevating them to main acts in their own right, as opposed to sideshows. Omnivorous chefs are making the case for eating widely and with pleasure *without meat*. They include Mark Bittman, journalist and author of *How to Cook Everything Vegetarian*, and Yotam Ottolenghi, restaurateur and author of *Plenty*. Initiatives such as Meatless Monday and VB6 (vegan before six p.m.), as well as stories that highlight athletic heroes who eat plant-based diets (such as Tom Brady of the New England Patriots), are helping to shift biases around reduced meat consumption. Debunking protein myths and amplifying the health benefits of plant-rich diets can also encourage individuals to change their eating patterns. Instead of being the exception, vegetarian options should become the norm, especially at public institutions such as schools and hospitals.

Beyond promoting "reducetarianism," if not vegetarianism, it is also necessary to reframe meat as a delicacy, rather than a staple. First and foremost, that means ending price-distorting government subsidies, such as those benefiting the U.S. livestock industry, so that the wholesale and resale prices of animal protein more accurately reflect their true cost. In 2013, $53 billion went to livestock subsidies in the thirty-five countries affiliated with the Organisation for Economic Co-operation and Development alone. Some experts are proposing a more pointed intervention: levying a tax on meat—similar to taxes on cigarettes—to reflect its social and environmental externalities and dissuade purchases. Financial disincentives, government targets for reducing the amount of beef consumed, and campaigns that liken meat eating to tobacco use—in tandem with shifting social norms around meat consumption and healthy diets—may effectively conspire to make meat less desirable.

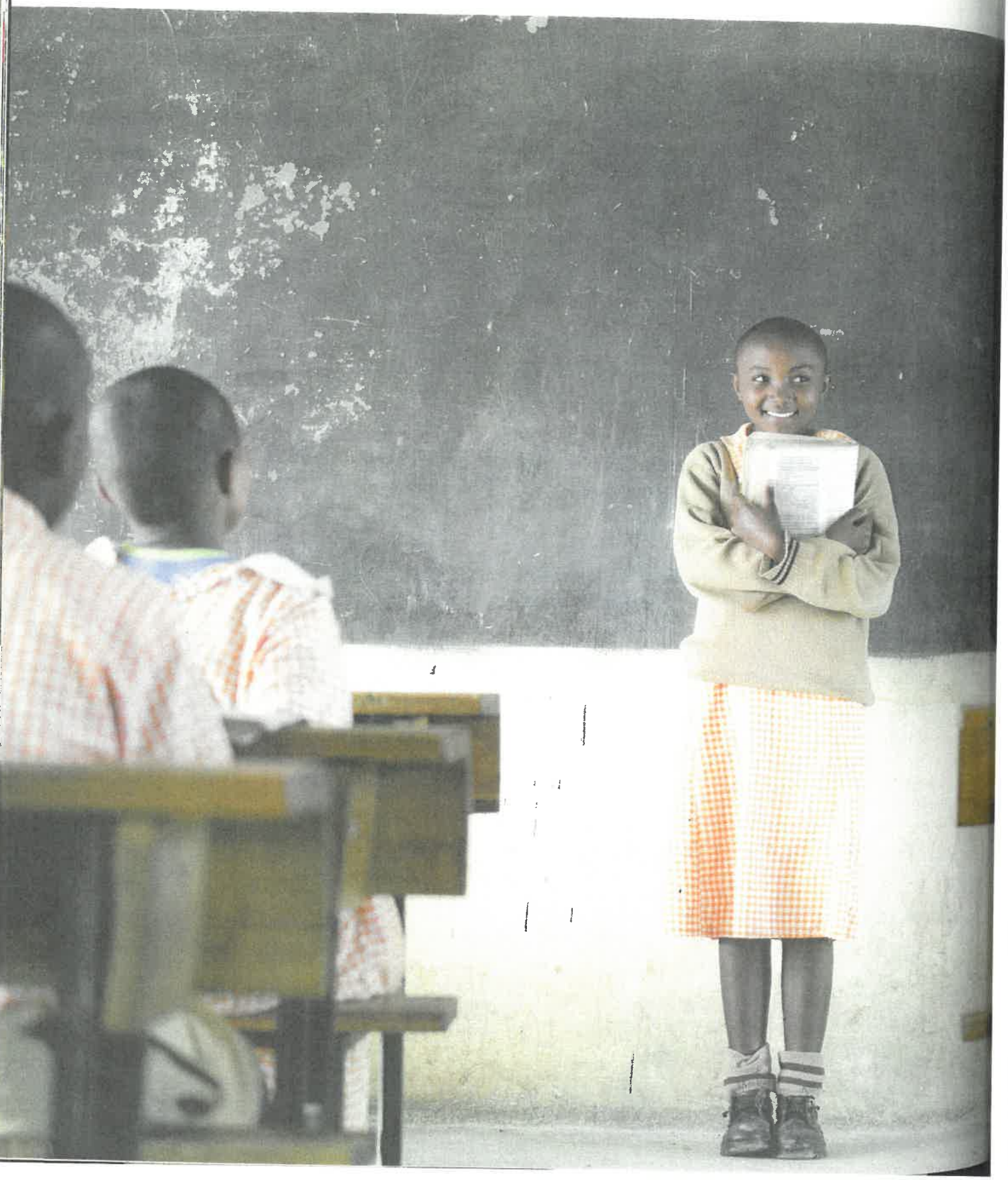
However they are achieved, plant-rich diets are a compelling win-win for society. Eating with a lighter footprint reduces emissions, of course, but also tends to be healthier, leading to lower rates of chronic disease. Simultaneously, it does less damage to freshwater resources and ecosystems—for example, the forests bulldozed to make way for cattle ranching and the immense aquatic "dead zones" created by farm runoff. With billions of animals currently raised on factory farms, reducing meat and dairy consumption reduces suffering that is well documented, often extreme, and commonly overlooked. Plant-based diets also open opportunities to preserve land that might otherwise go into livestock production and to engage current agricultural land in other, carbon-sequestering uses. As Zen master Thich Nhat Hanh has said, making the transition to a plant-based diet may well be the most effective way an individual can stop climate change. Recent research suggests he is right: Few climate solutions of this magnitude lie in the hands of individuals or are as close as the dinner plate.

IMPACT: *Using country-level data from the Food and Agriculture Organization of the United Nations, we estimate the growth in global food consumption by 2050, assuming that lower-income countries will consume more food overall and higher quantities of meat as economies grow. If 50 percent of the world's population restricts their diet to a healthy 2,500 calories per day and reduces meat consumption overall, we estimate at least 26.7 gigatons of emissions could be avoided from dietary change alone. If avoided deforestation from land use change is included, an additional 39.3 gigatons of emissions could be avoided, making healthy, plant-rich diets one of the most impactful solutions at a total of 66 gigatons reduced.*

Green chilies going on sale at the Sadarghat Market in Dhaka, Bangladesh.

WOMEN AND GIRLS

EDUCATING GIRLS

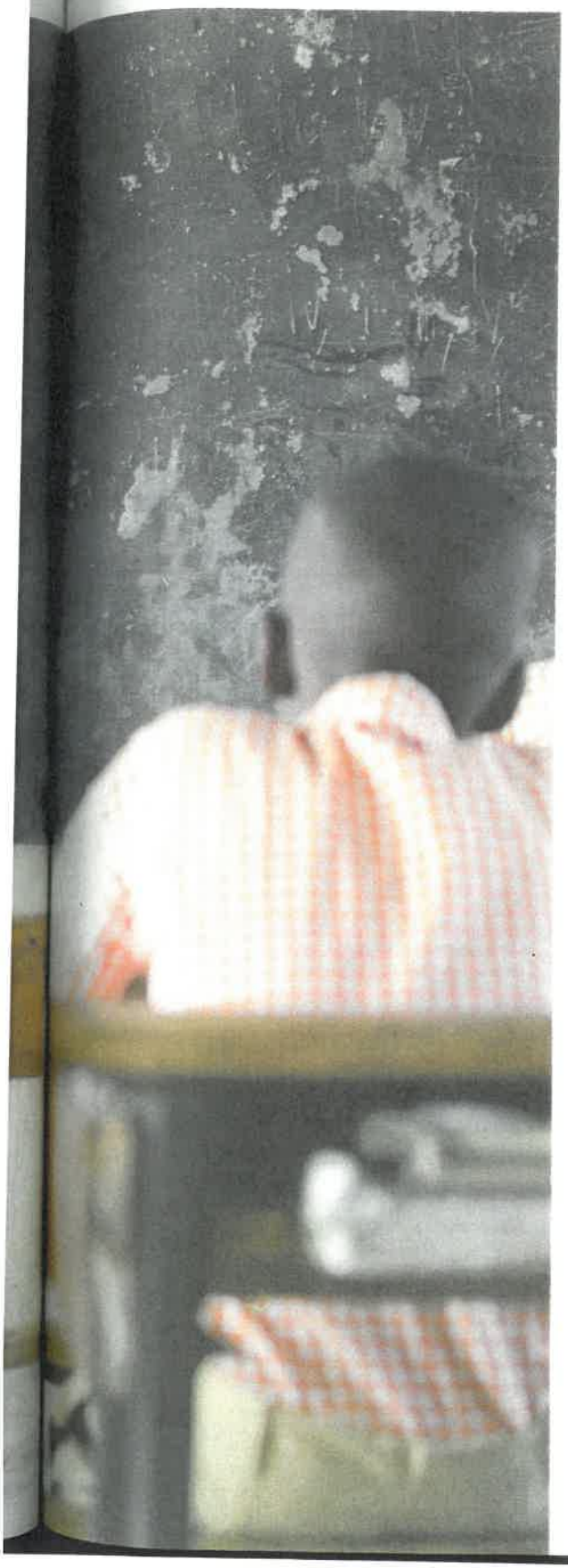


RANKING AND RESULTS BY 2050

#6

59.6 GIGATONS
REDUCED CO2

SEE IMPACT BELOW



Girls' education, it turns out, has a dramatic bearing on global warming. Women with more years of education have fewer, healthier children and actively manage their reproductive health. In 2011, the journal *Science* published a demographic analysis of the impact of girls' education on population growth. It details a "fast track" scenario, based on South Korea's actual climb from one of the least to most educated countries in the world. If all nations adopted a similar rate and achieved 100 percent enrollment of girls in primary and secondary school, by 2050 there would be 843 million fewer people worldwide than if current enrollment rates sustain. According to the Brookings Institution, "The difference between a woman with no years of schooling and with 12 years of schooling is almost four to five children per woman. And it is precisely in those areas of the world where girls are having the hardest time getting educated that population growth is the fastest."

In the poorest countries, per capita greenhouse gas emissions are low. People do not have enough energy to properly sanitize their water, read or study at night, or power their small businesses. There are 1.1 billion people who do not have any electricity at all. From one-tenth of a ton of carbon dioxide per person in Madagascar to 1.8 tons in India, per-capita emissions in lower-income countries are a fraction of the U.S. rate of 18 tons per person per year. Nevertheless, changes in fertility rates in these countries would have multiple benefits on virtually every level of global society.

Nobel laureate and girls' education activist Malala Yousafzai has famously said, "One child, one teacher, one book, and one pen, can change the world." An enormous body of evidence supports her conviction: For starters, educated girls realize higher wages and greater upward mobility, contributing to economic growth. Their rates of maternal mortality drop, as do mortality rates of their babies. They are less likely to marry as children or against their will. They have lower incidence of HIV/AIDS and malaria—the "social vaccine" effect. Their agricultural plots are more productive and their families better nourished. They are more empowered at home, at work, and in society. An intrinsic right, education lays a foundation for vibrant lives for girls and women, their families, and their communities. It is the most powerful lever available for breaking the cycle of intergenerational poverty, while mitigating emissions by curbing population growth. A 2010 economic study shows that investment in educating girls is "highly cost-competitive with almost all of the existing options for carbon emissions abatement"—perhaps just $10 per ton of carbon dioxide.

Education also shores up resilience in terms of climate change impacts—something the world needs as warming mounts. Across low-income countries, there is a strong link between women and the natural systems at the heart of family and community life. Women often and increasingly play roles as stewards and managers of food, soil, trees, and water. As educated girls become educated women, they can fuse inherited traditional knowledge with new

Kenya has made significant gains in education, with more than 80 percent of all boys and girls currently enrolled in primary schools. In secondary schools, the rate of enrollment drops to 50 percent for both boys and girls. Poverty is the main cause of low overall enrollment, and given socioeconomic norms, boys receive priority for higher education when there are financial constraints.

Malala Yousafzai is an activist for girls' education who was born in the Swat Valley in northern Pakistan. Largely educated by her father, Yousafzai was recognized early in life by the global community for her commitment to education rights under the specter of the Taliban's growing influence in Swat. In October 2012, a Taliban gunman attempted to assassinate Yousafzai as she was riding a bus home after taking an exam. Malala is the youngest recipient of the Nobel Peace Prize, and continues both her studies and her work through the Malala Fund, which aims to secure 12 years of safe, quality education for girls the world over.

information accessed through the written word. As cycles of change play out in the times to come—new diseases blighting fruit trees, soil composition shifting in garden plots, altered seed-sowing times—educated women can marshal multiple ways of knowing to observe, understand, reevaluate, and take action to sustain themselves and those who depend on them.

Education also equips women to face the most dramatic climatic changes. A 2013 study found that educating girls "is the single most important social and economic factor associated with a reduction in vulnerability to natural disasters." *The single most important*. It is a conclusion drawn from examining the experiences of 125 countries since 1980 and echoes other analyses. Educated girls and women have a better capacity to cope with shocks from natural disasters and extreme weather events and are therefore less likely to be injured, displaced, or killed when one strikes. This decreased vulnerability also extends to their children, families, and the elderly.

In the past twenty-five years, the global community has learned a great deal about educating girls. So many challenges impede girls from realizing their right to education, and yet, around the world, they are striving for a place in the classroom. Economic barriers include lack of family funds for school fees and uniforms, as well as prioritizing the more immediate benefits of having girls fetch water or firewood, or work a market stall or plot of land. Cultural barriers encompass traditional beliefs that girls should tend the home rather than learn to read and write, should be married off at a young age, and, when resources are slim, should be skipped over so boys can be sent to school instead. Barriers are also safety related. Schools that are farther afield put girls at risk of gender-based violence on their way to and from, not to mention dangers and discomforts at school itself. Disability, pregnancy, childbirth, and female genital mutilation also can be obstacles.

The barriers are real, but so are the solutions. The most effective approaches concurrently tackle access (school affordability, proximity, and suitability for girls) and quality (good teachers and good learning outcomes). Mobilizing communities to support and sustain progress on girls' education is a powerful accelerant. The encyclopedic book *What Works in Girls' Education* maps out seven areas of interconnected interventions:

1. Make school affordable.
   For example, provide family stipends for keeping girls in school.
2. Help girls overcome health barriers.
   For example, offer deworming treatments.
3. Reduce the time and distance to get to school.
   For example, provide girls with bikes.
4. Make schools more girl-friendly.
   For example, offer child-care programs for young mothers.
5. Improve school quality.
   For example, invest in more and better teachers.
6. Increase community engagement.
   For example, train community education activists.
7. Sustain girls' education during emergencies.
   For example, establish schools in refugee camps.

Today, 130 million girls are denied the right to attend school. The situation is most dire in secondary classrooms. In South Asia, less than half of girls—16.3 million—are enrolled in secondary school. In sub-Saharan Africa, fewer than one in three girls attends secondary school, and while 75 percent of all girls start school, just 8 percent finish their secondary education. Currently, international aid for education projects is about $13 billion annually. Given the link between girls' education and climate change, funds for climate mitigation and adaptation could enable the world to scale solutions rapidly. It could be a powerful match between education's need for funds and the world's need for proven climate solutions. Moreover, synchronizing investments in girls' education with those in family planning would be complementary and mutually reinforcing. Education is grounded in the belief that every life bubbles with innate potential. When it comes to climate change, nurturing the promise of each girl can shape the future for all.

IMPACT: *Two solutions influence family size and global population: educating girls and family planning. Because the exact dynamic between these solutions is impossible to determine, our models allocate 50 percent of the total potential impact to each. We assume that these impacts result from thirteen years of schooling, including primary through secondary education. According to the United Nations Educational, Scientific, and Cultural Organization, by closing an annual financing gap of $39 billion, universal education in low- and lower-middle-income countries can be achieved. It could result in 59.6 gigatons of emissions reduced by 2050. The return on that investment is incalculable.*

ENERGY
ROOFTOP SOLAR

The year was 1884, when the first solar array appeared on a rooftop in New York City. Experimentalist Charles Fritts installed it after discovering that a thin layer of selenium on a metal plate could produce a current of electricity when exposed to light. How light could turn on lights, he and his solar-pioneering contemporaries did not know, for the mechanics were not understood until the early twentieth century when, among other breakthroughs, Albert Einstein published his revolutionary work on what are now called photons. Though the scientific establishment of Fritts's day believed power generation depended on heat, Fritts was convinced that "photoelectric" modules would wind up competing with coal-fired power plants. The first such plant had been brought online by Thomas Edison just two years earlier, also in New York City.

Today, solar is replacing electricity generated from coal as well as from natural gas. It is replacing kerosene lamps and diesel generators in places where people lack access to the power grid, true for more than a billion people around the world. While society grapples with electricity's pollution in some places and its absence in others, the mysterious waves and particles of the sun's light continuously strike the surface of the planet with an energy more than ten thousand times the world's total use. Small-scale photovoltaic systems, typically sited on rooftops, are playing a significant role in harnessing that light, the most abundant resource on earth. When photons strike the thin wafers of silicon crystal within a vacuum-sealed solar panel, they knock electrons loose and produce an electrical circuit. These subatomic particles are the only moving parts in a solar panel, which requires no fuel.

While solar photovoltaics (PV) provide less than 2 percent of the world's electricity at present, PV has seen exponential growth over the past decade. In 2015 distributed systems of less than 100 kilowatts accounted for roughly 30 percent of solar PV capacity installed worldwide. In Germany, one of the world's solar leaders, the majority of photovoltaic capacity is on rooftops, which don 1.5 million systems. In Bangladesh, population 157 million, more than 3.6 million home solar systems

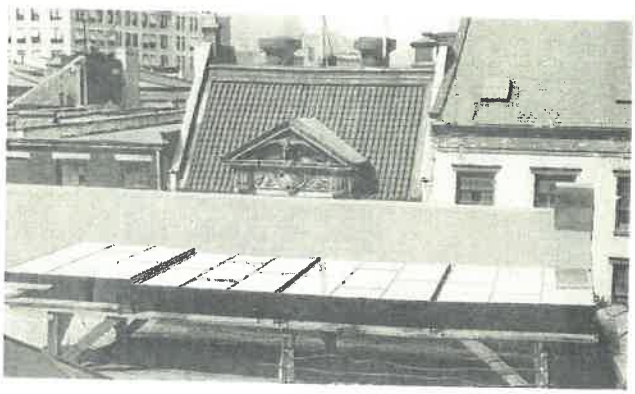
An Uros mother and her two daughters live on one of the 42 floating islands made of totora reeds on Lake Titicaca. Their delight upon receiving their first solar panel is infectious. Installed at an elevation of 12,507 feet, the panel will replace kerosene and provide electricity to her family for the first time. As high tech as solar may be, it is a perfect cultural match: The Uru People know themselves as Lupihaques, Sons of the Sun.

have been installed. Fully 16 percent of Australian homes have them. Transforming a small section of rooftop into a miniature power station is proving irresistible.

Roof modules are spreading around the world because of their affordability. Solar PV has benefited from a virtuous cycle of falling costs, driven by incentives to accelerate its development and implementation, economies of scale in manufacturing, advances in panel technology, and innovative approaches for end-user financing—such as the third-party ownership arrangements that have helped mainstream solar in the United States. As demand has grown and production has risen to meet it, prices have dropped; as prices have dropped, demand has grown further. A PV manufacturing boom in China has helped unleash a torrent of inexpensive panels around the world. But hard costs are only one side of the expense equation. The soft costs of financing, acquisition, permitting, and installation can be half the cost of a rooftop system and have not seen the same dip as panels themselves. That is part of the reason rooftop solar is more expensive than its utility-scale kin. Nonetheless, small-scale PV already generates electricity more cheaply than it can be brought from the grid in some parts of the United States, in many small island states, and in countries including Australia, Denmark, Germany, Italy, and Spain.

The advantages of rooftop solar extend far beyond price. While the production of PV panels, like any manufacturing process, involves emissions, they generate electricity without emitting greenhouse gases or air pollution—with the infinite resource of sunlight as their sole input. When placed on a grid-connected roof, they produce energy at the site of consumption, avoiding the inevitable losses of grid transmission. They can help utilities meet broader demand by feeding unused electricity into the grid, especially in summer, when solar is humming and electricity needs run high. This "net metering" arrangement, selling excess electricity back to the grid, can make solar panels financially feasible for homeowners, offsetting the electricity they buy at night or when the sun is not shining.

Numerous studies show that the financial benefit of rooftop PV runs both ways. By having it as part of an energy-generation portfolio, utilities can avoid the capital costs of additional coal or gas plants, for which their customers would otherwise have to pay, and broader society is spared the environmental and public health impacts. Added PV supply at times of highest electricity demand can also curb the use of expensive and polluting peak generators. Some utilities reject this proposition and posit contradictory claims of rooftop PV being a "free rider," as they aim to block the rise of distributed solar and its impact on their revenue and profitability. Others accept its inevitability and are trying to shift their business models accordingly. For all involved, the need for a grid "commons" continues, so utilities, regulators, and stakeholders of all stripes are evolving approaches to cover that cost.



The first solar array installed by Charles Fritts in 1884 in New York City. Fritts built the first solar panels in 1881, reporting that the current was "continuous, constant and of considerable force not only by exposure to sunlight but also to dim, diffused daylight, and even to lamplight."

Off the grid, rooftop panels can bring electricity to rural parts of low-income countries. Just as mobile phones leapfrogged installation of landlines and made communication more democratic, solar systems eliminate the need for large-scale, centralized power grids. High-income countries dominated investment in distributed solar until 2014, but now countries such as Chile, China, India, and South Africa have joined in. It means rooftop PV is accelerating access to affordable, clean electricity and thereby becoming a powerful tool for eliminating poverty. It is also creating jobs and energizing local economies. In Bangladesh alone, those 3.6 million home solar systems have generated 115,000 direct jobs and 50,000 more downstream.

Since the late nineteenth century, human beings in many places have relied on centralized plants that burn fossil fuels and send electricity out to a system of cables, towers, and poles. As households adopt rooftop solar (increasingly accompanied and enabled by distributed energy storage), they transform generation and its ownership, shifting away from utility monopolies and making power production their own. As electric vehicles also spread, "gassing up" can be done at home, supplanting oil companies. With producer and user as one, energy gets democratized. Charles Fritts had this vision in the 1880s, as he looked out over the roofscape of New York City. Today, that vision is increasingly coming to fruition.

IMPACT: *Our analysis assumes rooftop solar PV can grow from .4 percent of electricity generation globally to 7 percent by 2050. That growth can avoid 24.6 gigatons of emissions. We assume an implementation cost of $1,883 per kilowatt, dropping to $627 per kilowatt by 2050. Over three decades, the technology could save $3.4 trillion in home energy costs.*