# ensia

A NEW LOOK AT ENVIRONMENTAL CHALLENGES — AND SOLUTIONS

2016

FROM THE DIRECTOR

# SHAPING A MORE HOPEFUL FUTURE

## WHY ENSIA? WHY ARE WE DOING WHAT WE DO?

We've all heard about the environmental challenges facing the world today — climate change, deforestation, species loss, water pollution and on and on. But much of the time it feels like we're not moving fast enough to solve these problems, even though we might have the means and knowledge to do so.

On top of all this, environmental communication is facing tough times.

In-depth reporting is less common. Environmental journalism educational programs have closed their doors. Professional environmental communicators are being replaced by generalists and bloggers who often lack the context and, in some cases, the impartiality needed to provide credible, compelling coverage. Communication tends to focus on "doom and gloom" and is increasingly partisan, polarized, superficial and at times even counterproductive to bringing about the change we need.

Yet all around the world individuals, companies, governments and organizations are working on solutions to environmental grand challenges. Where are those stories?

What's needed is a powerful catalyst — a media platform that brings individuals and their ideas, innovation and inspiration together in a way that will change the world.

This is where Ensia comes in.

In 2008, we introduced Ensia's print magazine predecessor, *Momentum*. Our aim was to move beyond doom-and-gloom reporting to shine a light on solutions to environmental challenges happening around the world. To accomplish this goal, we broadened the conversation beyond the "usual suspects" by engaging people from all places, sectors, disciplines and political persuasions in shaping solutions.

In 2013, recognizing the need to extend our approach beyond our limited print audience, we took the bold step of re-launching *Momentum* as Ensia with a powerful online presence. Today top-tier journalists and global thought leaders are coming to us to share their biggest ideas. We're increasingly seen as a leading and trusted source for environmental reporting. Our mentor program is providing guidance from seasoned environmental journalists to a new generation of journalists and storytellers. And our growing network of more than 35 media partners brings our stories to millions of people around the world in more than a dozen languages.

This special year-end issue includes a selection of some of our most compelling articles and commentaries from the past year. You'll find stories on underreported issues, such as Elizabeth Grossman's exploration of the effect environmental chemicals are having on our children's brains. Stories where we ask important questions others have ignored: How did palm oil become such a problem in the first place? There are stories that resonated with our readers and media partners. And stories that, well, just tell a great story.

*WHAT'S NEEDED IS A POWERFUL CATALYST — A MEDIA PLATFORM THAT BRINGS INDIVIDUALS AND THEIR IDEAS, INNOVATION AND INSPIRATION TOGETHER IN A WAY THAT WILL CHANGE THE WORLD.*

We also ask 10 experts from around the world to look into a crystal ball and give us their take on what 2016 — and beyond — might hold for the environment as it relates to business, energy, agriculture, water and much more.

If you like what you see, we invite you to follow us online over the course of the coming year. We'll be launching new partnerships, expanding our multimedia content, targeting new audiences, hosting additional live events and mentoring more storytellers as we continue to publish high-quality, award-winning content focused on moving the conversation from problems to solutions.

PHOTO BY JEN MENEGHIN

We look forward to hearing from you, too. What are the stories we should be covering? Who are the emerging environmental leaders we should be talking to? And how can we further expand Ensia's impact and influence in the search for environmental solutions?

Together, let's work toward a more hopeful future for both people and the planet.

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Ensia is a magazine showcasing environmental solutions in action. We cover a broad spectrum of environment and sustainability issues, looking to the crossroads of sectors, disciplines, ideologies and geographies for new ideas to emerge. Our mission is to share environmental solutions and spark conversations that motivate, empower and inspire people to create a more sustainable future. Ensia is powered by the Institute on the Environment at the University of Minnesota. This annual issue was made possible with support from major foundations and private individuals.

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ON THE COVER

*Norwegian photographer Vilde J. Rolfsen creates mysterious images with a nod toward everyday objects, throwaway culture and consumerism. To learn more about the cover and see more of her work, turn to page 96.*

This publication is printed on environmentally friendly paper with 30% postconsumer waste.

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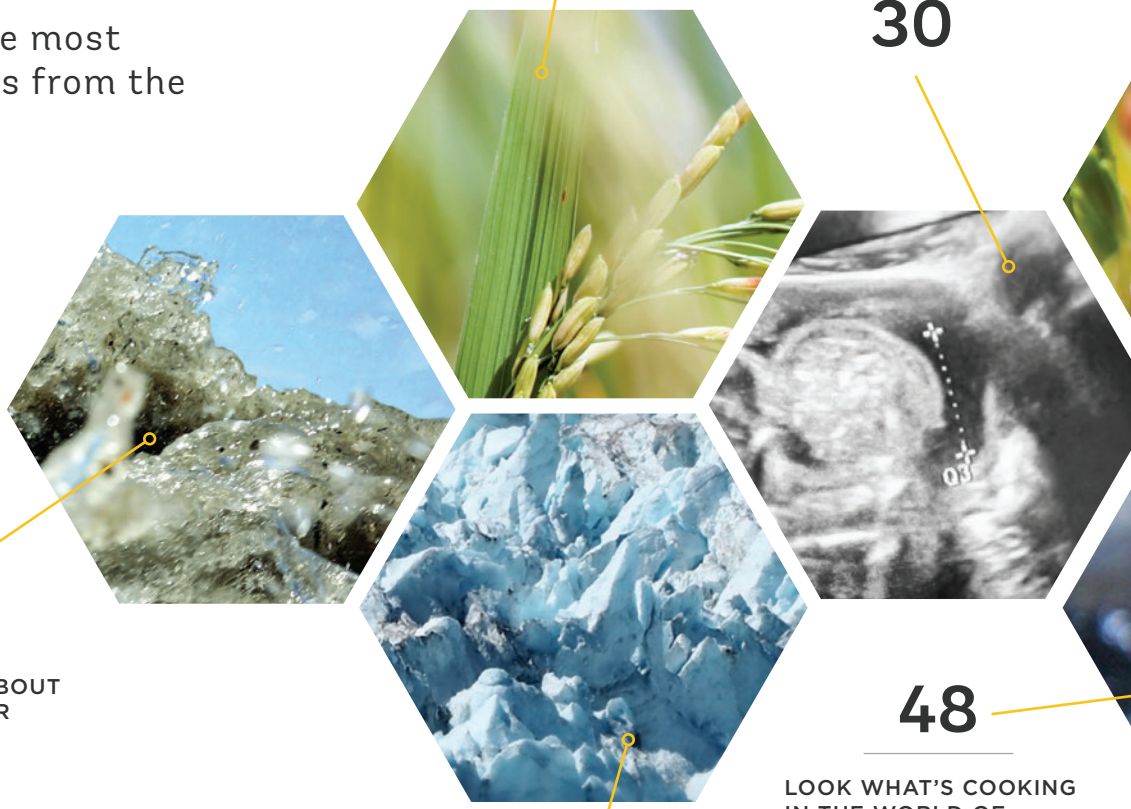
# SPOTLIGHT

A collection of the most compelling stories from the past year

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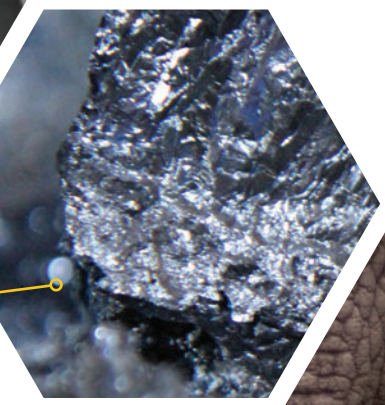

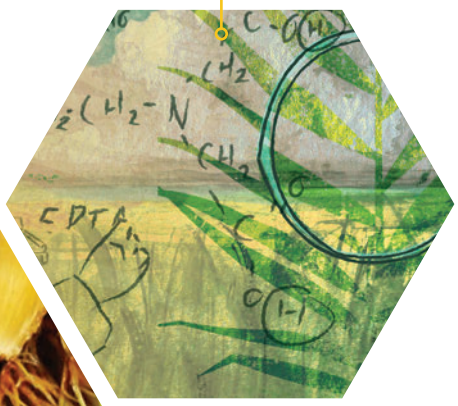

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*THE*

# LONG VIEW

Futurist Jamais Cascio and author Ramez Naam discuss the issues affecting the environment a decade or more into the future.

# SPOTLIGHT

**FROM THE ARCTIC TO AFRICA,** Ensia's stories spanned the globe over the past year. Here, we compile some of the most compelling, along with updates, maps, graphics and other additions. We invite you to take a fresh look as Elizabeth Grossman writes about the astonishing — and frightening — number of chemicals suspected to affect brain development; Greg Breining surprises us with the ways genetic engineering is being considered as a tool for revitalizing species on the brink; Elizabeth Royte uncovers a surging interest in urban agriculture; Cynthia Barnett starts a conversation about one of the most undervalued resources in America; Shreya Dasgupta leads readers on a journey to beleaguered rice fields in the Bay of Bengal; Adam Welz joins the wild race to save rhinos from extinction; Michael Kodas takes us to Indonesia and beyond to get to the roots of the palm oil problem; Phil McKenna peeks into the future of renewable energy; and Edward Struzik explores a part of the world that's changing faster than any other place on the planet. In addition, you'll enjoy a sample of the more than 50 pieces we published in 2015 from global experts who shared their opinions on how best to advance environmental solutions.

PHOTO © ISTOCKPHOTO.COM/TRAPPEDPIXELS

HEY, AMERICA:

*IT'S TIME TO TALK ABOUT THE*

# PRICE OF WATER

RECENT WOES HAVE DRAWN UNPRECEDENTED ATTENTION TO THE WORTH OF FRESH, CLEAN WATER. CAN IT CHANGE THE WAY WE PAY FOR THE WORLD'S MOST UNDERVALUED RESOURCE?

*BY CYNTHIA BARNETT*

ORIGINALLY PUBLISHED:
OCTOBER 2014

## WHY THIS MATTERS

In the summer of 2014, the media reported on a variety of water crises across the U.S., covering each as an individual story. What was missing was a look at the underlying question: What do we need to do differently to prevent future incidents such as Lake Erie becoming tainted with toxic green algae or nearly century-old water pipes bursting? When we asked veteran water journalist Cynthia Barnett to investigate, the answer became clear: Water is the most undervalued resource in the U.S., and we need to pay what it's worth if we want to keep it safe and available. Barnett's feature for Ensia gives concerned citizens and anyone else working on water issues the information they need to argue for such changes.

In the summer of 2014, a 90-year-old water pipe burst under Sunset Boulevard in Los Angeles, sending a geyser 30 feet (9 meters) into the air and a flood of troubles over the University of California, Los Angeles, campus. Raging water and mud trapped five people, swamped 1,000 cars and flooded five university buildings — blasting the doors off elevators and ruining the new wooden floor atop the Bruins' storied basketball court.

As the campus dried out, though, Angelenos seemed less upset about the replaceable floorboards at Pauley Pavilion than they were over another loss: 20 million gallons (75 million liters) of freshwater wasted in the middle of the worst drought in California history. L.A. mayor Eric Garcetti took heat for his earlier campaign promise not to raise water rates in a city with a long backlog of repairs for aging water pipes.

Five days after the L.A. pipeline rupture, officials in Toledo, Ohio, declared the tap water for half a million people unsafe to drink, tainted by toxic algae spreading in the warm waters of Lake Erie. As residents of one of the most water-blessed regions in the world waited in lines to buy bottled water, an issue that had held little political urgency rose near the top of Ohio's gubernatorial and legislative races. Former Toledo mayor Mike Bell held back an "I told you so" for council veterans who'd resisted rate increases to pay for upgrades to the city's 73-year-old water-treatment plant.

In Los Angeles and Toledo and across the U.S., historic drought, water-quality threats heightened by warming waters and poorly maintained infrastructure are converging to draw public attention to the value of fresh, clean water to a degree not seen since Congress passed the Clean Water Act in 1972. The problems are also laying bare the flawed way we pay for water — one that practically guarantees pipes will burst, farmers will use as much as they can and automatic sprinklers will whir over desiccated aquifers.

Squeezed by drought, U.S. consumers and western farmers have begun to pay more for water. But the increases do not come close to addressing the fundamental price paradox in a nation that uses more water than any other in the world while generally paying less for it. And some of the largest water users in the East, including agricultural, energy and mining companies, often pay nothing for water at all.

As a result, we're subsidizing our most wasteful water use — while neglecting essentials like keeping our water plants and pipes in good repair. "You can get to sustainability," says David Zetland, a water economist and author of the book *Living With Water Scarcity*. "But you can't get there without putting a price on water."

### CHEAP, ABUNDANT ILLUSION

Water is the most essential utility delivered to us each day, meeting our drinking and sanitation needs and many others, from fire protection to irrigation. Incongruously, it is also the resource we value least. This is true generally for both the way we use water and the price we put on it.

On the global scale, Americans pay considerably less for water than people in most other developed nations. In the U.S., we pay less for water than for all other utilities. That remains true in these times of increasing water stress, says Janice Beecher, director of the Institute of Public Utilities at Michigan State University, whose data show the average four-person household spends about US$50 a month for water, compared with closer to US$150 for electricity and telephone services.

Water's historically cheap price has turned the U.S. hydrologic cycle abjectly illogical. Pennies-per-gallon water makes it rational for homeowners to irrigate lawns to shades of Oz even during catastrophic droughts like the one gripping California. On the industrial side, water laws that evolved to protect historic uses rather than the health of rivers and aquifers can give

In recent years algae have spread in Lake Erie, prompting officials in Toledo, Ohio, to declare drinking water unsafe.

PHOTO BY PETER ESSICK

farmers financial incentive to use the most strained water sources for the least sustainable crops. In just one example, farmers near Yuma, Arizona — the driest spot in the United States, with an average rainfall of 3 inches (8 centimeters) per year — use Colorado River water to grow thirsty alfalfa; under the law of the river, if they don't use their allotment, they'll lose their rights to it.

For both municipal waterworks and those that carry irrigation water to farms, the illusion of cheap, abundant water arose with the extensive federal subsidies of the mid-20th century. The Bureau of Reclamation built tens of billions of dollars' worth of irrigation and supply projects that were supposed to have been reimbursed by beneficiaries; most were not repaid. After passage of the Clean Water Act and the Safe Drinking Water Act in the 1970s, the feds doled out billions more dollars, this time to local communities to help upgrade water plants and pipes. Since ratepayers didn't have to bear the costs, they didn't balk at treating water destined for toilets and lawns to the highest drinking-water standards in the land.

*WATER IS THE MOST ESSENTIAL UTILITY DELIVERED TO US EACH DAY, MEETING OUR DRINKING AND SANITATION NEEDS AND MANY OTHERS, FROM FIRE PROTECTION TO IRRIGATION.*

Americans got used to paying wee little for a whole lot of pristine water. At the same time, many utilities delayed the long-term

capital investments needed to maintain their pipes and plants. Water boards are often run by local elected officials, making decisions uneasily political. A board member with a three-year term might not vote for a water project that would pay off in year six. Officials who tried to raise rates risked being booted out of office. It was easier to hope federal subsidies would continue to flow. They did not. A Reagan Administration phase-out of water-infrastructure grants began 25 years ago. Over the past decade, U.S. Environmental Protection Agency water infrastructure funding has declined (with the exception of 2009, the year of the American Recovery and Reinvestment Act), and policy has shifted from grants to loans.

Unfortunately for water utilities, the timing coincided with the arrival of requirements to scrub dozens of newly regulated contaminants out of drinking water and record numbers of water mains and pipes bursting due to age and extreme temperatures, both hot and cold.

## PLAYING CATCH-UP

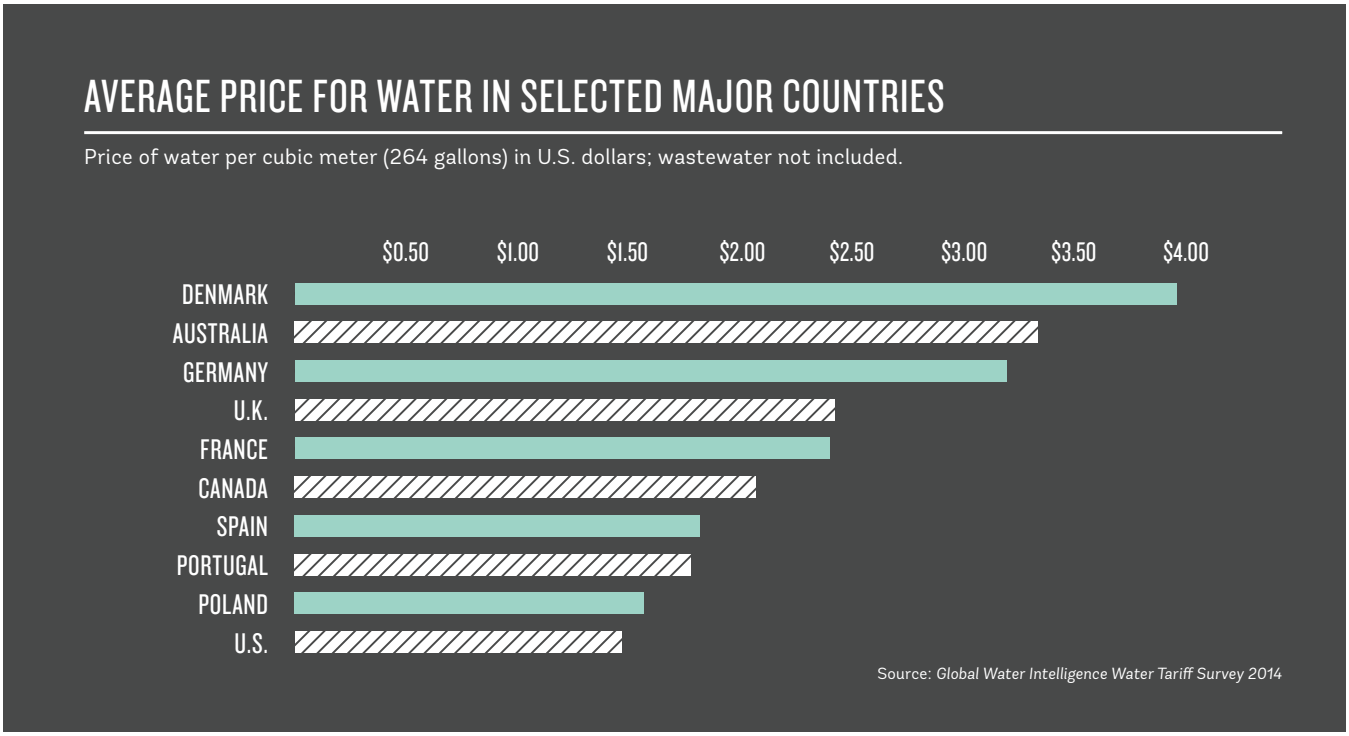
In recent years, municipalities have begun raising rates to play catch-up. Since 2007, city water prices have risen at rates faster than the overall cost of living. Even so, the water sector reports it is not enough to pay for an estimated US$1 trillion in anticipated repair costs for buried water pipes and growth-related infrastructure costs over the next 25 years.

When it comes to meeting needs associated with growth, many of the most promising solutions are found on the demand side. Americans still use more water per person than anywhere else in the world. But the U.S. today taps less water overall than it did 40 years ago despite population and economic growth, thanks to increased efficiency and awareness. From irrigation to manufacturing to toilet flushing, everything we do takes a lot less water than it used to.

Because utilities' funding relies on revenue generated by water sales, efficiency has many utilities up a creek and churning blame. In August 2014, *The Washington Post* published a story, reprinted in newspapers around the nation, that blamed "federally mandated low-flow toilets, shower heads and faucets" for water utilities' financial woes. Conservation, the story said, was the cause of higher water rates and new fees.

The reality is just the opposite, says Mary Ann Dickinson, president and CEO

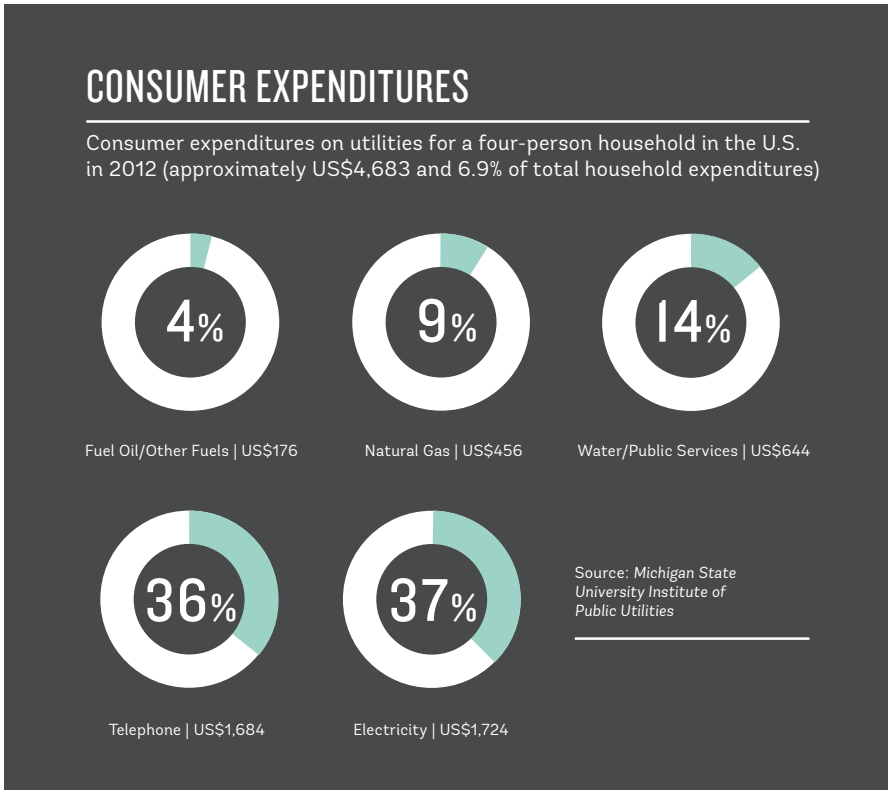
*EVERYONE IS BEGINNING TO PAY MORE FOR WATER — BUT COMMUNITIES THAT CONSERVE HAVE LOWER LONG-TERM COSTS THAN THOSE THAT DON'T.*



of the Alliance for Water Efficiency, a Chicago-based nonprofit dedicated to sustainable water use. Everyone is beginning to pay more for water — but communities that conserve have lower long-term costs than those that don't. In many cases, simply saving water can eliminate the need for costly new sources, Dickinson says. Growing, water-stressed cities including San Antonio and Perth, Australia, have saved ratepayers more than a billion dollars in long-term capital costs by helping them slash water use in half. An analysis by the city of Westminster, Colorado, found that reduced water use by citizens since 1980 saved residents and businesses 80 percent in tap fees and 91 percent in water rates, compared to the costs of acquiring the new water — close to US$220 million on Colorado's Front Range.

Efficiency will be the answer in many communities, although it cannot save the day in financially strapped cities that are losing population. Detroit's emergence from bankruptcy depends in part on its ability to sell water, but it has lost a quarter of its population over the past decade. Under pressure to reduce more than US$90 million in bad debt, the Detroit Water and Sewerage Department in the spring began ordering shutoffs for customers who had fallen behind on their bills, prompting a global outcry and a warning from the United Nations.

Pictures of American families bathing and brushing teeth from five-gallon buckets hold a mirror to the nation's "hydro-illogical" cycle: We subsidize water for the largest users in the United States, including agriculture and energy plants, yet we do not ensure a basic amount of water for the poorest citizens.




## AGRICULTURE AT THE TABLE

Likewise, efficiency doesn't solve water-quality issues like Toledo's, where ratepayers could be looking at US$1 billion for a new drinking-water plant advanced enough to filter out the pollutants brewing in Lake Erie, their water source. Donald Moline, commissioner of Toledo's public utilities department, says the cost issues are opening up much-needed dialogue with the agricultural community on its contribution to nonpoint-source pollution in Lake Erie. Fueled by farming, septic systems, urban runoff and other causes, nonpoint-source pollution is the largest contributor to water-quality problems in the United States. "It used to be we just weren't allowed to get into the agricultural causes, but given the science of this, we can't ignore that piece," Moline says.

Indeed, concerns over both quality and quantity make agriculture an increasingly important part of the conversation about how we value and price water, says University of Arizona law professor Robert Glennon, author of the books *Water Follies* and *Unquenchable: America's Water Crisis and What to Do About It*.

Irrigation costs differ significantly for American farmers depending on whether they operate in the West or in the East. Reclamation Reform Acts in the 1980s and '90s began to shift the costs of major U.S. irrigation projects — which move river water around the West — from federal taxpayers to western farmers, whose bill depends on an arcane mix of water rights,

*CONCERNS OVER BOTH QUALITY AND QUANTITY MAKE AGRICULTURE AN INCREASINGLY IMPORTANT PART OF THE CONVERSATION ABOUT HOW WE VALUE AND PRICE WATER.*

allocations and contracts. But in the Colorado River basin, century-old water law can still create a tragedy of the commons in which farmers risk losing their allotment if they don't use it. To solve this waste-encouraging dilemma, Glennon advocates a regulated system of markets and trading that would allow farmers to sell their water allotments to cities in times of drought or let a manufacturer pay to convert a large farm from flood to drip irrigation in exchange for the saved water.

Groundwater presents yet another paradox of price: Rising energy costs and declining water levels in troubled aquifers such as the Ogallala in the U.S. Great Plains have helped motivate many farmers to use less water. Agricultural and industrial water users pay for the wells, pumps and energy to draw water up from belowground, but in much of the country they still pay nothing for the water itself — which in some cases has provoked a race to the bottom that can dry up neighbors' wells and even collapse the ground underfoot. In one hot spot in California's San Joaquin Valley, U.S. Geological Survey scientists found that steady groundwater pumping in the nut-tree region south of Merced is sinking the ground nearly a foot a year, threatening infrastructure damage to local communities.

In August 2014, the California legislature passed a package of laws to regulate groundwater pumping for the first time in state history. But the laws won't slow damage to aquifers without meaningful limits on groundwater withdrawals or a charge for extraction, says Zetland, the water economist. Both are tough to pull off in politically regulated systems. Florida has required permits for large groundwater withdrawals since 1972. But governor-appointed water boards are reluctant to deny them, which has aggravated aquifer depletion, drying springs and coastal saltwater intrusion in some parts of the state. For decades, various Florida councils, committees and commissions have concluded that a small fee on groundwater withdrawals — between a penny and 20 cents for every 1,000 gallons (4,000 liters) — would reduce pumping

A boat ramp was far from the Millerton Lake shoreline as California entered its fourth year of drought in 2015.

PHOTO BY SONYA DOCTORIAN

and fund water-resource protection with "minimal adverse economic impacts" to industry and agriculture, according to one analysis by Chase Securities. But the agricultural lobby keeps the idea from getting very far in the state legislature.

## NEW APPROACHES

Going forward, water infrastructure, supply and quality challenges intensified by the droughts, floods, temperature extremes and other influences of a changing climate will require new approaches to not only price, but also ethics: using less and polluting less, recycling more, and sharing costs among all users.

At the local utility level, higher prices and tiered price structures, in which households that use more pay more, are both working to encourage conservation. Utilities are also turning to new types of bonds to cover long-term projects, such as the 100-year "green bond" sold by the District of Columbia Water and Sewer Authority to finance environmentally friendly stormwater solutions.

Water-science and engineering groups such as the American Society of Civil Engineers make the case that the U.S. infrastructure crisis is severe enough that local communities cannot solve it alone; they suggest that federal investment is crucial to forestall significant costs in emergency repair and business losses.

Market fixes and agricultural partnerships are also part of the answer — especially if water law can evolve to do a better job of protecting the environment and local communities. Over the past two decades, drought-addled Australia has built the world's largest water market, trading U.S.$2.5 billion per year and allowing the government to buy back overallocated rights and return water to nature. Price trends are up — both utility customers and agricultural users are paying more for water — while overall consumption is down. However, feared adverse social impacts may be coming to pass; researchers from Griffith University in Queensland found governments trading "with little regard or knowledge of Indigenous interests, and many Indigenous people believe that contemporary water resource management is amplifying inequities."

Human rights advocates often oppose water markets on the grounds that we should not commodify an essential human need. But U.S. water use and price have been so skewed for so long that market solutions may be the only politically feasible way to right them. If we are to subsidize anyone, perhaps it should be the poor: A sustenance level of water for those who need it — free or dirt cheap — and higher prices for those who want more and choose to pay. "I argue for a human right to water," says Glennon. "If we can't guarantee that in the richest country in the world, we are a sorry lot."

*U.S. WATER USE AND PRICE HAVE BEEN SO SKEWED FOR SO LONG THAT MARKET SOLUTIONS MAY BE THE ONLY POLITICALLY FEASIBLE WAY TO RIGHT THEM.*

Key tenets as U.S. water law and policy evolves, Glennon says, are making sure the environment and communities where water originates are not harmed. "It's glacial, but we are finally seeing people do things differently," he says. "Across California, you see block rates and municipalities paying people to rip out lawns. Price is going to give us the opportunity to do some things before crisis becomes a catastrophe."

**CYNTHIA BARNETT** is a journalist and author of the books *Mirage: Florida and the Vanishing Water of the Eastern U.S.*, *Blue Revolution: Unmaking America's Water Crisis*, and *Rain: A Natural and Cultural History*.

**WRITER UPDATE:** *Economics and pricing may not be the sexiest topics on the water beat. But, second to ethical changes in the way we use water — using less and polluting less — they are the most important part of the solution to America's water woes. When I wrote "Hey, America: It's Time to Talk About the Price of Water," unprecedented drought in the West and water-quality emergencies in the East were laying bare the flawed way we pay for water. Since then, both threats have become more acute. But amid such a dramatic and visible drought, it seems to me that the West is doing a better job of embracing more ethical water use and higher prices. Eastern communities are seeing spikes in toxic algae, including the largest ever reported in the Ohio River. Yet this is a quieter threat and does not capture the public imagination the way a thirsting reservoir does — much less a willingness to pay more to improve water treatment and tackle pollution at its source. The next drinking-water plant shutdown will grab attention once more. Perhaps then we will have a national conversation about the price of water — which is, of course, priceless.*
*— CYNTHIA BARNETT*

PHOTO © ISTOCKPHOTO.COM/ENVIROMANTIC

*CAN*

# GRAINS OF THE PAST

*HELP US WEATHER*

# STORMS OF THE FUTURE?

COMBINING SCIENCE WITH TRADITIONAL KNOWLEDGE, RESEARCHERS TURN TO ANCIENT RICE AS A SOURCE OF CLIMATE RESILIENCE.

*BY SHREYA DASGUPTA*

ORIGINALLY PUBLISHED:
FEBRUARY 2015

Cyclone Aila wreaked havoc in eastern India in May 2009, clocking in at speeds of over 120 kilometers per hour (75 miles per hour). Aila hit the Sundarbans, the largest continuous block of mangrove forest in the world, located in the Ganga-Brahmaputra tidal delta on the Bay of Bengal.

The storm killed hundreds of people and livestock, damaged close to a million houses, and washed away roads. Heavy winds and high waves breached the mud embankments that protected the islands. This brought in a deluge of salt water from the Bay of Bengal, flooding villages, turning drinking water brackish and affecting nearly 125,000 hectares (309,000 acres) of cropland.

As floodwaters subsided, thin white lines of salt appeared in the soil. The modern, high-yielding varieties of rice that had been cultivated there previously could not grow in this salt-encrusted soil. For the rice-dependent agrarian inhabitants of the delta, this was cause for serious concern.

A month after the catastrophe, Debal Deb, a plant scientist and founder of Vrihi, a non-governmental rice seed bank, visited three Aila-struck villages in the Sundarbans. He brought with him four varieties of indigenous rice from his own seed bank — Talmugur, Lal Getu, Sada Getu and Nona Khirish — that could tolerate high levels of salinity in the soil.

Deb had collected these salt-tolerant varieties from Sundarban farmers back in 1997. On his seed farm, he had managed to double the salt-tolerance limit of two of the varieties — Lal Getu and Sada Getu — by meticulous selective breeding of the crop at different salinity levels.

Most traditional rice varieties, including the ones Deb carried that day, are adapted to local climates and regions. But with the advent of modern high-yielding varieties of rice, local varieties became disused, and many were subsequently lost. Fortunately, a handful of rice conservationists in India have managed to save some of them.

Deb's seed bank, for instance, holds more than 1,000 different kinds of indigenous rice, which he grows on his 2.3-acre (1 hectare) farm and distributes among farmers for free. Some of these varieties, like the ones he reintroduced to the Sundarbans, are salt tolerant. Others can withstand long bouts of drought or floods.

When Deb brought the four salt-tolerant varieties to the Sundarbans in June of 2009, only one was still being grown by local farmers. The other three remained only in their memories.

The farmers were initially suspicious of the salt-tolerant varieties, Deb says. "They had received many seeds from the government, but none of them had grown in their saline soil after Aila. When they saw that the seeds I gave them were germinating, they were very happy."

That year, Deb managed to distribute the four varieties to 11 eager farmers.

He returned the following year, with a Kolkata-based organization called ENDEV-Society for Environment and Development. Asish Ghosh, president of ENDEV, had scouted for and acquired more seeds of the salt-tolerant varieties from different sources. In 2010 and 2011, ENDEV worked with Deb and five local organizations to distribute these seeds to the Sundarbans farmers.

*DEB'S SEED BANK, FOR INSTANCE, HOLDS MORE THAN 1,000 DIFFERENT KINDS OF INDIGENOUS RICE, WHICH HE GROWS ON HIS 2.3-ACRE FARM AND DISTRIBUTES AMONG FARMERS FOR FREE.*

## WHY THIS MATTERS

As agriculture becomes more streamlined and industrialized, diverse native crops are being replaced by more uniform plantings. Concerned that the diverse genetic material native crops contain will be lost forever — which could have negative consequences on crop productivity in a world facing increasing climate extremes — scientists around the globe are maintaining gene banks as refuges for seeds and other plant tissue. By demonstrating the use of banked varieties in helping a region recover from natural disaster, this article underscores the importance of crop gene banking and inspires others to consider turning to such resources in the wake of disaster.

PHOTOS BY JASON TAYLOR

Rice plant scientist Debal Deb (second from left) is working with residents of the Sunderbans to boost food production in the face of adverse environmental conditions with the help of indigenous rice varieties.

A few of the hundreds of varieties of rice that plant scientist Deb grows on his seed farm undergo preparation for planting.

PHOTO COURTESY OF ENDEV

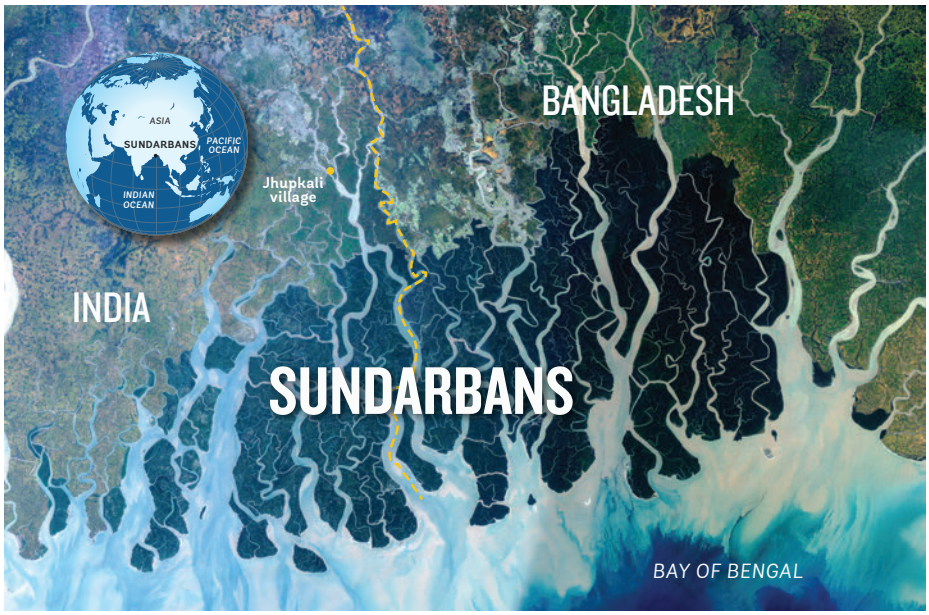
"These varieties are financially lucrative," explains Ghosh. "They do not require costly inputs of fertilizers or pesticides, and produce better quality straw for cattle feed and roofing of houses."

In 2013, Deb reintroduced two additional varieties of rice, Matla and Hamilton, which he received from other plant scientists in West Bengal. According to a report by WWF-India, these varieties have such high salt tolerance that farmers once cultivated them in areas without any embankments to keep salt water out.

As of 2014, more than 70 Sundarbans farmers are growing the six salt-tolerant varieties, Deb says.

Radheshyam Das, a 52-year-old rice farmer in Jhupkali village in the Sundarbans,

**ABOVE:** Salt-tolerant rice has helped Sundarbans farmer Bhagyadhar Pramanik maintain production after Cyclone Aila inundated the farmland with salt water. **RIGHT:** The low-lying Sundarbans, which includes parts of India and Bangladesh, is vulnerable to disruption by monsoons and typhoons.




LEARN MORE ABOUT GLOBAL EFFORTS TO ENSURE LEGACY SEEDS ARE AVAILABLE FOR FUTURE FARMERS AT **ENSIA.US/GENEBANK**.

## "A GREAT PROGRAM":

**FREELANCE WRITER SHREYA DASGUPTA HAD AN IMPORTANT STORY TO TELL,** but she didn't have a place to share it. Then she heard from another writer about Ensia's mentor program, which pairs aspiring communicators — often students or early career scientists — with seasoned environmental journalists to produce an article, photo gallery, infographic or other piece of content for Ensia. Dasgupta applied to the program and was accepted to write this article. Award-winning

is happy with his rice yield, which he measures in one-third-acre (one-eighth-hectare) units of land area called *bighas*. "Since Aila, my rice production with high-yielding varieties fell to about two bags of rice per bigha," he says. "Last year, with the salt tolerant variety, I had a harvest of seven bags per bigha."

In another village on Mousuni Island in the Sundarbans, farmer Sindhupada Middya experimented with a salt-tolerant variety and a modern variety. The plot of land he grew them in lay close to an embankment and would frequently be inundated by salt water during high tides. While the salt-tolerant variety yielded 240 kilograms (530 pounds) of rice from less than one-tenth of a hectare (one-fourth of an acre) of land, the high-yielding variety produced nothing.

His success encouraged nearly 40 other farmers on the island to adopt these salt-tolerant varieties, according to Soma Saha, a member of the WWF-India team that has been introducing these rice varieties as part of its climate change adaptation initiatives.

In another part of the Sundarbans, a group of farmers has even composed a folk song that celebrates the traditional seeds. The song talks about the resilience of the seeds, the happiness they have brought and why others should use them.

As our planet warms in the decades to come, rising sea level, changing rainfall pattern and increasing frequency of cyclones such as Aila are expected to continue to erode and submerge islands in the Sundarbans. And the resulting salt intrusion is expected to continue to render crop fields unsuitable for modern rice varieties.

*WHILE THE SALT-TOLERANT VARIETY YIELDED 240 KILOGRAMS OF RICE FROM LESS THAN ONE-TENTH OF A HECTARE OF LAND, THE HIGH-YIELDING VARIETY PRODUCED NOTHING.*

But by combining science with traditional knowledge, Ghosh says, farmers will be able to continue to produce food for themselves and their communities.

"We did not develop these varieties," Ghosh says. "The farmers did — many, many years ago. Some of us simply rediscovered their 100 year-old traditional knowledge, located the seeds and motivated the farmers to start using them again."

When she wrote this article, **SHREYA DASGUPTA** was a freelance science and environmental writer based in Bangalore, India.She is now a staff writer at Mongabay.

## IMPACT

"Grains of the Past" was republished by Gizmodo and Public Radio International. The article also was shared widely on social media by The Nature Conservancy, the Global Resilience Partnership, Climate Central and numerous others.


environmental and science journalist Michelle Nijhuis, whose work appears in outlets such as *National Geographic* and *The New Yorker*, provided guidance by reviewing an outline, suggesting sources and providing feedback on a draft.

"This is a great program for early career journalists like me, especially those based outside the USA, to learn from professional journalists they admire," Dasgupta wrote later as she reflected on the experience. "The mentor program has pushed me to improve my writing skills."

To date, more than a dozen participants have produced Ensia pieces through the mentor program, on topics ranging from mosquito control to lion conservation.

PHOTO BY TODD REUBOLD

# THE END + BEGINNING OF THE ARCTIC

AT THE TOP OF THE WORLD, IT'S TIME TO GET READY FOR A NEW FUTURE.

*BY EDWARD STRUZIK*

ORIGINALLY PUBLISHED:
DECEMBER 2014

## WHY THIS MATTERS

As the U.S. prepared to take over the chair of the Arctic Council in April 2015, we were considering everything we had been hearing about the changing Arctic: It's warming twice as fast as the rest of the planet, it's faced massive fires, thawing permafrost is releasing methane, entire ecosystems are being altered. And all of this — and more — is happening much faster than most predictions and certainly faster than most people realize. By taking a comprehensive look at all the things happening in the Arctic, this piece helps readers, as author Edward Struzik writes, "understand and manage the end of the Arctic as we know it so we are prepared to deal with the new Arctic that is unfolding" — including implications for geopolitics, global economies and the people who call the Arctic home.

Over the winter of 2013–14, hundreds of milk-white birds with luminous yellow eyes and wingspans of up to 5 feet (2 meters) descended on beaches, farmers' fields, city parks and airport runways throughout southern Canada and the United States.

Traditionally, snowy owls spend most of their time in the Arctic and subarctic regions. But every four years or so when populations of lemmings — among the owls' favorite foods — cycle downward, a small number of young, inexperienced birds that are less adept than their elders at hunting will fly farther south than they might normally rather than starve to death. No one, however, had seen an irruption as big and as far-reaching as this one, which was the second major such event in North America in three years.

By the first week of December, the big birds were spotted from North Dakota to Maine and from Newfoundland to Bermuda. At one point, owls collided with five planes at Kennedy, LaGuardia and Newark airports.

Snowy owl irruptions are not in themselves a sure sign that something extraordinary is happening in an Arctic world that is warming nearly twice as fast as the global rate. But given the rapid-fire fashion in which similar unexpected events have been unfolding throughout the circumpolar region, it's clear that the Arctic we know is coming to an end, and that a new and very different Arctic is taking over.

What happens in the Arctic matters. The ecological, cultural and economic shifts that are currently underway will not only alter the lives of the Inuit, Gwich'in, Nenets and other aboriginal people who live there, they are likely to affect mid-latitude weather patterns, the migrating birds we see, the air we breathe, the fuel we burn and the way in which we transport goods from one continent to another. The question then becomes, how do we understand and manage the end of the Arctic as we know it so we are prepared to deal with the new Arctic that is unfolding?

### A PICTURE OF CHANGE

The past 10 years paint a dramatic picture of climate-related changes at the top of the world. First there were massive forest fires that torched a record 4.2 million hectares (10.3 million acres) of trees in the Yukon and Alaska in 2004. Smoke from those fires could be detected all the way to the east coast of Canada and throughout many parts of the contiguous United States. Parts of the Alaska Highway were shut down for days at a time. Alaskans suffered for 15 days when air quality in cities such as Fairbanks was deemed to be hazardous to health by U.S. Environmental Protection Agency standards.

Then it was the collapse of the 9-mile-long (14-kilometer-long), 3-mile-wide (5-kilometer-wide), 120-foot-thick (37-meter-thick) Ayles Ice Shelf off the north coast of Ellesmere Island in 2005. Scientist

PHOTO © ISTOCKPHOTO.COM/RYANVINCEPHOTOGRAPHY

PHOTO © ISTOCKPHOTO.COM/CHRISHOWEY

Warwick Vincent likened the collapse, the largest recorded in the Canadian Arctic, to a cruise missile hitting the shelf after it registered as a small earthquake at a seismic station 150 miles (241 kilometers) away.

In 2006 we learned of the world's first wild polar bear–grizzly bear hybrid, of further increases in relatively warm Pacific water flowing north through the Bering Strait, of gray whales overwintering in the Beaufort Sea instead of migrating to the California coast and — from the U.S. National Snow and Ice Data Center — news that September sea ice was declining 8.6 percent per decade or 23,328 square miles (60,419 square kilometers) per year. At the time, some scientists scoffed when NSIDC research scientist Julienne Stroeve predicted that the Arctic Ocean would have no ice in September by 2060. But when Arctic sea ice retreated to another record low a year later, many suggested September ice might be gone by 2040.

Then came 2007 — the year in which it became crystal clear that winter's freeze was losing its ability to keep up with summer's melt. A rare, extraordinarily large tundra fire on the north slope of Alaska accounted for 40 percent of the area burned in the state that summer. Avian cholera, a disease that is common in the south but largely absent in the eastern Arctic, killed nearly one-third of the nesting female common eiders at East Bay, home to the largest colony of the species in the region. It was so warm that summer that the Inuit of Grise Fiord, the most northerly civilian community on the continent, were forced to stockpile sea ice for drinking water because runoff from a nearby glacier dried up.

For the third year in a row, hundreds of beluga whales and narwhals made the mistake of staying in the Canadian Arctic longer than they should have because there was still so much open water when summer came to an end. In Lancaster Sound alone, Inuit hunters shot more than 600 belugas that would have otherwise drowned as the small pools of open water they were trapped in shrank to nothing over a 10-day period.

But what really made the big melt of 2007 an eye-popping one was the absence

*IT'S CLEAR THAT THE ARCTIC WE KNOW IS COMING TO AN END, AND THAT A NEW AND VERY DIFFERENT ARCTIC IS TAKING OVER.*

PHOTO BY TROY MABEN, AP

Grizzly and polar bear hybrids, like this one shot by Glenn Ferry in Canada's Northwest Territories in 2006, are icons of the changes taking place as traditional Arctic habitat disappears.

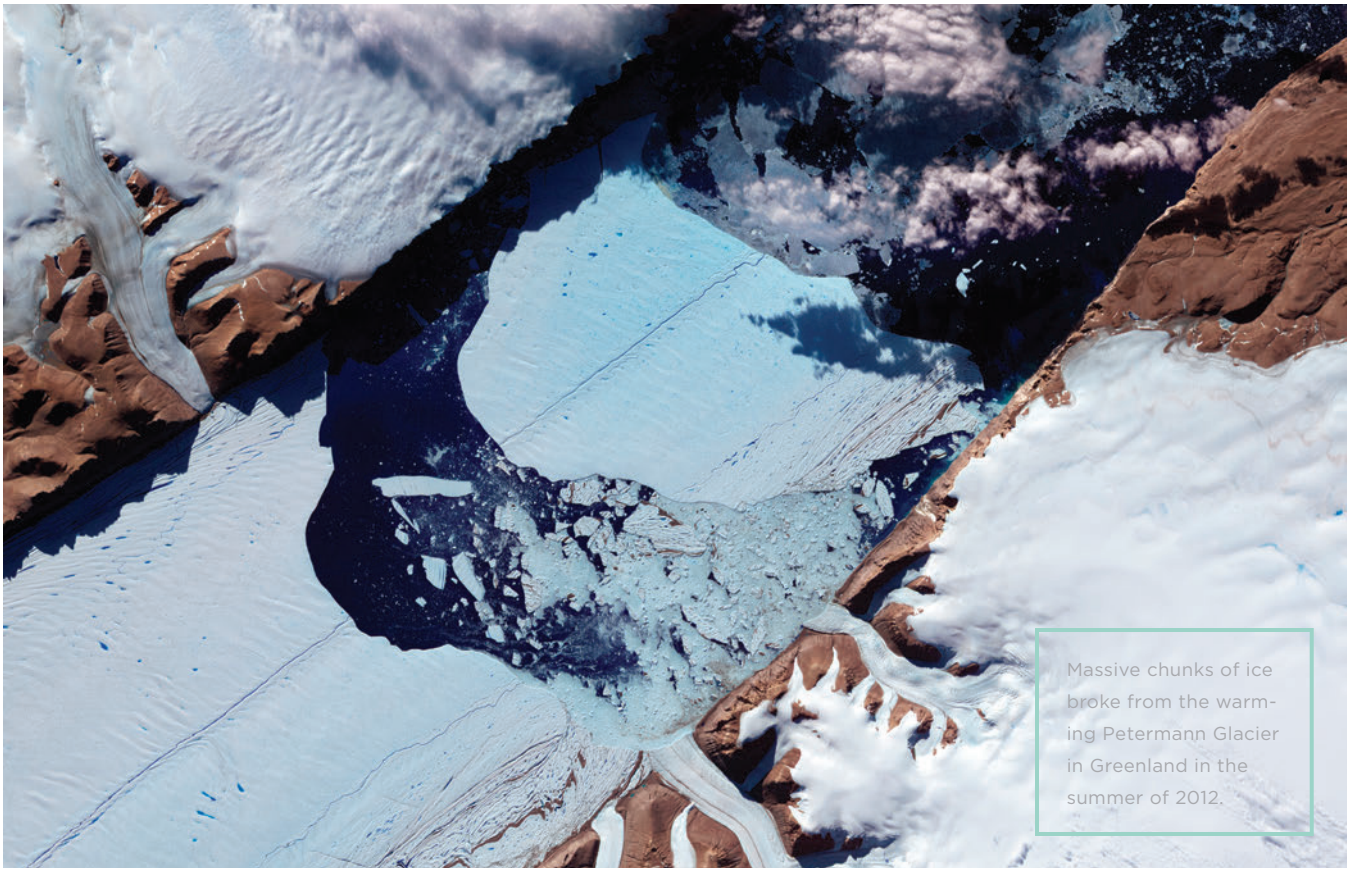
of ice in areas where it almost never thaws. The so-called "mortuary" of old ice that perennially chokes M'Clintock Channel in the High Arctic of Canada virtually disappeared that August. The "birthplace" of a great deal of new ice that is manufactured in Viscount Melville Sound to the north was down to half of its normal ice cover. "The ice is no longer growing or getting old," said John Falkingham, chief forecaster for the Canadian Ice Service.

Extraordinary as the events of 2007 were, the changes that have been brought on by a rapidly warming Arctic have not let up since then. In 2010 and 2012, 100 square miles (259 square kilometers) and 46 square miles (119 square kilometers), respectively, broke away from the Petermann Glacier in Greenland. The presence of so much warm open water in 2012 — when another record low for sea ice cover was established — fueled an unusually powerful summer cyclone that tore through the Arctic for nearly two weeks.

*WHAT REALLY MADE THE BIG MELT OF 2007 AN EYE-POPPING ONE WAS THE ABSENCE OF ICE IN AREAS WHERE IT ALMOST NEVER THAWS.*

It wasn't just sea ice that was being churned up and melted more quickly by these increasingly powerful storms. In the Yukon-Kuskokwim delta in Alaska, which is already vulnerable to rising sea levels, storm surges sent waves of saltwater more than 30 kilometers (20 miles) inland on three occasions between 2005 and 2011. This doesn't bode well for the million birds that nest in the delta nor for the Chinook (king) salmon, which have been in steep decline in the region for more than a decade. This year's run of between 71,000 and 117,000 was expected to be as poor as last year's, which established a record low.

Even among all this, one of the most recent signs of change has been especially alarming. All across the Arctic, scientists have been detecting abnormally high concentrations of methane seeping out of the thawing permafrost. In one spectacular example discovered along Siberia's Yamal Peninsula in 2014, concentrations of the greenhouse gas 50,000 times higher than the atmospheric average were found to be rising from a 200-foot-deep (60-meter-deep) crater that was formed when a massive sheet of permafrost thawed



Massive chunks of ice broke from the warming Petermann Glacier in Greenland in the summer of 2012.

PHOTO COURTESY OF NASA EARTH OBSERVATORY

and collapsed. In another case in Canada's western Arctic, three of many seeps in the area were found to be emitting as much greenhouse gases in a year as are emitted by 9,000 average-size cars.

We are already seeing the effects of some of these changes ripple through various ecosystems. Capelin, not Arctic cod, is now the dominant fish in Hudson Bay. Killer whales, once stopped by sea ice, are now preying on narwhals and beluga whales throughout the Arctic Ocean. Pacific salmon of all types are moving into many parts of the Canadian Arctic where they have never been seen before. Polar bears at the southern end of their range are getting thinner and producing fewer cubs than they have in the past. Chukchi Sea walrus are hauling out on land by the tens of thousands, as 35,000 of them did in September 2014 when there was no more sea ice to use as platforms.

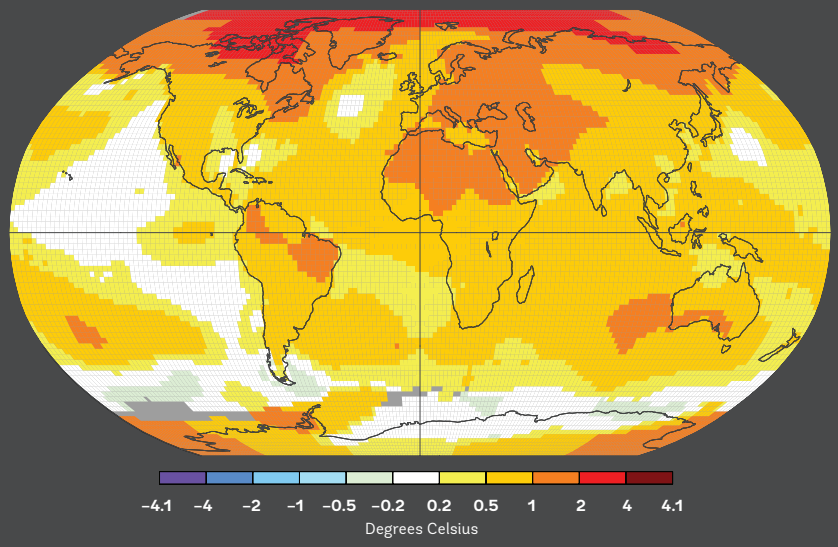
The changes that are occurring are circumpolar. In the Norwegian archipelago of Svalbard, fjords on the west coast have not been frozen for several years. Tundra there is being overtaken by shrubs, just as it is in Siberia, Chukotka, Arctic Canada and the north slope of Alaska where barren ground caribou — fixtures on the summer tundra — are dramatically declining. According to the CircumArctic Rangifer Monitoring and Assessment Network, which is run on a voluntary basis by veteran biologists Don Russell, Anne Gunn and others, half of the world's 23 barren-ground caribou herds that are routinely counted are in decline. Only three, maybe four, are increasing, and they are doing so only modestly. Measured another way by biologists Liv Vors and Mark Boyce, who included the fate of boreal forest and mountain caribou in their survey, 34 of the 43 major herds scientists have studied worldwide in the past decade are in a freefall.

## FLASH FORWARD

If the past tells us anything about the future, it's that there will be many more changes that

## GLOBAL SURFACE TEMPERATURE CHANGE

The map below displays the difference between the annual mean surface temperature for 2010–14 and for 1951–80. The annual mean global surface temperature for the 2010–14 period was 0.67 °C (1.21 °F) higher than the average for the 1951–80 period. In Arctic regions the difference between those two time periods was in the range of 2–4 °C (4–7 °F) warmer. Gray areas signify missing data.




Source: *NASA Goddard Institute for Space Studies*

In an ominous positive feedback loop, a recently discovered crater in the thawing Siberian permafrost is spewing methane, a potent greenhouse gas, into the atmosphere.

PHOTO BY MARYA ZULINOVA, PRESS SERVICE OF THE GOVERNOR YANAO

were not anticipated. A few things, however, we know with some degree of confidence.

First, temperatures will continue to rise, resulting in the Arctic Ocean being seasonally ice-free by 2040 or possibly earlier. Two-thirds of the world's polar bears will be gone a decade later, as will one-third of the 45,000 lakes in the Mackenzie, one of the largest deltas in the Arctic.

In 2100, when trees and shrubs overtake much of the grasses and sedges on the tundra, what we think of as traditional habitat for barren-ground caribou will have shrunk by as much as 89 percent. Coniferous forests will be replaced by deciduous ones in many places. Some trees will have begun to take root on the south end of the Arctic Archipelago. Most of the polar ice caps on Melville Island will have melted away.

And summer storms in the Arctic will continue to pick up steam as melting ice and warming waters contribute to further rises in sea levels. The pounding these storms inflict on frozen shorelines will accelerate the thawing of permafrost, which currently traps massive amounts of methane. The Arctic Ocean will continue to acidify as its upper surface absorbs the greenhouse gases emitted from both the ground and from the burning of fossil fuels.

The future is not necessarily all doom and gloom, however. There is compelling evidence to suggest that some subarctic and Arctic animals — such as the bowhead whale, the musk ox and the barren-ground grizzly bear — will likely thrive in this warmer world. So too may the wood bison, which emerged from the 19th century greatly diminished in the subarctic due to habitat loss and overhunting before animals were reintroduced to parts of the Northwest Territories, the Yukon, Siberia and Alaska. There are even signs that cougars could stage a comeback in a land in which the maneless Beringian lion once preyed on animals such as the saiga antelope.

Still, as daunting as the future Arctic looks to be, it may in fact be much worse. What we think we know about the future of the region may be grossly underestimated because scientists are uncomfortable talking about or putting pen to predictions that are not backed by 95 percent certainty.

Benjamin Abbott, then research assistant at the University of Alaska Fairbanks, and University of Florida researcher Edward Schuur anonymously surveyed climate and fire experts in 2013, asking them how much boreal forest and tundra will burn in the future. Nearly all respondents painted a picture that is much worse than what most experts had publicly claimed. In a "business-as-usual" scenario, they predicted that emissions from boreal forest fires will increase 16 to 90 percent by 2040. Emissions from tundra fires will grow even more rapidly.

*IF THE PAST TELLS US ANYTHING ABOUT THE FUTURE, IT'S THAT THERE WILL BE MANY MORE CHANGES THAT WERE NOT ANTICIPATED.*

As much as we know and think we know about what the future Arctic might look like, it's what we don't know that worries scientists like Henry Huntington, co-chair of the National Research Council committee that recently examined emerging research questions in the Arctic. "Many of the questions we've been asking are ones we've been asking for some time," says Huntington. "But more and more, there are new questions arising from insights that have been made only in recent years, or phenomena that have only begun to occur."

## QUESTION OF COOPERATION

All together, the changes past and present in the Arctic paint a picture of a future unfolding with potentially large economic and geopolitical ramifications.

Receding sea ice, for example, is revealing 22 percent of the undiscovered, technically recoverable hydrocarbon resources in the world, as well as the potential for a commercial fishing industry. It is opening up shipping lanes that are far shorter and more economical than existing routes that must pass through the Panama and Suez canals.

This will prove to be challenging. Most of the Arctic currently belongs to the five coastal Arctic states — the United States, Canada, Russia, Norway, Denmark and Greenland. But a big part of it — the so-called 1.2 million-square-mile (3.1 million-square-kilometer) "donut hole" in the central Arctic Ocean — does not fall under any country's jurisdiction.

Until recently, security issues, search and rescue protocols, indigenous rights, climate change, and other environmental priorities were the main concerns of the Arctic Council, an intergovernmental forum that includes the eight voting states bordering the Arctic and several indigenous organizations that have participant status. But the recent admission of China and other major Asian economic powers as observer states is yet another strong sign that the economic development of an increasingly ice-free Arctic is becoming a top priority of nations in the region and beyond.

As this interest in the Arctic's future wealth grows, willingness to cooperate and compromise may shrink.

The United States, for example, continues to challenge Canada's claim that the Northwest Passage is part of its inland waters and not an international strait. Nor does the United States recognize Canada's claim to a small, resource-rich region in the Beaufort Sea. In the meantime, Canada and Denmark have agreed to disagree over the ownership of Hans Island in the eastern Arctic as they continue to work out a tentative agreement on the maritime boundary

PHOTO BY COREY ACCARDO, AP/NOAA

Unable to find sufficient sea ice to lie on, thousands of walrus took to the shores of the Chukchi Sea in September 2014.

As shipping lanes open in the Arctic, cargo ships will become a more common sight.

in the Lincoln Sea. And Russia continues to flex its military might in the Arctic in a way that has NATO allies concerned.

On the positive side, the current process of dividing up the unclaimed territory in the Arctic may well be resolved by protocols set forth by the United Nations Convention of the Law of the Sea. The five coastal Arctic states have been spending hundreds of millions of dollars mapping the Arctic Ocean floor to make a case for extending their territories northward. But the recommendations that will eventually be put forth are likely to come in the distant future, and they are not legally binding.

Alternatively, there may be some hope, because headway has been made in the development of an international fisheries agreement that would protect the waters of the central Arctic Ocean.

*ON THE POSITIVE SIDE, THE CURRENT PROCESS OF DIVIDING UP THE UNCLAIMED TERRITORY IN THE ARCTIC MAY WELL BE RESOLVED BY PROTOCOLS SET FORTH BY THE UNITED NATIONS CONVENTION OF THE LAW OF THE SEA.*

The dark horse in all this is China, which as an exporting nation and major energy consumer stands to gain from shorter trade routes through the Arctic and from the energy resources there that remain largely unexploited. It may or may not play along with the Arctic Council's current efforts to focus on sustainable economic development and environmental protection in the Arctic. A Canadian think tank — the

PHOTO BY EDWARD STRUZIK

Receding ice in the Arctic is revealing new technically recoverable hydrocarbon resources. But offshore oil and gas development bring environmental risks.

New expanses of open water mean new opportunities for commercial fishing in the Arctic.

Macdonald-Laurier Institute — recently suggested that China's true intentions in the Arctic may amount to "positioning itself to influence heavily, if not outright control, the awarding of select Arctic energy and fishing-related concessions as well as the rules and political arrangements governing the use of strategic waterways now gradually opening due to melting ice."

## NOW WHAT?

With all of this in mind, what should be done? One clear course of action is to halt the activity giving rise to the change — fossil fuel consumption and the release of methane gas as permafrost thaws and sea ice melts. Given the pace of change and the long lag time, however, there is very little that can be done to stop the Arctic from warming in the short term. Humans have already released so much greenhouse gas that even if we stop right now, it will take centuries to halt or reverse the decline of sea ice cover, the thawing of permafrost, the meltdown of glaciers and the acidification of the Arctic Ocean, which is directly attributable to the increase in emissions.

New economic opportunities may arise from oil and gas developments and commercial shipping, but those economic benefits could be offset by a blowout or shipping accident that could prove to be even more catastrophic than the *Exxon Valdez* disaster and BP's Deep Water Horizon. Unlike Prince William Sound or the Gulf of Mexico, there is ice in the Arctic and no ports and few runways from which to stage a cleanup. There is also no practical way of separating oil from ice. There is, therefore, a need to develop technologies to increase safety of oil and gas extraction before exploration and extraction proceeds. There is also a need to identify and protect biological hot spots that are vulnerable to this kind of human activity.

One of the biggest challenges in planning for the future is to figure out what the new Arctic (including the subarctic) might look like. Against a backdrop of boreal forest, tundra, permafrost, polar deserts, glaciers, ice caps, mountains, rivers, deltas, sea ice, polynyas, gyres and open ocean, that won't be easy to do. There are thousands of pieces to this puzzle. They include the 21,000 cold-climate mammals, birds, fish, invertebrates, plants and fungi we know a lot about. They also include countless microbes and endoparasites that remain largely a mystery. Further discoveries of microscopic creatures new to science, such as the picobiliphytes found in the Arctic in 2006, are inevitable.

A rigorous assessment of what the future might look like could help decision-makers understand who the winners and losers will be in a future Arctic and what other surprises we can expect. This will help identify which low-lying Arctic communities need to be shored up, moved or made fire safe. It could guide decision-makers in designing better rules and regulations for pipelines and resource development and for commercial shipping. It could also help decision-makers better understand, predict, mitigate and adapt to both changes in the Arctic itself and trickle-down effects to temperate regions.

This is already being done with some success on a small scale. A program in Old Crow, the most northerly community in the Yukon, for example, successfully paired scientists with community leaders to address the issue of food security in a quickly changing climate. Similarly, in Alaska, the Landscape Conservation Cooperatives have facilitated partnerships between the U.S. Fish and Wildlife Service and other federal agencies, states, tribes, non-governmental organizations, universities and stakeholders within a number of ecologically defined areas.

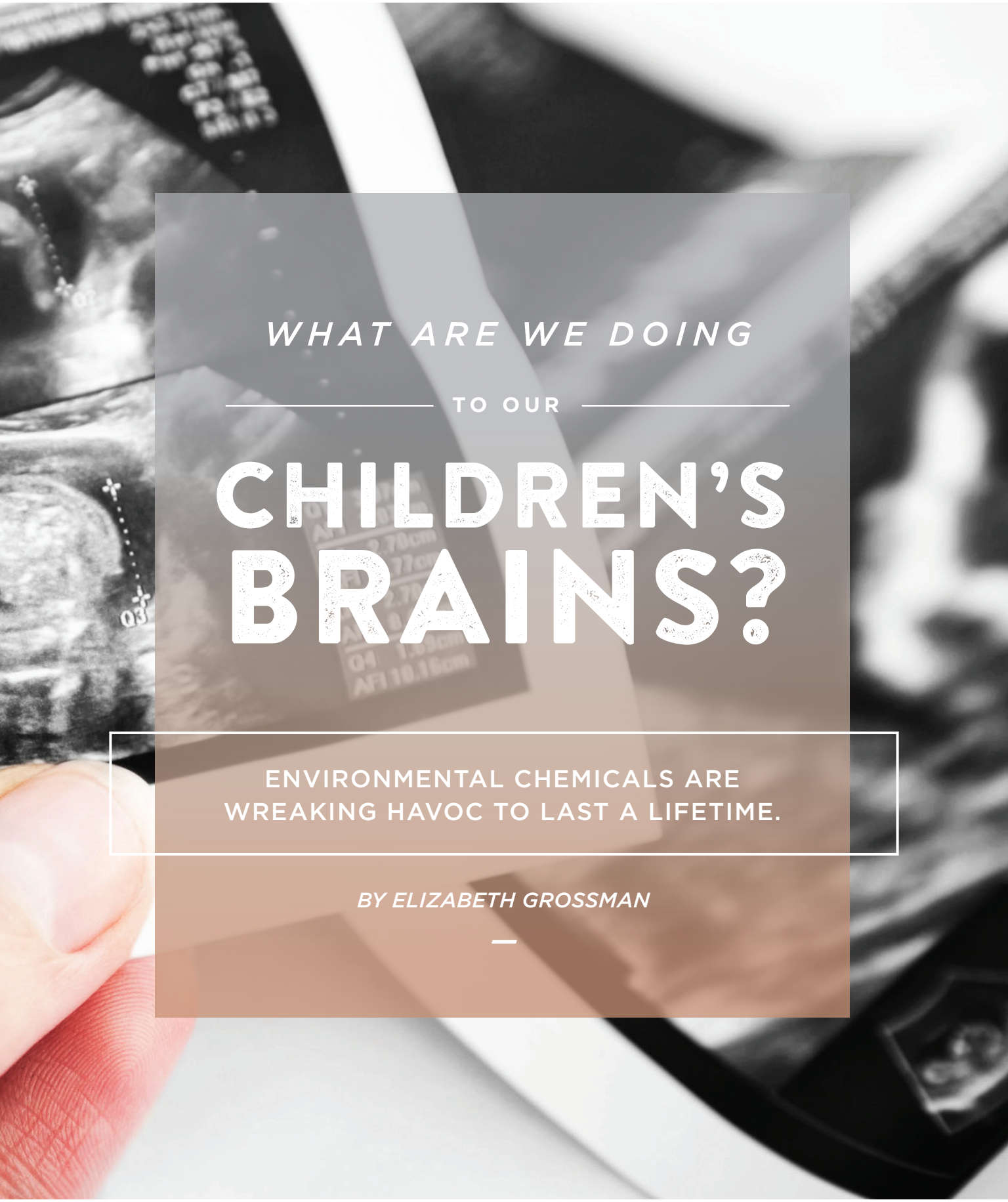
What the Arctic really needs, in addition to these and other small-scale initiatives, is international cooperation either through an overarching treaty or through a series of binding agreements. The issues are too big, too complex and in many cases too overlapping to be left to individual countries to address. In order for this to happen, the role of the Arctic Council needs to be strengthened. Science needs to be funded much better than it has been, the indigenous people of the Arctic must be equal partners in the decision-making process, and non-Arctic countries such as China must be included in the conversation.

The future of the Arctic is not necessarily completely bleak. But if we continue to ignore or underestimate the changes that are taking place in this part of the world, it will, as climatologist Mark Serreze bluntly said in 2009, "bite us [and] bite hard."

*WHAT THE ARCTIC REALLY NEEDS, IN ADDITION TO THESE AND OTHER SMALL-SCALE INITIATIVES, IS INTERNATIONAL COOPERATION EITHER THROUGH AN OVERARCHING TREATY OR THROUGH A SERIES OF BINDING AGREEMENTS.*

**EDWARD STRUZIK** has lived in, and spent the better part of the past 35 years exploring and writing about, the circumpolar Arctic. He is currently a fellow at the School of Policy Studies, Queen's Institute for Energy and Environmental Policy at Queen's University in Canada. His new book, *Future Arctic: Field Notes from a World on Edge,* is published by Island Press.

PHOTO © ISTOCKPHOTO.COM/PHOTOSPOWER



# WHAT ARE WE DOING TO OUR CHILDREN'S BRAINS?

ENVIRONMENTAL CHEMICALS ARE WREAKING HAVOC TO LAST A LIFETIME.

*BY ELIZABETH GROSSMAN*

ORIGINALLY PUBLISHED:
FEBRUARY 2015

The numbers are startling. According to the U.S. Centers for Disease Control and Prevention, about 1.8 million more children in the U.S. were diagnosed with developmental disabilities between 2006 and 2008 than a decade earlier. During this time, the prevalence of autism climbed nearly 300 percent, while that of attention deficit hyperactivity disorder increased 33 percent. CDC figures also show that 10 to 15 percent of all babies born in the U.S. have some type of neurobehavorial development disorder. Still more are affected by neurological disorders that don't rise to the level of clinical diagnosis.

And it's not just the U.S. Such impairments affect millions of children worldwide. The numbers are so large that Philippe Grandjean of the University of Southern Denmark and Harvard T.H. Chan School of Public Health and Philip Landrigan of the Icahn School of Medicine at Mount Sinai in New York — both physicians and preeminent researchers in this field — describe the situation as a "pandemic."

While earlier and more assiduous diagnosis accounts for some of the documented increase, it doesn't explain all of it, says Irva Hertz-Picciotto, professor of environmental and occupational health and chief of the University of California, Davis, MIND Institute. Grandjean and Landrigan credit genetic factors for 30 to 40 percent of the cases. But a significant and growing body of research suggests that exposure to environmental pollutants is implicated in the disturbing rise in children's neurological disorders.

What, exactly is going on? And what can we do about it?

## CHEMICALS AND THE BRAIN

Some chemicals — lead, mercury and organophosphate pesticides, for example — have long been recognized as toxic substances that can have lasting effects on children's neurological health, says Bruce Lanphear, health sciences professor at Simon Fraser University. While leaded paint is now banned in the U.S., it is still present in many homes and remains in use elsewhere around the world. Children can also be exposed to lead from paints, colorings and metals used in toys, even though these uses are prohibited by U.S. law (remember Thomas the Tank Engine) and through contaminated soil or other environmental exposure as well as from plastics in which lead is used as a softener. Mercury exposure


## WHY THIS MATTERS

At one point in this piece, journalist Elizabeth Grossman asks a blunt question: "Assuming we want to stop harming our children's brains, how do we proceed?" That question is at the heart of why this piece matters. In recent decades scientists have begun to recognize that children and infants are far more vulnerable to chemical exposures than are adults who were historically the subjects of chemical neurotoxicity testing. The story Grossman produced provides a frightening look at the scale of the problem, along with actionable ways we can begin to address it — assuming we do indeed want to stop harming our children's brains.

sources include some fish, air pollution and old mercury-containing thermometers and thermostats. While a great many efforts have gone into reducing and eliminating these exposures, concerns continue, particularly because we now recognize that adverse effects can occur at exceptionally low levels.

But scientists are also now discovering that chemical compounds common in outdoor air — including components of vehicle exhaust and fine particulate matter — as well as in indoor air and consumer products can also adversely affect brain development, including prenatally.

Chemicals in flame retardants, plastics, and personal care and other household products are among those Lanphear lists as targets of concern for their neurodevelopment effects.

Chemicals that prompt hormonal changes are increasingly suspected to have neurological effects, says Linda Birnbaum, director of the National Institute of Environmental Health Sciences and National Toxicology Program. Among the chemicals now being examined for neurological impacts that occur early in life are flame retardants known as PBDEs that have been used extensively in upholstery foams, electronics and other products; phthalates, widely used as plasticizers and in synthetic fragrances; the polycarbonate plastic ingredient

PHOTO © ISTOCKPHOTO.COM/BRIANAJACKSON

**1.8 million =**
additional U.S. children reported to have developmental disabilities in 2006–08 compared with 1997–99

**300 =**
percent rise in prevalence of autism between 1997–99 and 2006–08

**10–15**
percent of U.S. babies born with a neurobehavorial development disorder

**Tens of thousands =**
likely number of chemicals in use that have not been fully tested for potentially harmful effects

**–6 to –8**
difference in IQ scores between children exposed prenatally to elevated levels of certain phthalates and children with lower prenatal exposures

bisphenol A, known commonly as BPA; perfluorinated compounds, whose applications include stain-, water- and grease-resistant coatings; and various pesticides.

## PRECISE CHOREOGRAPHY

As Grandjean and Landrigan explain, the fetus is not well protected against environmental chemicals that can easily pass through the placenta. There's evidence from in vitro studies, they say, that neural stem cells are very sensitive to neurotoxic substances. An infant's brain is also vulnerable to such contaminants. At early stages of development — prenatally and during infancy — brain cells are easily damaged by industrial chemicals and other neurotoxicants. Such interference can affect how the brain develops structurally and functionally — effects that lead to lasting adverse outcomes.

"The brain is so extremely sensitive to external stimulation," says Grandjean.

Historically, chemical neurotoxicity was examined in adults — often through cases of high levels of occupational exposure. In the past 30 to 40 years, however, scientists have begun to recognize that children and infants are far more vulnerable to chemical exposures than are adults. It has also been discovered that very low levels of exposure early in life can have profound and lasting effects. Another important discovery is that understanding how an infant or child is affected by a chemical exposure involves far more than simply calculating potential effects on a physically smaller person. Stage of development — and timing of exposure — must also be considered. Early stages of brain development involve "a very precise choreography," explains Frederica Perera, professor of environmental health sciences at Columbia University's Mailman School of Public Health. "Any chemical that can disrupt [brain] chemistry at this stage can be very damaging," she says.

For example, explains Deborah Kurrasch, an assistant professor at the University of Calgary's Cumming School of Medicine who specializes in neurological research, during the early stages of brain development — when cells are becoming neurons — "timing determines destination."

Results of Kurrasch's latest study investigating neurodevelopmental effects of BPA illustrate what she means. In a study published in January 2015, Kurrasch and colleagues examined the effects on neurodevelopment of BPA and a common BPA substitute, bisphenol S. Specifically, they investigated how exposure to BPA and BPS — at levels comparable to those present in her community's local drinking water supply — might affect neuron development in zebrafish at a stage comparable to the second trimester of human pregnancy, when neurons are forming and moving to the correct location in the brain.

"It's as if they're getting on a bus to where they need to be," Kurrasch says. After exposure to BPA and BPS it was as if, explains Kurrasch, "twice as many neurons got on an early bus and half as many got on a late bus." The researchers found that these exposures appeared to alter nerve development — neurogenesis — in a way that caused the fish to become hyperactive. Such an alteration, produced in this case by a "very little bit of BPA," can cause permanent effects, Kurrasch says.

Many of the chemicals under scrutiny for their effects on brain development — BPA, phthalates, perfluorinated compounds, brominated flame retardants and various pesticides among them — appear to act by interfering with the function of hormones essential for healthy brain development. Among these are thyroid hormones, which regulate the part of the brain involved in a variety of vital functions, including reproduction, sleep, thirst, eating and puberty.

During the first trimester of pregnancy, the fetus is not making its own thyroid hormone, says R. Thomas Zoeller, director of the Laboratory of Molecular, Cellular

and Developmental Endocrinology at the University of Massachusetts Amherst. If an environmental exposure to a substance such as a polychlorinated biphenyl or perchlorate interferes with the mother's thyroid hormones in this period — as could happen through water pollution, for example — that could in turn affect her child at a critical stage of brain development.

Another thing to consider in the context of endocrine-disrupting chemical exposures, says Zoeller, is that a substantial portion of women of childbearing age in the U.S. have some iodine deficiency that may be suppressing their thyroid hormones. While these deficiencies may not be prompting clinically adverse effects, they may be sufficient to impair fetal neurodevelopment. "Impacts can happen at levels far below safety standards," says Zoeller. And there are a great many chemicals to which such women may be exposed environmentally with the potential to affect thyroid hormones, among them PBDEs, PCBs, BPA, various pesticides, perfluorinated compounds and certain phthalates.

## SOMETHING IN THE AIR

One particularly concerning source of exposure to chemicals that are suspected to harm children's brain development is air pollution, which is a complex mixture of various chemicals and particulate matter.

Perera and colleagues recently investigated the links between exposure to polycyclic aromatic hydrocarbons, a fossil fuel–related component of air pollution, and incidence of ADHD in 9-year-olds. Their study found that mothers who were exposed to high levels of PAH during pregnancy were five times more likely to have children with ADHD and to have children with more severe ADHD symptoms than those who did not have such exposure. While this study is the first to make such a connection, it joins a growing body of research pointing to links between outdoor air pollutants, including PAHs, and adverse impacts on children's brain health and development.

Looking at air pollution's effects on brain health is relatively new, explains Kimberly Gray, health science administrator at the National Institutes of Health. Research increasingly suggests that airborne contaminants can have subtle but significant effects on early neurological development and behavior, she says. In addition to links between prenatal PAH exposure and impaired brain function, researchers are also now investigating potential connections between black carbon, volatile organic compounds and fine particulate matter — among other components of air pollution — and impairments such as autism and lowered IQ.

In a study published in December 2014, Marc Weisskopf, Harvard T.H. Chan School of Public Health associate professor of environmental and occupational epidemiology, and colleagues looked at children whose mothers were exposed to high levels of fine particulate matter (PM2.5, particles 2.5 microns in diameter or smaller), particularly during the third trimester of pregnancy. The study, which involved more than 1,000 participants living all across the U.S., found that these children appeared to be twice as likely to be diagnosed with autism as children whose mothers had only low levels of such exposures. Exposure to larger particles — between 2.5 and 10 microns (what's known as PM10) — did not appear to be associated with increasing risk for autism.

"This is very important from an epidemiological point of view" because it "places a spotlight on the mother's exposure," says Weisskopf. It also highlights the importance of timing and neurodevelopmental effects. Although many other factors may contribute to autism, Weisskopf explains, this study strengthens the suggestion that environmental exposures can play a role. That it appears it is the very small particles that are associated with these effects adds to what other research is finding: What might seem quantitatively small can "be quite important" when it comes to affecting brain development, Weisskopf explains.

In early 2015 Columbia University researchers published an additional study linking common air pollutants to cognitive and behavioral impairment in children.

## WIDESPREAD EXPOSURE

As Grandjean and Landrigan point out, one of the disturbing recent realizations concerning environmental exposure to developmental neurotoxicants is how widespread exposure appears to be and the ubiquity of such compounds. "More neurotoxic chemicals are getting into products," says Landrigan.

Phthalates, which are used as plasticizers — including in polyvinyl chloride plastics — and in synthetic fragrances and numerous personal care products, comprise one category of widely used chemicals that appear to have adverse impacts on brain development. Researchers at Columbia University's Mailman School of Public Health recently found that children exposed prenatally to elevated levels of certain phthalates had IQ scores that were, on average, between 6 and 8 points lower than children with lower prenatal exposures. Children with reduced IQ scores also appeared to have trouble with working memory, perceptional reasoning and information processing speeds.

*ONE OF THE DISTURBING RECENT REALIZATIONS CONCERNING ENVIRONMENTAL EXPOSURE TO DEVELOPMENTAL NEUROTOXICANTS IS HOW WIDESPREAD EXPOSURE APPEARS TO BE AND THE UBIQUITY OF SUCH COMPOUNDS.*

PHOTO © ISTOCKPHOTO.COM/VADIMGUZHVA

The phthalates examined in this study, known as DnBP and DiBP, are used in numerous household products, including toiletries and cosmetics, among them shampoo, nail polish, lipstick, hair styling products and soap, as well as vinyl fabrics and dryer sheets. Exposure levels associated with reduced IQ in the study are within the range that the CDC reports finding in its National Health and Nutrition Examination Survey, a nationwide ongoing biomonitoring assessment of chemical exposures. "Pretty much everybody in the U.S. is exposed," says study co-author Robin Whyatt, deputy director of the Columbia Center for Children's Environmental Health at Columbia University's Mailman School of Public Health.

While such a drop in IQ may sound small, Pam Factor-Litvak, the study's lead author and professor of epidemiology at the Columbia University Medical Center, notes that at the population — or classroom — level, this means fewer children at the high end of the intelligence scale and more at the less capable end. "The whole curve shifts downward," she explains.

"Five or six IQ points may not sound like much, but it means more children requiring special education programs and fewer that are gifted," says Maureen Swanson, Learning Disabilities Association of America's Healthy Children Project director. "The potential economic impact is huge," says NIEHS's Birnbaum.

## THE STRESS FACTOR

What prompts neurological disorders in children is "very complex," notes Frederica Perera. Adding to the challenge of disentangling the various contributing factors is that while research on — and regulation of — chemicals typically looks at one substance at a time, people are exposed to multiple chemicals concurrently. Further adding to this complexity when it comes to brain development are social stresses that "act on the same part of the brain region," explains University of Rochester professor of environmental medicine Deborah Cory-Slechta. She and others are finding increasing evidence that nonchemical stressors such as maternal, domestic and community distress can prompt adverse effects on early brain development, either on their own or in combination with neurotoxic chemicals.

Birnbaum says this apparent interaction between chemicals and nonchemical stressors is "very concerning and very important."

Epidemiological studies, Cory-Slechta explains, typically correct for what are called confounding factors — other conditions that might influence the condition being measured. Many studies, she says, "are clearly not modeling what is going on in the human environment." What she and her colleagues hope to do is "reproduce in animal studies what goes on in human communities," particularly in communities that are most vulnerable to adverse social stressors and most exposed to chemical contaminants, including lead, pesticides and air pollution.

Lead and stress affect the same part of the brain, she says, and so can act synergistically very early in life to produce permanent changes in brain structure. These changes can result in lowered IQ, learning and behavioral problems.

Cory-Slechta's lab is now working on replicating conditions of stress and chronic deprivation in animal models that would mirror those experienced by communities of poverty. The aim is to better understand how these effects cross the placenta and become the fetal basis of lifelong disorders. She and her colleagues are investigating, not only associations between exposures and neurodevelopment, but also the mechanisms by which effects occur.

## WHAT TO DO?

Assuming we want to stop harming our children's brains, how do we proceed?

An important step is to improve our ability to determine which chemicals have neurodevelopmental effects. A rapid screening system would be ideal, says Birnbaum, because there are so many chemicals — including newly invented ones — to which people are exposed. While such a program to test large numbers of chemicals quickly

*WHEN IT COMES TO PROTECTING THE EXQUISITELY SENSITIVE DEVELOPING BRAIN, THE MEASURES CURRENTLY USED TO ASSESS CHEMICAL RISK AND SET SAFETY STANDARDS FALL SHORT, SAYS CORY-SLECHTA.*

using robotics has been launched by NIH, EPA and other federal agencies, there are tens of thousands that may be in use, most of which have not been fully tested for these effects.

When it comes to reducing existing exposures, some chemicals can be avoided through consumer choice. But it's often difficult, given that many of these substances are used — like BPA on receipts — in products that don't carry ingredient labels. Others, including air pollutants, are much harder given their ubiquity or lack of available alternatives. And, as Maureen Swanson notes, such choices are not necessarily feasible for people at all economic levels, which raises environmental justice issues.

Grandjean and Landrigan point out that the U.S. system of chemical regulation, which lacks requirements for full premarket toxicity testing, does not do a very good job when it comes to proactive chemical safety. "Untested chemicals should not be presumed to be safe to brain development, and chemicals in existing use and all new chemicals must therefore be tested for developmental neurotoxicity," they wrote in an article published in *The Lancet*.

While some sources of neurotoxicity might appear to have been adequately addressed, they have not. For example, considerable progress has been made in curtailing lead exposure through policy and public health education in the U.S. and elsewhere. However, current understanding is that virtually any amount of lead exposure can cause damage, and harmful exposures continue — especially in countries where leaded paints and gasoline are still used. And in the U.S., CDC funding for lead prevention programs was dramatically reduced in 2012.

Meanwhile, children around the world — especially in less well-off countries — continue to be exposed to dangerous neurotoxicants released in industrial emissions, from waste sites and through child labor. Examples abound, and include exposures to chemicals released in electronics recycling in various locations in Asia and Africa, to lead and mercury from mining activity, to agricultural pesticides, to products contaminated with heavy metals, including food and candy.

When it comes to protecting the exquisitely sensitive developing brain, the measures currently used to assess chemical risk and set safety standards fall short, says Cory-Slechta. "It should be about primary prevention, but it's not," she says.

In the absence of what many environmental health advocates feel is adequate U.S. federal regulation of chemicals, many individual U.S. states have recently passed their own laws to protect children from harmful chemical exposures. Many address chemicals with neurotoxic effects, particularly those of heavy metals such as cadmium, lead and mercury. And even though some states are beginning to include language in their legislation to protect pregnant women from chemical hazards, this timing of exposure is left largely unaddressed.

While we now know a great deal about developmental neurotoxicants, more such exposures appear to be occurring than ever before. And there appears to be wide agreement among researchers that these exposures are taking a toll on the world's children.

"To me it is very clear we have to set up a different system to better protect the brains of the future," says Grandjean.

**ELIZABETH GROSSMAN** is an independent journalist and writer specializing in environmental and science issues. She is the author of *Chasing Molecules, High Tech Trash, Watershed* and other books.

## IMPACT

This story struck a chord on social media, garnering more than 5,000 Facebook recommendations and hundreds of tweets, and catalyzed a hearty conversation by online commenters, several of whom added new dimensions to the piece by sharing their own perspectives on chemicals of concern. It was also republished by our media partners Quartz and Global Voices, and translated into Russian, German, Spanish, French, Japanese, Czech, Polish and Bulgarian.

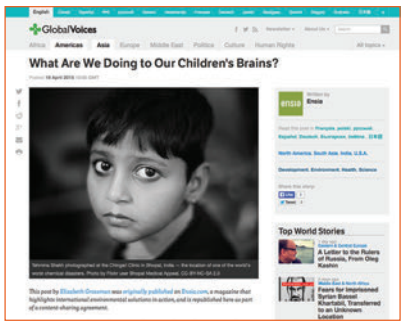
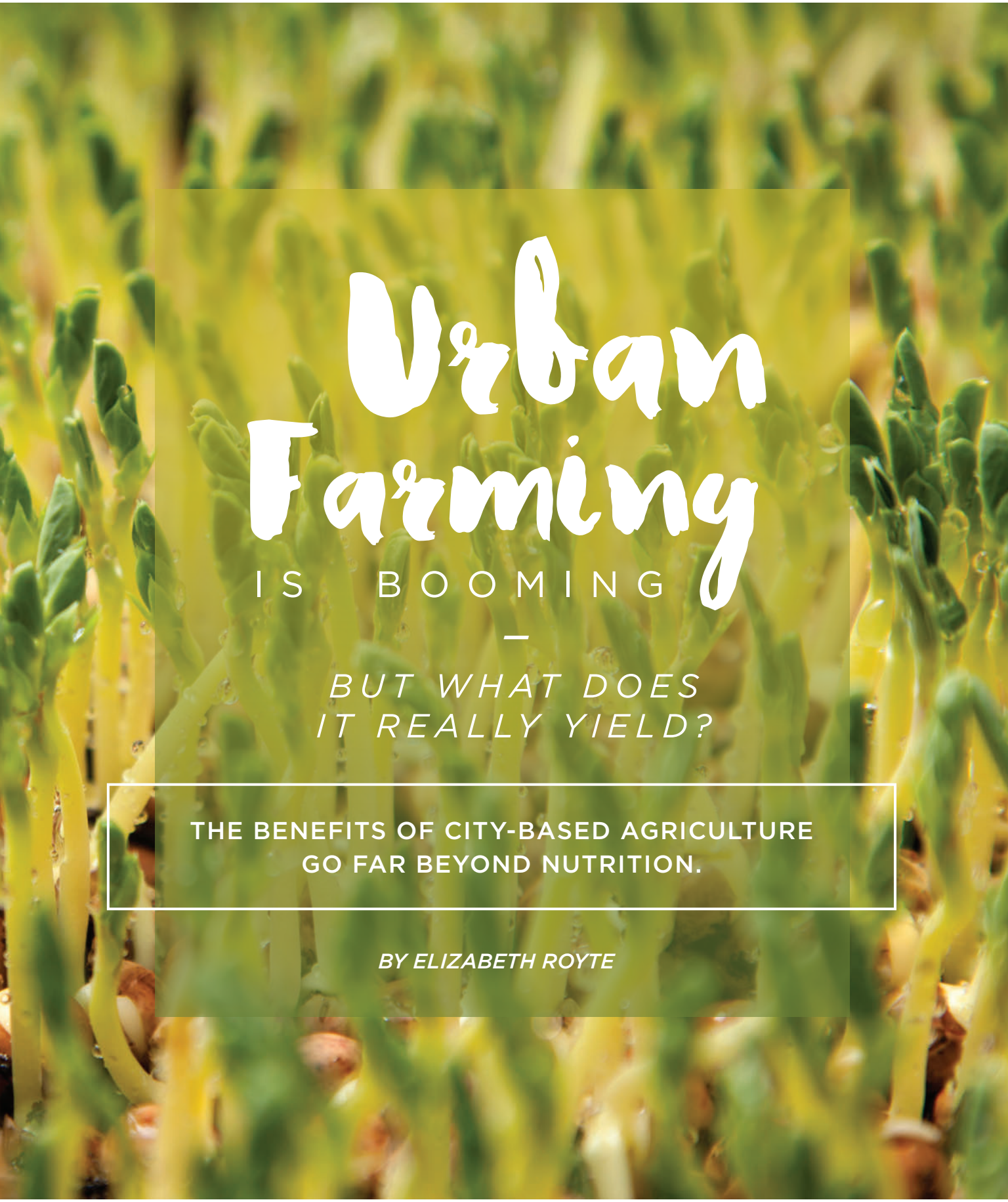


PHOTO BY MARCIN SZCZEPANSKI



# Urban Farming IS BOOMING — *BUT WHAT DOES IT REALLY YIELD?*

**THE BENEFITS OF CITY-BASED AGRICULTURE GO FAR BEYOND NUTRITION.**

***BY ELIZABETH ROYTE***

ORIGINALLY PUBLISHED:
APRIL 2015

## WHY THIS MATTERS

Urban farming has garnered increased attention in recent years as people become more aware of and invested in the origins of their food. But can city-based agriculture really make meaningful contributions to feeding our growing global population? If not, are there other benefits that make it worth pursuing? Or is it a red herring, distracting us from pursuing the advances we really need in an increasingly ravenous world? Despite numerous "one-off" stories about rooftop gardens, urban beekeeping and other such projects, the conversation seemed to be failing to address these critical questions. The answers, uncovered here by writer and author Elizabeth Royte, provide important perspective as individuals and governments make choices about where and how to promote future food production.

Midway through spring, the nearly bare planting beds of Carolyn Leadley's Rising Pheasant Farms, in the Poletown neighborhood of Detroit, barely foreshadow the cornucopian abundance to come. It will be many months before Leadley is selling produce from this one-fifth-acre (one-tenth-hectare) plot. But the affable young farmer has hardly been idle, even during the snowiest days of winter. Twice daily, she has been trekking from her house to a small greenhouse in her side yard, where she waves her watering wand over roughly 100 trays of sprouts, shoots and microgreens. She sells this miniature bounty, year round, at the city's eastern market and to restaurateurs delighted to place some hyperlocal greens on their guests' plates.

Leadley is a key player in Detroit's vibrant communal and commercial farming community, which in 2014 produced nearly 400,000 pounds (181,000 kilograms) of produce in its more than 1,300 community, market, family and school gardens. Other farms in postindustrial cities are also prolific: In 2008, Philadelphia's 226 community and squatter gardens grew roughly 2 million pounds (900,000 kilograms) of mid-summer vegetables and herbs, worth US$4.9 million. Running at full bore, Brooklyn's Added-Value Farm, which occupies 2.75 acres (1.11 hectares), funnels 40,000 pounds (20,000 kilograms) of fruit and vegetables into the low-income neighborhood of Red Hook. And in Camden, New Jersey — an extremely poor city of 80,000 with only one full-service supermarket — community gardeners at 44 sites harvested almost 31,000 pounds (14,000 kilograms) of vegetables during an unusually wet and cold summer. That's enough food during the growing season to feed 508 people three servings a day.

That researchers are even bothering to quantify the amount of food produced on tiny city farms — whether community gardens, like those of Camden and Philly, or for-profit operations, like Leadley's — is testament to the nation's burgeoning local-foods movement and its data-hungry supporters. Young farmers are, in increasing numbers, planting market gardens in cities, and "local" produce (a term with no formal definition) now fills grocery shelves across the U.S., from Walmart to Whole Foods, and is promoted in more than 150 nations around the world.

The Food and Agriculture Organization of the United Nations reports that 800 million people worldwide grow vegetables or fruits or raise animals in cities, producing what the Worldwatch Institute reports to be an astonishing 15 to 20 percent of the world's food. In developing nations, city dwellers farm for subsistence, but in the U.S., urban ag is more often driven by capitalism or ideology. The U.S. Department of Agriculture doesn't track numbers of city farmers, but based on demand for its programs that fund education and infrastructure in support of urban-ag projects, and on surveys of urban ag in select cities, it affirms that business is booming. How far — and in what direction — can this trend go? What portion of a city's food can local farmers grow, at what price, and who will be

PHOTOS BY MARCIN SZCZEPANSKI

Carolyn Leadley, founder of Rising Pheasant Farms in Detroit, produces and sells greenhouse-grown sprouts, shoots and other produce to local markets and restaurateurs throughout the year.

In addition to raising vegetables, urban gardens can help families like Carolyn Leadley's raise kids who enjoy the outdoors.

privileged to eat it? And can such projects make a meaningful contribution to food security in an increasingly crowded world?

## URBAN ADVANTAGES

Like anyone who farms in a city, Leadley waxes eloquent on the freshness of her product. Pea shoots that have traveled 3 miles (5 kilometers) to grace a salad are bound to taste better and be more nutritious, she says, than those that have traveled half a continent or farther. "One local restaurant that I sell to used to buy its sprouts from Norway," Leadley says. Fresher food also lasts longer on shelves and in refrigerators, reducing waste.

Food that's grown and consumed in cities has other advantages: During times of abundance, it may cost less than supermarket fare that's come long distances, and during times of emergency — when transportation and distribution channels break down — it can fill a vegetable void. Following large storms such as Hurricane Sandy and the blizzards of this past winter, says Viraj Puri, cofounder of New York City–based Gotham Greens (which produces more than 300 tons (270 metric tons) of herbs and microgreens per year in two rooftop hydroponic operations and has another farm planned for Chicago), "our produce was the only produce on the shelf at many supermarkets across the city."

Despite their relatively small size, urban farms grow a surprising amount of food, with yields that often surpass those of their rural cousins. This is possible for a couple reasons. First, city farms don't experience heavy insect pressure, and they don't have to deal with hungry deer or groundhogs. Second, city farmers can walk their plots in minutes, rather than hours, addressing problems as they arise and harvesting produce at its peak. They can also plant more densely because they hand cultivate, nourish their soil more frequently and micromanage applications of water and fertilizer.

Though they don't get as much press as for-profit farms and heavily capitalized rooftop operations, community gardens — which are collectively tended by people using individual or shared plots of public or private land, and have been a feature in U.S. cities for well over a century — are the most common form of urban agriculture in the nation, producing far more food and feeding more people, in aggregate, than their commercial counterparts. As social enterprises, community gardens operate in an alternate financial universe: they don't sustain themselves with sales, nor do they have to pay employees. Instead, they rely on volunteer or cheap youth labor, they pay little or nothing in rent, and they solicit outside aid from government programs and foundations that support their social and environmental missions. These may include job training, health and nutrition education, and increasing the community's resilience to climate change by absorbing stormwater, counteracting the urban heat island effect and converting food waste into compost.

*AS SOCIAL ENTERPRISES, COMMUNITY GARDENS OPERATE IN AN ALTERNATE FINANCIAL UNIVERSE: THEY DON'T SUSTAIN THEMSELVES WITH SALES, NOR DO THEY HAVE TO PAY EMPLOYEES.*

New York City–based Gotham Greens produces more than 300 tons (270 metric tons) per year of herbs and greens in two hydroponic facilities.

PHOTO BY TIA (FLICKR/CREATIVE COMMONS)

Funders don't necessarily expect community gardens to become self-sustaining. These farms may increase their revenue streams by selling at farmers markets or to restaurants, or they may collect fees from restaurants or other food-waste generators for accepting scraps that will be converted into compost, says Ruth Goldman, a program officer at the Merck Family Fund, which funds urban agriculture projects. "But margins on vegetable farming are very slim, and because these

farms are doing community education and training teen leaders, they're not likely to operate in the black."

Several years ago, Elizabeth Bee Ayer, who until recently ran a training program for city farmers, took a hard look at the beets growing in her Youth Farm, in the Lefferts Gardens neighborhood of Brooklyn. She counted the hand movements involved in harvesting the roots and the minutes it took to wash and prepare them for sale. "Tiny things can make or break a farm," Ayer notes. "Our beets cost US$2.50 for a bunch of four, and people in the neighborhood loved them. But we were losing 12 cents on every beet." Ultimately, Ayer decided not to raise the price: "No one would have bought them," she says. Instead, she doubled down on callaloo, a Caribbean herb that cost less to produce but sold enough to subsidize the beets. "People love it, it grows like a weed, it's low maintenance and requires very little labor." In the end, she says, "We are a nonprofit, and we didn't want to make a profit."

PHOTOS BY MARCIN SZCZEPANSKI

Noah Link checks on his bees (left) and chickens (below) at Food Field, a commercial farm in Detroit.

## SUSTAINABLE AND RESILIENT

Few would begrudge Ayer her loss leader, but such practices can undercut for-profit city farmers who are already struggling to compete with regional farmers at crowded urban markets and with cheap supermarket produce shipped from California and Mexico. Leadley, of Rising Pheasant Farms, realized long ago that she wouldn't survive selling only the vegetables from her outdoor garden, which is why she invested in a plastic-draped greenhouse and heating system. Her tiny shoots, sprouts, amaranth and kohlrabi leaves grow year-round; they grow quickly — in the summer, Leadley can make a crop in seven days — and they sell for well over a dollar an ounce.

Nodding toward her backyard plot, Leadley says, "I grow those vegetables because they look good on the farm stand. They attract more customers to our table, and I really love growing outdoors." But it's the microgreens that keep Leadley from joining the ranks of the vast majority of U.S. farmers and taking a second job.

Mchezaji Axum, an agronomist with the University of the District of Columbia, the first exclusively urban land-grant university in the nation, helps urban farmers increase their yields whether they are selling into wealthy markets, like Leadley, or poorer markets, like Ayer. He promotes the use of plant varieties adapted to city conditions (short corn that produces four instead of two ears, for example). He also recommends biointensive methods, such as planting densely, intercropping, applying compost, rotating crops and employing season-extension methods (growing cold-tolerant vegetables like kale, spinach or carrots in winter hoop houses, for example, or starting plants in cold frames — boxes with transparent tops that let in sunlight but protect plants from extreme cold and rain).

"You learn to improve your soil health, and you learn how to space your plants to get more sunshine," Axum says. Surveying D.C.'s scores of communal gardens, Axum has been surprised by how little food they

URBAN AGRICULTURE IS JUST ONE EXAMPLE OF INNOVATIONS IN FOOD PRODUCTION THAT HAVE GAINED POPULARITY IN RECENT YEARS. WHAT TIES THEM ALL TOGETHER, UNIVERSITY OF CALIFORNIA, BERKELEY, FOOD SYSTEMS RESEARCHER MAYWA MONTENEGRO WRITES IN HER FIRST VOICES PIECE FOR ENSIA, IS A QUEST FOR A SUSTAINABLE FOOD SYSTEM — A QUEST SHE ARGUES SHOULD ULTIMATELY LEAD TO AGROECOLOGY. READ MORE AT **ENSIA.US/AGROECOLOGY**.

## TEAMING UP:

**THIS PIECE WAS PRODUCED** in collaboration with the Food & Environment Reporting Network, a New York–based non-profit investigative news organization. The partnership allowed us to tell the story in far more depth than otherwise would have been possible, include photos from the field and extend the piece's reach to influential new audiences.

**400,000 =**
pounds (200,000 kilograms) of produce Detroit urban farmers produced in 2014

**US$4.9 million =**
value of food from Philadelphia gardens in 2008

**15–20 =**
percent of world's food produced in cities

**40 =**
percent of city dwellers engaged in agriculture in Africa

actually grow. "People aren't using their space well. More than 90 percent aren't producing intensively. Some people just want to grow and be left alone.

"Using biointensive methods may not be part of your cultural tradition," Laura J. Lawson, a professor of landscape architecture at Rutgers State University and the author of *City Bountiful: A Century of Community Gardening in America,* says. "It depends who you learned gardening from." Lawson recalls the story of a well-meaning visitor to a Philadelphia garden who suggested that the farmers had planted their corn in a spot that wasn't photosynthetically ideal. The women told their visitor, "We always plant it there; that way we can pee behind it."

Axum is all about scaling up and aggregating hyperlocal foods to meet the demands of large buyers like city schools, hospitals or grocery stores. Selling to nearby institutions, say food policy councils — established by grassroots organizations and local governments to strengthen and support local food systems — is key to making urban food systems more sustainable and resilient, to say nothing of providing a living to local growers. But scaling up often requires more land, and therefore more expensive labor to cultivate it, in addition to changes in local land use and other policies, marketing expertise and efficient distribution networks.

"Lots of local institutions want to source their food here," says Detroit farmer Noah Link, whose Food Field, a commercial operation, encompasses a nascent orchard, vast areas of raised beds, two tightly wrapped 150-foot-long (46-meter-long) hoop houses (one of which shelters a long, narrow raceway crammed with catfish), chickens, beehives and enough solar panels to power the whole shebang. "But local farms aren't producing enough food yet. We'd need an aggregator to pull it together for bulk sales."

Link doesn't grow microgreens — the secret sauce for so many commercial operations — because he can break even on volume: His farm occupies an entire city block. Annie Novak, who co-founded New York City's first for-profit rooftop farm in 2009, doesn't have the luxury of space. She realized early on that she couldn't grow a wide enough diversity of food to satisfy her community-supported agriculture customers in just 5,800 square feet (540 square meters) of shallow raised beds. "So I partnered with a farm upstate to supplement and diversify the boxes," she says. Now, Novak focuses on niche and value-added products. "I make a hot sauce from my peppers and market the bejesus out of it," she says. She also grows microgreens for restaurants, plus honey, herbs, flowers and "crops that are narratively interesting, like purple carrots, or heirloom tomatoes, which give us an opportunity to educate people about the value of food, green spaces and our connection to nature," she says.

Sometimes being strategic with crop selection isn't enough. Brooklyn Grange, a for-profit farm atop two roofs in New York City, grows more than 50,000 pounds (20,000 kilograms) of tomatoes, kale, lettuce, carrots, radishes and beans, among other crops, each year. It sells them through its CSA, at farm stands and to local restaurants. But to further boost its income, Brooklyn Grange also offers a summerlong training program for beekeepers (US$850 tuition), yoga classes and tours, and it rents its Edenic garden spaces, which have million-dollar views of the Manhattan skyline, for photo shoots, weddings, private dinners and other events.

"Urban farms are like small farms in rural areas," says Carolyn Dimitri, an applied economist who studies food systems and food policy at New York University. "They have the same set of problems: people don't want to pay a lot for their food, and labor is expensive. So they have to sell high-value products and do some agritourism."

### UNDER CONTROL

On a miserable March morning, with a

Brooklyn Grange in New York grows more than 50,000 pounds (20,000 kilograms) of produce each year in its rooftop gardens.

PHOTO © BROOKLYN GRANGE ROOFTOP FARM / ANASTASIA COLE PLAKIAS

sparkling layer of ice glazing a foot of filthy snow, a coterie of Chicago's urban farmers toils in shirtsleeves and sneakers, their fingernails conspicuously clean. In their gardens, no metal or wood scrap accumulates in corners, no chickens scratch in hoophouse soil. In fact, these farmers use no soil at all. Their densely planted basil and arugula leaves sprout from growing medium in bar-coded trays. The trays sit on shelves stacked 12 feet (3.7 meters) high and illuminated, like tanning beds, by purple and white lights. Fans hum, water gurgles, computer screens flicker.

FarmedHere, the nation's largest player in controlled environment agriculture — CEA — pumps out roughly a million pounds (500,000 kilograms) per year of baby salad greens, basil and mint in its 90,000-square-foot (8,000-square-meter) warehouse on the industrial outskirts of Chicago. Like many hydroponic or aquaponic operations (in which water from fish tanks nourishes plants, which filter the water before it's returned to the fish), the farm has a futuristic feel — all glowing lights and stainless steel. Employees wear hairnets and nitrile gloves. But without interference from weather, insects or even too many people, the farm quickly and reliably fulfills year-round contracts with local supermarkets, including nearly 50 Whole Foods Markets.

"We can't keep up with demand," Nick Greens, a deejay turned master grower, says.

*WITH 25 HIGH-DENSITY CROPS PER YEAR, AS OPPOSED TO A CONVENTIONAL FARMER'S FIVE OR SO, CEA YIELDS ARE 10 TO 20 TIMES HIGHER THAN THE SAME CROP GROWN OUTDOORS.*

Unlike outdoor farms, CEA has no call for pesticides and contributes no nitrogen to waterways. Its closed-loop irrigation systems consume 10 times less water than conventional systems. And with 25 high-density crops per year, as opposed to a conventional farmer's five or so, CEA yields are 10 to 20 times higher than the same

PHOTO BY NANA KOFI ACQUAH/IMWI

PHOTO BY APOLLO HABTAMU/IMWI

Urban farming is common in Ghana and other sub-Saharan countries.

crop grown outdoors — in theory sparing forests and grasslands from the plow.

Is CEA the future of urban farming? It produces a lot of food in a small space, to be sure. But until economies of scale kick in, these operations — which are capital intensive to build and maintain — must concentrate exclusively on high-value crops like microgreens, winter tomatoes and herbs.

Reducing food miles reduces transit-related costs, as well as the carbon emissions associated with transport, packaging and cooling. But growing indoors under lights, with heating and cooling provided by fossil fuels, may negate those savings. When Louis Albright, an emeritus professor of biological and environmental engineering at Cornell University, dug into the numbers, he discovered that closed-system farming is expensive, energy intensive and, at some latitudes, unlikely to survive on solar or wind power. Growing a pound of hydroponic lettuce in Ithaca, New York, Albright reports, generates 8 pounds (4 kilograms) of carbon dioxide at the local power plant (a pound of tomatoes would generate twice that much). Grow that lettuce without artificial lights in a greenhouse and emissions drop by two-thirds.

## FOOD SECURITY

In the world's poorest nations, city dwellers have always farmed for subsistence. But more of them are farming now than ever before. In Africa, for example, it's estimated that 40 percent of the urban population is engaged in agriculture. Long-time residents and recent transplants alike farm because they're hungry, they know how to grow food, land values in marginal areas (under power lines and along highways) are low, and inputs like organic wastes — fertilizer — are cheap. Another driver is the price of food: People in developing nations pay a far higher percentage of their total income for food than Americans do, and poor transportation and refrigeration infrastructure make perishable goods, like fruits and vegetables, especially dear. Focusing on these high-value crops, urban farmers both feed themselves and supplement their incomes.

*IN THE WORLD'S POOREST NATIONS, CITY DWELLERS HAVE ALWAYS FARMED FOR SUBSISTENCE. BUT MORE OF THEM ARE FARMING NOW THAN EVER BEFORE.*

In the U.S., urban farming is likely to have its biggest impact on food securi-

ty in places that, in some ways, resemble the global south — that is, in cities or neighborhoods where land is cheap, median incomes are low and the need for fresh food is high. Detroit, by this metric, is particularly fertile ground. Michael Hamm, a professor of sustainable agriculture at Michigan State University in East Lansing, calculated that the city, which has just under 700,000 residents and more than 100,000 vacant lots (many of which can be purchased, thanks to the city's recent bankruptcy, for less than the price of a refrigerator), could grow three-quarters of its current vegetable consumption and nearly half its current fruit consumption on available parcels of land using biointensive methods.

No one expects city farms in the U.S. to replace peri-urban or rural vegetable farms: cities don't have the acreage or the trained farmers, and most can't produce food anything close to year-round. But can city farms take a bite from long-distance supply chains? NYU's Dimitri doesn't think so. Considering the size and global nature of the nation's food supply, she says, urban ag in our cities "isn't going to make a dent. And it's completely inefficient, economically. Urban farmers can't charge what they should, and they're too small to take advantage of economies of scale and use their resources more efficiently."

That doesn't mean that community gardeners, who don't even try to be profitable, aren't making a big difference in their immediate communities. Camden's 31,000 pounds (14,000 kilograms) of produce might not seem like a lot, but it's a very big deal for those lucky enough to get their hands on it. "In poor communities where households earn very little income," says Domenic Vitiello, an associate professor of city and regional planning at the University of Pennsylvania, "a few thousand dollars' worth of vegetables and fruit grown in the garden makes a much bigger difference than for more affluent households."

History tells us that community gardening — supported by individuals, government agencies and philanthropies — is here to stay. And whether these gardens ultimately produce more food or more knowledge about food — where it comes from, what it takes to produce it, how to prepare and eat it — they still have enormous value as gathering places and classrooms and as conduits between people and nature. Whether or not cultivating fruits and vegetables in tiny urban spaces makes economic or food-security sense, people who want to grow food in cities will find a way to do so. As Laura Lawson says, "City gardens are part of our ideal sense of what a community should be. And so their value is priceless."

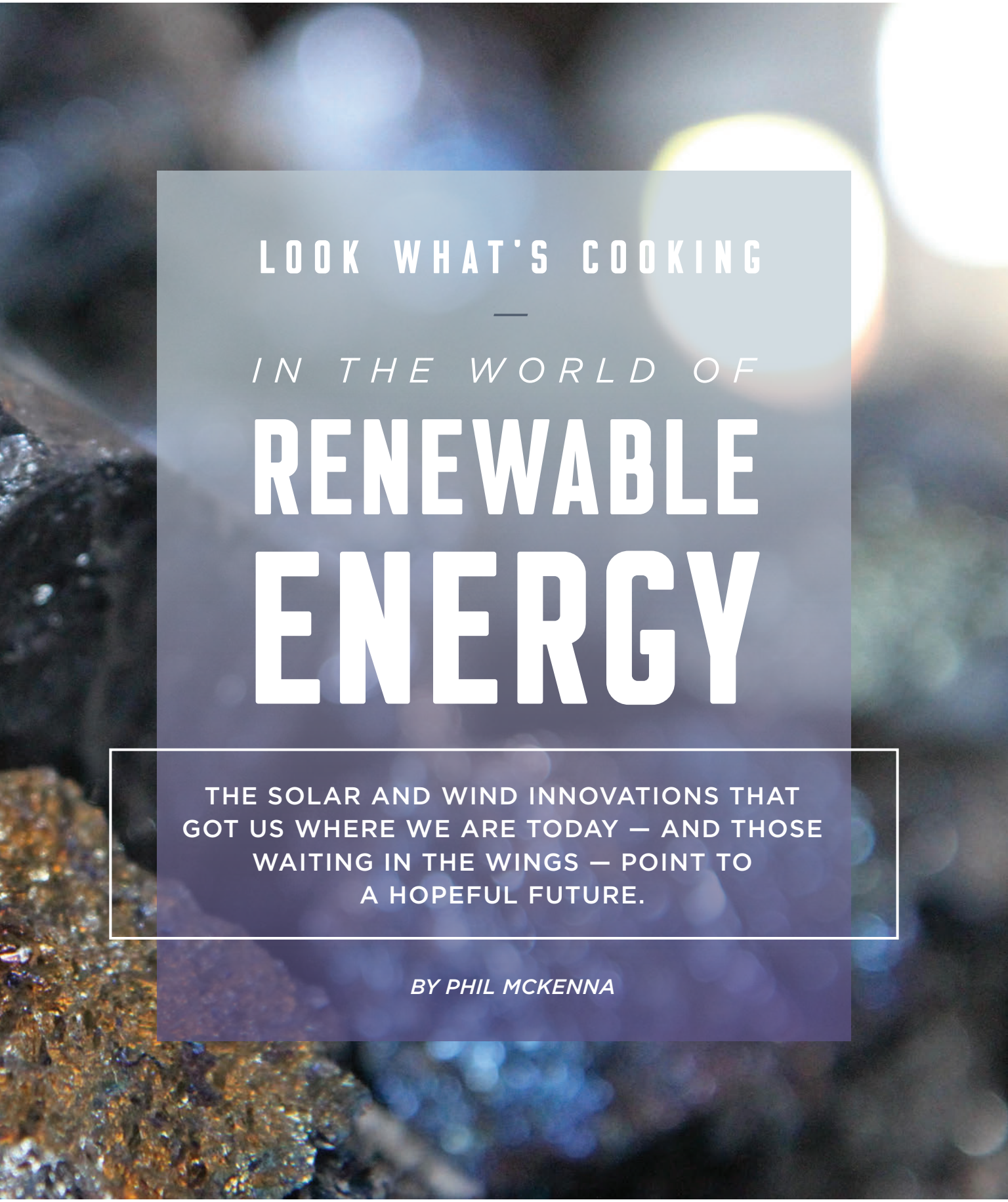
*WHETHER OR NOT CULTIVATING FRUITS AND VEGETABLES IN TINY URBAN SPACES MAKES ECONOMIC OR FOOD-SECURITY SENSE, PEOPLE WHO WANT TO GROW FOOD IN CITIES WILL FIND A WAY TO DO SO.*

**ELIZABETH ROYTE** is a Brooklyn-based freelance writer and author of three books. Her work has appeared in *Harper's, National Geographic, Outside* and other national publications.

## IMPACT

With urban farming a hot topic around the world, it's no surprise that this article was widely shared through social media and republication. So far it has been recommended on Facebook 11,000 times, tweeted more than 1,000 times (including by food thought leaders Michael Pollan and Danielle Nierenberg) and republished by Quartz, Global Voices and other outlets.


PHOTO COURTESY OF KAZATOMPROM



# LOOK WHAT'S COOKING

## *IN THE WORLD OF*

# RENEWABLE ENERGY

THE SOLAR AND WIND INNOVATIONS THAT GOT US WHERE WE ARE TODAY — AND THOSE WAITING IN THE WINGS — POINT TO A HOPEFUL FUTURE.

*BY PHIL MCKENNA*

ORIGINALLY PUBLISHED:
APRIL 2015

Somewhere inside a sprawling single-story office building in Bedford, Massachusetts, in a secret room known as the Growth Hall, the future of solar power is cooking at more than 2,500 °F (1,300 °C. Behind closed doors and downturned blinds, custom-built ovens with ambitious names like "Fearless" and "Intrepid" are helping to perfect a new technique of making silicon wafers, the workhorse of today's solar panels. If all goes well, the new method could cut the cost of solar power by more than 20 percent in the next few years.

"This humble wafer will allow solar to be as cheap as coal and will drastically change the way we consume energy," says Frank van Mierlo, CEO of 1366 Technologies, the company behind the new method of wafer fabrication.

Secret rooms or not, these are exciting times in the world of renewable energy. Thanks to technological advances and a ramp-up in production over the past decade, grid parity — the point at which sources of renewable energy such as solar and wind cost the same as electricity derived from burning fossil fuels — is quickly approaching. In some cases it has already been achieved, and additional innovations waiting in the wings hold huge promise for driving costs even lower, ushering in an entirely new era for renewables.

## SOLAR SURPRISE

In January 2015, Saudi Arabian company ACWA Power surprised industry analysts when it won a bid to build a 200-megawatt solar power plant in Dubai that will be able to produce electricity for 6 cents per kilowatt-hour. The price was less than the cost of electricity from natural gas or coal power plants, a first for a solar installation. Electricity from new natural gas and coal plants would cost an estimated 6.4 cents and 9.6 cents per kilowatt-hour, respectively, according to the U.S. Energy Information Agency.

Technological advances, including photovoltaics that can convert higher percentages of sunlight into energy, have made solar panels more efficient. At the same time economies of scale have driven down their costs.

For much of the early 2000s, the price of a solar panel or module hovered around US$4 per watt. At the time Martin Green, one of the world's leading photovoltaic researchers, calculated the cost of every component, including the polycrystalline silicon ingots used in making silicon wafers, the protective glass on the outside of the module, and the silver used in the module's wiring. Green famously declared that so long as we rely on crystalline silicon for solar power, the price would likely never drop below US$1 per watt.

The future, Green and nearly everyone else in the field believed, was with thin films, solar modules that relied on materials other than silicon that required a fraction of the raw materials.

Then, from 2007 to 2014, the price of crystalline silicon modules dropped from US$4 per watt to US$0.50 per watt, all but ending the development of thin films.

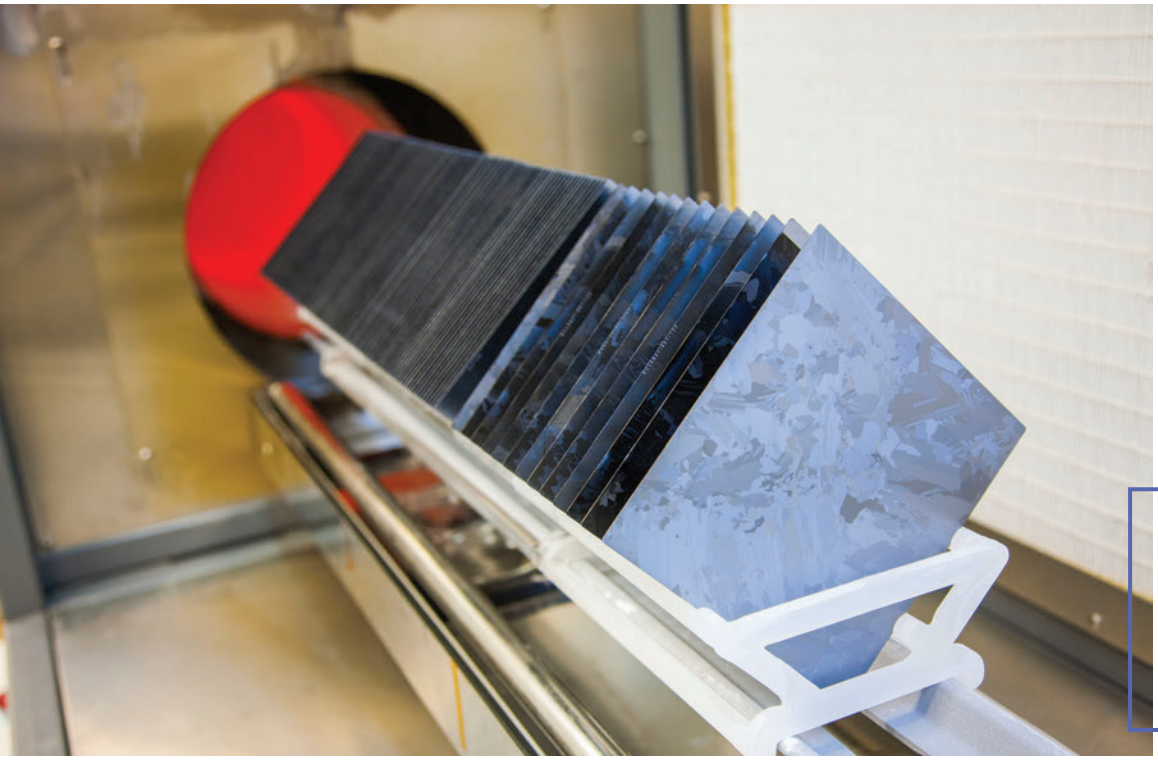
The dramatic reduction in cost came from a wide number of incremental gains,

PHOTO COURTESY OF 1366 TECHNOLOGIES

## WHY THIS MATTERS

Currently, two-thirds of the world's electricity comes from fossil fuels. In the U.S., electrical generation is responsible for one-third of total carbon emissions. Solar and wind generation, which have relatively small carbon footprints, hold huge potential as substitutes for much of this generation capacity, but factors such as cost and engineering constraints limit application of existing technologies. By highlighting efforts to improve solar and wind technologies, this Ensia feature is helping to inspire individuals and institutions to imagine — and help create — a future less dependent on greenhouse-gas-emitting fossil fuels.

SOURCE: IEA KEY WORLD ENERGY STATISTICS 2014; HTTP://WWW.C2ES.ORG/TECHNOLOGY/OVERVIEW/ELECTRICITY

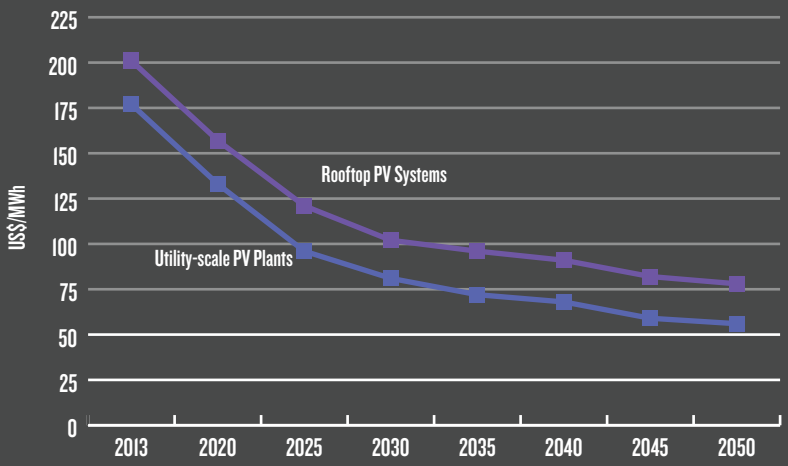


Silicon wafers that some say hold the key to affordable, cost-competitive solar power are stacked before a furnace at 1366 Technologies in Bedford, Massachusetts.

Cost-reducing thin film solar photovoltaic technology could be experiencing a renaissance, thanks to recent efficiency innovations by U.S. manufacturer First Solar.

## SOLAR ENERGY COST PROJECTIONS THROUGH 2050

In its "high-REN" scenario, in which renewables reach 79 percent and solar reaches 27 percent of global electricity generation in 2050, the International Energy Agency projects that levelized costs of energy for new utility scale photovoltaic plant and rooftop PV systems will decline dramatically.




Source: *International Energy Agency / Solar Photovoltaic Energy Technology Roadmap (2014)*

PHOTO COURTESY OF FIRST SOLAR, INC.

says Mark Barineau, a solar analyst with Lux Research. Factors include a new, low-cost process for making polycrystalline silicon; thinner silicon wafers; thinner wires on the front of the module that block less sunlight and use less silver; less-expensive plastics instead of glass; and greater automation in manufacturing.

"There is a tenth of a percent of an efficiency gain here and cost reductions there that have added up to make solar very competitive," Barineau says.

## 25 CENTS PER WATT

"Getting below US$1 [per watt] has exceeded my expectations," Green says. "But now, I think it can get even lower."

One likely candidate to get it there is 1366's new method of wafer fabrication. The silicon wafers behind today's solar panels are cut from large ingots of polycrystalline silicon. The process is extremely inefficient, turning as much as half of the initial ingot into sawdust. 1366 takes a different approach, melting the silicon in specially built ovens and recasting it into thin wafers for less than half the cost per wafer or a 20 percent drop in the overall cost of a crystalline silicon module. 1366 hopes to begin mass production in 2016, according to van Mierlo.

the efficiency of its solar cells while scaling up production. The company now says it can manufacture solar modules for less than 40 cents per watt and anticipates further price reductions in coming years.

Ten years from now we could easily see the cost of solar modules dropping to 25 cents per watt, or roughly half their current cost, Green says. To reduce costs beyond that, the conversion efficiency of sunlight into electricity will have to increase substantially. To get there, other semiconducting materials will have to be stacked on top of existing solar cells to convert a wider spectrum of sunlight into electricity.

"If you can stack something on top of a silicon wafer it will be pretty much unbeatable," Green says.

Green and colleagues set a record for crystalline silicon solar module efficiency at 22.9 percent in 1996 that still holds today. Green doubts the efficiency of crystalline silicon alone will ever get much higher. With cell stacking, however, he says "the sky is the limit."

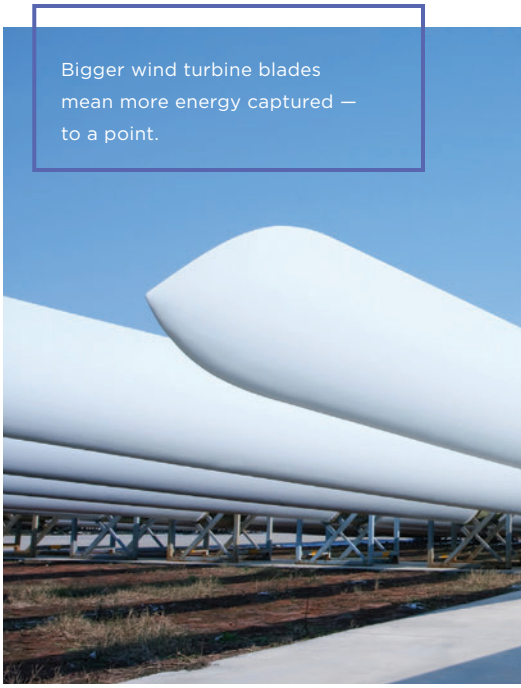
## A MATTER OF SIZE

While solar power is just starting to reach grid parity, wind energy is already there. In 2014, the average worldwide price of onshore wind energy was the same as

*"I FULLY EXPECT TO SEE 100-METER BLADES AND BEYOND."*
*— D. TODD GRIFFITH*

Meanwhile, thin films, once thought to be the future of solar power, then crushed by low-cost crystalline silicon, could experience a renaissance. The recent record-setting low-cost bid for solar power in Dubai harnesses thin-film cadmium telluride solar modules made by U.S. manufacturer First Solar. The company not only hung on as the vast majority of thin film companies folded, but has consistently produced some of the least expensive modules by increasing electricity from natural gas, according to Bloomberg New Energy Finance.

As with solar, the credit goes to technological advances and volume increases. For wind, however, innovation has mainly been a matter of size. From 1981 to 2015 the average length of a wind turbine rotor blade has increased more than sixfold, from 9 meters (30 feet) to 60 meters (200 feet), as the cost of wind energy has dropped by a factor of 10.



Bigger wind turbine blades mean more energy captured — to a point.

PHOTO © ISTOCKPHOTO.COM/HUDIEMM

"Increasing the rotor size means you are capturing more energy, and that is the single most import driver in reducing the cost of wind energy," says D. Todd Griffith of Sandia National Laboratories in Albuquerque, New Mexico.

Griffith recently oversaw the design and testing of several 100-meter-long (300-foot-long) blade models at Sandia. His group didn't actually build the blades, but created detailed designs that they subsequently tested in computer models. When the project started in 2009, the biggest blades in commercial operation were 60 meters (200 feet) long. Griffith and his colleagues wanted to see how far they could push the trend of ever-increasing blades before they ran into material limitations.

Their first design was an all-fiberglass blade that used a similar shape and materials as those found in relatively smaller commercial blades at the time. The result was a prohibitively heavy 126-ton (114-metric-ton) blade that was so thin and long it would be susceptible to vibration in strong winds and gravitational strain.

The group made two subsequent designs employing stronger, lighter carbon fiber and a blade shape that was flat-backed instead of sharp-edged. The resulting 100-meter (300-foot) blade design was 60 percent lighter than the initial model.

Since the project began in 2009 the largest blades used in commercial offshore wind turbines have grown from 60 meters (200 feet) to roughly 80 meters (260 feet) with larger commercial prototypes now under development. "I fully expect to see 100-meter (300-foot) blades and beyond," Griffith says.

As blades grow longer, the towers that elevate them are getting taller to catch more consistent, higher speed wind. And as towers grow taller, transportation costs are growing increasingly expensive. To counter the increased costs GE recently debuted a "space frame" tower, a steel lattice tower wrapped in fabric. The new towers use roughly 30 percent less steel than conventional tube towers of the same height and can be delivered entirely in standard-size shipping containers for on-site assembly. The company recently received a US$3.7 million grant from the U.S. Department of Energy to develop similar space frame blades.

## OFFSHORE INNOVATION

Like crystalline silicon solar panels, however, existing wind technology will eventually run up against material limits. Another innovation on the horizon for wind is related instead to location. Wind farms are moving offshore in pursuit of greater wind resources and less land use conflict. The farther offshore they go, the deeper the water, making the current method of fixing turbines to the seafloor prohibitively expensive. If the industry moves instead to floating support structures, today's top-heavy wind turbine design will likely prove too unwieldy.

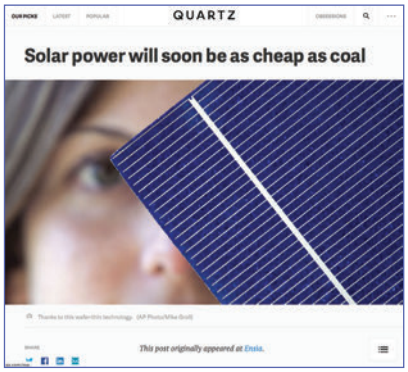
One potential solution is a vertical axis turbine, one where the main rotor shaft is set vertically, like a merry go round, rather than horizontally like a conventional wind turbine. The generator for such a turbine could be placed at sea level, giving the device a much lower center of gravity.

"There is a very good chance that some other type of turbine technology, very well vertical axis, will be the most cost effective in deep water," Griffith says.

The past decade has yielded remarkable innovations in solar and wind technology, bringing improvements in efficiency and cost that in some cases have exceeded the most optimistic expectations. What the coming decade will bring remains unclear, but if history is any guide, the future of renewables looks extremely positive.

## IMPACT

In addition to attracting abundant attention at Ensia, "Look what's cooking in the world of renewable energy" was republished at Quartz and was one of the more popular articles on Reddit in April 2015. All told, it has garnered more than 250,000 views to date.




**PHIL MCKENNA** covers the convergence of fascinating individuals and intriguing ideas for *The New York Times, Smithsonian, WIRED, Technology Review* and other outlets.

**WRITER UPDATE:** *When I wrote this piece about recent advances in solar and wind energy, I was struck by the plummeting price of solar power and the rapid growth of solar installations. Since the article published, both trends have only continued to accelerate.*

*The combination of federal, state and local subsidies now makes residential solar less expensive than electricity from the grid in many locations across the United States, according to a study by the Massachusetts Institute of Technology. In July, a utility in Austin, Texas, announced bids for a new round of solar construction that were below US$40 per megawatt-hour, besting the then-lowest price of US$60 per megawatt-hour (6 cents per kilowatt-hour) I reported in my article about a solar installation in Dubai. Construction workers in West Texas are now building a solar farm more than 900 football fields in size.*

*The scale of this and other installations planned for the region is mind-boggling. But what is most noteworthy is that these solar farms are being built in Texas, a state that does not subsidize solar power. The installations do benefit from generous federal tax breaks that are set to expire at the end of 2016. Yet, if the cost of solar continues to decline, the end of such subsidies may be little more than a speed bump in solar's ongoing rise. — PHIL MCKENNA*

PHOTO © AFP/GETTY IMAGES

# HOW DID PALM OIL BECOME SUCH A PROBLEM – AND WHAT CAN WE DO ABOUT IT?

PRODUCTION OF THIS UBIQUITOUS INGREDIENT IS DEVASTATING FOR THE ENVIRONMENT. SOLUTIONS ARE COMPLEX, BUT THEY ARE OUT THERE.

*BY MICHAEL KODAS*

ORIGINALLY PUBLISHED:
NOVEMBER 2014

From the window of a jet high over Sumatra in August 2014, I counted nearly a dozen plumes of smoke rising from the vast jungles and plantations below. Some more than a half-mile wide, they looked like pillars holding up the sky. That week the Indonesian Disaster Mitigation Agency detected 143 new wildfires in Riau Province, the area beneath my flight. All of the fires were almost certainly related to deforestation for timber operations and agriculture — predominantly oil palm cultivation.

Palm oil — which appears in a dizzying amount of food and cosmetic products, and is a feedstock for biofuel — poses many environmental problems. It's the largest driver of Indonesian deforestation, which destroys habitat and contributes to climate change. And ponds of wastewater at palm oil refineries release immense amounts of methane, a greenhouse gas 34 times more potent than carbon dioxide.

Solutions to the environmental problems posed by palm production are complicated, partly because of palm oil's ubiquity, but also because alternatives lack many of the benefits of the versatile oil. But they are out there.

## BURNING BELOW

A few days after I arrived in Riau, as I marched to the jungle to see one of the fires, I looked back at where my footprints sank some 12 inches (30 centimeters) into the peat and saw smoke rising from my tracks.

It's here, in the peat burning below the forests, where the greatest climate impact from palm production can be seen. When forests are cleared to make way for oil palm plantations, the area is usually burned, and most of Riau's massive fires burn on peat — swampy layers of partially decayed vegetation that spreads up to 60 feet (18 meters) deep beneath most of the province's forests.

Peatlands hold up to 28 times as much carbon as rainforests growing on mineral soil. The peat is so carbon rich that if it is buried long enough, say for a million years or so, pressure, time and heat will turn it into coal. A single hectare (2.5 acres) of peatland rainforest can release 6,000 metric tons (6,600 tons) of planet-warming carbon dioxide when it's converted into a plantation. Researchers estimated that in 2012 nearly 70 percent of the carbon released during the transformation of Sumatran rainforests into palm plantations came from peatlands, a 75 percent increase over their portion of emissions in the 1990s and an indication that palm is increasingly expanding into peat.

And it's not just $CO_2$: In 2013 the nation's then president, Susilo Bambang Yudhoyono, apologized to Singapore and Malaysia for the brown cloud from Sumatran fires that shattered air pollution records in the neighboring nations, filled hospitals with tens of thousands of smoke-sickened patients and forced officials to close schools. Indonesian aircraft seeded clouds above the fires with tons of salt in hopes of bringing rain to drench fires smoldering in the peat.

When the forests ignited again six months later, more than 9,000 tweets bombarded the president's office. During an emergency trip to Riau he said he was

PHOTO BY VINCENT POULISSEN (FLICKR/CREATIVE COMMONS)

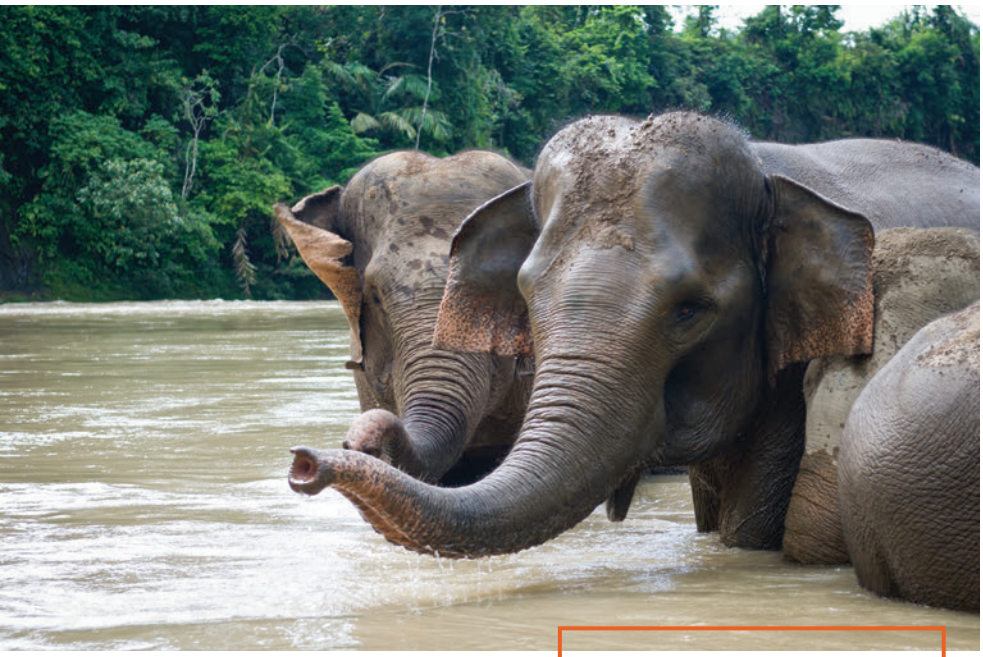
## WHY THIS MATTERS

In 2013, humans produced 58 million metric tons (64 million tons) of palm oil. In 1985, Indonesia had fewer than 2,500 square miles (6,500 square kilometers) of palm oil plantations. By 2025 the Indonesian government projects they will cover at least 100,000 square miles (259,000 square kilometers). This palm oil boom warranted a look at just what is creating such demand and what we can do to minimize the negative effects of plantation expansion, which contributes to global deforestation, climate change and species and habitat loss.

"ashamed" of the fires. Nearly 50,000 Sumatrans sought treatment for the impacts of smoke on their lungs, eyes and skin. Aircraft again seeded the clouds.

The fires burn thousands of Indonesians out of their homes and destroy the habitat of endangered elephants, rhinos, tigers and orangutans. A United Nations report warned that no wild orangutans may exist outside protected areas by 2020. And at the current rate of habitat destruction, the International Union for Conservation of Nature estimated the Sumatran elephant could be extinct within 30 years.

"Effective action on the ground should be taken immediately to protect Sumatran elephants from extinction," a report from the IUCN urged in 2013. "Especially in Riau."



Victims of habitat destruction driven in part by palm oil production, Sumatran elephants are now considered critically endangered by the International Union for Conservation of Nature.

Fires associated with clearing land for oil palm plantations in the Indonesian province of Riau release massive amounts of carbon into the atmosphere and spread health-harming haze across the landscape.

## GETTING SERIOUS

In the past, Indonesia and the world paid lip service to stopping palm oil industry's destruction of Indonesian forests and warming of the global climate, but more recently they have appeared to get serious.

In 2010 Norway promised US$1 billion to Indonesia to keep its forests standing, and the next year Yudhoyono pledged that by 2020, with international assistance, the nation would reduce its greenhouse gas emissions by 41 percent from its "business-as-usual" trajectory. Last August, Singapore began imposing fines of up to US$2 million on local and foreign companies that contribute to the haze from fires. The following month, Indonesia, after years of stalling, became the last of the 10 members of the Association of Southeast Asian Nations to ratify a treaty intended to reduce the smoke that has become a perennial strain on its relations with its Southeast Asian neighbors. Shortly afterward, at the U.N. Climate Summit in New York, 150 companies — including McDonalds, Nestlé and Procter and Gamble — pledged to cut deforestation worldwide in half by 2020 and to eliminate it altogether by 2030.

Then, within days of taking office in October of 2013, Indonesia's new president, Joko Widodo, proposed merging the country's Ministry of Environment and Ministry of Forestry. That reform could help the nation meet its ambitious forest protection and emissions reductions goals if the Ministry of Environment, which negotiates with the U.N. and determines how the nation will meet its emissions goals, gains some authority over the nation's forests and peatlands. On the other hand, the powerful and territorial Ministry of Forestry could usurp some of the Ministry of Environment's authority.

"Combining exploitation and conservation authorities into one body does not guarantee balanced decision making," Greenpeace Indonesia chairman Longgena Ginting told the *Jakarta Post.*

PHOTO BY AULIA ERLANGGA FOR CENTER FOR INTERNATIONAL FORESTRY RESEARCH

## PALM OIL BOOM

Ultimately, however, laws, treaties, government agencies and incentives will have little impact without fundamental changes to how palm oil is produced and consumed. And unfortunately, there are few viable alternatives to palm.

"There are benefits to palm oil which cannot be ignored," Alan Townsend, dean of the Nicholas School of the Environment at Duke University, told me before I traveled to Indonesia. "Palm is one of the most productive crops on the planet, with the ability to grow in a remarkable range of places. Couple that with large profit margins, an incredible diversity of uses for palm oil and a lack of economically competitive substitutes, and you can quickly see why the industry has grown so rapidly."

In 2013 the world produced 58 million metric tons (64 million tons) of palm oil. Indonesia and Malaysia satisfy 85 percent of the demand for the world's most popular food oil. In 1985, Indonesia had less than 2,500 square miles (6,475 square kilometers) of palm oil plantations. By 2025 the Indonesian government projects plantations will cover at least 100,000 square miles (259,000 square kilometers).

A month before my arrival in Riau a paper in the journal *Nature Climate Change* reported that in 2012 Indonesia deforested nearly twice as much land as Brazil, which until recently was destroying its forests faster than any other nation.

The exponential growth of palm oil plantations is to a large degree an unintended consequence of economics, and food and energy policies elsewhere in the world.

In 2006 U.S. food labels, under mandate from the Food and Drug Administration, began listing "trans fats" because they increase risk of heart disease. That led to a rapid increase in the use of tropical oils that aren't trans fats, particularly palm. The television physician Dr. Oz promoted palm oil's benefits to the heart and brain, helping drive a sixfold increase in consumption in the United States since 2000.

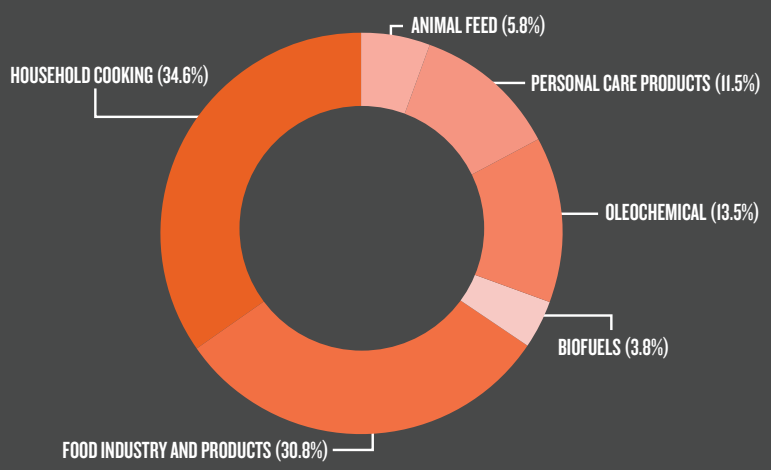
In Europe, efforts to avoid genetically modified foods pushed palm, which is so bountiful it hasn't yet drawn much interest from genetic tinkerers. In China and India, the growing middle classes' hunger for high-grade food oils can currently be satisfied only by palm.

The boom is fueled by what we drive, too. Increasing interest in biofuels is replacing environmental damage due to crude oil with the devastation palm production inflicts on tropical forests and the climate.

Some of the consequences of palm oil production, including deforestation and

### GLOBAL PALM OIL CONSUMPTION (2010)

In 2010, 52 million tons (47 million metric tons) of palm oil was consumed globally, double the amount used in 2000, with household cooking being the primary use.




Source: *Food and Agriculture Organization / FAOSTATS*

## A FRESH LOOK:

**OTHER COVERAGE OF PALM OIL'S ENVIRONMENTAL IMPACTS** seems to focus on the theme: Palm oil use is horrible and needs to be curbed. In this feature story by Michael Kodas, journalist and associate director of the Center for Environmental Journalism at the University of Colorado Boulder, we took a step back and asked, "How did we get here? Why is palm oil so popular, and are there good alternatives that we should be using?" In doing so we discovered, among other things, that

habitat destruction, have led to consumer boycotts. But such actions increase the demand for oil crops that are even more destructive to forests and the climate.

"There presently aren't great alternatives to palm oil," Rhett Butler, the founder of the rainforest reporting and research site Mongabay, wrote in an email. "If the goal is to meet growing global demand for edible oils, palm oil provides the most oil volume for a given patch of land. If one were to instead grow coconut or rapeseed, more land would be required to produce the same amount of oil."

*ONE ALTERNATIVE OIL TO PALM REQUIRES NO LAND AT ALL.*

## PROMISING ALTERNATIVE

As demand for alternatives grows, however, that could change. In fact, one promising alternative oil to palm requires no land at all.

Solazyme, a California company, uses microalgae to produce oils for biodiesel that have already powered United Airlines jets and U.S. Navy ships. It's expanded into oils for soaps, cosmetics and foods, which have higher profit margins than fuels. In 2013 consumer products powerhouse Unilever announced plans to use 3 million gallons (11 millions liters) of Solazyme's algal oil instead of palm in an effort to lower its environmental impact.

"Think beer," Jill Kauffman Johnson, the company's director of sustainability, says, describing the vats in which Solazyme grows its algae. "A plant in Illinois is actually in a former Pabst Blue Ribbon plant."

"We can make a heart-healthy high oleic oil. The next day you put in a different strain and you can produce a sustainable alternative to palm or palm kernel oil," she says. "It's got the lowest level of polyunsaturated fats of any oil on the market, no trans fats and (grows) in a matter of days, not months in the field."

The microalgae's versatility makes them a good competitor with palm as a source of oil.

"Our goal is to try and help alleviate the pressure on the equatorial tropics," Kauffman Johnson says. Since Solazyme's algae grow wherever the company places its tanks, Solazyme can site its plants where they are most convenient to customers, partners and feedstocks, thus shortening supply chains. Cellulosic feeds such as

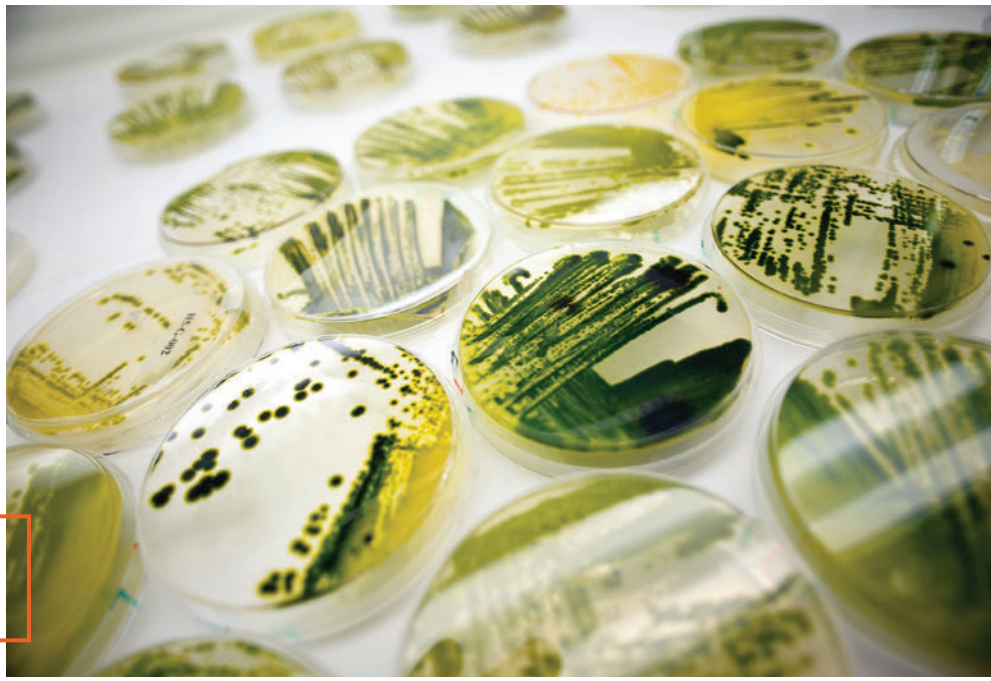


PHOTO COURTESY OF SOLAZYME

Microalgae cultivated by California-based Solazyme show promise as a source of palm oil substitutes.

simply banning the use of palm oil could in fact create bigger problems.

A follow-up article looked at Latin America to see if the region can avoid some of the devastation seen in Southeast Asia as more oil palm plantations come online. The resulting piece, "Can Latin America Do Palm Oil Right?" (**ensia.us/palm**), was written by a participant in our mentor program — which pairs an emerging writer with a seasoned journalist to report a story — and was translated into Spanish by our partner site LatinAmericanScience.org in an effort to better reach those who will benefit most from the information and ideas it presents.

switchgrass also minimize environmental impacts. The company just opened a 100,000-metric-ton (110,000 ton) plant in Brazil that uses sugarcane.

"Our technology is capable of ramping up very quickly," Kauffman Johnson says.

Nonetheless, consumer tastes and agricultural economics are slow to embrace algae-based oils, so it will likely take years for these oils to replace more than a few drops in the flood of palm oil.

## DOING PALM BETTER

A more immediate solution, Butler says, is cleaning up the palm industry.

"Establishing policies and best practices that avoid conversion of forests is something that companies can get behind," he says. "There has been a groundswell of zero-deforestation commitments from buyers and producers in recent months."

Philip Taylor, a postdoctoral scholar at the University of Colorado's Institute of Arctic and Alpine Research who works with Townsend and has done extensive research in the tropics, says most palm plantations don't produce the yields they are capable of.

"There are big gaps between what's being achieved and what's possible," he says. "Right now the average yield in Malaysia and Indonesia is 18½ metric tons (20 tons) of fresh fruit bunches per hectare. In places with the best management practices, they're already getting 30 metric tons (33 tons) per hectare."

Yields of palm fruit, Taylor notes, have been stagnant since 1975, while in that same time, soy productivity has improved almost 100 percent.

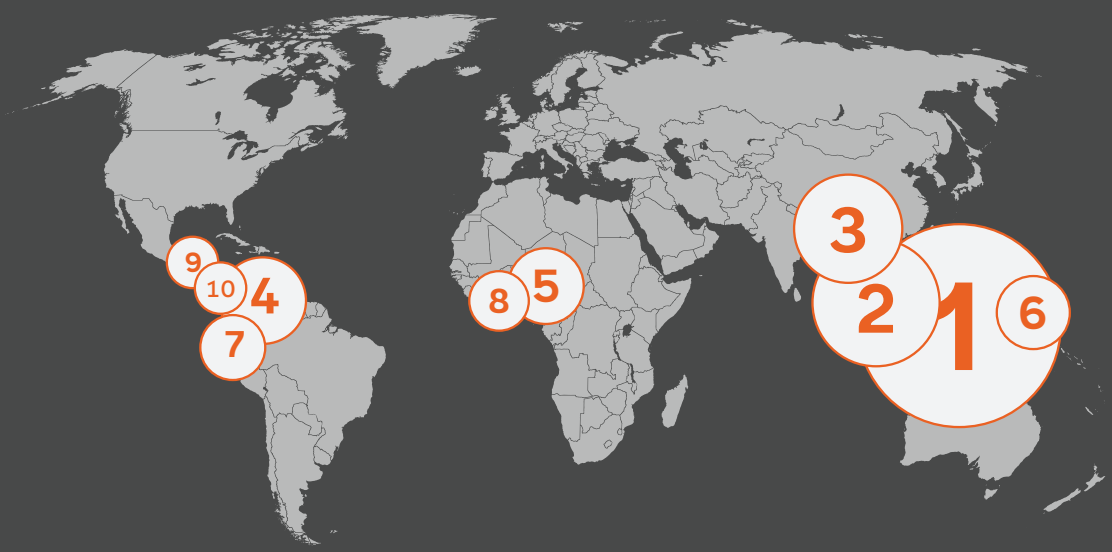
"Some of it is knowledge based," he says. "The right seeds in the right places, the right fertilizer at the right time."

Incentivizing the transfer of productivity-boosting knowledge among palm producers could make each hectare of plantation as productive as possible. But the Union of Concerned Scientists, in its report *Recipes for Success*, notes that the increased profits that accompany improved yields can spur fur-

***INCENTIVIZING THE TRANSFER OF PRODUCTIVITY-BOOSTING KNOWLEDGE AMONG PALM PRODUCERS COULD MAKE EACH HECTARE OF PLANTATION AS PRODUCTIVE AS POSSIBLE.***

## TOP 10 COUNTRIES FOR PALM OIL PRODUCTION (2014)

Indonesia produces more palm oil annually than the next nine countries combined.




| | |
|---|---|
| 1) Indonesia | 33,000 * |
| 2) Malaysia | 19,800 |
| 3) Thailand | 2,000 |
| 4) Colombia | 1,108 |
| 5) Nigeria | 930 |
| 6) Papua New Guinea | 630 |
| 7) Ecuador | 575 |
| 8) Ghana | 495 |
| 9) Honduras | 470 |
| 10) Guatemala | 440 |

** 1,000 metric tons per year (1,100 tons per year)*

Source: *U.S. Department of Agriculture*

ther expansion of plantations. Additionally, researchers from the U.K. and Singapore noted in an October 2014 essay in the journal *Science* that increased yields and palm crops more suitable for growing in difficult conditions could lead to more land in Africa and Latin America being devoted to palm — both of which have yet to see the explosive planting of palm that has occurred in Southeast Asia. Therefore, improved yields must be accompanied by stricter protections of forests. Indonesia has had a ban on deforestation since 2011, but it's riddled with loopholes. The Roundtable on Sustainable Palm Oil started certifying palm oil that met environmental standards 10 years ago, but many of its members continued to cut down forests. Last summer's promises to stop the destruction of forests from government, palm producers and companies that use the oil show those efforts are strengthening.

"You have to have a moratorium on deforestation," Taylor says, noting that the recent commitments by companies like Wilmar and Golden Agri to end deforestation is a significant step in the right direction. "These guys are a huge share of the palm industry," he says.

At the other end of the production chain, Taylor pointed to more low-hanging fruit for reducing palm oil's environmental toll. Taylor's and Townsend's research shows that the methane released from palm oil refineries accounts for more than one-third of the palm industry's impact on the climate, and a single pond of palm refinery wastewater annually puts out climate-warming gases equivalent to 22,000 cars. That methane could be used to make electricity by simply covering the pond and placing a biogas generator beside it. If all of the more than 1,000 palm oil refineries worldwide turned their methane into electricity, it would reduce the climate impacts of the operations 34-fold. Yet only 5 percent of the facilities do so.

In Indonesia, palm mills and refineries already generate their own electricity by burning the fruit's solid waste. They're usually far from the grid, and lack policies and infrastructures to feed the electricity into it. But they could send power to nearby villages.

"That's being done by New Britain Palm and Musim Mas," Taylor says.

Indonesia's Sustainable Palm Oil initiative requires palm operations to begin developing biogas capture, which should speed more companies' adoption of the technology.

And the hundreds of vehicles involved in the nation's palm supply chain could burn liquefied natural gas — a transportation fuel that's seeing rapid development elsewhere in Asia. In Riau Province, I passed neither a road nor an hour that wasn't filled with bright yellow trucks loaded with scarlet bunches of palm fruit. All of those vehicles could run on a cheap and readily available fuel that would provide additional income to palm processors and mitigate their climate impacts.

"It's going to happen in the next couple of years," Taylor says.

But the coming years will also bring an increasingly ravenous hunger for palm oil. One producer, Asian Plantations, estimates that global demand for edible oils will more than quadruple by 2050. Palm will supply nearly 60 percent of that demand.

So perhaps the most important development in the search for palm oil alternatives is the sense of urgency.



**MICHAEL KODAS** is the associate director of the Center for Environmental Journalism at the University of Colorado Boulder, an award-winning photojournalist and reporter, and the author of the bestselling book *High Crimes: The Fate of Everest in an Age of Greed.*

PHOTO BY JAN STEJSKAL/ZOO DVŮR KRÁLOVÉ

*WELCOME TO THE WILD WORLD OF*

# RHINO CONSERVATION

FROM FAKE HORNS TO RELOCATION, TODAY'S WILDLIFE PROTECTORS ENLIST NEW — AND OFTEN UNPROVEN — STRATEGIES TO SAVE ENDANGERED SPECIES.

*BY ADAM WELZ*

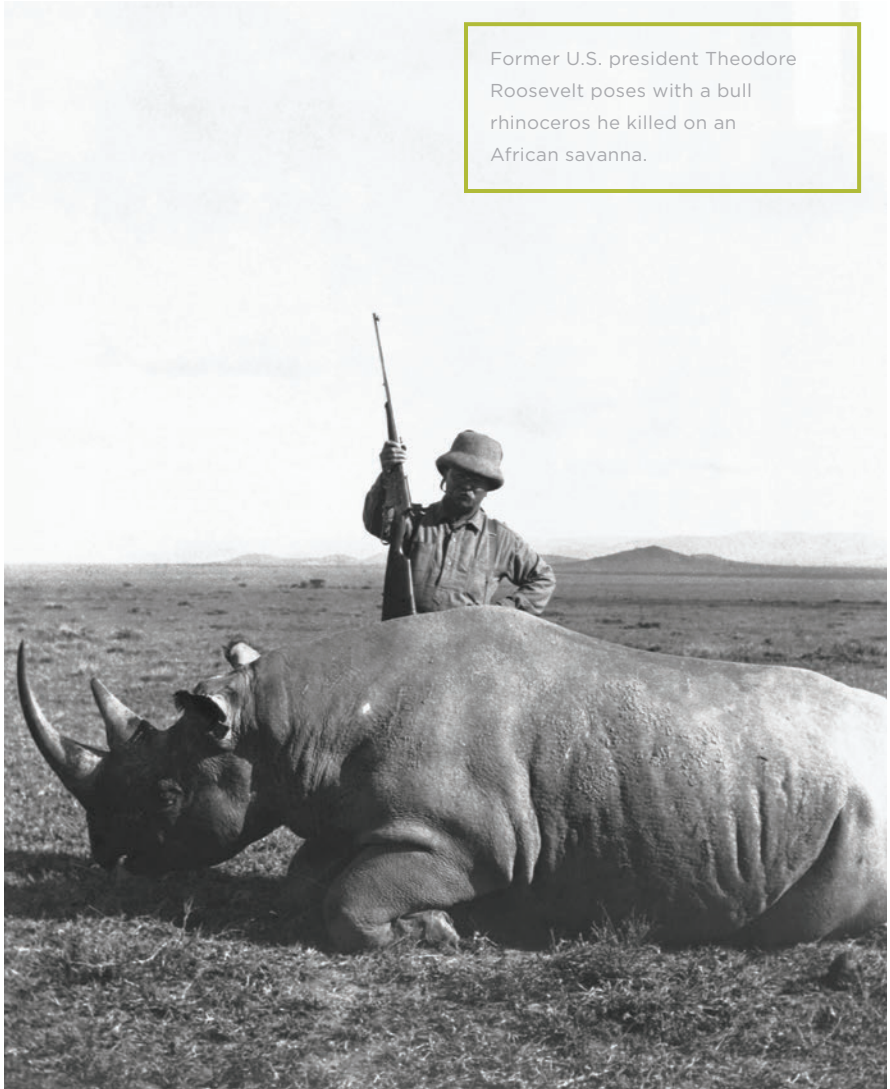
ORIGINALLY PUBLISHED:
MARCH 2015

After completing his second term as U.S. president in 1909, Theodore Roosevelt led an ambitious expedition across east Africa to shoot specimens for America's most famous museums. Along with his son Kermit and a handful of naturalists, he collected thousands of animals — everything from elephants to tiny songbirds. The expedition's bounty was preserved in 4 tons of salt and carried across vast savannas by large crews of African porters, some of whom died along the way.

The ultimate prize of Roosevelt's epic scientific safari was the Nile rhinoceros, a mysterious type of square-lipped rhino found along the Upper Nile in the regions today called southern South Sudan and northern Uganda. Zoologists noted that it was remarkably similar to the so-called white rhinoceros of southern Africa but smaller, and that it was separated from the southern white by thousands of miles. Were Nile and white rhinos the same species? Experts couldn't agree.

Teddy and Kermit shot only nine Nile rhinos between them, though they saw tens more. "Too little is known about these northern square-mouthed rhino for us to be sure that they are not lingering slowly towards extinction," wrote Roosevelt. "We were not willing to kill any merely for trophies."

Roosevelt's caution was warranted: The Nile rhino, having suffered decades



Former U.S. president Theodore Roosevelt poses with a bull rhinoceros he killed on an African savanna.

PHOTO © CORBIS/KERMIT ROOSEVELT

## WHY THIS MATTERS

Rhinos have been roaming the face of the Earth for millennia, but in recent decades humans have decimated the species in Africa and Southeast Asia. At present, the Javan, Sumatran and northern white rhinoceros are all on the verge of extinction, and other rhino species aren't faring much better. According to the Africa Wildlife Foundation, the black rhinoceros population has dropped more than 90 percent since 1960 — and, as South African journalist Adam Welz explains here, at current rates of killing the southern white rhino could be gone in 12 years. The race to save rhinos and other species of plants and animals across the globe is now more critical than ever.

of trophy hunting and poaching, is on the very edge of extinction. Now often called the northern white rhino, it has only five individuals left, all in captivity, and none able to breed. The southern white rhino is under withering assault by poachers — although it's the most numerous of the world's rhino species, with perhaps 20,000 remaining, conservationists conservatively estimate that if killing continues to increase at current rates, all wild southern whites could be gone within 12 years.

The high-profile plight of these closely related species has brought forth a bewildering array of proposed solutions, many of which trigger serious ethical dilemmas, risk unintended and troubling consequences, or rely on unproven technology. We're charging headlong into an era in which new technology may allow us to save species once considered doomed, but also in which threats come in previously unimaginable forms that mainstream wildlife protectors cannot handle.

*WE'RE CHARGING HEADLONG INTO AN ERA IN WHICH NEW TECHNOLOGY MAY ALLOW US TO SAVE SPECIES ONCE CONSIDERED DOOMED, BUT ALSO IN WHICH THREATS COME IN PREVIOUSLY UNIMAGINABLE FORMS.*

## CRYO CONSERVATION

In Teddy Roosevelt's time, saving a species involved little more than declaring it illegal to hunt and protecting a place where it could live. This either worked, as with the American bison, or didn't, as with the heath hen, a ground-dwelling North American bird whose 1932 extinction resulted from a cascade of factors (including genetic problems from inbreeding) that conservationists didn't have the knowledge or tools to deal with at the time.

Had the Nile rhino been in its current predicament a century ago, it certainly would have gone extinct. But today's conservationists think they can save it by stretching the bounds of reproductive science.

Three of the remaining five Nile rhinos, two females and a male, live at Ol Pejeta Conservancy in Kenya. These animals have thus far failed to breed due to various reproductive problems. German and South African researchers will now pioneer artificial insemination techniques on a group of southern whites in South Africa that will be applied as soon as possible to the Nile rhinos in Kenya in a last-ditch attempt to breed from them.

The San Diego Zoo Institute for Conservation Research houses a "Frozen Zoo" where cells of many threatened animals, including 12 individual Nile rhinos, are deep-frozen in liquid nitrogen. Working in parallel with the German/South African effort, Frozen Zoo staff plan to use a technique developed at the Scripps Research Institute to transform the cryopreserved Nile rhino cells into stem cells, which can then theoretically be used to make embryos that can be incubated in the zoo's southern white rhinos. Many pieces of the puzzle remain to be figured out, but the San Diego team has received a grant to map the genetic differences between Nile and southern white rhinos, a vital part of the process.

Some conservationists fear that if scientists figure out how to make new animals from preserved cells cheaply stored in a bottle, so to speak, tax money will be directed away from conservation and into things that are more immediately popular. There are also fears that young Nile rhinos raised by captive southern whites may not learn behaviors vital for their survival in the

Barbara Durrant, director of reproductive physiology and Henshaw Chair with the San Diego Zoo Institute for Conservation Research, removes vials of frozen cells from a liquid nitrogen–cooled stainless steel container.

PHOTO © AP PHOTO/LENNY IGNELZI

wild. Can we really say we've saved the Nile rhino if it acts like a zoo-dwelling southern white? How important is learned "culture" to the makeup of a species, and how do we revive that?

## MOVING EXPERIENCE

The steps being taken to save southern white rhinos from the relentless onslaught of ever more organized poachers and traffickers — who sell their horns for extraordinary sums in Asia to consumers who believe that rhino horn cures cancer and other ailments and businesspeople seeking status symbols — are no less fraught with uncertainty.

The largest population of southern white rhinos, perhaps 7,000 animals, resides in South Africa's Kruger National Park. It's the epicenter of world rhino poaching: 827 carcasses were found there in 2014, and the actual number poached may have been over 1,000. Despite reinforcing park rangers with military units and gathering extensive intelligence on poaching gangs, park authorities have been unable to stem the slaughter.

Large-scale translocation projects are now moving hundreds of rhino from Kruger and other at-risk preserves to other parks across South Africa and even to neighboring countries like Botswana — their exact destinations shrouded in secrecy because poaching gangs have even been known to hijack relocation trucks to kill the rhinos in them. One plan even calls for establishing populations of African rhinos in Australia.

But many South African conservationists are wary of large-scale rhino translocations because they're expensive and poachers are extremely mobile, now using low-flying helicopters and night vision equipment to find rhinos in remote areas. Large translocated populations might become new "poaching magnets," attracting poachers to previously untroubled places. National pride also comes into play; by sending rhinos to other countries, some South Africans feel like they're admitting defeat.

Carefully designed translocations are a proven part of conservation practice, and have been used to boost rhino populations and save many other species in the past. Clearly, the expense of rhino translocation must be weighed in context and the possibility of creating new poaching magnets should be considered (both these problems can be solved by only moving small, carefully chosen groups of animals). Misplaced national pride was the downfall of the last wild population of Nile rhinos, which lived in Garamba National Park in the Democratic Republic of the Congo. In the early 2000s conservationists planned to transfer some of the remaining 30 or so animals to Kenya to create an insurance population. Nationalist Congolese politicians stalled the transfer, poaching intensified and a 2008 survey found none remaining there.

*INTERNATIONAL OPPOSITION TO A LEGAL HORN TRADE IS INTENSE, MAKING IT EXCEEDINGLY UNLIKELY THAT INTERNATIONAL TREATIES COULD BE ALTERED WITHIN A TIMESCALE THAT'S MEANINGFUL TO RHINOS.*

## ALTERED APPEAL

Others aim to save rhinos by making their horns less appealing and valuable.

One group of South African rhino lovers has started injecting brightly colored poison into the horns of live rhinos. Their goal: to make the horns useless to poachers and at least a little dangerous to consumers. The approach is legally controversial, as horn-poisoners might be found liable for harm to consumers, even if the latter are acting illegally. And some scientists say the toxic mixture doesn't actually saturate the horn and so is a waste of time.

An influential group of South African wildlife ranchers are taking the opposite tack. If Asian consumers won't stop paying absurd prices for poached, illegally traded rhino horn, perhaps Africans should change international wildlife trade laws and create a legal trade in horn from farmed rhinos, they say. (Rhino horns can be carefully cut off every few years without harm to the animal; they eventually regrow.) Their idea is to flood the market with legal horn, drive criminals

## BIG DATA TACKLES A BIG PROBLEM:

**ACCORDING TO WWF,** the global wild tiger population has declined 97 percent over the past century, mainly due to habitat loss and poaching. The International Union for Conservation of Nature reports that tigers are now found in less than 6 percent of their historic range. Current numbers are between 3,000 and 4,000 in 11 countries with about 70 percent of all wild tigers located in India. At the same time, poaching spurred by international, organized criminal networks has spiked in recent years.

Roger Drouin's article for Ensia — "Can Big Data Save the Last of India's

A northern white rhino is watched over by armed guards in Ol Pejeta Conservancy in Laikipia, Kenya, Africa.

PHOTO BY ANN & STEVE TOON / SOLENT NEWS / REX FEATURES (AP IMAGES)

out of business and generate revenue for rhino conservation.

The reasoning is superficially appealing. What's not to like about generating dollars for rhinos' welfare without killing them? But critics who understand Asian markets say that legal trade in high-value wildlife products boosts demand by legitimizing them in the eyes of consumers, and creates channels through which to launder poached products. This is evident from the currently legal trade in elephant ivory and farmed tiger products in China. Far from reducing pressure on wild elephants and tigers, legal ivory and tiger parts have made these commodities

**Wild Tigers?" (ensia.us/tigers) — offers a rare ray of hope in combating illegal wildlife trade.**

**The article explores efforts to nab poachers in India by mapping 25,000 data points, including previous kills, trade hubs and locations of illegal sales. Lead researcher Koustubh Sharma and colleagues then built a computer model to "identify 73 key 'hot spots' with high likelihood of tiger poaching and trafficking in tiger parts." The resulting data can be used to better direct limited resources, such as field patrols and forest ranger activities, to locations where poachers are most likely to be active.**

**The story of hope for the future of tigers resonated with Ensia readers — who shared it more than 13,000 times on Facebook alone.**

more visible and desirable in Chinese society, driving poaching to new heights. There's usually no way of telling poached and legally farmed wildlife products apart, making it easy for illegal material to be sold in legal marketplaces; poached and legally harvested rhino horns look identical, making law enforcement very difficult.

It would also be very difficult, perhaps impossible, for rhino farmers to meet the twin goals of generating large profits to fund conservation and flooding the market to drive horn traffickers out of business. Making money for conservation means maximizing the price of horn. Undercutting the wildlife crime industry means selling horn cheaply. How does one do both at the same time?

In any case, international opposition to a legal horn trade is intense, making it exceedingly unlikely that international treaties could be altered within a timescale that's meaningful to rhinos.

## MILITARY-GRADE SOLUTIONS

Rhino poaching often takes place in massive, rugged, hard-to-police areas: the Kruger Park, for example, is roughly the size of Israel, and other African parks are even larger. But a few new companies are repurposing military surveillance technology to boost conservationists' ability to monitor such expanses. A dizzying array of drones, long-range cameras, hypersensitive microphones, cell phone monitoring stations and cutting-edge software is being packaged with the specific purpose of finding poachers before they strike.

Understaffed anti-poaching squads, desperate for help, are in favor of the military-tech approach. However, some critics balk at the expense of this hardware, pointing out that billions spent on similar gear has failed to stop people and illegal drugs flowing across America's borders. Others wonder if tourists will visit parks that increasingly resemble military camps.

## GROW YOUR OWN

If all that consumers care about is the horn part of the rhino, why not leave the animals in peace by growing horn in a lab? A Seattle-based company, Pembient, aims to grow nature-identical rhino horn (and ultimately other wildlife products) using cutting-edge biotechnology and a hefty dose of Silicon Valley techno-optimism.

Critics are worried that, just as with selling legally farmed horn, this approach may backfire horribly. It may disassociate horn from the gruesome business of poaching in the mind of some consumers, making its use more socially acceptable. And it could counterproductively increase demand for poached horn in other consumers, as "real" horn may be seen as more genuine or potent.

This already has happened with American ginseng, a plant that grows wild on forest floors across much of the northeastern U.S. and is highly desired in China for medicinal use. The creation of a large cultivated ginseng industry has made wild ginseng root appear better and more desirable, driving prices up and increasing pressure on wild populations. Ginseng collecting has gone from a small seasonal occupation to a big money spinner in places like Appalachia. Illegal harvesting is rife and violent conflicts now occur over natural ginseng patches in formerly peaceful rural communities.

## DROPPING DEMAND

The ultimate solution to poaching and the illegal trade in wildlife products is, of course, to persuade people not to buy

### THE VANISHING RHINOCEROS

The numbers below represent the estimated global rhino population — including both wild and captive animals — in 2013. Given the rise in poaching, these numbers are likely to have declined even further in recent years.

**4** Northern White Rhinoceros

**40–65** Javan Rhinoceros

**240–295** Sumatran Rhinoceros

**2,500–3,000** Indian Rhinoceros

**4,750–5,000** Black Rhinoceros

**20,000–21,000** Southern White Rhinoceros

Source: *International Union for the Conservation of Nature's Red List*

Former basketball star Yao Ming is working with the non-governmental agency WildAid to reduce demand for rhino horns and other animal parts across China and Southeast Asia.

PHOTO BY KRISTIAN SCHMIDT/COURTESY OL PEJETA CONSERVANCY

them — an approach known as "demand reduction." Most conservation groups paid little attention to this in the past, but organizations like the one I represent, WildAid, have made measurable progress in shifting public attitudes against wildlife products and driving down consumption using techniques pioneered by Hollywood and the advertising industry.

For example, WildAid partnered with Chinese basketball superstar Yao Ming and other celebrities to campaign against the cruel and wasteful killing of sharks for shark fin soup, a status item whose consumption was skyrocketing in China with that country's growing wealth. The campaign's TV ads and billboards have been seen by hundreds of millions in China, and last year 85 percent of respondents to a public survey said they'd stopped consuming shark fin in the previous three years, the most common reason cited being anti-shark-fin public awareness campaigns. Chinese wholesalers report massive declines in sales, and fishermen across Asia are getting out of the shark fin business because prices are too low.

Wildlife groups are now rolling out word-of-mouth, broadcast media and cell phone campaigns against ivory and rhino horn in Asia, and surveys reveal that public attitudes have begun to shift against these products as well. Much needs to be learned, however, in today's ever-evolving media landscape, and there's always a risk of a campaign having unintended consequences. Many conservation groups refuse to put a number on the sky-high street prices of rhino horn, for example, for fear of encouraging more trafficking.

## BEYOND IMAGINATION

In the recent past, conservation was mainly about understanding the biology of endangered species, protecting and managing their habitats, and lobbying for new laws. Today, saving high-value species like rhinos and elephants means outmaneuvering nimble poaching and trafficking networks, which are surprisingly well funded, able to exploit cutting-edge technology and unencumbered by tedious legal processes and governing committees.

Wildlife protectors, for their part, have to become expert gene manipulators, criminologists, military technologists and marketers. They must deal with practical and ethical problems that previous generations could not have imagined.

There is clearly no silver-bullet solution. Conservationists have no choice but to grasp the future and grapple with its risky technologies if rhinos — and thousands of other species — are to continue to exist in any condition resembling their wild, ancient way. e

**ADAM WELZ** is a writer/filmmaker, longtime naturalist, addicted birder and inveterate debater. He's also the South African representative of WildAid, a nonprofit that focuses on ending the demand for illegal wildlife products.

**WRITER UPDATE:** *Since this article was published in early 2015, the situation for rhinos has continued to worsen. Although significant seizures of illegally trafficked rhino horn have recently been made, many transnational rhino horn trafficking networks remain intact. Poaching of southern white rhino has continued to rise, with poachers increasingly focusing their attention on South Africa's Kruger National Park, which has lost an average of more than two rhinos per day so far in 2015. One of the last Nile rhinos died in a Czech zoo in July 2015, leaving only four individuals of this type alive. The Sumatran rhino was declared extinct in Malaysia in August 2015, leaving only a few tiny wild populations totaling a mere 100 animals in Indonesia. — ADAM WELZ*

PHOTO BY ANDY NEWHOUSE

*IN THE RACE TO SAVE SPECIES*

# GMOS ARE COMING TO NATURE

**BIG QUESTION: CAN WE USE GENETIC ENGINEERING TO SAVE SPECIES? BIGGER QUESTION: SHOULD WE?**

*BY GREG BREINING*

ORIGINALLY PUBLISHED:
AUGUST 2015

## WHY THIS MATTERS

Unbeknownst to most of us, scientists around the world are exploring the idea of genetically modifying wild plants and animals. GM technology holds huge promise for helping species survive onslaughts such as habitat loss, climate change or devastation by invasive organisms. But it also carries red flags: What if the engineering process imparts undesirable characteristics along with the desirable ones? What if engineered organisms end up in unintended places, causing unintended consequences for other species or entire ecosystems? As those developing this novel approach to conservation move closer to deploying them, we decided it was time to build awareness of what's being proposed so we as a society can weigh costs and benefits and make intelligent decisions about what to do — or not to do — with this emerging technology.

Regal American chestnuts once reached across the deciduous forests of the Appalachians and Eastern Seaboard. Their abundance was astonishing: Up to one in four of every large tree in eastern forests was a chestnut.

Birds nested in their branches. Squirrels and other small mammals clambered over their limbs. Bears, deer, turkeys, blue jays and squirrels ate their massive and consistent nut crop. Rural people gathered the nuts and logged the trees for their straight-grained, rot-resistant timber. The American chestnut was king of the eastern forest, a keystone species for humans and nature alike.

Then, probably in 1876, the fungus *Cryphonectria parasitica* escaped from a shipment of chestnut seeds from Japan. The fungus spread to American chestnuts, which — unlike their Asian counterparts that had co-evolved with the fungus — had no resistance. Within 50 years, the blight killed more than 3 billion American chestnuts. Except for saplings that periodically sprouted from diseased stumps and then died back, the chestnut had effectively disappeared from North American forests.

Beginning in the 1920s, government researchers tried crossing survivors with Asian chestnuts to produce disease-resistant trees that in all other ways resembled American chestnuts. Their efforts failed to yield a tree that both resisted disease and thrived in American forests. Later, the American Chestnut Foundation labored for decades to produce such a hybrid.

But in the 1990s, biologist William Powell tried a different approach. Powell used a bacterium to insert the genes for disease resistance into the American chestnut genome. In other words, Powell created a genetically modified organism that resembled an American chestnut in every way except that it resisted the chestnut blight as well as any Asian tree.

"I think if we can't get this tree deregulated and out in a restoration program, you're not going to get any genetically engineered tree out," says Powell, co-director with forest geneticist Charles Maynard of the American Chestnut Research and Restoration Program at the SUNY College of Environmental Science and Forestry. "You can't argue a better tree."

### ANTITHESIS OF GREEN?

To some, GMOs are the antithesis of green. Greenpeace calls them "genetic pollution," warning on its website that "GMOs should not be released into the environment since there is not an adequate scientific understanding of their impact on the environment and human health."

But scientists — still a minority — are beginning to wonder if genetic engineering can be used to help organisms adapt to change and actually increase the biodiversity of the planet.

*THIS ABILITY TO LOOK TO UNRELATED SPECIES FOR SOLUTIONS IS ONE OF THE ADVANTAGES OF GENETIC ENGINEERING OVER TRADITIONAL CROSSBREEDING.*

"I think it really isn't on the radar screen of the conservation community at all," says Kent Redford, former lead scientist at the Wildlife Conservation Society and now head of Archipelago Consulting. Redford organized one of the first conferences, in Cambridge, England, in 2013, to consider the gnarly intersection of genetic engineering, nature and conservation.

"I saw a need for this meeting because this field is offering enormous potential in a whole different set of human endeavors," says Redford. "And the conservation

community has the potential to be tremendously affected by the activities of synthetic biology. And yet we as a field are very often the last ones to learn about new innovations in society. I got tired of always being in the group that never knew about the latest thing."

Later that year in the scientific journal *Nature*, a half dozen scientists from several universities suggested that "facilitated adaptation" might be used in "rescuing a target population or species by endowing it with adaptive alleles, or gene variants, using genetic engineering."

C. Josh Donlan, one of the authors of the *Nature* paper and executive director of the nonprofit foundation Advanced Conservation Strategies, compares the strategy with proposals to help species survive climate change by moving them to a new location. "Obviously that's controversial. … If you're going to put a novel species in a new environment, what are the unexpected ecological consequences that could have?" Perhaps, he says, it's safer to use genetic engineering to help the organism adapt in place. "Instead of move the animal, move the genes to the species."

"Our techniques and our abilities to modify genomes is just becoming more precise," he says. "Instead of back-breeding or other, clunkier techniques, now we have the ability to modify genomes in a very precise way."

Think about it: Producing a white pine immune to blister rust or North American ash trees impervious to emerald ash borer. Engineering corals to thrive in more acidic waters. Inoculating frogs with a gene to protect against chytrid fungus. Creating a genetic based pesticide that kills only a single invasive species. Or restoring the American chestnut, which once cast tall shadows across the eastern United States.

## SPEEDY BREEDING

In trying to engineer blight resistance in chestnuts, Powell realized the fungus created fatal cankers by the production of oxalic acid. So he looked for a gene that detoxified the acid. It turns out the gene is widespread in nature. But he didn't find it in an Asian breed of chestnut; he found it in wheat.

PHOTO BY HANNAH WALKER, CORNELL ALLIANCE FOR SCIENCE

Forest geneticist Charles Maynard examines transgenic American chestnut trees at the tissue culture shoot stage.

This ability to look to unrelated species for solutions is one of the advantages of genetic engineering over traditional crossbreeding. "We can actually go a little further afield looking for resistance genes," says Powell. "In breeding you're basically limited to species that you can either cross naturally or force to cross."

Another advantage: speed. Other researchers spent decades crossing American and Asian chestnuts to acquire resistance, then had to backcross the hybrids with American chestnuts to re-acquire traits of the American chestnut that had been lost.

Powell and colleagues, on the other hand, were able to insert the gene for blight resistance and leave the rest of the American chestnut genome alone. "We don't have to carry a lot of baggage," says Powell. "We're being very precise with what we're adding in."

Powell has produced several candidate varieties with all of the genetics of American chestnut and even better resistance to chestnut blight than Asian species. Now all he needs is time — perhaps lots of it — to navigate the federal regulatory process. Powell and colleagues will have to work with the U.S. Environmental Protection Agency, the U.S. Department of Agriculture's Animal and Plant Health Inspection Service, and the Food and Drug Administration. APHIS, for example, treats genetically modified plants as potential pests and "regulates the import, handling, interstate movement, and release into the environment of regulated organisms that are products of biotechnology."

"All three of those agencies will have some part of the regulatory puzzle before we can pass these trees out to the general public," says Powell.

The regulatory gantlet affecting GMOs began shortly after the first laboratory genetic modifications more than 40 years ago. Genetic engineering had hardly been imagined, much less studied. "So they started setting up a lot of regulations so we didn't make any mistakes," says Powell. "But that was 40 years ago, and there's been a lot of research since then." Public apprehension has made it difficult to loosen regulation of GMOs, he says.

"I don't think the people who made those rules were actually thinking of chestnut. I've got a feeling that this is going to force them to rethink this whole process," says Powell. "I'm hoping we can get through it in about five years. I've got 10 years till my retirement."

## NO PANACEA

Meanwhile, other trees are waiting in the wings.

The emerald ash borer, an Asian beetle first detected in Michigan in 2002, has spread to 24 other states and Canada, threatening to vanquish native ash species in the wild. Paula Pijut, a plant physiologist with the U.S. Department of Agriculture Forest Service and Purdue University, has been developing a process to engineer ash tree species to express a protein from a strain of *Bacillus thuringiensis*, a natural insecticide commonly known as Bt.

"I think we have made some great advances in a short amount of time," Pijut says. "I would hope in the next four to five years we could say we have emerald ash borer–resistant material for planting purposes. We are getting really close."

Even so, as Pijut writes in a recent paper, while genetic engineering holds huge promise against emerald ash borer, it's "no panacea because of regulatory limitations."

Regulations on genetic engineering combine with restrictions built into green forest certification programs to stymie rapid and innovative use of GMO trees to

Scientists are working to develop a genetically engineered ash tree that resists the invasive and deadly emerald ash borer.

PHOTO BY MACROSCOPIC SOLUTIONS (FLICKR/CREATIVE COMMONS)

adapt to climate change and introduced pests, says Steven Strauss, professor of forest biotechnology at Oregon State University.

"No one can really use GMOs now because the regulations are very difficult and because we have these green certification systems," Strauss says. "Pretty much everywhere in the world, if you're green certified, they won't let you plant them, even for research."

The Forest Stewardship Council, one group that sets standards for forest certification, currently prohibits the use of GMOs in certified forests. "I think the precautionary principle underlies many of the concerns," says Brad Kahn, communications director with FSC's U.S. office. "In the absence of conclusive evidence that GMOs will not cause negative impacts on forests, the membership has decided they should not be used in the FSC system."

A better regulatory approach, says Strauss, would be to give agencies the ability to fast-track approval in response to a forest pest or other evolving threat. He also suggests that forest certifiers rethink their GMO policies.

Strauss himself experiments with GMO poplars, primarily for use in plantations. By engineering such trees to be more productive, he says, researchers can help conserve natural forests by reducing demand for wood products they produce. About 5 percent of the world's forests are planted in plantations, which supply about one-third of all industrial wood. "By being efficient and productive in a limited area, you really can reduce the area you need to harvest industrial wood," says Strauss. "This is one more technology for that."

Genetic engineering would also allow the creation of a productive but sterile commercial tree that produces wood products but won't jump into nearby natural forests because it can't reproduce. Says Strauss, "I consider that a very valuable conservation tool, because again you can get the productivity and the stress tolerance you want without worrying about the spread into wild areas."

Strauss is science advisor to the Forest Health Initiative, a collaborative biotechnology group that includes Powell's chestnut research. The group hopes to smooth the regulatory pathway for approval of other GMO trees to resist pests such as Dutch elm disease and hemlock woolly adelgid.

"From a conservation point of view, it's forest health that really matters — both industrial and natural," Strauss says. "We should be able to use these powerful tools without these extraordinary delays. But we can't. And it's a travesty. The world has been so set against it now for about 15 years that you almost have to restart the conversation. You know, reopen our minds. It's quite a challenge."

*"WE SHOULD BE ABLE TO USE THESE POWERFUL TOOLS WITHOUT THESE EXTRAORDINARY DELAYS. BUT WE CAN'T. AND IT'S A TRAVESTY." — STEVEN STRAUSS*

## OUSTING INVASIVES

One of the most visible proponents of biotech solutions to conservation has been the Long Now Foundation, founded by Stewart Brand, the technologist and environmental forward-thinker who famously wrote in the opening pages of the 1968 *Whole Earth Catalog,* "We are as gods and might as well get good at it."

In early 2015, in a two-day workshop in Sausalito, California, Long Now (under the rubric of its Revive & Restore program) invited 52 molecular biologists, conservation biologists, veterinarians and other spe-

## CONTINUING the CONSERVATION CONVERSATION

**GREG BREINING'S FEATURE** on the application of synthetic biology to biodiversity protection is just one of several pieces Ensia published in 2015 underscoring the evolving nature of conservation. Early in the year, publication of an opinion piece by biologist Daniel Simberloff and colleagues questioning trends toward legitimizing novel ecosystems catalyzed a response by invasion ecologist David M. Richardson — also published at Ensia — arguing that novel ecosystems have an important role to play in efforts to conserve biodiversity. The conversation continued online, with comments from readers on both sides of the fence. Read for yourself at **ensia.us/trojanhorse** and **ensia.us/novel**.

cialists to brainstorm biotech solutions to environmental problems.

Among the methods are RNA inhibitors — molecules that bind to and disable key worker molecules within cells — to eradicate invasive species that disrupt ecosystems and crowd out native species. "If you bind to the right ones you will stop a cellular process from happening and kill the cell," says Ben Novak, a researcher at Revive & Restore. "The cool thing about this is you can design these RNAis to match specific codes." So, for example, RNAi might be engineered to bond to the RNA of invasive Argentine ants — but only Argentine ants. The RNAi could then be sprayed like an insecticide that kills only a single invasive species. "If it works, it could be revolutionary, a game changer," says Novak. Workshop participants suggested that a similar approach might be used to weaken the fungus responsible for the currently fatal white-nose syndrome in bats.

To reduce the need for pesticides that can harm nontarget species as well as their intended target, researchers are investigating options for genetically modifying mosquitoes to suppress populations that carry diseases such as dengue and chikungunya. Release into the wild of male mosquitoes with this modification (a procedure known as "release of insects carrying a dominant lethal," or RIDL) would allow them to breed with unmodified females, producing nonviable offspring. By flooding an area with RIDL males (a twist on the decades-old sterile-male approach to pest management) authorities could ensure that nearly all attempts at reproduction produce … nothing. The FDA is considering giving approval to release RIDL mosquitoes in the Florida Keys. The method is also being discussed as a way to kill exotic mosquitoes in Hawaii that carry avian malaria, which is killing native forest birds, particularly honeycreepers.

But that could be only the beginning. A RIDL-type approach might also be used to confer a gene in mice so that all offspring are male. Swamping invasive mice, on an island for example, with hordes of modified mice would eventually extinguish the population. "When their life spans are done, the invasive rodents are gone," says Novak.

The ability to engineer an end to an invasive species raises a question, however: Should we? A zebra mussel engineered to rid the pest in the U.S. might find its way back aboard ship to southern Russia where it would wipe out the species in its native range. Moreover, just because a species is nonnative and invasive, is that a good reason to eradicate it? Some have proven useful over time, both economically and environmentally, or have established themselves so thoroughly in an ecosystem that to remove them could release a cascade of unintended consequences for native species. Without an adequate regulatory framework for the use of genetic modification to rout invasive species, Australian environmental scientist Bruce Webber and colleagues wrote in a recent article in the *Proceedings of the National Academy of Sciences,* "this putative silver bullet technology could become a global conservation threat."

*THE ABILITY TO ENGINEER AN END TO AN INVASIVE SPECIES RAISES A QUESTION, HOWEVER: SHOULD WE?*

## BIODIVERSITY BOOSTERS

Revive & Restore is also proposing genetic engineering to actually boost biodiversity.

Black-footed ferrets, once common in the Great Plains, were believed to be extinct due to attempts to eradicate prairie dogs and to sylvatic plague — until 1981, that is, when a Wyoming farm dog brought one home. A population of about 120 was discovered nearby. In 1987, two dozen were captured. Six died, but the remaining 18 entered a captive breeding program. Captive-bred ferrets eventually replenished the natural population.

There was one problem, however: The tiny number of participants in the captive breeding program meant low genetic diversity among the offspring — a condition that reduces resilience and could lead to future populations being threatened. So Revive & Restore is considering the use of genetic engineering to introduce traits using genetic material gleaned from museum specimens more than a century old. The organization is also exploring biotech creation of genetic resistance to the plague, which devastates both ferret populations and the colonies of prairie dogs on which they feed.

Other species that have been listed as possible candidates for genetic engineering as a way to boost foundering populations include the Hawaiian crow, Arabian oryx, Attwater's prairie chicken, golden lion tamarin, crested ibis, cheetah, northern white rhino, Yangtze giant softshell turtle, wombat and Tasmanian devil.

One of Revive & Restore's most extraordinary biodiversity-boosting projects is the use of genetic engineering to restore the long-extinct passenger pigeon — or something a lot like it. The foundation calls it "de-extinction."

Samples of toe-pad tissues from museum specimens (the pigeon went extinct in 1914) have yielded about 85 to 90 percent of the bird's genome. "That's as good as we're going to get," says Novak, the lead researcher on the project. He and colleagues have matched the DNA fragments to the genome of the closely related band-tailed pigeon.

Trying to genetically engineer all the differences between the passenger pigeon and the band-tailed pigeon would require — at least for now — an impossible amount of work. So instead, Novak will look for the important genetically coded differences

PHOTO BY J. MICHAEL LOCKHART / USFWS (FLICKR/CREATIVE COMMONS)

A program known as Revive & Restore is proposing to use genetic material from museum specimens to boost genetic diversity in black-footed ferrets as they return from the brink of extinction. Many other species have been listed as possible candidates for genetic engineering, including the crested ibis and the golden lion tamarin.

PHOTO BY TAMBAKO THE JAGUAR (FLICKR/CREATIVE COMMONS)

PHOTO BY JO CHRISTIAN OTERHALS (FLICKR/CREATIVE COMMONS)

between the species. "It might come down to that there are only five or six major traits that matter," says Novak. "There's no point engineering things that do nothing."

Revive & Restore plans to inject engineered germ cells into band-tailed pigeon embryos. Offspring will contain both band-tailed and passenger pigeon genes. "You breed enough babies and eventually one of them is going to be the cross between the engineered sperm and the engineered egg and you have your engineered bird," Novak says.

Objections to the enterprise include arguments that the engineered bird won't be a real passenger pigeon, the world doesn't need a pigeon that flocks by the hundred of millions, or Revive & Restore is messing with Mother Nature.

"Why bring about a genetically modified band-tailed pigeon that looks somewhat like a passenger pigeon? I really can't think of a good reason," David Blockstein, senior scientist for the National Council for Science and the Environment, wrote in an essay for the Center for Citizens and Nature. "Certainly from the perspective of biodiversity and ecological integrity it is difficult to imagine why a pseudo–passenger pigeon is better than none. The ecological niche of the passenger pigeon is as gone as the bird."

"There are people who feel that no matter what we do, this is going to be a horrible distraction, a horrible mistake, and they're completely against it," Novak says.

But, says Novak, the point is not to create a "still frame from the past." It's really about using genetic engineering to promote something more functional. Those "somethings" might include extinct aurochs, Tasmanian tigers and even woolly mammoths.

Re-creating replicas of departed species "is about trying to facilitate the management of whole ecosystems by recognizing the many different ecological roles that an ecosystem needs to function and trying to get those functions back," says Novak. "That's the motivation for bringing back a passenger pigeon or a mammoth or any other type of extinct animal. We're not really after the animal itself. We're after the role that it plays in the environment."

For now, GMO approaches to boosting conservation remain in the laboratory. But someday soon, conservationists still fighting a rear-guard strategy against species loss will find it necessary to decide what to do about applying this technology — which juxtaposes perhaps their greatest hopes with perhaps their greatest fears — to solve some of their most challenging problems. It will be an interesting call.

## IMPACT

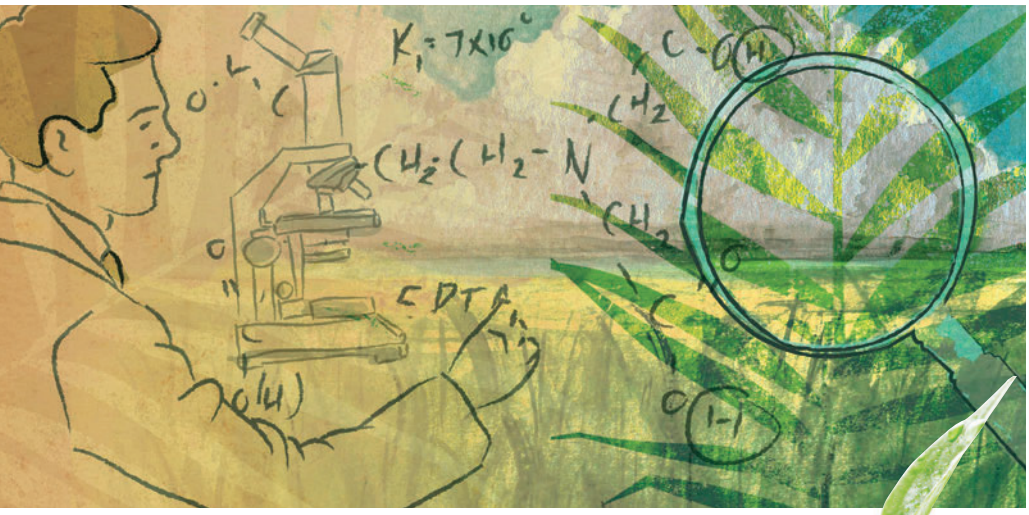
The idea of using genetic engineering as a conservation tool drew more than 350,000 online visitors to this popular Ensia piece.

**GREG BREINING** writes about science, nature and travel for the *New York Times, Audubon* and many other publications. He has written more than a dozen books on topics ranging from the Yellowstone supervolcano to kayaking around Lake Superior.

# CHANGING THE CONVERSATION

**WHETHER IT'S FORMER SECRETARY OF STATE** Madeleine Albright discussing the moral imperative of global food security, Ceres president Mindy Lubber exploring reasons to be optimistic or economists weighing climate change against other "worst-case scenarios," Ensia's Voices section is where you'll find some of today's great thinkers wrestling with some of today's toughest issues. Check out the links for the rest of the story.

BUSINESS CULTURE ECOSYSTEMS ENERGY FOOD HEALTH TECHNOLOGY WORLD



***EVERYTHING IN NATURE HOLDS A STORY WE CAN CONNECT TO. AND WE HAVEN'T EVEN COME CLOSE TO HEARING THEM ALL.***

ENSIA.US/MYTH

***Manu Saunders***
*Ecologist, Charles Sturt University*

*The most important thing that can happen is a change in mindset that recognizes soil is not dirt. It's life beneath our feet.*

ENSIA.US/SOILWEST

***Paul West*** *| Co-director and lead scientist, Global Landscapes Initiative*

*The U.S. was once a nation prized for its thought leadership on difficult issues. We need to again start teaching our children the skills that will allow them to see and understand what really matters — before it's too late.*

ENSIA.US/3THINGS

***Rebecca Boyles***
*Senior manager of Stakeholder Engagement, Future 500*

LAYOUT BY JEREMY NELSON; ILLUSTRATION BY ERIN DUNN; SOIL PHOTO © ISTOCKPHOTO.COM/ARISTOTOTOO; PLANT PHOTO © ISTOCKPHOTO.COM/ TEMMUZCAN

# Global food security is a moral imperative.

ENSIA.US/MORAL

**MADELEINE ALBRIGHT**

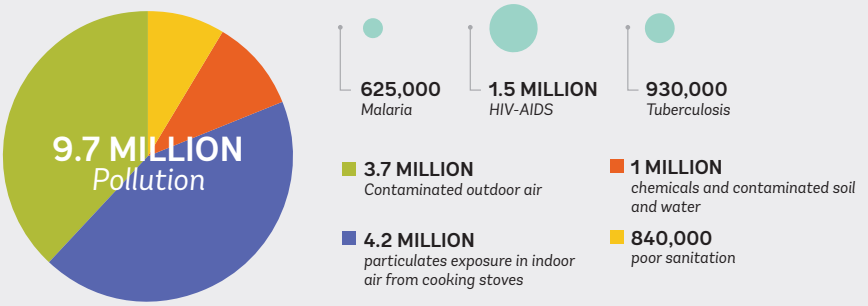
*Former secretary of state and co-chair, Aspen Food Security Strategy Group*

THE WORLD HEALTH ORGANIZATION CONSIDERS POLLUTION A RISK FACTOR — A THREAT TO HUMAN HEALTH SIMILAR TO OBESITY, SMOKING, MALNUTRITION OR POOR EXERCISE. BUT POLLUTION IS THE KING OF ALL RISK FACTORS. WORLDWIDE, ITS FATALITY NUMBERS DWARF THOSE CAUSED BY ANY OTHER RISK FACTOR IN ANY OTHER CONTEXT.

ENSIA.US/POLLUTION

***Richard Fuller***
*President, Pure Earth*

## 56 MILLION DEATHS IN 2012:




*The magnitude of human-driven degradation of ecosystems is so huge that pragmatic approaches such as the novel ecosystems framework simply must be given careful consideration.*

ENSIA.US/NOVEL

***David M. Richardson***
*Director, Centre for Invasion Biology, Stellenbosch University*

*The path to a just, fair, equitable and sustainable world is within our grasp, but only if we work together — and work quickly — to make it a reality.*

ENSIA.US/SDGS

***Felix Dodds***
*Sustainable development expert and author*

*We face a new reality in which our economic self-interest and the long-term well-being of the planet are coming into alignment.*

ENSIA.US/CAPITALISM

***Matthew Fitzmaurice***
*Managing director, Craig-Hallum Capital Group*

*History shows us that when governments listen to environmental advocates, the economy doesn't collapse, our way of life isn't ruined, and the terrorists don't win.*

ENSIA.US/PAST

***Peter Dykstra***
*Environmental reporter*

***PRODUCING ENERGY AT A COST EQUAL TO CONVENTIONAL FOSSIL FUEL SOURCES IS THE HOLY GRAIL FOR WIND AND SOLAR ENERGY PRODUCERS, AND THAT DAY IS ARRIVING.***

ENSIA.US/9REASONS

***Mindy Lubber***
*President, Ceres*

CHART SOURCE: WORLD HEALTH ORGANIZATION; SOLAR PHOTO © ISTOCKPHOTO.COM/KOYA79

***THE LONG AMERICAN LOVE AFFAIR WITH THE INTERNAL COMBUSTION ENGINE IS UNLIKELY TO DIE COMPLETELY WITH THE ELECTRIC CAR. BUT THE ELECTRIFICATION OF TRANSPORTATION HAS THE POTENTIAL TO BE REVOLUTIONARY FOR THE AMERICAN ENERGY SECTOR.***

ENSIA.US/TRANSPORT

***Marian Swain***
*Conservation analyst, The Breakthrough Institute*
***Iddo Wernick***
*Senior fellow, The Breakthrough Institute*

*From cost savings to new partnerships to stronger fan engagement, the sustainability movement is an avenue for sports to both be green and see green.*

ENSIA.US/SPORTS

***Kellen Klein***
*Senior manager of stakeholder engagement, Future 500*

*The continent's continued dependence on yesterday's energy solutions is due in large part to money — or the lack of it. There's simply not enough investment capital flowing into African clean energy projects.*

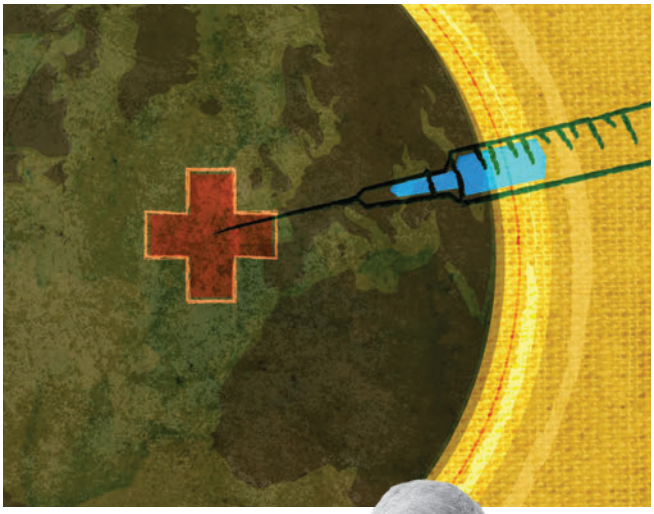
ENSIA.US/AFRICAENERGY

***Peyton Fleming***
*Senior director, Ceres*

*It's simply not fair to reap the benefits of our lifestyles while outsourcing the costs to other people, places and times.* ▶

ENSIA.US/TOGETHER

***David Doody***
*Senior editor, Ensia*



*As a risk manager, I was taught to worry about worst-case scenarios — even while recognizing that I was not likely to see them coming.*

ENSIA.US/AVIATIONKEY

**ROBERT LITTERMAN**
*Partner, Kepos Capital, LP*

TESLA COURTESY OF TESLA; ILLUSTRATION BY ERIN DUNN; GERNOT WAGNER PHOTO BY YUKI KOKUBO; MARTIN WEITZMAN PHOTO BY JENNIFER WEITZMAN

*Climate is not the only "worst-case scenario" imaginable. Others, too, deserve more attention. But there's perhaps no other problem where the probability of disaster multiplied by the magnitude of disaster is as high as with climate.*

ENSIA.US/WORSTCASE

**GERNOT WAGNER | MARTIN L. WEITZMAN**

*Lead senior economist, Environmental Defense Fund*

*Professor of economics, Harvard University*

SELF-SUFFICIENT NATION STATES IN THE MIDDLE OF THE OCEAN MIGHT BE OUR TICKET TO A SUSTAINABLE FUTURE.

ENSIA.US/SEASTEADING

***Shilpi Chhotray*** *| Senior manager of stakeholder engagement, Future 500*

TO VIEW MORE COMMENTARIES, VISIT **ENSIA.COM/VOICES**

ILLUSTRATION COURTESY OF THE SEASTEADING INSTITUTE

***THERE'S A SYSTEMS PROBLEM WITH THE MANY INCARNATIONS OF "SUSTAINABLE FOOD." GOOD INTENTIONS NOTWITHSTANDING, MOST ALTERNATIVES LEAVE UNTOUCHED THE UNDERLYING STRUCTURES AND FORCES OF THE AGRI-FOOD SYSTEM. SUSTAINABLE FOOD, IT TURNS OUT, LACKS A SCIENCE WITH WHICH TO DEAL WITH A SYSTEM AS COMPLEX AS FARMING AND FOOD.***

ENSIA.US/AGROECOLOGY

***Maywa Montenegro*** *Food systems researcher, University of California, Berkeley*

*We need to erase the false lines dividing population, consumption and production that should have been dismissed decades ago. With climate change snapping at our heels we can't afford to waste any more time on scapegoats.*

ENSIA.US/POPULATION

***Stephanie Feldstein*** *Director of the Population and Sustainability Program, Center for Biological Diversity*

*The main reason the health care industry should look to act more boldly on issues stemming from climate change is because of its ultimate mission to make the world a healthier place.*

ENSIA.US/HEALTHCARE

***Leo Raudys*** *Adjunct faculty in Corporate Sustainability, University of Minnesota*

*THE*

# YEAR AHEAD

**WHAT TECHNOLOGICAL ADVANCE** will boost sustainability most significantly in 2016? What will be the most surprising development related to water? How will corporate sustainability evolve over the coming year? And where will the world look for the latest solutions to environmental challenges?

Ensia recruited an all-star team of eight pundits to share their vision of the year ahead for the environment as it relates to business, culture, ecosystems, energy, food, health, water and the world.

What do you think? Do you agree or disagree with their hopes and dreams for the next 12 months? Were you surprised by any of their responses? Only time will tell whether they come true.

THE YEAR AHEAD

# IN 2016 ...

BUSINESS

## BUILD SOCIALLY RESPONSIBLE BOARDS

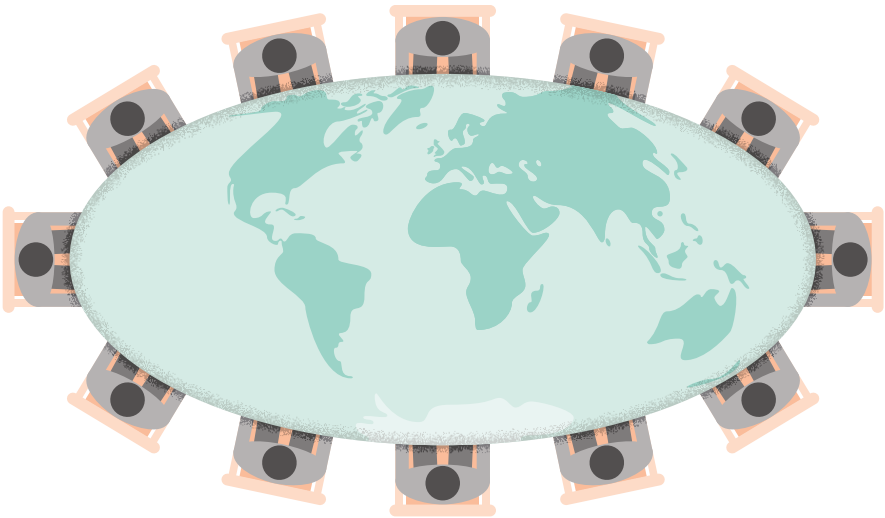
**Alice Korngold**
Author | *A Better World, Inc.: How Companies Profit by Solving Global Problems...Where Governments Cannot*

***In 2016, how can businesses transform corporate social responsibility?***

For leading companies, corporate social responsibility has moved from the cubicle to the boardroom. While CSR once referred to philanthropy and volunteering that merely complemented the business, smart companies recognize that CSR can power their core strategies for today's dynamic global marketplace.

Multinational corporations that lead the way in CSR seek to maximize profits, reduce costs and mitigate risks by finding innovative solutions to the world's greatest challenges — social, economic and environmental. Ambitious companies understand that the 3 billion people entering the middle class in emerging markets will become valuable consumers and employees. These companies recognize the benefits of building vibrant and prosperous communities in emerging economies through enterprise development, job training, education and health care.

Leading companies also see that by reducing energy costs and mitigating their vulnerability to climate change and ecosystems loss, they will save money and improve their bottom lines. And they recognize they can further profit by creating similar solutions for their customers.



My research for *A Better World, Inc.: How Companies Profit by Finding Solutions to Global Problems…Where Governments Cannot* revealed that the companies that are most successful in transforming CSR to a business advantage do three things well. First, their boards of directors understand the imperative for the company to find solutions to global problems as a strategy to grow shareholder value. Second, these companies are effective in engaging with stakeholders, including communities in which their employees and consumers live and work, as well as investors, shareholders, consumers, employees, nonprofits and governments. Third, they realize that they can only thrive in solving global problems by partnering effectively with non-governmental organizations, nonprofits and, often, local governments. Additionally, they recognize the imperative for transparency and accountability to all stakeholders.

To ensure that a company grows shareholder value, the best-qualified board is composed of people from diverse backgrounds and perspectives who have the required business and financial expertise. By including directors who understand the social, economic and environmental challenges facing the world, boards will be best equipped to maximize shareholder value, while also helping to build a better world. •

ILLUSTRATIONS BY DEANNA HALSALL

ENERGY

# NURTURE NUCLEAR

**Alex Trembath**
Senior analyst | The Breakthrough Institute

***In 2016, what is the best way we can reduce energy's carbon footprint?***

In 2015, researchers from Sweden and Tasmania set out to determine the fastest route to a zero-carbon electricity system. In May, they published their findings in the journal PLOS ONE. It was no surprise to those of us who study energy transitions that, historically, nuclear power has proved the fastest way to decarbonize national electricity sectors.

Sweden and France set a high bar for quickest decarbonization. France went from a fossil-fueled power system to 80 percent low-carbon electricity, the bulk of this transition occurring between 1975 and 1990. Cases like these completely upend the notion that nuclear is too slow, expensive and complex to drive rapid and significant decarbonization.

But nuclear power has been on defense for the past few years due to post-Fukushima difficulties, public opposition and low natural gas prices in the United States. Several nuclear plants are on the verge of being prematurely shut down in the United States. Germany, Japan and Sweden have also all faced early shutdowns — leading to skyrocketing carbon emissions in Japan and a resurgence of coal power in Germany. What can be done to keep these plants open and, even more important, accelerate the expansion of nuclear power?

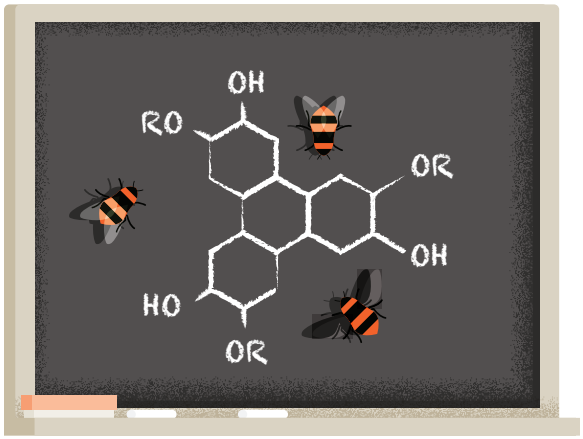
In the United States, we can start by introducing incentives for nuclear plants' reliability and low pollution, as some states already do, in much the same way that states incentivize renewables through portfolio standards, tax incentives and "priority dispatch." This will ensure that they run for several more decades. Beyond this, we can use our national laboratories as test beds for new, innovative reactor designs. Next-gen technologies like small modular designs, passively safe molten salt reactors and pebble-bed reactors all have the potential to scale after successful demonstrations.

If we really want a clean energy future for the whole planet, however, we have to look beyond U.S. borders. Energy demand is growing fastest in countries like China, India, Indonesia and South Africa — and where there's demand, there's innovation. Rich countries should partner with rapidly industrializing nations to design, demonstrate and deploy the low-carbon solutions — nuclear and otherwise — that will create a high-energy, low-carbon planet. •

HEALTH

# IMPROVE CHEMISTRY EDUCATION

**Amy Cannon**
Executive director | Beyond Benign




***In 2016, how can we create a less toxic world?***

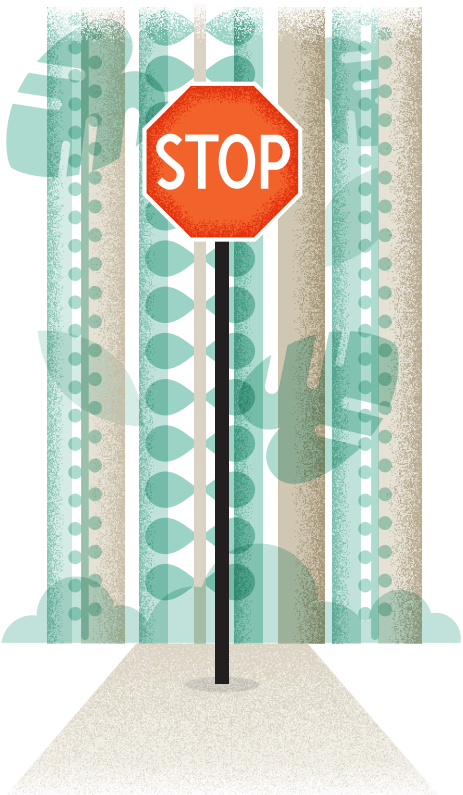
The top thing we could do in 2016 to create a less toxic world is to support change in chemistry education.

I know what you are thinking: "Chemistry education? What could that have to do with creating a less toxic world? I thought chemistry was the problem!" From my perspective, chemistry is the solution — and changing how academic institutions educate chemists could be the missing piece to creating a sustainable world.

A student who studies chemistry today is not required to understand toxicology or environmental impact. The very students who will design the next generation of chemical products and processes are not trained how to recognize whether a molecule is hazardous to humans, whether it will persist in the environment, or how it will affect wildlife and ecosystems. As a result, companies have workforces that also lack these skills.

As we ask companies to create products that are safe and healthy for humans and the environment, let's also ask that our academic institutions provide students the education they need to be able to help those same companies design sustainable, healthy products. They can do this by teaching green chemistry — the design of chemical products and processes that reduce or eliminate the use or generation of hazardous substances.

The field of green chemistry has grown substantially over the past two decades. Its defining principles are used as guidelines for chemists to create more sustainable products and processes. It is beginning to make its way into educational institutions from kindergarten through higher education and is becoming more and more visible as a means for incorporating toxicology and hazard considerations into the design portfolio of chemists to reduce harm to humans and the environment. We must support and encourage more of this transition. •




ECOSYSTEMS

# LIMIT ROAD EXPANSION

**William Laurance**
Distinguished research professor and Australian Laureate
James Cook University, Cairns, Australia

***In 2016, what should be the focus of efforts to conserve rain forests?***

In 2016, efforts to conserve rain forests need to focus on two things.

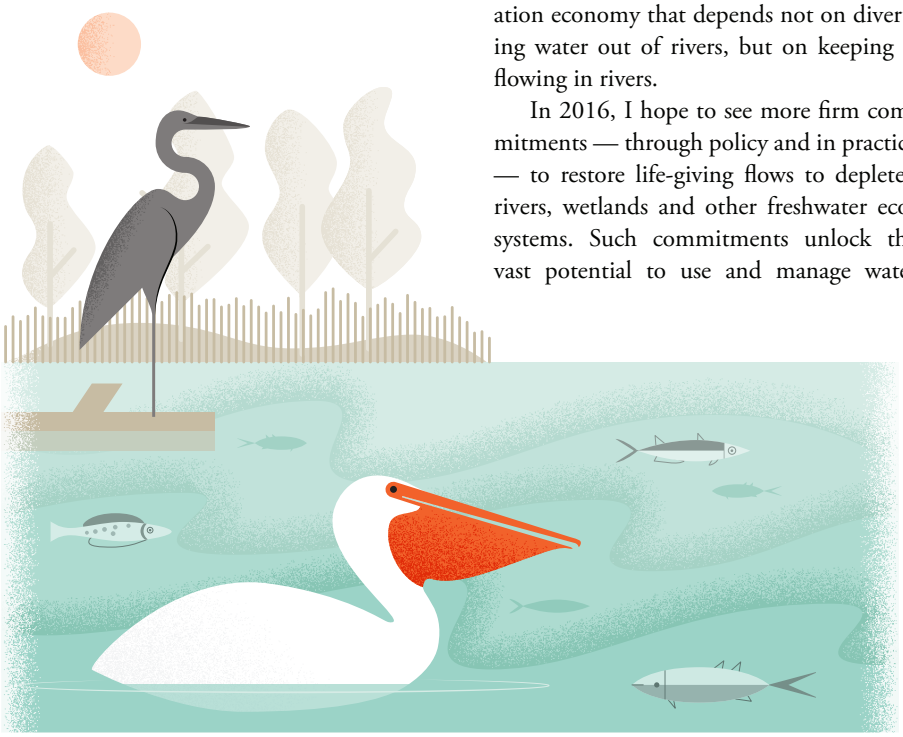
First, conserving logged tropical forests is a critical priority. Currently some 400 million hectares (around 1 billion acres) of tropical forest are held in forestry reserves — an area larger than Mexico and Indonesia combined. These forests have often been selectively logged, which means they've had tracks bulldozed through them, and many of the larger, commercially valuable trees have been felled and removed. But these forests still retain important conservation values — for biodiversity, carbon storage and climate regulation.

The alarming thing is that logged forests are intensely vulnerable, particularly because they are crisscrossed by roads and so are easily colonized. Many are being destroyed for oil palm or pulpwood plantations, soy farms, slash-and-burn farming and other uses. Much of the world's lowland rainforests and virtually all forests in tropical Asia outside of protected areas have now been logged. Protecting these logged forests and giving them a chance to recover is a vital priority.

Second, we must limit the explosive expansion of roads and other infrastructure into the world's last surviving tropical frontiers. Everywhere one looks — from the Amazon to Borneo and the Congo Basin to Madagascar — roads are cutting into the last remaining tropical wildernesses.

The International Energy Agency estimates that by 2050, we'll need another 25 million kilometers (15 million miles) of new roads on Earth — enough to encircle the planet more than 600 times. Nine-tenths of these new roads will be in developing nations, which sustain many of the planet's most biologically rich and environmentally important ecosystems.

When it comes to wildernesses, roads often open a Pandora's box of environmental evils, such as illegal colonization, poaching, wildfires and land speculation. It's vital to keep roads out of the last surviving wildernesses — avoid the first cut — so we can keep the worst of Pandora's evils at bay and protect some of our world's most vital ecosystems. •



WATER

# RESTORE & REPLENISH

**Sandra Postel**
Director of the Global Water Policy Project, Freshwater Fellow of the National Geographic Society and co-creator of Change the Course

***In 2016, what advance related to water would you most like to see?***

It's often said that water will be to the 21st century what oil was to the 20th century. But this sentiment vastly understates water's importance. Water is not just an essential "input" to our economic activities, it is the basis of life on the planet. And there are no substitutes for it.

Water left in its place in nature services our economies in numerous ways, although we rarely place a market value on those services. Healthy rivers, floodplains and watersheds purify and store water, mitigate floods and droughts, and provide habitats for numerous species of fish, birds and wildlife. In North America, the Colorado River Basin supports a US$26 billion per year recreation economy that depends not on diverting water out of rivers, but on keeping it flowing in rivers.

In 2016, I hope to see more firm commitments — through policy and in practice — to restore life-giving flows to depleted rivers, wetlands and other freshwater ecosystems. Such commitments unlock the vast potential to use and manage water more productively and to increase the value of water.

The binational agreement signed in late 2012 between Mexico and the United States to restore flows to the desiccated Colorado River delta was a groundbreaking achievement of this kind. It called for a five-year experiment — including a "pulse flow" through the delta, which occurred during the spring of 2014, along with sustaining base flows — to restore pockets of native habitat for birds and wildlife. The restoration involves less than 1 percent of the Colorado's historic flow, but is yielding tangible ecological benefits.

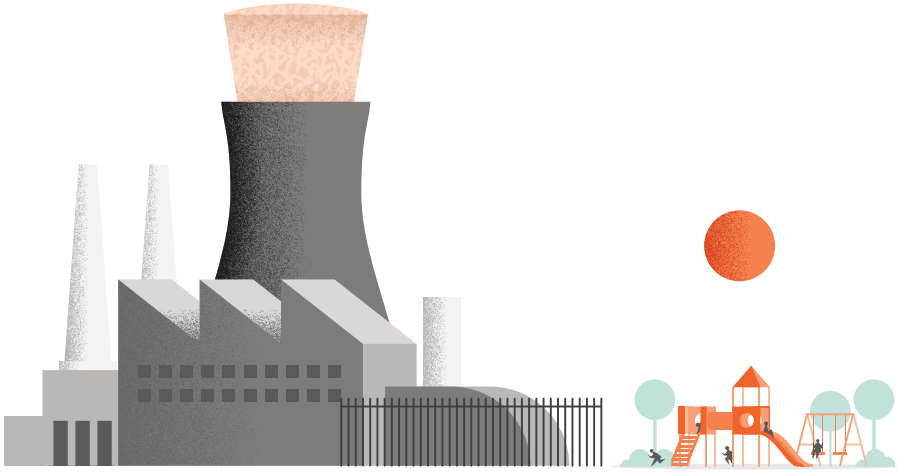
On the heels of Australia's Millennium Drought, during which many beloved rivers and wetlands dried up, the nation is taking bold action in the Murray-Darling River Basin to rebalance the allocation of water between economic and environmental purposes. The government is investing on the order of AU$12 billion to buy water entitlements from willing sellers and to invest in irrigation efficiency and infrastructure improvements. By reducing water allocations by a volume equivalent to 12 percent of the Murray River's historic flow, the basin's water authority is boosting the productivity and value of water and securing water for the environment.

If we get smarter about how we use and manage water, and apply the best of our technologies and ingenuity to that cause, we can have healthy rivers and healthy economies side by side. And as the planet warms and we experience more floods and droughts, strategically rebuilding nature's infrastructure — rivers, wetlands, floodplains and forested watersheds — will be among the best insurance policies we can buy. •

CULTURE

# ACCEPT THE ENVIRONMENTAL JUSTICE FRAMEWORK

**Robert Bullard**
Dean | Barbara Jordan–Mickey Leland School of Public Affairs, Texas Southern University



***In 2016, how can environmental issues become everyone's issues?***

In 2016, environmental issues could become everyone's issues if everyone accepted the environmental justice framework adopted at the 1991 First National People of Color Environmental Leadership Summit. The environment is where we live, work, play and learn, as well as the physical and natural world. While emphasizing the sacredness of Mother Earth and all of its inhabitants, plants and animals alike, the environmental justice framework attempts to uncover the underlying assumptions that contribute to and produce unequal protection; incorporates the principle of the "right" of all individuals and communities to be protected from environmental degradation; adopts a public health model of prevention (elimination of the threat before harm occurs); and rests on the precautionary principle for protecting workers, communities and ecosystems. The EJ framework is premised on protecting the most vulnerable in our society — a frame that is consistent with a sentiment often attributed to Mahatma Gandhi: "A nation's greatness is measured by how it treats its weakest members."

The EJ framework is our preferred alternative to the dominant environmental protection paradigm which for decades institutionalized unequal enforcement; traded human health for profit; placed the burden of proof on the victims and not the polluting industry; legitimized human exposure to harmful chemicals, pesticides and hazardous substances; promoted "risky" technologies; exploited the vulnerability of economically and politically disenfranchised communities; subsidized ecological destruction; created an industry around risk assessment; and failed to develop pollution prevention as the overarching and preferred strategy. Yet today, a quarter-century after the environmental justice framework was adopted, all communities are still not created equal. The EJ movement is a response to injustice, exploitation of land and exploitation of people. I look forward to the day when ZIP code and race are no longer the best predictors of health and well-being in our society. Why not make 2016 the year we all get serious about making it happen? •

FOOD

# EMPOWER WOMEN & YOUTH

**Danielle Nierenberg**
President | Food Tank

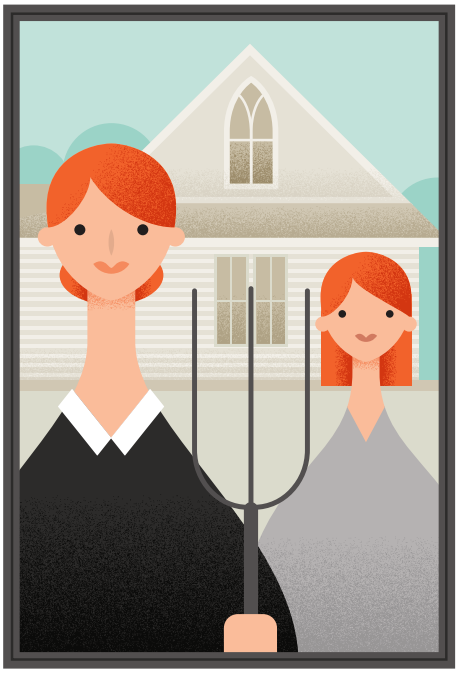
***In 2016, what could be the biggest global food security success story?***

In 2016, the biggest global food security success story could be diversifying the human dimensions of agriculture by recognizing the important role of women farmers, encouraging investment in women-led agricultural enterprises, and cultivating the next generation of agricultural leaders.

Women make up more than half of the world's population — and nearly half of the world's farmers — but their contributions in agriculture are almost universally ignored. According to the U.N. Food and Agriculture Organization, if women farmers had the same access to resources as male farmers — including land, credit, and banking and financial services — and more

decision-making power they could lift as many as 150 million people of out hunger. Additional investment in women farmers would not only help alleviate hunger and poverty, but also build more just societies, empower girls and women, and improve the health of entire families and communities worldwide.

At the same time women need support for their contributions to food security, so do young people. Farming populations are aging around the globe — in the U.S., the average age of farmers is 58 while in sub-Saharan Africa it's 56. Yet there are more than 4.5 million unemployed youth around the globe. The food system could provide tremendous economic opportunities for young people, helping them see agriculture as a viable career opportunity rather than something they feel forced to do. Policy-makers need to invest in growing the next generation not only of food producers but also extension agents, agronomists, scientists, policy-makers and food business leaders who work to nourish both people and the planet. •



WORLD

# IMAGINE NEW APPROACHES

**Jessica Hellmann**
Director | Institute on the Environment, University of Minnesota
Professor | Ecology, Evolution & Behavior

***In 2016, where should the world look for new solutions to grand environmental challenges?***

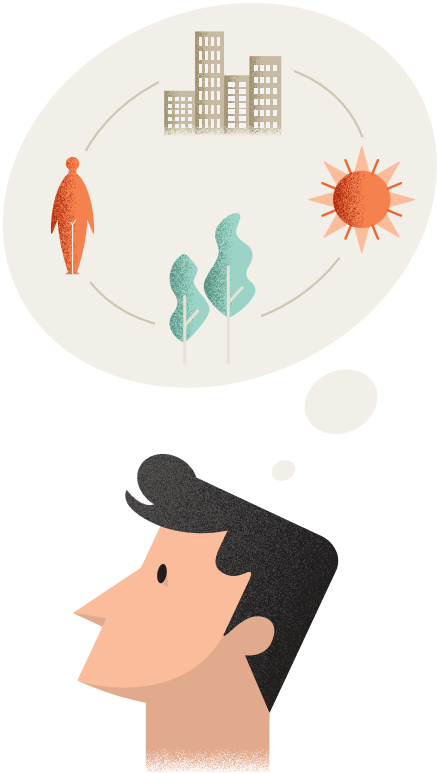
In 2016, we have to imagine new ways of sustaining human and nonhuman life on Earth. Without this reimagination, climate change and other forces of global change threaten to undermine the well-being of the built and natural systems on which humanity depends.

There is reason to be optimistic because we have reimagined humanity's relationship with nature before. For example, conservation science has evolved to recognize the value of conserving species and ecosystems not just for their grandeur but because they are vital to human well-being. We now understand that humans are not separate from nature; we are wholly dependent upon it.

But the planet is changing, and it is changing fast. This means the ways we manage and conserve human and natural systems need to evolve again. This time we need to manage for change. We cannot look to the past for guidance about how the world should be, but need to foster and reengineer systems to be more flexible, dynamic and adaptable.

In 2015, for example, Californians experienced conditions that were warmer and drier than the historic "normal," and heat waves in India and Pakistan killed thousands and stressed ecosystems. We have high confidence that such events will increase in number and geographic extent. How humanity will react to these changes, however, is quite uncertain.

As our environment shifts around us, farmers, foresters, conservation biologists, urban planners and other system managers must embrace change in earnest, tolerating



and even fostering it to keep the underlying systems strong. Practices based on change and resiliency offer the greatest opportunity for sustaining the goods, services and other system values that matter to us most.

Fortunately, when we recognize and embrace change in system management, we also see the importance of interconnections between human and nonhuman life. We rediscover the importance of diversity — in life forms, in organizations and in solutions. Going with the flow of change, assisted by the creative forces of diversity, is our best hope for thriving in a changing, human-dominated world.

# THE LONG VIEW

**CORPORATE LEADERS OFTEN** make decisions with an eye to the next quarterly report. Politicians and policy-makers look toward the next election. But the environment operates on a much longer time frame. And as we're reminded time and again, the decisions we make today may have consequences decades — if not centuries — into the future.

In an effort to look at things with a longer time frame in mind, we invited futurist Jamais Cascio and author Ramez Naam to have a free-flowing conversation about what they think we need to know about our world in the decades to come. Settling into a discussion centered around climate change, geoengineering, transportation, production and energy, the result is one of the most fascinating conversations you'll read all year — and hopefully one that will help you think about the world and our place in it for years to come.

THE LONG VIEW

# A LOOK INTO THE FUTURE

**Ramez Naam:** How pessimistic or optimistic are you about the future of addressing climate change?

**Jamais Cascio:** That's a difficult question because some of what I would consider optimistic most other people would consider pessimistic. Our best chance of success would be to go back in time and start fixing things 25 years ago. Given that's probably not going to be possible any time soon, we are stuck with a panoply of bad options. It's a case of, will we be able to follow the least-bad path? But even the least bad path is going to be difficult for many people. It's going to be deadly for many people. This also leads us to what I think is going to end up being one of the most troubling aspects of what the next 20 years are going to hold around climate: the lag between action and result. We could stop putting any carbon in the atmosphere, go to complete zero, and there have been some pretty good studies showing that we'd see another 10 years, at least, of warming. What it comes down to is that we could embark on the most expensive and globally challenging innovation exercise ever and transform our society and not have any kind of result.

**Naam:** A short-term evident result.

**Cascio:** Short term. Because of our media policy and our media culture, and because of how the general culture is, that's very difficult to make that argument.

**Naam:** Yeah, would voters and citizens have the patience to put up with that? Would they understand that we had done something good?

**Cascio:** Right, and would they forgive? What I fear is a scenario where we do all the right things, nothing seems to happen as a result, and there's a backlash against science.

**Naam:** Yeah, I think that's quite probable. I guess my optimistic scenarios are also considered pessimistic by most. There's a lot of talk lately about whether or not 450 parts per million of carbon dioxide in the atmosphere is an achievable goal, whether we can stay to underneath 2 degrees Celsius of total warming. While I think it is physically possible, I think it's unlikely. I think it's very likely at this point that we will end up with higher than 450 ppm in the atmosphere, which will put us on a path for probably more than 2 degrees Celsius of warming. I don't think we will see 3 degrees. But even beyond 2 degrees I think there will be enormous damage, especially to natural ecosystems and to people who live in least-developed countries. I don't think it will spell anything like the end of civilization or extinction of the human race. I do think some of the scars that build up from climate change take millions of years possibly to undo or can't really be undone.

**Cascio:** I suspect that you are correct that we won't hit 3 degrees, but not necessarily because we get enough things right. I think that we probably won't hit 3 degrees for a couple of reasons. One is that all of the problems that accumulate due to climate disruption will end up lowering overall global productivity, and there's a very strong correlation between productivity and carbon emissions. The second is the kind of scenario where we are likely to try some kind of solar radiation management geoengineering — basically, something to try to hold the temperatures down.

*"I DON'T THINK WE WILL SEE 3 DEGREES. BUT EVEN BEYOND 2 DEGREES I THINK THERE WILL BE ENORMOUS DAMAGE, ESPECIALLY TO NATURAL ECOSYSTEMS AND TO PEOPLE WHO LIVE IN LEAST-DEVELOPED COUNTRIES." –RAMEZ NAAM*

**Naam:** You wrote about a book about geoengineering a few years ago. It was a

PHOTO BY BART NAGEL

## JAMAIS CASCIO

Selected by *Foreign Policy* magazine as one of its Top 100 Global Thinkers, Jamais Cascio focuses on the importance of long-term, systemic thinking, emphasizing the power of openness, transparency and flexibility as catalysts for building a more resilient society. To read essays Cascio has written for Ensia, go to **ensia.us/cascio**.

PHOTO BY CHRISTOPHER MICHEL

## RAMEZ NAAM

Ramez Naam is a computer scientist, futurist and author of five books whose work has appeared in or been reviewed by *The New York Times*, *The Wall Street Journal*, *The Atlantic*, *Wired*, *Scientific American* and more. To read an excerpt of Naam's book *The Infinite Resource: The Power of Ideas on a Finite Planet*, go to **ensia.us/infiniteresource**.

very balanced book, I thought. What's your stance on it now?

**Cascio:** A terrible idea that we'll probably do because we have to. The big issues around solar radiation management geoengineering from my perspective are less technical and more political. We actually have a pretty good handle on the basic science of it. It's really the dilemmas around who controls it: who says yes, who says no, who says it's time to shut it off, who's liable? Because if we start doing something like this, no matter how careful and how well-modeled ahead of time, the moment there is any kind of environmental disaster somewhere — certainly if it's weather related — geoengineering will be blamed. How do you deal with that? Do you ignore the countries that are demanding a response? Not a good idea. Do you pay? That just opens up your wallet to everybody. It's a difficult problem without a clear answer. And that's really the least frightening version of that scenario, because there's interesting precedent in official government war game–type situations, where the onset of unilateral geoengineering is seen as a provocation to war. Especially if it's something where China does this and it seems to have an adverse effect on American agriculture, or vice versa.

**Naam:** Right. And there is evidence that solar radiation management, while it reduces heat, changes rainfall patterns.

**Cascio:** Yeah, it changes rainfall patterns. It doesn't do a thing about ocean acidification. All sorts of questions still remain. But the dilemma's always going to be, how do we respond to the unexpected? And we haven't in the last century developed good institutions for that.

**Naam:** One thing that interests me about geoengineering — particularly the kind where we reflect more sunlight back — is, while I said that I am sort of cautiously optimistic we won't hit 3 degrees, there is always this worry of positive feedback loops, where warming changes the world in some way that it increases the rate of warming. The Arctic seems to be where people most worry about these. There are some scenarios there that I think most people think are unlikely, but if they happened would be extremely bad to the point of 30 years' worth of human carbon emissions going up at one time. So one reason that I think we should be ready with geoengineering is in case something like that does start to happen. We could

more rapidly cool the Arctic via that method than any other.

**Cascio:** The possibility of the carbon dioxide reduction geoengineering intrigues me. Because all of the things that we've looked at so far, the experiments around algae blooms and discussions of reforestation, they're all very slow. But I think you and I have been thinking about the kinds of technologies that could actually accelerate that — things that pull carbon dioxide from the atmosphere to turn it into stuff. That's not going to happen next week, but it's definitely something that's plausible within a generation.

**Naam:** To me, that comes down to economics. Right now the cost of reducing carbon emissions by switching to renewable energy, for instance, looks like it's much lower than the cost of pulling carbon out of the air. Especially when we talk about pulling it out of the open air rather than out of a coal plant power flue. The question is, if we eventually get to zero or net-zero or close to that and there's no more decarbonization of energy we can do, but atmospheric concentrations of carbon are 500 ppm, should we do something like that, and what's the value? Then, who pays for it?

**Cascio:** What could be done culturally around climate change? Do you think a movie? Or a really powerful Kanye West album?

**Naam:** [Laughs] Once Kanye runs for president in 2020, I think we'll solve this problem once and for all.

I'm fascinated by the work of Dan Kahan at Yale who has studied how people form their opinions about climate change and other issues, like vaccines and genetically modified foods. What he shows is it's tribal; "motivated reasoning" is the term he and Chris Mooney use for this. What that means is that people have in mind the end result of holding a belief, and they choose their beliefs based on that.

A couple of things are really fascinating in Kahan's work. One is, you would think that the more scientifically literate someone is in general, the more likely they would be to believe in climate change, and across the general population that's true. But if you look at staunch Republicans, people who have more scientific literacy are less likely to believe in climate change. The reason is they have picked the belief they want to have, perhaps subconsciously, and then they can use their scientific knowledge to cherry-pick a set of facts that fit their narrative.

The other is a study done at Duke University by Troy Campbell and Aaron Kay where they brought people in to give them a survey about whether or not climate change is true. One set of Republicans was told of policy solutions about how to address climate change: "We have to constrain economic growth. It's going to cost a lot of money. We have to live more modest lives, drive less, etc." When asked, "Do you believe in climate change?," most said basically "no." Another set of Republicans was given policy solutions such as, "Addressing climate change is something we can do by innovating in green energy and clean technology, and it's going to open up multibillion-dollar markets for U.S. products." When they surveyed those people, answers were much more likely to be "yes." They've heard no new evidence about whether or not climate change is real, but the outcome of holding that belief seems more amenable to them.

So, you're asking, "What can we do culturally?" and I want to be careful in how I say this. I think that Bill McKibben, Naomi Klein, the authors of *Limits to Growth*, all of those folks serve a very important purpose, and they can sway a community and add new perspectives among the left, basically. But their message actually scares conservatives and some moderates away from believing in climate change.

Naomi Klein's book *This Changes Everything* — the subtitle is *Capitalism vs. the Climate.* When you say "capitalism vs. the climate," you are going to alienate a very large set of people. If I thought she was right, I'd say, "Tough luck, this is what we actually have to do." But I don't. I think there are ways to fix markets to create the incentives to solve problems like this, and we need a different message to lead with for conservative and even moderate audiences about innovation, new technology, new science and how this is an addressable problem if we do the right things, as opposed to the gloom-and-doom message, which reduces belief, in my view.

*"A LOT OF WHAT WE CALL CAPITALISM TODAY IS EXTREMELY SHORT-TERM FOCUSED. WHEN YOU HAVE AN INSTITUTIONAL SYSTEM THAT IS FOCUSED ON THE NEAR TERM, IT'S VERY DIFFICULT TO GET PEOPLE TO THINK ABOUT COMPLEX, LONGER TERM CONSEQUENCES AND ANSWERS. IF WE CAN MAKE THAT KIND OF CHANGE, TERRIFIC. BUT IT'S GOING TO BE DIFFICULT." —JAMAIS CASCIO*

**Cascio:** I think there's good evidence on that. I do think that the kinds of changes that we would need to make to markets, to capitalism, that would make these kinds of innovation-driven solutions not just possible but basically all over the place would be so extreme, I think you could question, is this still capitalism? A lot of what we call capitalism today is extremely short-term focused. When you have an institutional system that is focused on the near term, it's very difficult to get people to think

about complex, longer term consequences and answers. If we can make that kind of change, terrific. But it's going to be difficult.

**Naam:** I think there's more long-term focus in big sectors of the market economy than people think. Insurance and reinsurance is a great one, or anybody who buys a 30-year bond has a certain view of things. And, for that matter, when power companies build a new power plant they expect it to run for 30 to 40 years. So they're making investments with that length of time in mind.

**Cascio:** At what point will we start to see the electric vehicle technology moving into long-haul trucking and other kinds of commercial capital vehicles? That's really where a lot of the emissions come from for transportation.

**Naam:** We still have to get the range up [and] the cost and the recharge time down. There's a case to be made that electric vehicles might be easier to manage for things like delivery vans than it is for some consumers, because they can control the routes and the charging infrastructure.

**Cascio:** The charging question is an interesting one for a couple of reasons. The first is the big question of standardization: Eventually we'll need to settle on a standard that will make it easy for anyone just to pull up. The second is a more fundamental problem: There is a limit to how much voltage you can push through wires before everything melts. I've seen at least one argument that there is a minimum time for recharge of any significant electric vehicle battery that's going to be at least 15 to 20 minutes.

**Naam:** It's interesting, too, because at a macro level, we're doing abysmally overall on decarbonization. But if you look at the leading indicators on electricity we at least have technology right now that is getting market penetration. So we have this momentum happening in electricity, but electric vehicles were something like 0.04 percent of new car sales this year. People make arguments around, "The total cost of ownership will become lower for an electric vehicle." I think it's got to be the up-front purchase price and then the range anxiety and charging anxiety issues. So that's still a technology hurdle, I think.

**Cascio:** So do you have an expected surprise — looking ahead 10 to 20 years, something that's probably not obviously likely, but something that makes you think, "Yeah, we're probably going to see something like that."

**Naam:** Here's one that's economic. I hear people talk about the carbon bubble, meaning that if you look at trying to stay under 2 degrees Celsius, we can only burn about one-quarter of the US$22 trillion worth of carbon reserves that we have in fossil fuels. I think if we look at that in one way it's an ecological thing, but it really is an economic thing. Right now we have coal companies that are going bankrupt or their stock prices have plummeted. I think a decade from now we might be talking about utility company bailouts that are necessary economically because utility company bonds are owned by pension and retirement funds. And these companies that, knowing that climate change was real, went ahead with building coal and a lot of natural gas over the last decade, suddenly are seeing that because of policy and the dropping price of renewables, those resources — that sunk cost — now are underwater assets, and they will be demanding bailouts from their communities and the federal government in order to keep running. It's a terrible irony to be paying people who have, in some cases, helped cause the problem. But I think it'll probably be irresistible.

What about you? What surprises do you see?

**Cascio:** I think it's likely we'll see some kind of really interesting manufacturing breakthrough, whether it's around atomically precise manufacturing or it's around multi-material 3D printing — something that will radically change the nature of international trade. If you look at the carbon output from transport ships, it's awful. If that can be changed, if the economic model that leads us to use these transport ships changes, if we see a growth in local manufacturing because it becomes really inexpensive and easy to do, and the environmental costs are so much lower, that could be a wild card. That could be something that really starts to change our international politics, but also starts to change how we think about our energy use and carbon production.

I have one last question for you. Human civilization: good idea or failed experiment?

**Naam:** It's a good idea. I can't disagree with it in broad strokes. How about you?

**Cascio:** Jury's still out.

*"RIGHT NOW WE HAVE COAL COMPANIES THAT ARE GOING BANKRUPT OR THEIR STOCK PRICES HAVE PLUMMETED. I THINK A DECADE FROM NOW WE MIGHT BE TALKING ABOUT UTILITY COMPANY BAILOUTS THAT ARE NECESSARY ECONOMICALLY BECAUSE UTILITY COMPANY BONDS ARE OWNED BY PENSION AND RETIREMENT FUNDS." —RAMEZ NAAM*

ON THE COVER

# PLASTIC LANDSCAPES

**WHERE MOST PEOPLE SEE TRASH,** Norwegian photographer Vilde J. Rolfsen looks for beauty. In her series "Plastic Bag Landscapes," she uses bags found on the street to create surreal images. "When the studio lights hit the plastic and the colors shine through, the bag does not look like a plastic bag anymore, but rather an imaginary landscape," says Rolfsen. Ensia was drawn to this collection of images for their ability to see beyond the throwaway and the everyday and imagine new — and beautiful — possibilities where you would least expect to find them.

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