
ensia
ENVISIONING A BRIGHT FUTURE
FOR PEOPLE AND OUR PLANET
2017

FROM THE PUBLISHER

TOGETHER WE CREATE THE FUTURE

WHAT PERCENTAGE OF major media coverage in the U.S. do you think is devoted to deforestation, sustainable agriculture, ocean pollution and other environmental issues? 10 percent? 5 percent?

According to a recent analysis by the Project for Improved Environmental Coverage, less than 1 percent of news stories in the U.S. focus on the environment. Some of the biggest challenges of our time are being treated as though they were afterthoughts.

It's very likely that you want to see this change. It's also likely that you want to see environmental problems resolved — and real, lasting solutions advanced. As events at the close of 2016 make clear, now more than ever we need to ensure that fact-based, solutions-focused reporting continues to be a key element in informing and empowering people to make the changes they desire.

By sharing stories and presenting new perspectives on environmental challenges and solutions, Ensia helps people connect with new ideas and information and start conversations that break through barriers to progress. Our belief has always been that environmental issues are everyone's issues, regardless of political persuasion or affiliation. And solutions can come from all directions — with the very best tending to emerge where diverse perspectives come together in pursuit of common goals.

AS WE MOVE INTO 2017, WE'RE PLANNING TO DOUBLE DOWN ON OUR EFFORTS TO PROVIDE THE BEST IN ENVIRONMENTAL JOURNALISM TO LEADERS OF ALL KINDS ACROSS GEOGRAPHIES AND IDEOLOGIES.

As we move into 2017, we're planning to double down on our efforts to provide the best in environmental journalism to leaders of all kinds across geographies and ideologies. We're also planning to engage more people in a conversation about the future of the global environment. Because the future doesn't just happen: We create it, together.

In this issue we revisit some of the stories from the past year that do just that. Jeremy Leon Hance takes a critical look at whether deforestation is really decreasing globally. Berlin-based journalist Anja Krieger writes about one of the greatest threats facing our oceans — plastic pollution. Rowan Jacobsen travels to Israel to report on how a new source of water could contribute to peace in the Middle East. And Kayla Walsh, an Ensia Mentor Program participant, explores the rights of climate-displaced persons — an issue certain to grow in prominence in coming years.

We also look forward, asking a panel of experts, "What will be the most important issues in 2017, and what should we be doing about them now?"

If you like what you see here, we invite you to share Ensia with your family, friends and colleagues — especially those who might not otherwise engage with environmental news. And we welcome your ideas for future content. Together, let's shine a light on environmental challenges — and move toward solutions.

PHOTO BY JEN MENEGHIN

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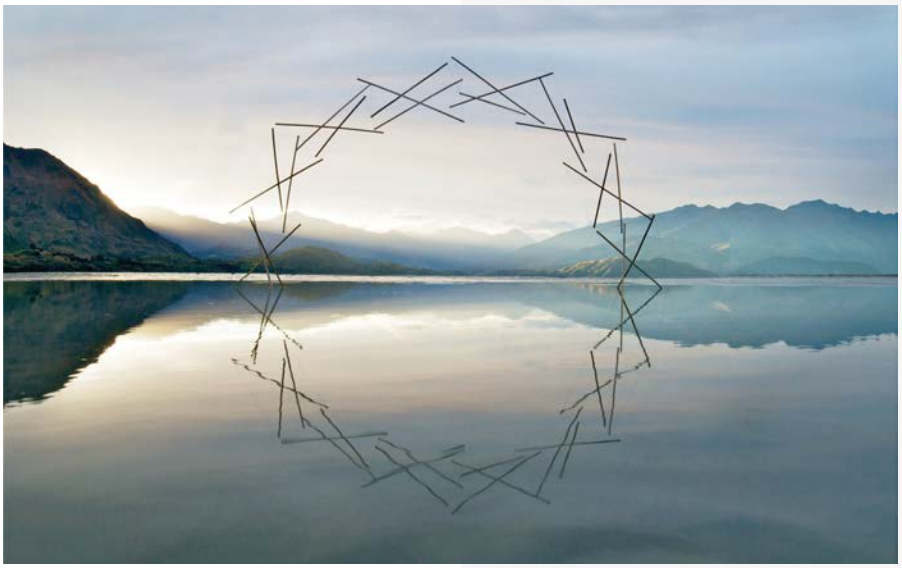

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Ensia is an independent nonprofit magazine presenting new perspectives on environmental challenges and solutions to a global audience. We cover a broad spectrum of issues and ideas at the crossroads of different sectors, disciplines, ideologies and geographies. Our mission is to share stories and ignite conversations that motivate and empower 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

"Synergy" by environmental artist Martin Hill uses the reflective nature of nature to create a circular continuum using the structural principle of tensegrity, interconnecting bulrush stems with a network of flax threads. To learn more about Hill and his work, see page 96.

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

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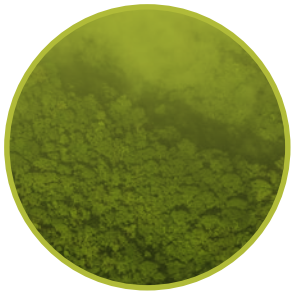
04 FEATURES

A fresh look at some of Ensia's best stories from the past year



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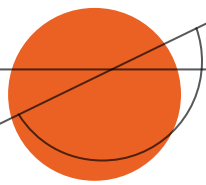
FEA



TURES

OVER THE PAST YEAR

Ensia's features have spanned the globe from Indonesia to Israel, Canada to Costa Rica and numerous points in between. In this section we take a fresh look at eight stories that were among the best of the year, along with writer updates, impact highlights, new graphics and more. Rowan Jacobsen travels to the Middle East to report on one of the planet's most ambitious desalination efforts. Ben Goldfarb writes about how researchers around the world are listening to and learning from indigenous communities. Anja Krieger explores the massive challenge of removing plastic pollution from the world's oceans. Ensia's editor in chief, Mary Hoff, discusses strategies for combating consumer food waste. Jeremy Leon Hance covers the ongoing struggle to stem global deforestation. Dave Levitan asks experts around the world whether nuclear power is part of our energy future. Rachel Cernansky finds companies looking for ways to reduce toxics in electronics. And Elizabeth Grossman ventures into the field to explain the challenges of tackling nitrogen pollution.

We hope this collection will inspire you to learn more about these issues, share these stories with others and visit ensia.com to read more environmental stories from around the world.

COSTA RICA PHOTO © RHETT A. BUTLER/MONGABAY / CUT TREE PHOTO © SHUTTERSTOCK.COM/ROUNDSTRIPE

global DEFORESTATION is decreasing. *Or is it?*

A new look at the complex picture of land use change suggests that when it comes to forests, we're far from being out of the woods.

by JEREMY LEON HANCE

ORIGINALLY PUBLISHED:
JANUARY 2016

WHY THIS MATTERS

"Is deforestation globally increasing or decreasing?" Like most things, the answer is complicated — and depends on whom you ask and what data they use. Still, one thing is certain: Deforestation is among the greatest environmental challenges facing the world today. Since 1990, 129 million hectares (319 million acres) have been lost around the world, with dire consequences for biodiversity, indigenous communities and the Earth's climate. Even Brazil — touted for the country's declining rate of deforestation in recent years — saw a spike in logging during the middle of 2016 according to data from Imazon, a group monitoring deforestation in the country. But as the story points out, there are rays of hope: China has undertaken ambitious forest planting programs in an effort to slow desertification and soil erosion, and forest cover in temperate regions has been increasing over the past 15 years. As author Jeremy Hance writes toward the end of the story, though: "Even if we go with the best-case slowdown scenario, deforestation is still happening at an unsustainable pace."

It started, as many things do, with a rumor. In 2013 Matt Finer, a researcher with the Amazon Conservation Association, heard from locals that someone was cutting down rainforest deep in the Peruvian Amazon, far from prying eyes. So Finer and colleagues did something that would have been unheard of 10 years before: Using high resolution satellite imagery, they found a couple hectares of felled trees in a seemingly impenetrable sea of forest.

"You could just see this little smidge of forest loss and we said, 'maybe that's it,'" says Finer.

Over the next few years, the team watched the destruction spread from just a few hectares to more than 2,000. It eventually connected the loss to United Cacao, a company based in the Cayman Islands with ambitions to become the "world's largest and lowest cost corporate grower of cacao," according to its website. Armed with dramatic satellite images, Finer and colleagues took the story to the Peruvian government and press, hoping to make a difference. The case is now in Peruvian court to determine if the company undertook the proper steps before clearing the forest. In the meantime, according to Finer, the agriculture ministry has responded by slapping United Cacao with a "paralyzation" order to halt its operation. But, says Finer, weekly satellite imagery shows United Cacao is not complying. "The deforestation is happening as we speak," he says.

In 2008, biodiversity expert Norman Myers said that deforestation in the tropics was "one of the worst crises since we came out of our caves 10,000 years ago." Ongoing loss is driving fears of mass extinction. But the loss of forests — both tropical and temperate — also plays a big role in the global climate crisis: Experts estimate that 10 to 15 percent of current greenhouse gas emissions are due to land use change. Not only that, but forests are vital to mitigating soil erosion, reducing risk of floods, maintaining precipitation and even boosting human health and happiness.

The world has struggled for decades to stem deforestation through a variety of means, including setting aside new protected areas, improving laws and enforcement at the national level, creating international programs such as REDD+, and making corporate commitments to cut out deforestation altogether.

Yet nothing has changed how we approach deforestation like satellite monitor-

ing. In recent years, this has revolutionized our ability to track deforestation. Instead of relying on local government statistics, researchers and activists are now able to monitor changes in the forest from their laptops and smartphones.

What does this information tell us about how we're doing at beating deforestation — and what we might do to make further progress toward this goal?

GLOBAL ASSESSMENTS

In 2015, the Food and Agriculture Organization of the United Nations released its latest Global Forest Resources Assessment. According to the assessment, we have seen a net loss of forests of 129 million hectares (319 million acres) since 1990, an area about the size of Peru. But the report, released every five years, also found that the rate of deforestation had slowed recently: Forests experienced 56 percent less net loss annually in the past five years than during the 1990s. The Global Forest Resources Assessment found a significant slowdown in deforestation in the tropics, while net forest cover in temperate regions was either stable or rising.

Anssi Pekkarinen, leader of the FAO's Forest Monitoring and Assessment Team, says the team is "quite confident" that de-

Smoke rises from an oil palm plantation and forest in Riau province, Indonesia, in 2015.

PHOTO © RHETT A. BUTLER/MONGABAY

"LARGEST FIRES ON EARTH"

Related to the topic of forest loss, freelance science writer XiaoZhi Lim wrote a feature story for Ensia in June 2016 on the challenges of extinguishing underground peat fires. The following is an excerpt from "These fires are huge, hidden and harmful. What can we do?"

PEAT, A CARBON-RICH SOIL created from partially decomposed, waterlogged vegetation accumulated over several millennia and the stuff that fueled Indonesia's megafires in 2015, also appears in the boreal forests that span Canada, Alaska and Siberia. With the intense heat from the Fort McMurray fires, "there's a good chance the soil in the area could have been ignited," says Adam Watts, a fire ecologist at Desert Research Institute in Nevada.

Unlike the dramatic wildfires near Fort McMurray, peat fires smolder slowly at a low temperature and spread underground, making them difficult to detect, locate and extinguish. They produce little flame and much smoke, which can become a threat to public health as the smoke creeps along the land and chokes nearby villages and cities.

And although they look nothing like it, peat fires are the "largest fires on earth," says Guillermo Rein, a peat fire researcher at Imperial College London in the United Kingdom.

READ MORE AT **ENSIA.US/PEAT**.

forestation has slowed in the tropics. Between 1990 and 2000, tropical forests lost more than 9 million hectares (22 million acres) annually, but over the past five years annual losses slightly exceed 6 million hectares (15 million acres), according to the Global Forest Resources Assessment. Critics, however, contend the FAO data are marred by dependence on local governments with varying abilities — and desires — to accurately monitor or report forest cover. Moreover, definitions of forest vary depending on the government and the time period, making comparing forest loss over decades difficult.

Meanwhile, one of the most rigorous studies in recent years found that forest loss actually accelerated by 62 percent in the tropics from 1990 to 2010.

Lead author Do-Hyung Kim, a Ph.D. student at the University of Maryland, College Park, says the study, published in 2015 in the journal *Geophysical Research Letters,* was meant to provide an "alternative" to FAO data based on "a consistent definition and methods." To do the analysis, Kim and colleagues analyzed 5,444 Landsat satellite images, comparing past and present forest cover using the same definitions.

Kim's conclusions are buttressed by findings from a 2013 study in *Science* that found forest loss in the tropics jumped by more than 200,000 hectares (500,000 acres) every year from 2000 to 2012. The research declared that Brazil's recent crackdown on deforestation was negated by rising destruction in other tropical countries, such as Indonesia and Malaysia.

"Brazil is the exception, not the rule at all, in reducing its rate of deforestation," says lead author Matt Hansen, a remote sensing scientist at the University of Maryland.

There is little disagreement, however, that deforestation has slowed in temperate regions. For one thing, the data are generally more reliable in these areas. According to the Global Forest Resources Assessment, net forest cover has actually risen in countries such as the U.S., Russia and China over the past 15 years. This doesn't mean these nations aren't continuing to clear-cut forests, but the total amount of land devoted to forests has grown. China, for example, has undertaken ambitious forest planting programs to combat desertification and soil erosion (although most of these are monoculture plantations rather than diverse forests).

APPLES AND ORANGES

Worldwide, Global Forest Watch — an interactive online mapping tool — has found that tree cover loss steadily increased (with some fluctuations) between 2001 and 2014. But Rachael Petersen, a research analyst for World Resources Institute, which operates GFW, says comparing the FAO and GFW data is like "comparing apples to oranges." This is because FAO largely measures land use change, while GFW covers tree cover loss. For example, clear-cutting a forest in the southern United States is not considered deforestation by FAO so long as the land remains designated as a production forest — that is, clear-cut and regrown at regular intervals. But GFW will detect loss for that year, because the satellites see felled trees — even if forests will soon grow there again.

"Taken together, [the GFW and Global Forest Resources Assessment] data give us a more complete understanding of how forest landscapes are changing," says Petersen.

ANOTHER MAJOR ISSUE PLAGUING THE DATA TODAY IS WHETHER MONOCULTURE PLANTATIONS SHOULD BE COUNTED AS FORESTS.

Another major issue plaguing the data today is whether monoculture plantations

In Brazil, protected areas such as Chapada Diamantina National Park help shelter forests from destruction.

PHOTO © RHETT A. BUTLER/MONGABAY

should be counted as forests. FAO says it does not include oil palm plantations or fruit tree monocultures under its definition of forests, but it does include pulp and paper plantations as well as replanting efforts that usually depend on a single species. And most analyses of satellite data sets don't distinguish between forest plantations and diverse forests, meaning that research dependent on satellites usually counts mature oil palm, rubber, acacia or other plantations as forest simply because from a bird's eye view they look like forest.

But the idea that any monoculture plantation is a forest drives ecologists crazy.

"They're about as biologically similar to native forests as my front lawn," says William Laurance, an expert on tropical forests with James Cook University in Australia.

INDONESIA VS. BRAZIL

In the end, no measurement of deforestation is without fault. But, ultimately, we may be missing the point by focusing on relative rates of global deforestation. Even if we go with the best-case slowdown scenario, deforestation is still happening at an unsustainable pace. Every year, our planet has less forest than it did before — and much less primary forest. Every year, more species — many of them not even named — become threatened with extinction or go extinct. And every year more planet-warming carbon enters the atmosphere from destroyed forests.

This is nowhere more evident than in Indonesia, which in 2015 saw 2.1 million hectares (5.2 million acres) of land — much of it peat and rain forest — go up in smoke.

During the dry season, farmers and plantations routinely clear peat and rain forest in Indonesia by burning it, creating a toxic haze that blankets the wider region. But in 2015 — due in part to El Niño and global warming — the fires proved particularly fierce and long lasting. Erik Meijaard, an Indonesia-based ecologist, dubbed them "the biggest environmental crime of the 21st century" even as the months-long crisis failed to capture anywhere near the global media attention as the Deepwater Horizon oil spill in the Gulf of Mexico in 2010.

In all, the disaster resulted in the direct deaths of 21 people, at least half a million acute respiratory infections, hundreds of cancelled flights and immeasurable impacts to wildlife. The World Bank estimated a total loss to the Indonesian economy estimated at more than US$16 billion. It also released a carbon bomb: At the height, the fires emitted more carbon dioxide on a daily basis than the entire U.S. economy.

For those who have followed the turmoil of Indonesia's forest policies, none of this was surprising. Suffering from decades of corruption, lax laws, decentralized governance and powerful industrial players, Indonesia's forests are in crisis.

10–15
Percent of greenhouse gas emissions due to land use change

129 million
Hectares of forest lost globally since 1990, an area the size of Peru

US$5 billion
Commitment by Norway, Germany and the UK to the REDD+ program

But maybe Indonesia should look to Brazil. The Amazonian country was once the global pariah when it came to rain forest destruction. Now experts repeatedly point to it as a model for how to really take on deforestation. A leader in the application of satellite monitoring, Brazil has combined the new technology with strong governance, tough forest laws and vast protected areas. And it's working: Deforestation in Brazil slowed 70 to 80 percent from the early 2000s to today — though it has risen slightly in recent years.

"Brazil is the best to date in intervening in an ongoing deforestation dynamic and actually greatly reducing it," says the University of Maryland's Hansen, who points to the country's "vigorous civil society, government mandates and an engaged private sector" as key to the initial success. In a nutshell, Brazil's many stakeholders came together to take on a hugely complex, but not unsolvable, problem. The battle is not over there, but it is moving in the right direction.

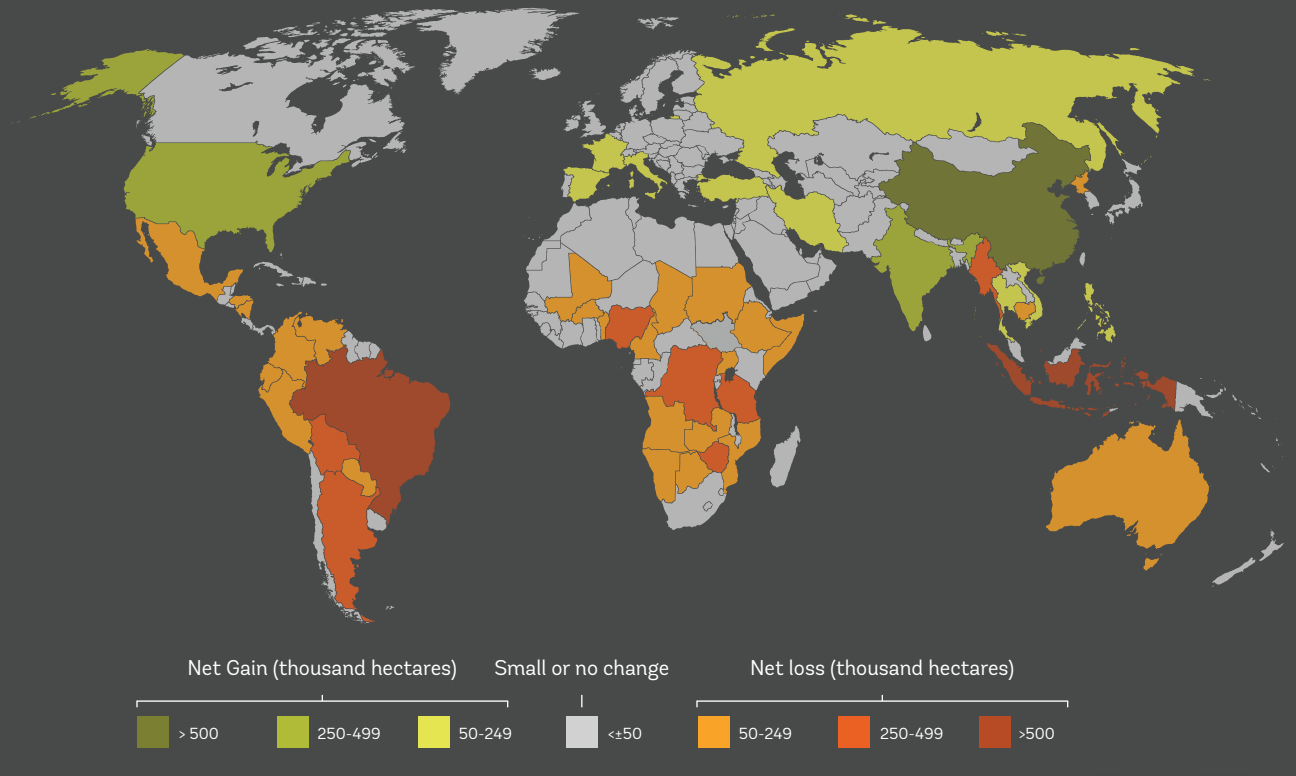
"Replicating those conditions elsewhere may prove challenging," Hansen says. For instance, in Indonesia, the palm oil industry routinely plays down the problem and the government still sends mixed messages on the importance (or lack thereof) of protecting forests, even going so far as to criticize recent zero deforestation pledges by corporations.

MOVING FORWARD

Many hold out hope that the Paris climate agreement, signed by virtually every nation in the world in December 2015, could point to a new era for the world's forests.

FOREST GAIN AND LOSS BY COUNTRY (1990–2015)

The map below shows annual net forest losses and gains by country from 1990 to 2015. Brazil leads the way with 984,000 hectares (2.43M acres) lost during this time period, while China has added 1.54M hectares (3.81M acres) of forest cover.



Graphic courtesy of WWF

Included in the agreement is a request that countries conserve and enhance forests in order to mitigate carbon emissions.

The Paris agreement also lent considerable support to REDD+, a long-debated program that establishes a mechanism by which wealthy nations pay poor tropical countries to keep their forests standing. Under discussion for a decade, the program has yet to prove itself and still faces a number of critics. But a commitment of US$5 billion by Norway, Germany and the UK to REDD+ announced on day one of the Paris talks should see the program finally kick into high gear.

At the same time, every year more of the world's biggest corporations and industries are announcing "zero deforestation" pledges, a trend started in Brazil in 2008. Many of these pledges don't go into effect for 5 or even 15 years and, even more problematic, such pledges often only apply to so-called high conservation forests, a definition that remains under heavy debate but basically means forests with high carbon content or rare species. Still, such pledges show that at least some in the private sector are beginning to view deforestation as no longer permissible.

Finally, experts say that recognizing the rights of local people and indigenous groups to their traditional forests could be one of the easiest, cheapest and most effective ways to protect standing forests from razing. Many indigenous groups still lack legal tenure to their traditional lands in tropical countries, but where they have secured their rights — for example, in parts of Brazil — research often shows that forests are well protected. In some cases indigenous groups were even better at halting deforestation than government-sanctioned protected areas. Efforts to achieve indigenous rights to forests are ongoing, but sluggish for many of those groups that are watching their forests — and their way of life — vanish to chainsaws.

Concerned citizens elsewhere are also doing their part by being conscientious about purchases that may come with deforestation baggage, including everything from paper to timber and beef to palm oil. Just as important is to support courageous groups and individuals putting pressure on world leaders to protect our remaining forests amid the twin climate and biodiversity crises. If Brazil is any example, we'll need all hands on deck — governments, industry and citizens — to truly end deforestation.

IMPACT

In addition to being featured on ensia.com and receiving over 700 social media shares, this story was republished by Quartz, Greenbiz, Global Voices and other media outlets around the world.

Freelance journalist **JEREMY LEON HANCE** runs a blog for the Guardian called Radical Conservation. He writes regularly for Mongabay and Alert: Conservation. He lives in St. Paul, Minnesota.

WRITER UPDATE: *At the time of this update, some eight months after this piece was originally written, two countries once again appear to stand out with respect to deforestation: Brazil and Indonesia. But their stories appear to be changing. While Brazil is at risk of backsliding in its historic success in combating deforestation, Indonesia may be on the cusp of finally standing up to forest wreckers.*

Deforestation in Brazil has been creeping up since reaching a nadir in 2012. Now, amid political turmoil, aggressive lobbying by the country's powerful agribusiness politicians could push through new laws that drastically undercut protections in the Amazon. While the country is nowhere near deforestation rates seen in the 1990s and 2000s, it's playing a dangerous game.

At the same time, Indonesia is showing tentative signs of finally beginning to combat its deforestation crisis. In April, Indonesia announced a five-year moratorium on new palm oil plantations. If effectively enforced — and this is always key when discussing Indonesia — this pause could give the country breathing room to figure out a new way forward.

Still, there's one thing we can say for sure: there is less tropical forest today than there was when this article was published in January 2016, and more still needs to be done to slow global deforestation. — JEREMY LEON HANCE

NUCLEAR POWER STATIONS © ISTOCKPHOTO.COM/TOLGART / NUCLEAR REACTOR © 4X-IMAGE

the mysterious future of NUCLEAR POWER

Identical data yield drastically different conclusions about the role nuclear will play in meeting climate goals.

by **DAVE LEVITAN**

ORIGINALLY PUBLISHED:
FEBRUARY 2016

Nuclear power is dead. Long live nuclear power. Nuclear power is the only way forward. Nuclear power is a red herring. Nuclear power is too dangerous. Nuclear power is the safest power source around. Nuclear is nothing. Nuclear is everything.

It is now generally agreed that the world must rapidly reduce carbon emissions in order to fight off dangerous climate change, but the "how" of that process remains up for debate. And within that debate, nothing seems to produce such starkly opposing viewpoints as nuclear energy. Some experts and advocates argue that carbon-free nuclear power represents the only real hope of keeping the planet's temperature in check. Others claim that nuclear is risky, unnecessary and far too expensive to make a dent.

The same basic data set — nuclear plants currently in existence, those under construction, the status of new technologies, the history of costs and delays, and a few striking accidents — produces those totally contradictory opinions and predictions. Nuclear power is a Rorschach test: You see what you want to see — a rosy nuclear future or an old-world dinosaur in a slow death spiral — reflecting your own views on the energy present and future. In all likelihood, no one will be proven right or wrong for decades.

TODAY AND TOMORROW

Nuclear power today accounts for around 10 percent of the total electricity generation around the world. This varies sharply by country — in the U.S. the rate is about 20 percent, in Russia and Germany it is a bit lower than that, while some other European countries get 40 and 50 percent from nuclear reactors. France has long led the way proportionally, at more than 75 percent (it has the second most total reactors, behind the U.S.). China, though building rapidly, drew less than 3 percent of its power from nuclear in 2014.

There are 442 reactors currently in operation globally, and the International Atomic Energy Agency says 66 are currently under construction. Twenty-four of those are in China; no other country is currently building more than eight.

That's the nuclear landscape now. The question is, how will it change in the coming years? And equally important, how *should* it change? The answers to both of these depend on whom you ask.

The International Energy Agency's World Energy Outlook 2014, which includes a close analysis of nuclear power, projects a 60 percent leap in global installed capacity by 2040, with almost half of that growth coming from China.

"I think we definitely need it in the battle against climate change. This is broadly recognized," says Jacopo Buongiorno, a professor of nuclear science and engineering at the Massachusetts Institute of Technology. "Because now there is such an overwhelming concern about climate change, it's like a tide that lifts all boats. Anything that is perceived as clean is going up. I think it is absolutely necessary."

That type of take on nuclear isn't particularly hard to find, but neither is this one: "I don't think nuclear power is a necessary component at all," says M. V. Ramana, a research scholar at Princeton's Nuclear Futures Lab. "Nuclear power as a share of electricity generation is only likely to decline in the foreseeable future. If we hold that up as a means of emission reductions, then we will not be successful with meeting any of the ambitious climate goals set" in the recent Paris agreement, in which 195 countries agreed to reduce emissions sharply.

In the run-up to that agreement, a group of the most prominent nuclear proponents — climate scientist James Hansen, Stanford's Ken Caldeira and others — wrote in the *Guardian* that "nuclear will make the difference between the world missing crucial climate targets or achieving them."

WHY THIS MATTERS

Audit and consulting firm PwC's 2015 "Low Carbon Economy Index" predicted we'll use up this century's entire carbon budget — the amount of carbon that can be released worldwide while still retaining a reasonable probability of limiting global surface temperature warming to 2 °C — by 2034. To extend this date and avert a climate catastrophe, we'll need to dramatically ramp up the use of low-carbon energy sources worldwide. As this article shows, a number of experts argue that nuclear power should play a significant role in our energy future, while others predict nuclear power's slow decline. When it comes to the role of nuclear in drastically reducing global carbon emissions, the outlook can best be summarized in one word: uncertain.

This nuclear power plant in Taishan, Guangdong province, added a new reactor in 2013, part of China's larger push to increase its nuclear capacity.

PHOTO © EPA EUROPEAN PRESSPHOTO AGENCY B.V. / ALAMY STOCK PHOTO

This was met with particularly harsh disdain from Naomi Oreskes, Harvard science historian and co-author of *Merchants of Doubt,* who wrote a response at the *Guardian* branding this "a new, strange form of denial."

The heart of Hansen's and Oreskes' disagreement regards the necessity for nuclear and the technical feasibility of scaling up renewables: Are other energy sources sufficient to wean us from fossil fuels? Or is the reliable, large-scale (a single new reactor can reach 1,600 megawatts capacity, three times the size of the world's largest solar plants) baseload power that nuclear provides a necessary component of the low-carbon future?

HOW WILL IT CHANGE IN THE COMING YEARS? AND EQUALLY IMPORTANT, HOW SHOULD *IT CHANGE?*

The anti-nuclear side of the argument focuses on several studies that have illustrated a renewables-only way to the goal, which could be cheaper and free of the risks associated with nuclear. Mark Jacobson, director of the Atmosphere/Energy Program at Stanford University, has published state-specific plans showing how 100 percent renewables penetration would be achievable in the U.S. The National Renewable Energy Laboratory, part of the U.S. Department of Energy, published its "Renewable Electricity Futures Study" in 2012 and explained a clear path to 80 percent penetration in the U.S. Others have shown similar routes forward.

Nuclear proponents argue that there are impediments to having a grid entirely run on renewables. Buongiorno, for example, says that the intermittency of solar and wind can realistically only be addressed by adding large amounts of electricity storage (in the form of large batteries or other newer tech such as compressed air) to the grid, and that would change the ongoing "renewable prices are plummeting" narrative.

"When I hear people say 'Oh, the costs are coming down,' the costs for *generation* may be coming down, but if installing that capacity forces me to have energy storage, you have to add those costs," he says. Think of it like buying a car: The baseline price sounds okay, but it's all the options and add-ons that'll get you. Buongiorno says he expects the costs of nuclear construction will come down, and that when storage costs for renewables are factored in, nuclear — with its reliable, 24/7 output — starts to look much more attractive as an alternative.

BILLIONS AND BILLIONS

When it comes to any energy source, it is cost that sits at the root of the discussion. Adding more nuclear to the grid could reduce some

CONTINUING THE CONVERSATION

This story generated a robust online conversation, with hundreds of comments posted to Ensia and across news outlets where the piece was republished. Below are three comments from ensia.com that add new dimensions — and questions — to the discussion:

"I don't see how you can discuss the additional costs of the needed energy storage for renewables without balancing it against the cost for waste disposal (so far nonexistent) for nuclear. That doesn't add up (literally)."

"No energy technology, including nuclear, is carbon emission free: they must be assessed on the basis of all emissions in the production cycle. For example, the nuclear fuel cycle — including mining, refining, milling, transportation, preparation, security, installation, decommissioning and storage (securely and permanently — inherently still an infinite value) — can only fairly be viewed as producing more emissions than it avoids."

"To power the grid with nuclear rather than renewables, you need about the same amount of storage that's needed to make solar and wind viable. That's because while solar and wind are intermittent, nuclear is exactly the opposite — output cannot be adjusted to follow demand. It takes days to start up a plant and days to shut it down. While it's running, the output can be adjusted only slowly. In other words, demand varies much faster than nuclear can follow. So the storage issue is a red herring in this debate."

PHOTO COURTESY OF TVO

Construction of a new reactor at Olkiluoto Nuclear Power Plant in Eurajoki, Finland, is nine years behind schedule and more than $US5 billion over budget.

of the burden on renewables and storage, but the economics of nuclear itself could prove an insurmountable roadblock.

In general, the more experience accumulated with a given technology, the less it costs to build. This has been dramatically illustrated with the falling costs of wind and solar power. Nuclear, however has bucked the trend, instead demonstrating a sort of "negative learning curve" over time.

According to the Union of Concerned Scientists, the actual costs of 75 of the first nuclear reactors built in the U.S. ran over initial estimates by more than 200 percent. More recently, costs have continued to balloon. Again according to UCS, the price tag for a new nuclear power plant jumped from between US$2 billion and US$4 billion in 2002 all the way to US$9 billion in 2008. Put another way, the price shot from below US$2,000 per kilowatt in the early 2000s up to as high as US$8,000 per kilowatt by 2008.

Steve Clemmer, the director of energy research and analysis at UCS, doesn't see this trend changing. "I'm not seeing much evidence that we'll see the types of cost reductions [proponents are] talking about. I'm very skeptical about it — great if it happens, but I'm not seeing it," he says.

"AS NUCLEAR TECHNOLOGY HAS MATURED COSTS HAVE INCREASED, AND ALL THE PRESENT INDICATIONS ARE THAT THIS TREND WILL CONTINUE." —M. V. RAMANA

Some projects in the U.S. seem to face delays and overruns at every turn. In September 2015, a South Carolina effort to build two new reactors at an existing plant was delayed for three years. In Georgia, a January 2015 filing by plant owner Southern Company said that its additional two reactors would jump by US$700 million in cost and take an extra 18 months to build. These problems have a number of root causes, from licensing delays to simple construction errors, and no simple solution to the issue is likely to be found.

In Europe the situation is similar, with a couple of particularly egregious examples casting a pall over the industry. Construction began for a new reactor at the Finnish Olkiluoto 3 plant in 2005 but won't finish until 2018, nine years late and more than US$5 billion over budget. A reactor in France, where nuclear is the primary source of power, is six years behind schedule and more than twice as expensive as projected.

"The history of 60 years or more of reactor building offers no evidence that costs will come down," Ramana says. "As nuclear technology has matured costs have increased, and all the present indications are that this trend will continue."

Some experts, however, dispute the idea that the "negative learning curve" is intrinsic to the nuclear industry. In a recent paper Ted Nordhaus of the energy think tank The Breakthrough Institute pointed out that the history of nuclear plant construction costs varies dramatically by country. South Korea, for example, has demonstrated a fairly consistent drop in costs over time; it imported its first designs from foreign companies with more experience before homegrown designs took hold, and all the country's plants are built and owned by a single utility. Nordhaus wrote, "with the right policies and institutions, nuclear plants can be built quickly, safely, and cheaply."

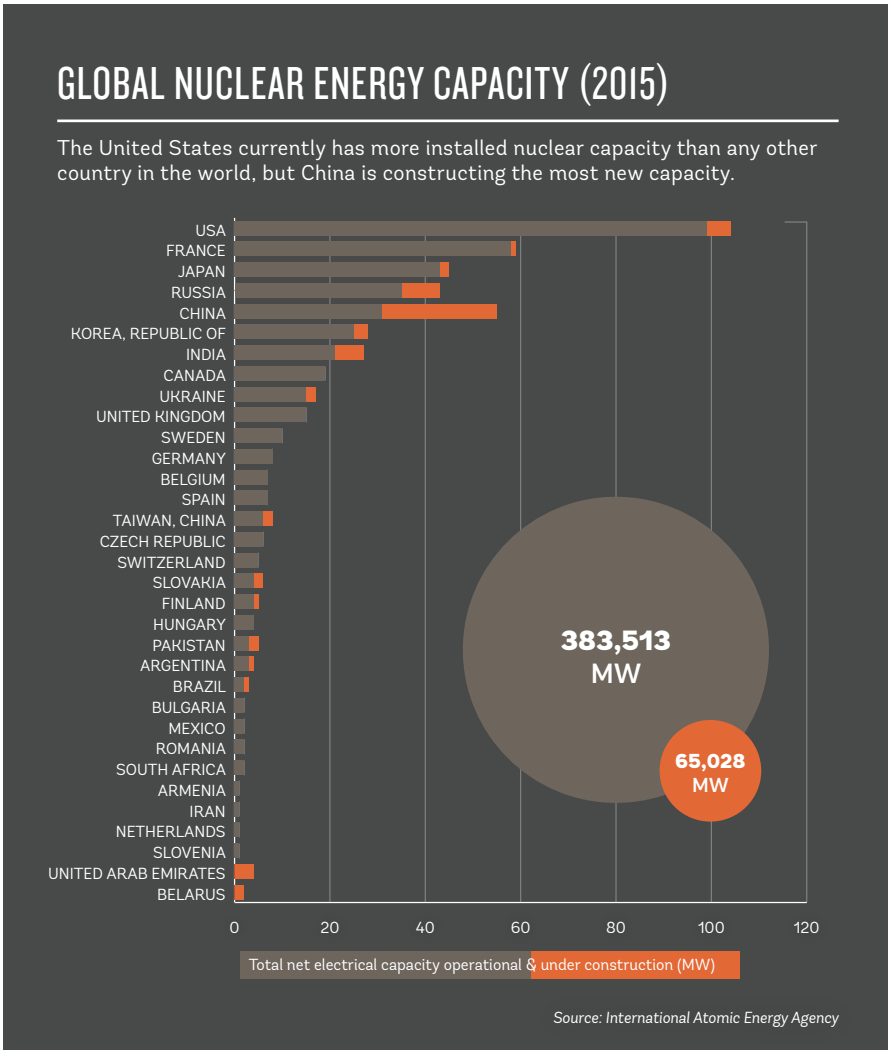
Still, most countries have seen costs increase. As it stands, only China's non-free market may allow for a truly rapid build-out of nuclear plants; the country's current domination of the nuclear construction world reflects this idea, and the 2016 Five-Year Plan includes provisions to approve and build six to eight new plants each year.

The industry, for its part, argues that the benefits of nuclear are worth the price tag. The Nuclear Energy Institute, which represents plant owners, builders, designers, suppliers and related companies, notes that in the U.S. nuclear power generates as much as US$50 billion each year from electricity sales and revenue, and provides around 100,000 jobs. The lack of carbon emissions, of course, only adds to the benefits.

FUKUSHIMA POWER

Along with price hikes, the specter of major accidents hovers over every discussion of a nuclear scale-up. By most measures nuclear power is among the safest forms of energy ever devised. But when it does go wrong, it goes wrong in spectacular and terrifying fashion.

The accident at Fukushima Daiichi in Japan in 2011 led to a shutdown of all the plants in that country (with very limited



reactor restarts coming only last year), and it has convinced Germany and Belgium to phase out the energy source entirely. Though those phase-outs will account for only a handful of total reactors, they put a damper on the idea of a revolutionary nuclear scale-up.

Many argue the fearful reactions and phase-outs are not entirely logical in the context of climate change. Fukushima clearly did result in a drop in global support for nuclear energy, but public opinion continues to vary sharply by country. In the U.S., a Gallup poll on nuclear favorability has shown a decline since Fukushima, but not a dramatic one. In 2015 public support for the use of nuclear energy hovered at 51 percent, down from a peak of 62 percent in 2010. The same poll, though, found that only 35 percent think the government should place "more emphasis" on nuclear; for comparison, 79 percent want more focus on solar power.

Cousins to the fear of a massive meltdown are both the worry over nuclear weapons proliferation and concerns over waste disposal. Spent nuclear fuel is currently stored on the site of nuclear plants in pools of water or sealed in dry cask storage, and decades-old arguments over geologic repositories are unlikely to be resolved any time soon. With regard to weapons, nuclear plants produce plutonium during the course of their reactions, which can be made into bombs if enough is accumulated; terrorism and theft are thus constant worries. Both of these issues work to extend the shadow of risk stretching out behind nuclear power, and both lack immediate solutions.

"HOPEFULLY AT SOME POINT IT WILL BE ENOUGH OF A WAKE-UP CALL THAT WE'LL BE DEMANDING ACTION TO ADDRESS CLIMATE CHANGE AND REDUCE EMISSIONS." —STEVE CLEMMER

TECHNOLOGICAL BREAKTHROUGHS?

Supporters of nuclear power hold out hope that new technologies will improve the economics and reduce the fear factor. There are ongoing efforts to develop small modular reactors, which produce about a third or less of a full-size reactor's output and can theoretically be built faster and cheaper. Allison Macfarlane, director of George Washington University's Center for International Science and Technology Policy and the former chairman of the U.S. Nuclear Regulatory Commission, notes that of the various companies working on these only one (NuScale Power) is currently expected to actually submit application materials to regulators in 2016 — a step that is still years removed from actual functioning reactors.

Other technological unicorns, though in many cases on the drawing board for decades, still remain off in the distance: different fuel sources such as thorium, molten salt-cooled reactors, even building plants on floating platforms like those used for oil drilling (a project that Buongiorno at MIT is heavily involved in) are all on the table. These have varying potential advantages: A floating plant could use seawater as a cheap and easy way to cool the reactor and would alleviate some of the safety fears by keeping the plant away from people and near a coolant should an accident occur; thorium could reduce waste and produce power more efficiently, though a U.K. government report in 2013 called the benefits "overstated" and experts have warned it could increase proliferation risks; and molten salts can operate at lower pressures than standard water-cooled reactors, offering some safety benefit.

Nuclear research and development, though, moves at a snail's pace, largely for safety reasons. If the goal is rapid emissions reduction, it is unclear if any of this new tech can play a role.

"I think we need to do some work on it, see if we can develop some new technologies, but they are not going to be a solution in the near term at all," Macfarlane says about the small modular reactors. "Some of these other things that just exist on paper right now? I think they're much further out."

Clemmer, of UCS, agrees that the next 15 years or so are unlikely to feature much

10
Percent of global electricity generation from nuclear

66
Nuclear reactors currently under construction (including 24 in China)

442
Nuclear reactors currently in operation around the world

US$9 billion
Cost of a new nuclear plant in 2008, according to the Union of Concerned Scientists

of a nuclear revolution. He says the 2030 to 2050 period, though, will be a crucial time for nuclear, with many existing plants in the U.S. and elsewhere due to retire — the IEA projects almost 200 reactor retirements by 2040. In that time frame, perhaps some of the new technology could make it to market.

CHANGING PERSPECTIVES

In the coming years, it may boil down to just how dramatic the effects of climate change become to force the Rorschach muddle to resolve into a clear image.

"As time goes on, and the impacts of climate change become more and more real — droughts and heat waves and sea-level rise and storm surge, coastal flooding issues, more powerful hurricanes and devastating storms and things like that are also a wake-up call to people," says Clemmer. "Hopefully at some point it will be enough of a wake-up call that we'll be demanding action to address climate change and reduce emissions. In that world, maybe there's more of a positive light that would be shed on nuclear."

Macfarlane also suggests that the changing perspectives on energy requirements could shift nuclear fortunes. "We go through these different transitions as a society," she says. In the past, these transitions have replaced wood with coal to help cities grow, and added oil to feed a boom in transportation.

"Nuclear never fulfilled one of those kinds of needs," she says. "We're going through another transition where we need to decarbonize our energy sources, and maybe it will fill more of a natural need now. We'll see."

Small modular reactors like this NuScale design aim to increase the versatility, affordability and safety of nuclear power.

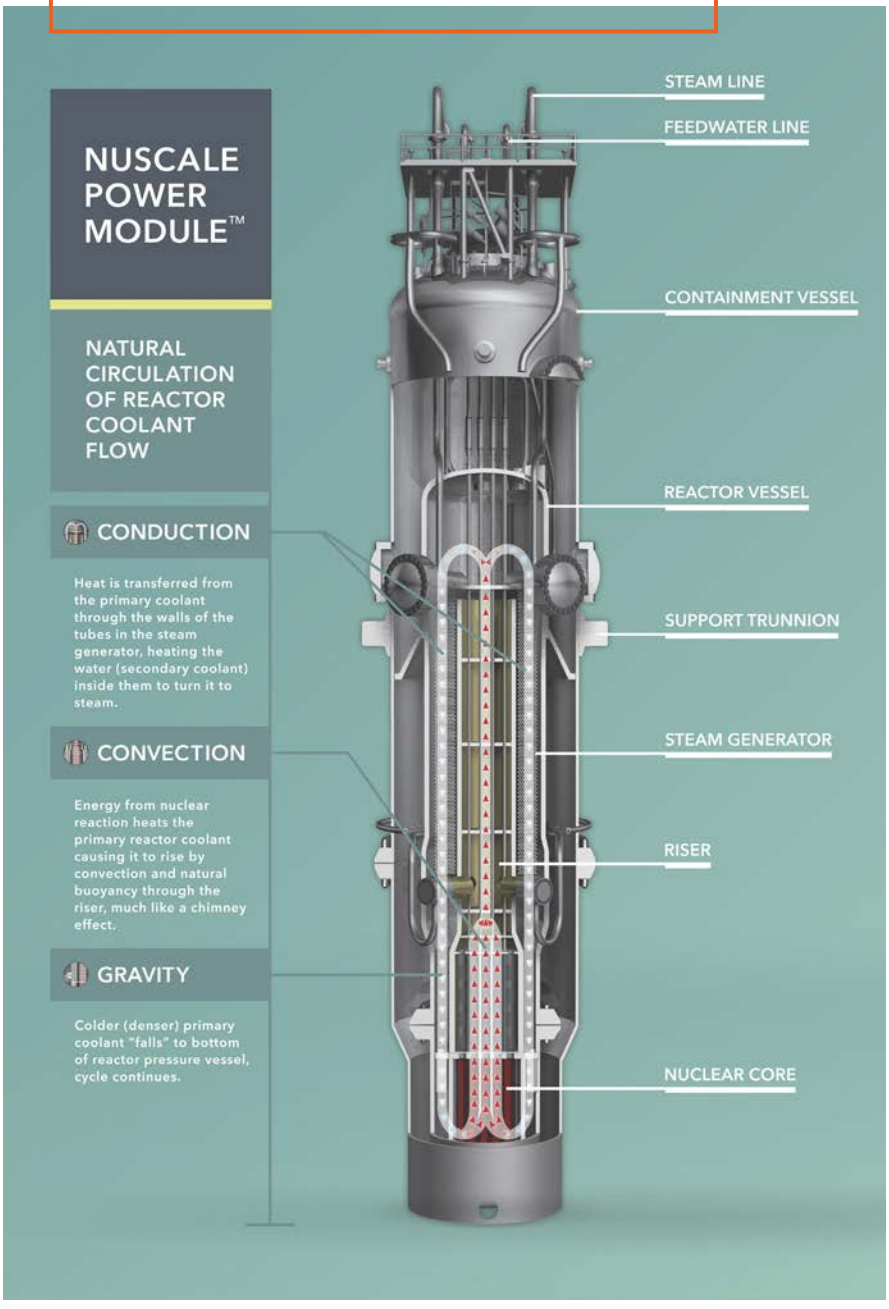
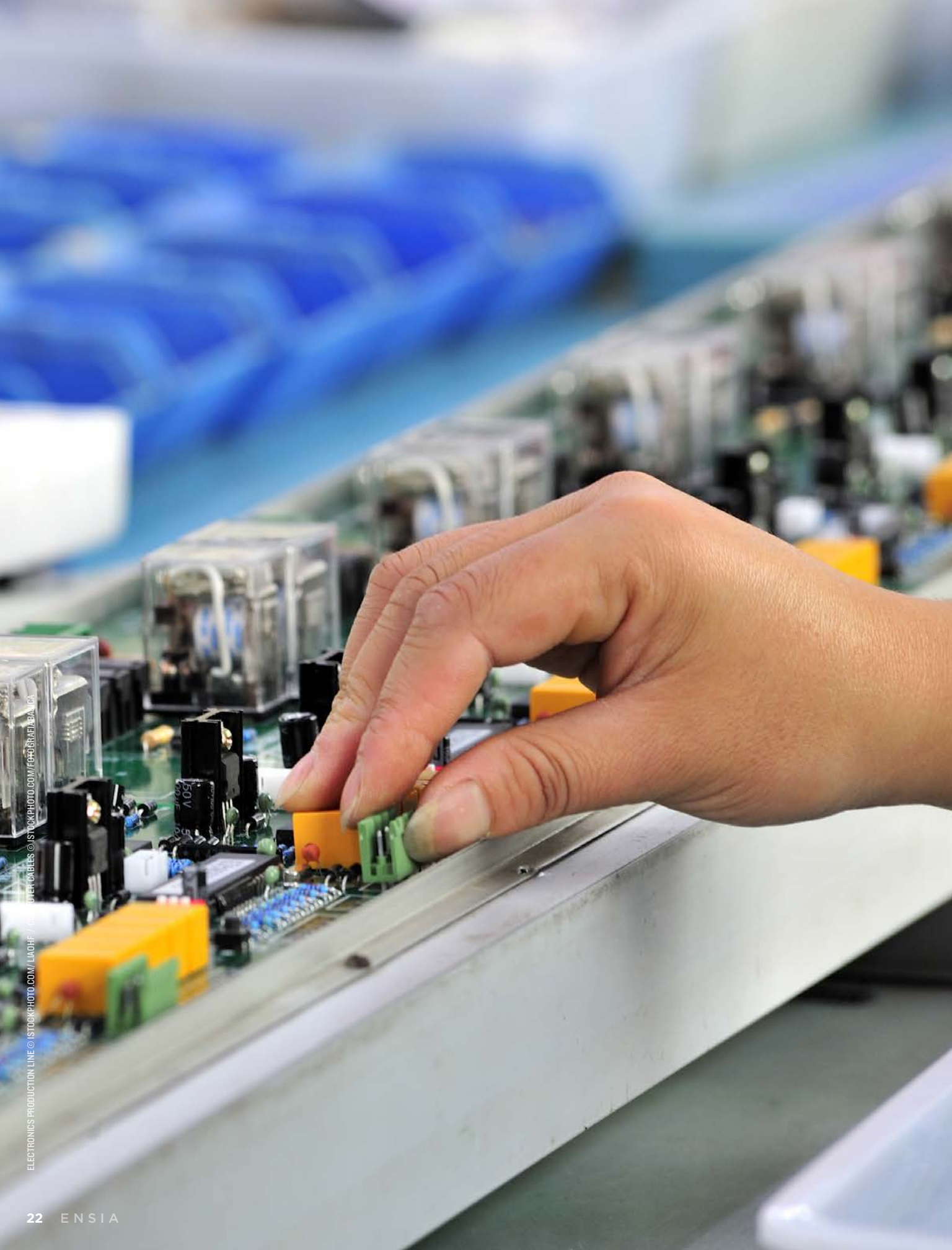


IMAGE COURTESY OF NUSCALE POWER

DAVE LEVITAN has covered science and the environment for more than a decade. His forthcoming book *Not A Scientist: How Politicians Mistake, Misrepresent, and Utterly Mangle Science* will be released in April 2017 by W. W. Norton.



ELECTRONICS PRODUCTION LINE © ISTOCKPHOTO.COM/ LIAOHF / COMPUTER CABLES © ISTOCKPHOTO.COM/FOTOGRAFIABASICA

the QUEST *for* environmentally friendly ELECTRONICS

As global consumption of cellphones and other devices soars, industry searches for ways to decrease the threat of components to people and the environment.

by RACHEL CERNANSKY

ORIGINALLY PUBLISHED:
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WHY THIS MATTERS

Production of consumer electronics is on the rise, thanks to growing global market penetration and consumers' perpetual desire for the latest shiny thing. And many if not most electronics contain materials that can contaminate the environment and cause health problems ranging from acute poisoning to cancer and birth defects. One way to reduce risks to human health and the environment is to capture and recycle potentially toxic substances. But even better in the "3-R" hierarchy are reducing use in the first place and reusing products, since those options demand less material processing, management and transportation. By presenting ways in which various manufacturers are approaching the challenge, this story offers information and ideas others can use to rethink and improve their own electronics design, production and management strategies.

On a Wednesday in late February 2010, Hewlett-Packard hosted an unusual training session at its offices in Fort Collins, Colorado. The technology company had decided to eliminate polyvinyl chloride, or PVC — a type of plastic that releases harmful chemicals during production and when burned after disposal — from its power cords. But it realized that to get PVC out of its products, it was going to have to get its suppliers to do so, too. This training was an opportunity for those supplying power cables to the company (now known as HP) to learn about a tool that could help identify alternatives to PVC: GreenScreen for Safer Chemicals. Developed by the nonprofit Clean Production Action, GreenScreen provides a means of comparing hazard assessments of chemicals in order to choose safer alternatives.

"At HP, we buy a lot of power cables. We knew that because of our buying power, we could have some influence on what the industry was doing," says Paul Mazurkiewicz, a technologist for materials at HP. "We went really far back in the supply chain, to the people that fundamentally make these materials, and we trained them on how to use the GreenScreen and let them know that HP would be making choices based on the GreenScreen in the future."

HP is not alone: Around the world, electronics companies are working to reduce their use of chemicals that are known to be hazardous to human health, the environment or both.

WHAT'S THE PROBLEM?

From cellphones to computers to televisions, electronics are manufactured with a long list of substances that are known to be toxic, including metals such as lead and hexavalent chromium, and other contaminants such as phthalates and brominated flame retardants. They all serve specific roles: Lead is extremely effective as a solder, for example, and flame retardants keep our computers from bursting into flames while we type. But with many of these chemicals, there's a health trade-off: Hexavalent chromium is linked with cancer, for example, and lead causes irreversible damage to developing fetuses and children and can contaminate water supplies and harm plants and animals.

The use of such chemicals has given the electronics industry a reputation for jeopardizing the health of workers and the environment on both the manufacturing and disposal end of things. Some studies have suggested that electronics manufacturing workers, who are often exposed to chemicals such as benzene and lead that are known to have detrimental health impacts, experience elevated rates of certain cancers and other diseases. And globally, most electronic waste sent overseas is moved illegally to poor areas where people look to the waste as a source of income: They burn cables to get to the copper inside, for example, releasing extremely toxic substances such as cadmium, chromium and brominated flame retardants.

A GROWING NUMBER OF COMPANIES AS WELL AS NONPROFITS AND INDUSTRY ASSOCIATIONS SUCH AS THE INTERNATIONAL ELECTRONICS MANUFACTURING INITIATIVE ARE WORKING TO REDUCE OR ELIMINATE THE USE OF TOXIC CHEMICALS IN ELECTRONICS PRODUCTS AND REPLACE THEM WITH SAFER ALTERNATIVES.

INCENTIVE TO CHANGE

Growing awareness of these issues has led consumers to pressure companies to

become more sustainable. They're aided in the process by ratings systems such as the Electronic Product Environmental Assessment Tool, or EPEAT, which gives consumers information they need to choose products that reduce the threat of e-waste.

Facing this increase in public pressure — including demand for highly rated products — as well as emerging regulations around hazardous chemicals, such as the Restriction of Hazardous Substances in Electrical and Electronic Equipment and REACH in Europe, the industry is finding incentive to change how it operates. That incentive is buoyed by initiatives such as the Sustainable Purchasing Leadership Council in the U.S. and Electronics Watch in Europe, which encourage large-scale purchasers, such as governments, to prioritize sustainability in their product choices.

As a result, a growing number of companies as well as nonprofits and industry associations such as the International Electronics Manufacturing Initiative are working to reduce or eliminate the use of toxic chemicals in electronics products and replace them with safer alternatives. At the United Nations Environment Programme–hosted International Conference on Chemicals Management in Geneva in late 2015, participants, including more than 100 governments, non-governmental organizations and some industry representatives, signed a resolution detailing initiatives for reducing hazardous chemicals in electronics. Those initiatives include promoting public and private partnerships focused on product stewardship and extended producer responsibility; encouraging electronics designs that reduce the need for hazardous chemicals and allow materials to be recovered; working with retailers to expand sustainable options for consumers; and

Dell's closed-loop recycling program has turned 4.2 million pounds of discarded plastics into new products since 2013.

PHOTO COURTESY OF TECHWAY SERVICES

PICKING THE WINNERS

CONSUMER CHOICE can play a role in encouraging electronics manufacturers to minimize the use of harmful substances in the devices they make. But how is a purchaser to know which products contain environmentally friendly components?

Enter EPEAT — the Electronic Product Environmental Assessment Tool. Managed by the Green Electronics Council, this voluntary certification system gathers information from manufacturers on environment-related traits of electronic goods, independently verifies them and passes the information along to prospective purchasers so they can make choices that fit their sustainability criteria. Currently available for more than 4,400 products — including computers, printers, TVs and monitors — EPEAT certification discourages manufacturers from using inputs such as cadmium, mercury, lead, hexavalent chromium, flame retardants and PVC, and encourages product design that makes for easy disassembly and use of reusable or recyclable parts.

Hundreds of corporations, governments, schools and other major procurers around the world have signed on since the program began in 2003, including the U.S. Government, Marriott, the University of California system, Kaiser Permanente and Deutsche Bank. But EPEAT is not just for the big buyers. Individual consumers can check the system's online registry to determine which products best fit their preference, too.

adopting policies that work toward hazardous chemical reduction.

UPSTREAM SOLUTIONS

Delegates to the conference from several African countries that have become a growing outlet for electronic waste were prominent in the call for reducing the use of toxics in the first place.

"If you solve a problem at the upstream stage — if it's designed in a proper way, if the hazardous components are replaced by less or non-hazardous ones — the problem downstream will be less," says Tadesse Amera, a steering committee member of IPEN, a global network focused on safer use of chemicals, who participated in the Geneva discussions. "We are not talking about waste. We are talking about the whole process. That was our argument, and we were accepted for that."

To eliminate certain chemicals, electronics companies need to know if and where they're using them in the first place. But modern supply chains have become so long and complex that many companies don't actually know which substances are in all the parts they use in their products.

"IF YOU SOLVE A PROBLEM AT THE UPSTREAM STAGE — IF IT'S DESIGNED IN A PROPER WAY, IF THE HAZARDOUS COMPONENTS ARE REPLACED BY LESS OR NON-HAZARDOUS ONES — THE PROBLEM DOWNSTREAM WILL BE LESS," —TADESSE AMERA

Ted Smith, who is coordinator of the International Campaign for Responsible Technology, has been talking with major companies such as Apple and Seagate to increase their access to such information. Seagate, he says, has come a long way.

"They've been able to get all their suppliers to disclose all of their chemicals, and they've got thousands of suppliers around the world. It's not an insignificant task," he says.

Modular electronics such as this smartphone can reduce e-waste burdens by making it possible to reuse still-functional components when a device goes down.

PHOTO COURTESY OF FAIRPHONE

NOT EASY

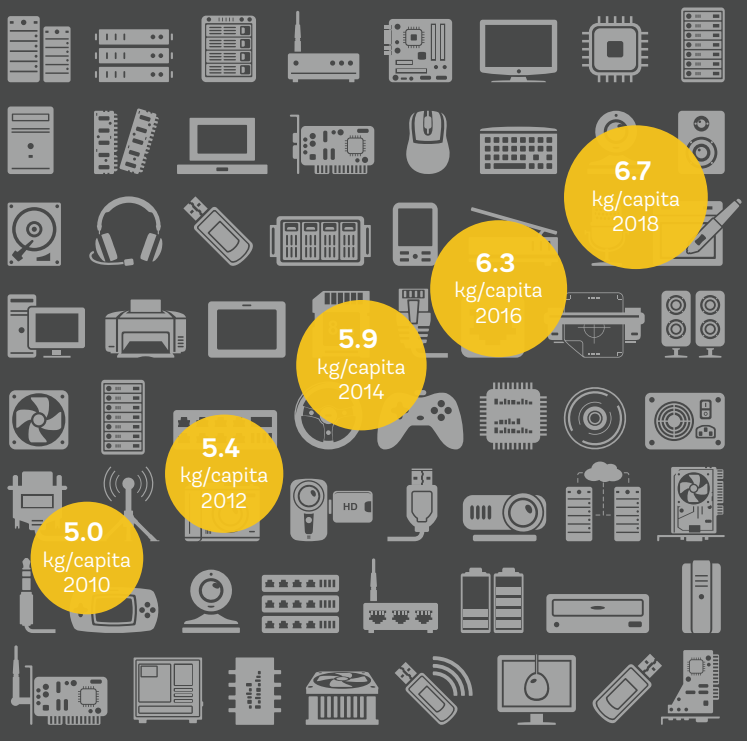
Eliminating a chemical from a product is not easy. A replacement substance — ideally, one that's safer — has to be found that can perform the same function as well or better. Reformulation may be necessary because the replacement may interact differently with the rest of the product.

Fortunately, the number of tools to help companies do this is also growing. GreenScreen gives companies like HP a way to identify hazardous chemicals and safer alternatives. Similar databases in Europe, such as the Substitution Support Portal, also help companies search for and evaluate alternatives to hazardous chemicals, as well as provide guidance on the process of chemical substitution.

"WHAT'S NEW IS GLOBAL COLLABORATION, STRONGER FOCUS ON PURCHASING, COLLABORATION AMONG ELECTRONICS COMPANIES REALLY STARTING TO DIG INTO THEIR SUPPLY CHAINS."
—JOEL TICKNER

GLOBAL E-WASTE PRODUCTION

The amount of e-waste generated per capita globally increased 26 percent between 2010 and 2016, and this number is projected to climb higher in coming years. The 45.7 million metric tons (50.4 million tons) of e-waste generated globally in 2016 is equivalent to the weight of more than 56 Golden Gate bridges.



Source: The Global E-waste Monitor 2014: Quantities, Flows and Resources

While HP is working to get PVC out of its power cables, it has taken on a number of other challenges as well, including eliminating halogenated substances. Apple, meanwhile, has eliminated its use of lead, reduced its use of brominated flame retardants and eliminated PVC from its power cords. It also has stopped using some solvents that are dangerous to workers during manufacturing, according to Joel Tickner, director of the Green Chemistry & Commerce Council, a project based at the University of Massachusetts Lowell.

"There's been a lot of writing about toxicity in the electronics supply chain. I think what's new is global collaboration, stronger focus on purchasing, collaboration among electronics companies really starting to dig into their supply chains," Tickner says. "That's what Apple and HP are doing."

LESS TO THROW AWAY

Despite efforts targeting specific chemicals, an enormous stream of electronic waste continues to enter communities in developing countries. And that waste stream only grows bigger and faster as electronics become cheaper (allowing more people to buy them) and as the industry plans obsolescence into its consumer products — encouraging people to buy a new phone every year, for example, and offering replacement products at prices equal to or cheaper than a repair when a computer or tablet is damaged.

"Until we have better global systems for electronics take-back, we have to assume that these are going to be put back into the environment somewhere at the end of their life," says Tickner.

While there is little sign of take-back systems becoming commonplace, Sarah O'Brien, director of the Clean Electronics Production Network, sees some hope in

PHOTO © ISTOCKPHOTO.COM/INGANIELSEN

The ready availability of cheap electronics and planned obsolescence point to a future filled with ever-growing heaps of e-waste. But recent advances in circular economy thinking, such as modular construction and closed-loop recycling, offer hope.

26
Percent increase in e-waste generated per person globally between 2010 and 2016

6.3
Kilograms of e-waste generated per person globally in 2016

45.7 million
Metric tons of e-waste generated globally in 2016 (equivalent to the weight of more than 56 Golden Gate Bridges)

Source: United Nations University

USB BY LEMON LIU FOR THE NOUN PROJECT

the area of reducing — or at least slowing the growth of — the overall waste stream. She points to the nascent modular phone as an example of innovative thinking that can mitigate this aspect of the electronics life cycle: If one piece breaks, you can repair or replace that part, rather than the whole phone, reducing discards and thus their adverse environmental and health impacts.

There are also efforts to turn things that would otherwise become e-trash into the raw materials for new products. Dell launched a closed-loop recycling program in 2014 that turns old plastics into new Dell products, for example. The program is focused on plastics, but the company is looking to expand the model.

As for HP, Mazurkiewicz says, "Ultimately, we want to make a fully edible computer. It sounds funny, but we want to get to the point where electronics fit very neatly into the circular economy — where maybe you mulch your computer at the end of the day, and grow materials that can be put into an HP 3-D printer."

Even though that might sound like science fiction, he says, "it's something we can achieve. But it's going to take time."

GLOBAL APPROACH

Much remains to be done, of course. The electronics industry innovates and grows at a pace that dwarfs efforts to phase out individual chemicals.

"It is an industry that's constantly churning, and where consumers are looking for more bells and whistles all the time," says O'Brien.

THE CONSENSUS SEEMS TO BE THAT THE INDUSTRY IS DOING MORE THAN EVER BEFORE, AND MOMENTUM IS GROWING.

Still, the consensus seems to be that the industry is doing more than ever before, and momentum is growing. Georg Steinberger, vice president of communications at Avnet — one of the world's biggest distributors of electronic parts — supports further efforts still, including some sort of

global standard regulating toxic chemicals in electronics.

"We would love to see global understanding on things like which hazardous substances should not be used," Steinberger says. "If a substance is dangerous, it's dangerous in any country. The electronics industry is not a clean industry. We are using lots of chemicals, and I think it's about time that we take some responsibility for the products we produce."

RACHEL CERNANSKY is a freelance journalist who writes about the environment, food, health and immigration for a variety of publications, including *Nature, Environmental Health Perspectives, Civil Eats, The Washington Post* and *The New York Times.*

MEGA PROBLEM, MICRO SOLUTION

OLD TVS, SMARTPHONES and other electronic waste too often end up in landfills — or in trash heaps in countries in the Global South, where noxious components hurt poor communities. When e-waste is recycled, it often ends up getting hauled over long distances to energy-intensive, unsightly industrial smelters.

Researchers at the University of New South Wales' Centre for Sustainable Materials Research and Technology (SMaRT) think they might have a better way. Led by UNSW materials scientist Veena Sahajwalla, they're looking into a new concept: Using mobile micro-factories to recycle e-waste.

The advantages? Cities and communities, SMaRT Centre researchers say, could use e-waste recycling technology at this smaller size more easily than they can industrial scale processors. Microfactories could be better than big smelters at minimizing loss of some of the valuable metals contained in e-waste. Local processing would cut down on the need to transport wastes long distances. And local facilities might bring local jobs to areas that desperately need them.

The UNSW team has been developing innovative technologies to safely make metal alloys from e-waste on a small scale and recently launched a facility to pilot-test the approach. If the technology develops as planned, urban municipalities and rural communities alike might one day set up their own micro-factories to transform waste from electronics into materials for manufacturing.

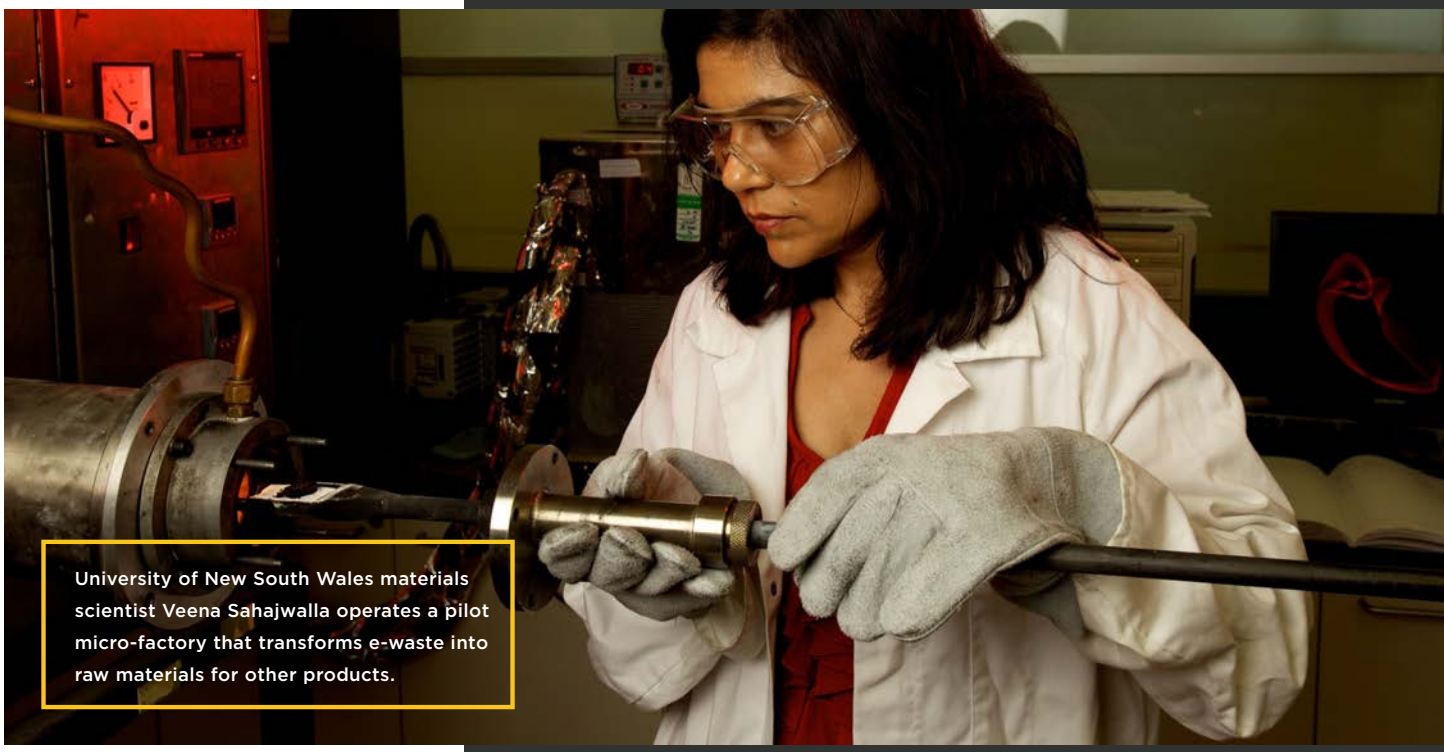


PHOTO BY PETER MORRIS

University of New South Wales materials scientist Veena Sahajwalla operates a pilot micro-factory that transforms e-waste into raw materials for other products.

PLASTIC WASTE ON SHORE © WATERFRAME / ALAMY STOCK PHOTO; PLASTIC IN OCEAN © ISTOCKPHOTO.COM/RICYCAREY

can we UNTRASH our OCEANS?

From drones to filters to artificial islands, innovators are working to reduce the threat plastics pose to marine ecosystems.

by ANJA KRIEGER

ORIGINALLY PUBLISHED:
FEBRUARY 2016

A few palm trees stand strong in the salty breeze. Located on the southern tip of the Pacific island chain of Hawaii, Kamilo Beach is an isolated stretch of black volcanic shoreline in the middle of nowhere. Just a few hundred yards from shore, humpback whales rise up from the depths, colorful fish fill the reefs and rare sea turtles swim in to nest on the beach.

But even in this remote place, garbage washes ashore each day. "We find a lot of toothbrushes and combs, plastic bottles and caps, over and over again," says Megan Lamson, a marine biologist working for a local non-governmental organization, the Hawai'i Wildlife Fund.

Old Hawaiian sayings have described the bay as a place where people went looking for loved ones lost at sea. "Historically that area has been kind of the catcher of things that are floating in the ocean," Lamson says. But over time, the composition of materials that wash ashore has changed dramatically. "Back in the day it was large pieces of heavy wood from other continents," she says, "now, unfortunately, it's a lot of plastic."

It's an all too familiar sight. Since the early 1970s, researchers have collected plastic from beaches and oceans around the globe. At a 9-mile (14-kilometer) stretch of coastline around the southern tip of the island alone, about 15 to 20 tons (14 to 18 metric tons) of trash wash up each year. "Here on Hawaiian beaches, we have debris from all around the North Pacific," Nikolai Maximenko, an oceanographer at the University of Hawaii at Manoa, explains. Some pieces come from Asia, others from the West Coast of North America, and, Maximenko adds, "of course we have local products, too."

GYRE TO GARBAGE PATCH

To understand how a remote place like Kamilo can get so swamped by massive amounts of trash, one must consider the hydrodynamics at play.

Hawaii is located in a huge circular system of ocean currents, the North Pacific Gyre. Within the gyre, trash can get trapped and circulate for years. One region between

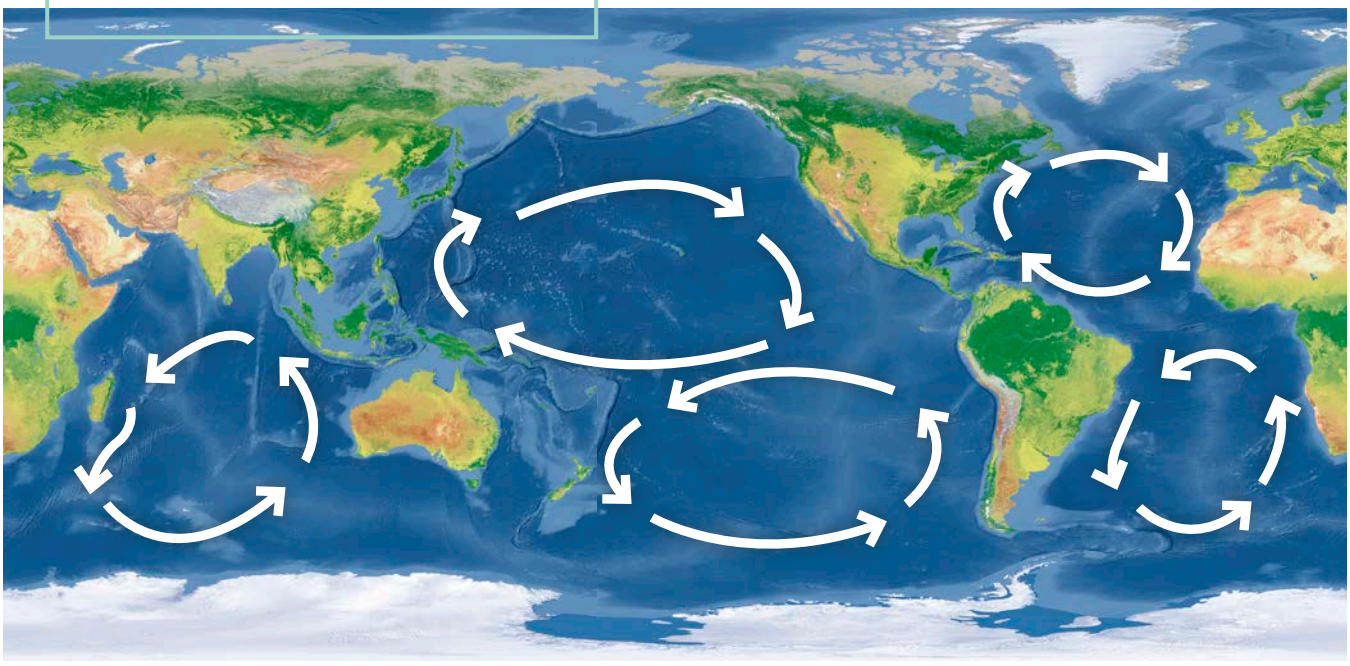
Piles of litter along Kamilo Beach in southern Hawaii represent just a fraction of the plastic trash — visible and invisible — inundating Earth's oceans each year.

PHOTO © HONOLULU CIVIL BEAT

WHY THIS MATTERS

According to the United Nations Environment Programme, an estimated 10 to 20 million metric tons (11 to 22 million tons) of plastic enter the ocean each year. Distributed by ocean currents, often broken into tinier and tinier bits, they alter ecosystems, injure and kill marine animals, and even make their way into seafood. With production expected to continue to increase, finding ways to stem this disruptive and deadly tide of plastics entering the ocean as well as to remove plastics already sullying our world's waters are arguably among the most urgent and important environmental issues we face today.

Five gyres — circular systems of ocean currents — concentrate plastics in marine debris "hot spots."



the islands and California contains such a high density of man-made debris that it has been nicknamed the Eastern Pacific Garbage Patch. When currents change, the garbage can wash back ashore — and so it is found on beaches like Kamilo.

At the International Pacific Research Center in Honolulu, Maximenko and his colleagues have taken major steps in understanding how marine debris travels the oceans' currents. He and his team have developed a computer simulation that can project the behavior of floating items at sea. By using drifter buoys and satellite data, the model indicates how trash accumulates in the oceans.

Most debris ends up in the five big subtropical ocean gyres located in the Pacific, Atlantic and Indian oceans, which rotate clockwise in the Northern Hemisphere and counterclockwise in the Southern. Water samples collected from these regions show elevated concentrations of plastic particles, and the evidence that the oceanic gyres are becoming marine debris hot spots continues to grow. According to new models by researchers from Australia, a sixth gyre might form in future decades — in the Arctic Barents Sea.

BACK FROM THE SEA

Each September, on International Coastal Cleanup day, hundreds of thousands of volunteers across the globe roam the shores to collect trash. The effort not only removes litter, but also generates data that can provide a glimpse of what the oceans might contain.

In 2015, nearly 800,000 participants collected over 18 million pounds (8.2 million kilograms) of trash in just one day. The top five most commonly found items were cigarette butts, food wrappers, bottle caps,

THERE'S NO LACK OF IMAGINATION WHEN IT COMES TO CONCEPTS TO RETRIEVE GARBAGE FROM THE SEA.

>18 Million
Pounds of plastic that volunteers collected on International Coastal Cleanup Day 2015

663
Number of species affected by ocean plastics, according to the Convention on Biological Diversity

100,000
Number of plastic fibers that can end up in wastewater from one washing machine load of synthetic clothing

Dutch inventor Boyan Slat (below) is one of many who have proposed novel — and sometimes controversial — technologies for removing plastics from the oceans.

PHOTOS COURTESY OF THE OCEAN CLEANUP

straws, stirrers and beverage bottles — common discards in today's consumer society. Collectors also found lawnmowers, light bulbs, wigs and even shopping carts.

Though many of these items are quickly discarded, they are made from a material that might last decades or even centuries.

The damage and suffering this causes for ocean life is severe. Plastics can be found in the stomachs of whales, fish and many other marine animals. Turtles suffocate when they confuse shopping bags with jellyfish, or drown when they get entangled in discarded nets. Seals get stuck in plastic rings from six-packs that slowly cut through their necks. In the middle of the Pacific, albatross chicks die, weakened from overconsumption of bottle caps and toys. The Convention on Biological Diversity counts 663 species affected by ocean plastics.

Another species that might be affected is the one that's responsible. In 2015, researchers sampled fish and shellfish being sold for human consumption in Indonesian and Californian markets. They found plastic and textile fibers in a quarter of the animals.

A GRAND PLAN

A solution is urgently needed. So why not just go and clean it up? There's no lack of imagination when it comes to concepts to retrieve

garbage from the sea. Designers and engineers have proposed marine drones and waterborne kites, even huge artificial drains for the gyres. A group of college students from London went so far as to promote the idea of creating biotechnological microorganisms to break up the plastics, and a Dutch architect wanted to turn the trash into a "Recycled Island" where people could settle sustainably. Despite the attention these concepts have gained, most of them have remained pretty 3-D renderings and — so far — unfulfilled ambitions.

Experts have tried to convey what a massive challenge it would be to clean up the ocean's trash. The National Atmospheric and Oceanic Administration has estimated it would take 68 ships an entire year to survey just 1 percent of the North Pacific. In another, more hypothetical calculation, ocean activist Charles Moore estimates that to clean all five garbage patches, 1,000 boats would need to filter the water 24 hours a day for 79 years, and that's only if the technology existed.

But Boyan Slat, a young Dutch inventor, has tried to challenge the skeptics. Just out of school, he presented his ambitious idea to filter the open ocean in 2012: Instead of sending out boats to go after the trash, he argued, why not take advantage of the forces provided by the rotating currents of the gyres?

If a filtering platform could be fixed to the seabed underneath the North Pacific garbage patch, one could get the trash out while the water flowed through it — and maybe even sell it for profit.

Slat's idea soon went viral and earned him a massive following, praise from around the world and millions of dollars in crowdfunding.

The project's feasibility, however, has been under critical scrutiny. Kim Martini and Miriam Goldstein, both ocean scientists and bloggers, warn that Slat's project could cause more harm than good by threatening delicate zooplankton and other animals living near the sea surface. The two also point out how difficult it would be to fix the structure to the seabed. They call Slat's current plans "under-engineered and likely to fail."

To many environmentalists, Slat's approach is flawed on a more fundamental level. They argue that by starting cleanup efforts when trash has already made it into the ocean diverts attention from the real solutions: reducing, reusing and recycling.

PLASTIC ISLANDS

For many decades, environmental organizations have tried to raise awareness of how anthropogenic debris affects marine life. But what finally sparked alarm among members of the public were reports of massive trash islands in the ocean, one reportedly "twice the size of Texas." The only problem? The islands don't really exist.

In fact, plastic is distributed quite widely over the vast oceans. The garbage patches are not solid islands, but regions where relatively high concentrations of small plastic pieces are dispersed in the upper part of the water column, hardly visible from above.

So how much is in there, really? Estimates on total plastic accumulation in the world's oceans have ranged from the thousands to hundreds of millions of tons. While some figures that have been cited by media are pure speculation, others rely on data that are decades old. "In the open ocean, the abundance, distribution, and temporal and spatial variability of plastic debris is poorly known," a team of experts concluded in 2010.

GLOBAL PLASTIC PRODUCTION ROSE FROM 1.7 MILLION METRIC TONS (1.9 MILLION TONS) IN 1950 TO CLOSE TO 299 MILLION METRIC TONS (330 MILLION TONS) IN 2013.

To produce more accurate estimates, scientists have carried out a number of studies in recent years, but figures still vary considerably. While it's possible that researchers will never come up with a precise figure, plastic pollution will most likely grow in scale with rising production.

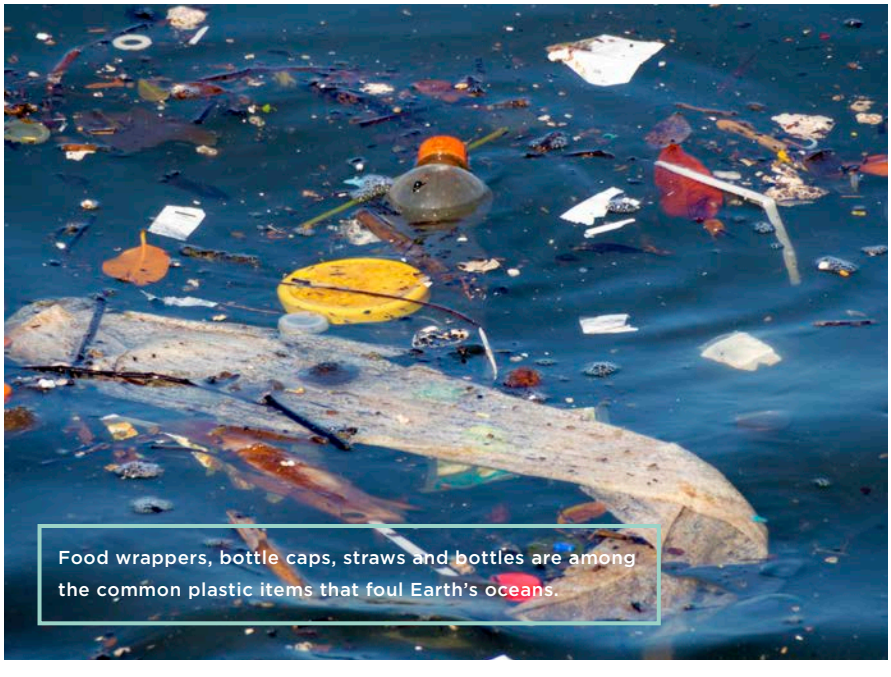
THE RISE OF PLASTICS

For a long time, the development of plastics was perceived as a big success story. And not without good reasons: Synthetic materials have advanced human civilization, wealth and comfort in uncountable ways.

In 1907, the Belgian-born chemist Leo Baekeland developed Bakelite, the first synthetic plastic polymer, branded "The Material of a Thousand Uses." Bakelite was moldable, heat-resistant and nonconductive, so it was soon used for a multitude of products, from electrical insulators and casings for telephones and radios to toys, poker chips and firearms.

In the years that followed, new synthetic materials started surfacing on the market.

Global plastic production rose from 1.7 million metric tons (1.9 million tons) in 1950 to close to 299 million metric tons (330 million tons) in 2013. And the numbers continue to grow. Today, it is hard to think of products that don't contain or aren't wrapped in plastics. Plastics make transportation more carbon efficient, keep food fresh to avoid wasting it and allow us to see through contact lenses — to just name a few benefits.



Food wrappers, bottle caps, straws and bottles are among the common plastic items that foul Earth's oceans.

But the negative effects on the environment have also been pervasive. A few decades of heavy use have spread plastics around the globe. Today, the remnants of our products can be found from the surface of oceans to deep-sea sediment, in lakes and rivers, even frozen in Arctic ice.

CATCHING THE TRASH

While efforts to find a viable method to clean existing ocean plastic are laudable, they won't stop more trash from entering the oceans, often through rivers and streams.

In Baltimore, Maryland, an inventor had an idea to catch the trash before it could reach the high seas. John Kellett worked near the city's heavily polluted harbor for many years — an "ugly piece of water" to most visitors, as he recalls.

Kellett realized that much of this plastic reaching the harbor came from the Jones Falls, a stream that accumulates trash as it winds through residential neighborhoods.

With local partners, Kellett began working to construct a device that would skim garbage from the surface of the river before it could float downstream: a solar- and wind-powered, trash-intercepting waterwheel.

No longer just an idea in Kellett's head, the Inner Harbor Water Wheel was deployed in 2014 and has become a prominent city landmark. Resembling a giant nautilus, it has orange booms that cover the 35-meter-wide (40-yard-wide) mouth of the Jones Falls and directs items floating on the surface to a conveyor belt, where they are collected before they can reach the harbor. The trash is then emptied into a large container under the waterwheel's white roof and hauled off.

Kellett estimates that around three-quarters of the trash that would have floated into the inner Baltimore harbor is now being caught instead.

"Its footprint is tiny, its reach is huge," deep-sea biologist Andrew David Thaler wrote about the waterwheel, and he is not the only marine scientist who has praised Kellett's attempts to clean up closer to the source.

So will waterwheels be a familiar sight at most river mouths one day? Kellett hopes this won't have to be the case. "We find that a small river is a challenging place to try to clean the trash out of," he admits. Although he has received a number of requests to deploy his technology in other places around the world, and he sees good potential to scale it up for midsize rivers and harbors, his ultimate goal is to put the waterwheel out of work. As he points out, if there were better education, legislation and technology, the trash might not show up in the rivers and travel to the ocean in the first place.

FROM TOOTHPASTES AND DEODORANTS TO SHOWER GELS, EYE SHADOW AND SUNSCREEN, NUMEROUS BEAUTY PRODUCTS CONTAIN TINY PLASTIC PARTICLES.

NEW CHALLENGE: MICROPLASTICS

At the Wuppertal wastewater treatment plant in Germany, foggy clouds hang low on the green hills around large pools. In a noisy hall, big metal rakes work hard to hold back the

HOW BIG OF A PROBLEM IS PLASTIC POLLUTION?

17 PERCENT OF OCEAN PLASTIC ENDS UP ON BEACHES

17 PERCENT OF OCEAN PLASTIC ENDS UP FLOATING ON OR JUST BELOW THE SURFACE

66 PERCENT OF OCEAN PLASTIC ENDS UP ON THE SEAFLOOR

PLASTIC MAKES UP **80 PERCENT** OF LITTER FOUND IN THE OCEANS TODAY

15 MILLION METRIC TONS ESTIMATED AMOUNT OF PLASTIC ENTERING THE WORLD'S OCEANS EACH YEAR

BY WEIGHT, THAT'S EQUIVALENT TO DUMPING MORE THAN **10 MILLION MIDSIZE CARS** INTO THE OCEAN ANNUALLY

40 PERCENT INCREASE IN THE NUMBER OF MARINE SPECIES HARMED BY PLASTICS BETWEEN 1997 AND 2012

US **$75 BILLION** NATURAL CAPITAL COSTS OF PLASTIC USED ACROSS THE GLOBAL CONSUMER GOODS INDUSTRY

ONE-THIRD OF THIS COST IS ASSOCIATED WITH PLASTIC PRODUCTION

US **$13 BILLION** DAMAGE TO GLOBAL MARINE ECOSYSTEMS ANNUALLY, INCLUDING FINANCIAL LOSSES SUCH AS THOSE INCURRED BY FISHERIES AND LOST TOURISM

To date, the Inner Harbor Water Wheel in Baltimore, Maryland, has collected more than 350 tons (320 metric tons) of garbage.

PHOTO BY DAVID STUCK / BALTIMORE JEWISH TIMES

solid trash that the wastewater carries with it, from wet wipes, condoms and toilet paper to wood and the occasional stone.

Outside, the water flows into large filtering pools, measuring 20 to 30 meters (70 to 100 feet) in diameter. There, everything heavier than water is separated mechanically. Only some Q-tips are light enough to escape. The water is then directed into bubbling pools, where bacteria digest all they can.

"Our microorganisms have a life span of around 10 days," explains Volker Erbe, senior vice president for technology at Wupperverband, the entity that takes care of water management around the river Wupper and runs the Wuppertal wastewater treatment plant. Plastics, however, are not on their menu, he says. Which is unfortunate, because there is a new challenge wastewater treatment plants have to deal with — and it's almost invisible.

Micro- and nanoplastics are the new category of plastic litter that even facilities in the most developed countries are not yet equipped for. And so, though the water may look clean, it really isn't.

The source can be inspected in many bathrooms around the world. From toothpastes and deodorants to shower gels, eye shadow and sunscreen, numerous beauty products contain tiny plastic particles, a 2015 U.N. Environment Programme report reveals. They deliver active ingredients, exfoliate, regulate viscosity and fulfill numerous other functions. And this is not new: Producers of cosmetics and cleaning agents have been adding plastics to their formulas for decades.

Some products are made up of 90 percent of these tiny plastic grains. They are so small their size is described in micrometers, which are a thousandth of a millimeter. For comparison: A human hair is around 100 micrometers thick. Some producers even go tinier and add nanoplastics, which are in the range of millionths of millimeters. To also put this into perspective: Human DNA is 2.5 nanometers in diameter.

How many of these particles reach rivers and streams, and eventually the ocean, is still unclear.

At the Alfred Wegener Institute for Polar and Marine Research in northern Germany, a research team under microbiologist Gunnar Gerdts has conducted a pilot study to find out how much plastic escapes wastewater treatment plants. "I expected that we wouldn't find very much, because nanomaterials are said to be held back pretty well by the sewage sludge," explains Gerdts, "but what we actually found was that wastewater treatment plants do emit microplastics into the rivers in substantial ways." He notes that the amounts his team found in samples from different facilities varied greatly, so more research is needed to understand the scope of the issue.

The impacts of the tiny particles and fibers on marine animals are still under investigation. For some species, such as mussels, lab experiments have shown adverse health effects such as inflammation. And there are other risks: Plastics can contain problematic additives such as bisphenol A, and microbeads show a tendency to attract persistent organic pollutants such as DDT from the water around them. That could result in quite a cocktail accumulating in animals up the food chain.

Micro- and nanoplastics are particles and not uniformly distributed, so measuring their concentration is a difficult process, unlike pharmaceuticals, which dissolve in water and are therefore present in every probe. To not only detect micro- and nanoplastics, but hold them back completely in a wastewater treatment plant, requires an additional stage of cleaning, which comes at a cost that is ultimately passed down to consumers.

"The moment of truth is out there when wastewater treatment plants decide that it's a priority for them not to let go of microplastics," says Lars Grønbæk, a process engineer working for the Danish wastewater purification company KD. Grønbæk is a specialist in membranes that can remove tiny particles from water using a principle similar to a coffee filter.

It's "not new rocket technology," Grønbæk says. His company's flat sheet membranes are

already capable of filtering down to a size of a tenth of a micron, he says, and they could be further refined. But at the moment, only a small fraction of wastewater treatment plants are deploying membrane filters, says Grønbæk. As long as there is no regulation requiring them to do so, this is unlikely to change.

Volker Erbe of Wupperverband believes there is a better way to tackle the issue: "We need to think about not using materials that can become a problem for the environment, instead of trying to remove them with expensive technologies from our wastewater."

It seems that the first steps in this direction are being taken. In late 2015, U.S. president Barack Obama signed the Microbead-Free Waters Act, which bans tiny plastics in cosmetics and other products.

FIBERS FROM WASHERS

Another, equally unexpected source of microplastic pollution seems further away from a solution: the plastic footprint of washing machines. Much of the clothing produced today is made out of synthetic materials. Each time these clothes are washed, thousands of tiny plastic fibers can leak from the machine into the wastewater.

Dick Vethaak, professor of ecotoxicology at the VU University of Amsterdam, observed that more than 100,000 of those fibers can escape in just one wash cycle. This is many times more than what previous studies had reported.

WITH A GLOBAL MARKET THAT SHIPS NOT ONLY PRODUCTS, BUT ALSO WASTE, THE PLASTIC PROBLEM IS A TRULY GLOBAL ONE.

While most people won't ever get to see the tiny fibers washing down their drains, a chance encounter had Blair Jollimore quickly looking for a solution. A mechanical engineer by day, Jollimore lives far from city drainage systems in a remote part of eastern Canada's Nova Scotia. His house requires its own septic system.

One day after moving into his new home, Jollimore recalls, the basement flooded with wastewater. The family soon found out what the problem was, says Jollimore: "a gray mat inside the septic tank" that had blocked the pipe.

He quickly realized that most of what had clogged the system was lint from the water flowing out of his washing machine. So he used a water filter housing and a stainless steel strainer to construct a filtering device that he inserted between the washer and the drain. The septic tank didn't overflow again.

What was initially just a solution to Jollimore's own problem turned into a small business on the side, and Jollimore now

HOW CAN WE SOLVE THE OCEAN PLASTICS PROBLEM?

AS THIS PIECE POINTS OUT, innovators are having a heyday imagining devices for removing plastics from the ocean, from giant vacuum cleaners to drones to microbial armies. With millions of tons of plastics already in the ocean, many people look to cleanup as an important part of the picture. However, experts point out that the challenge of removing plastics already in the ocean is huge. With annual production expected to top 600 million metric tons (660 million tons) within two decades, preventing plastics from entering the ocean in the first place is critical. Six strategies are catching producers' and policy-makers' eyes:

1 Reduce the use of plastics in the first place by educating consumers, creatively designing products and packaging to reduce the amount of plastic needed, including the environmental costs in pricing plastics, and prohibiting or providing disincentives for use (e.g., laws prohibiting or regulating the use of plastic bag, plastic bottles or microbeads).

2 Encourage reuse by designing and marketing plastic products for durable rather than disposable uses and changing the mindset that equates plastic with single use.

3 Boost recycling by having manufacturers be responsible for the fate of the plastics they make or use and providing consumers with incentives for recycling.

4 Improve solid waste and wastewater management systems so they release fewer plastics into the air and water.

5 Trap plastics before they reach the ocean.

6 Support research to develop plastics that degrade into harmless substances in the environment.

sells around 50 of his Lint LUV-R filters per month. Together with researchers working on marine debris, he is looking into options for a wider market application of his washing machine lint filter.

If such a filter came standard on washing machines, it would be a quick win for the environment. But experts say designing one that is both cost effective and convenient to build into commercial washing machines will be a huge technological challenge. Producing these filters would be expensive and they could easily clog, making it impractical for consumer use.

And there seems to be little incentive, because neither consumers nor legislators have called to further develop and standardize the technology.

Even if it did become standard, it would only solve a part of the problem. "The same fibers, they also enter the water by air pollution," Vethaak points out. "The real problem is that the textiles are not environmentally friendly."

EVERYTHING FALLS APART

The biggest source of microplastics, however, is larger items breaking down. Every piece of plastic that makes it to the oceans falls apart with time. Ultraviolet light and the force of the waves degrade fishnets, plastic bags, bottles, caps and toothbrushes into smaller and smaller pieces.

These resulting particles are likely to be the major source of microplastics found in the environment, dwarfing the amount coming from cosmetic products or textiles, a 2015 study by the Federal Environment Agency of Germany suggests.

Tackling the influx of bigger items into the ocean will therefore be key to eventually reducing microplastic pollution.

Some emerging economies are growing so fast that their waste management systems can't keep up, and so their contribution to marine debris is enormous. If just five countries — China, Indonesia, Vietnam, Thailand and the Philippines — improved their recycling and waste disposal systems, they could "cut global inputs by almost half," conclude the authors of a recent study by the Ocean Conservancy.

Though this won't stop plastic pollution entirely, it could buy us "time to rethink packaging more broadly and reduce the flow of plastic altogether," the authors explain in the *Guardian*.

Europe and North America may be better equipped to deal with their waste, but they also consume five times as much plastic per person annually as people in Asia, according to the Worldwatch Institute. And many of these richer countries export a large portion of their plastic waste, much of it ending up in China. With a global market that ships not only products, but also waste, the plastic problem is a truly global one.

Without a doubt, technology will play its role. But there's a high chance that no matter how smart and creative the ideas to techno-fix the marine litter issue are, they just won't be enough. To really solve this problem, the elephant in the room has to remain in plain sight: a mindset that treats plastics — a material made to last for years — as a throwaway commodity. Redefining what kinds of plastic products we really need, and how to regulate, use and dispose of them, will be at the core of the answer. The three Rs remain valid: Reduce, reuse, recycle. The closer we can move from the gyres to the source to solve plastic pollution, the better off our future oceans will be.

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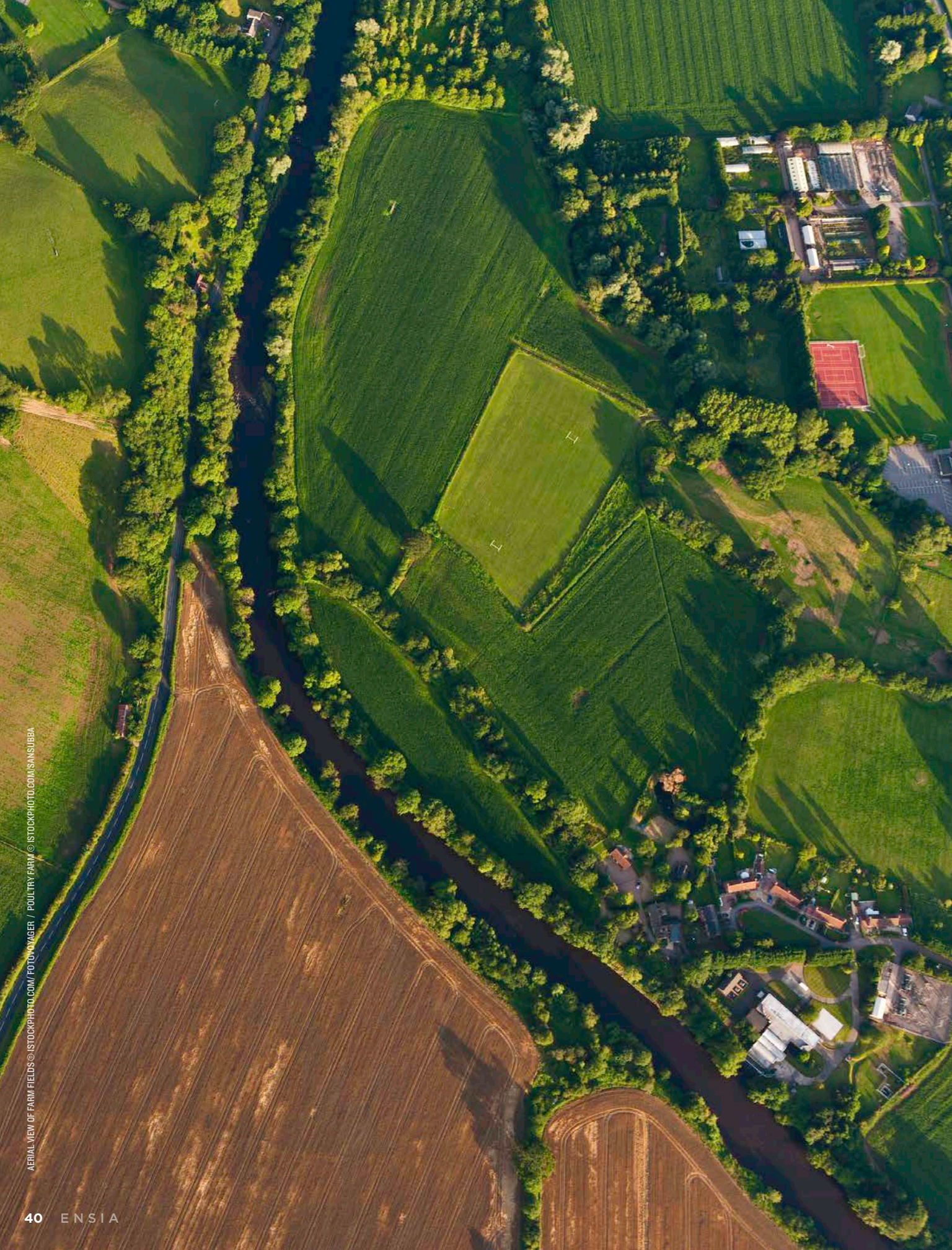
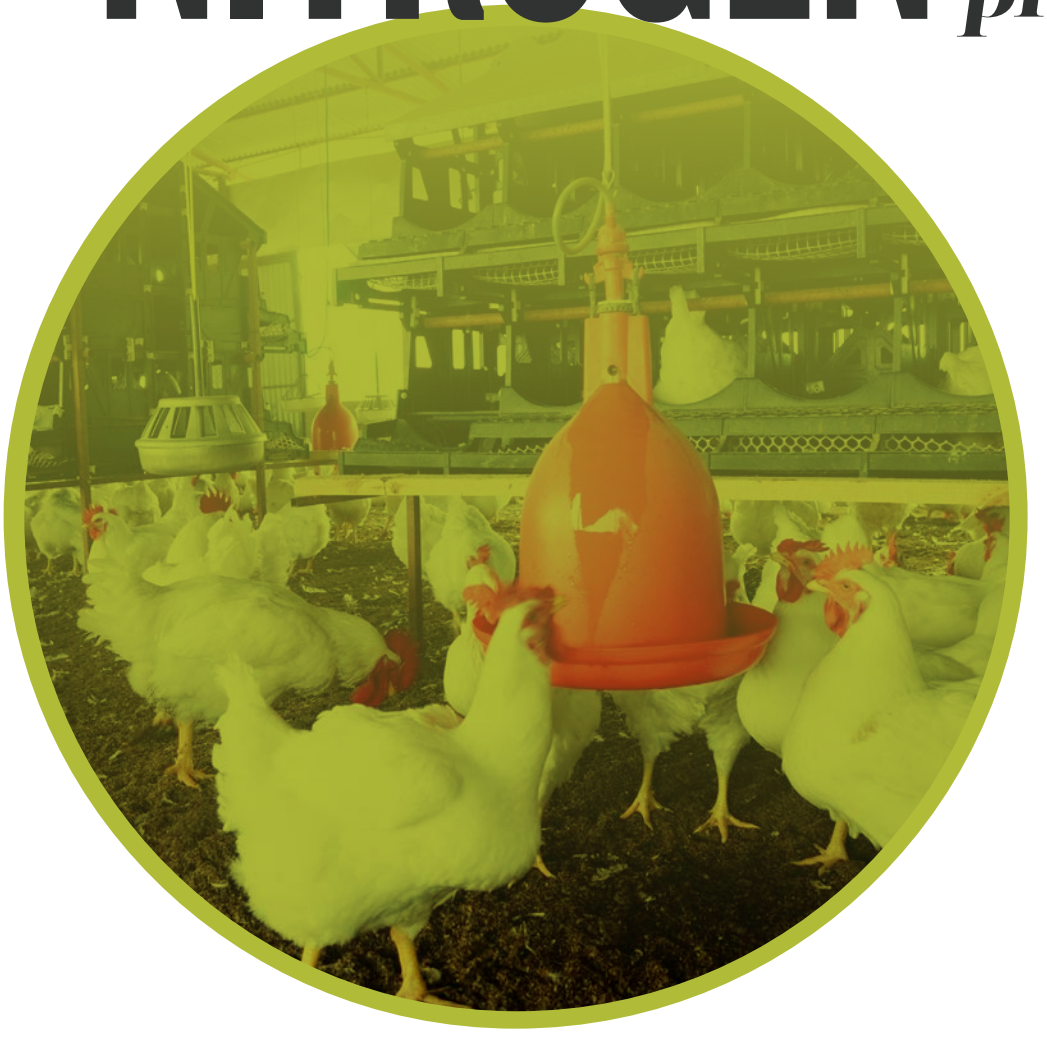
IMPACT

This story has been viewed more than 10,000 times online. It was republished or linked to by Vox, Corporate Knight, GreenBiz, Business Insider, Mother Earth News and AlterNet, and was one of Corporate Knights' top 10 most viewed articles in March 2016. The piece was the subject of more than 1,300 tweets, including a tweet by Blue Planet Society to 116,000 followers. More than 20 readers posted comments to the piece at ensia.com. Writer Anja Krieger notes the piece helped strengthen her future impact as well. "This was my first long-read feature article in English," she says. "It was a great opportunity to share and discuss what I'd been researching and writing about in German for years with a wider and much more international audience."



AERIAL VIEW OF FARM FIELDS © ISTOCKPHOTO.COM/ FOTOVOYAGER / POULTRY FARM © ISTOCKPHOTO.COM/SANSUBBA

putting NITROGEN *in its place*



In the process of producing food, we've inadvertently filled our planet with toxic forms of a life-giving nutrient. But scientists say we can improve this picture.

by ELIZABETH GROSSMAN

ORIGINALLY PUBLISHED:
MARCH 2016

Coastal dead zones, global warming, excess algae blooms, acid rain, ocean acidification, smog, impaired drinking water quality, an expanding ozone hole and biodiversity loss. Seemingly diverse problems, but a common thread connects them: human disruption of how a single chemical element, nitrogen, interacts with the environment.

Nitrogen is absolutely crucial to life — an indispensable ingredient of DNA, proteins and essentially all living tissue — yet it also can choke the life out of aquatic ecosystems, destroy trees and sicken people when it shows up in excess at the wrong place, at the wrong time, in the wrong form. And over this past century, people have released so much of this type of nitrogen, known as reactive nitrogen, that scientists say we've passed the limit of what the planet can safely handle.

The result of releasing so much nitrogen to the environment — through excessive and inefficient fertilizer use, agriculture-related nitrogen emissions and nutrient-laden wastewater, along with fossil fuel and biomass burning — is this slew of adverse environmental impacts. These impacts are occurring worldwide and are exacerbated by warming temperatures. Though the nitrogen problem gets far less press, we've now upset the naturally occurring balance of nitrogen even more than that of carbon.

While many things contribute to the problem — including energy use, urban runoff and sewage — agriculture is the largest source of environmentally damaging nitrogen. According to scientists studying this problem, approximately 80 percent of the nitrogen currently used in agriculture (primarily synthetic and other fertilizers, like manure) is lost to the environment at some point in the food supply chain. These losses occur on farms and in food production, sales, distribution, preparation and consumption. Or, as University of Virginia professor of environmental sciences Jim Galloway puts it, losses occur "all along the way from the field and bare soil to the sewage plant."

A big part of the problem, according to Jan Willem Erisman, University of Amsterdam professor of integrated nitrogen studies and CEO of the Louis Bolk Institute in the Netherlands, is that "people don't connect it to food and food production." In fact, in the U.S., European Union, Japan and likely China and elsewhere, food accounts for more than 75 percent of the average person's nitrogen footprint (individual contribution to nitrogen pollution), according to University of New Hampshire natural resources and environmental studies Ph.D. candidate Allison Leach, who is among the scientists working on the Nitrogen Footprint, a project designed to raise awareness of the issue. And it turns out that meat and other top-of-the-food-chain animal products are among the biggest culprits in contributing to excess nitrogen in a form that can be damaging to the environment.

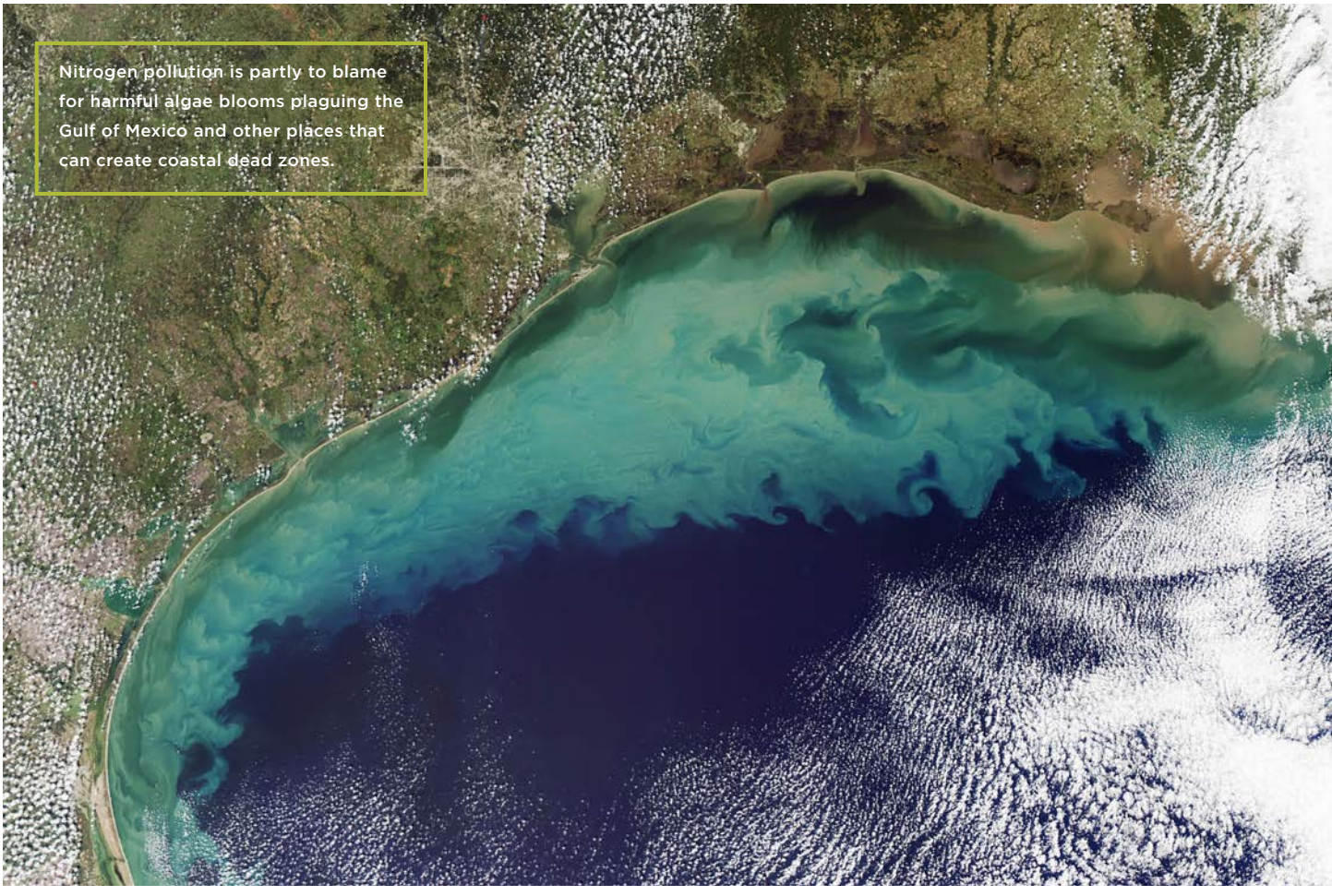
WHAT HAPPENS ON A FARM FIELD CAN SHOW UP AS ALGAE MANY MILES DOWNSTREAM AND OFFSHORE.

Such nitrogen pollution has contributed to harmful algae blooms plaguing Chesapeake Bay, the Great Lakes and the Gulf of Mexico; 2014's drinking water crisis in Toledo; and "blue baby syndrome," a potentially fatal oxygen depletion disorder that harms infants around the world — among other effects.

Part of the difficulty in making people aware of these connections is that they

WHY THIS MATTERS

Elizabeth Grossman's piece on excess nitrogen in the environment begins and ends with a recognition that the issue is not on the radar of most people the way, say, excess carbon in the atmosphere is. Too often, stories about the environment focus on retelling problems people already know a great deal about — climate change or biodiversity loss, for example — while leaving other critical issues underrepresented. This piece provides a refreshing break from that status quo as it brings to the fore a pollutant that contributes not only to climate change and biodiversity loss but to a litany of other environmental ills as well, yet has been relatively neglected by the mainstream media.



Nitrogen pollution is partly to blame for harmful algae blooms plaguing the Gulf of Mexico and other places that can create coastal dead zones.

IMAGE COURTESY OF JEFF SCHMALTZ, MODIS RAPID RESPONSE TEAM AT NASA GSFC

often show up as "disruptions in distant places," Erisman explains. What happens on a farm field can show up as algae many miles downstream and offshore, for example, or show up in groundwater that supplies well water to residents without direct connections to the source of contamination. Connecting water pollution or air pollution with food choices is even more of a stretch.

HOW WE GOT HERE

But before unraveling why a cheeseburger will expand your nitrogen footprint more than rice and beans, it helps to understand how we got to where we are now — with excess nitrogen creating dangerous river-choking algae blooms, fish-killing dead zones, unsafe drinking water and unhealthy levels of smog in cities worldwide — and how nitrogen works in the environment.

First, it's important to know that the type of nitrogen that makes up a large part of the Earth's atmosphere is not reactive but inert. For that nitrogen to be used by plants and other organisms, it must be converted into what's called a "fixed," or reactive, form. The main way this happens in nature is through microbes that live in soil and plant roots and convert inert nitrogen to ammonia, a reactive form that can be used in — and is essential to — plant growth. While plants need this reactive nitrogen to thrive, excessive amounts entering the environment contribute to a suite of adverse effects. And ammonia is not the only form of reactive nitrogen; others — nitrous oxide, nitrogen oxides, nitrate and nitrite — can also become serious air and water contaminants and prompt respiratory, cardiovascular and other diseases. Key to understanding this problem — and its solutions — is that this overload didn't happen on its own.

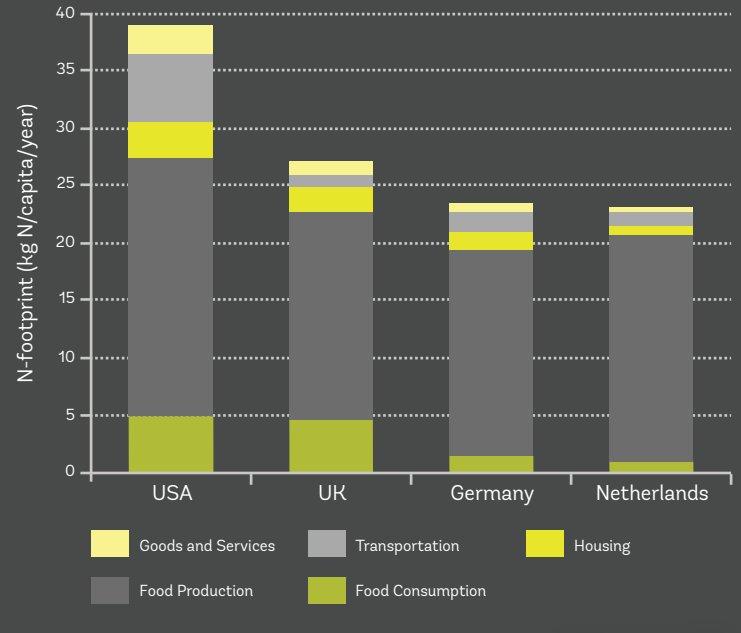
Without human intervention of some sort, the world's naturally occurring supply of reactive nitrogen essential to plant growth is relatively limited. So by the beginning of the 20th century it became

apparent that there wasn't going to be enough of this form of nitrogen available to produce the volume of food needed to adequately feed a growing population. This problem was solved by the invention of synthetic fertilizers that supply plants with nitrogen in a fixed form they can use. Agricultural productivity soared. But the use of these fertilizers has not been very efficient, resulting in the release of large amounts of reactive nitrogen into the environment. According to Galloway, Leach and colleagues, so much anthropogenic reactive nitrogen has been produced that by 2010, human activity was creating at least five times as much as were natural systems.

These releases, scientists have discovered, can last for decades. Not only is the nitrous oxide that comes off fertilized fields a potent greenhouse gas, but a recent study of fertilizer use in the U.S. Midwest shows that excess nitrogen can accumulate in soil and result in decades-long pollution of surface and groundwater — including drinking water wells — with unsafe levels of nitrates that can lead, for example, to blue baby syndrome. Even if fertilizer use were stopped today, the nitrogen pollution would persist for years, writes study co-author Nandita Basu, University of Waterloo professor of earth and environmental sciences and civil and environmental engineering.

COMPARING NITROGEN FOOTPRINTS

Average personal nitrogen footprints in the United States are larger than those in the United Kingdom, Germany and the Netherlands because of higher per capita meat consumption and transportation energy use, lower fuel efficiency, and less-advanced sewage treatment.



Graphic courtesy of WWF

MEAT AND WASTE

About three-quarters of reactive nitrogen comes from agriculture. And an enormous amount of what we grow — from about one-third of the world's arable land, according to the Food and Agriculture Organization of the United Nations — ends up as livestock feed.

"The choice of meat or plant is very important," says Erisman. "Plants' nutrient-use efficiency is much higher than that of meat." Plus, to produce meat you must first grow grain or other forage — whatever plant products the animals eat. As a result, many more times the amount of nitrogen is involved in producing meat than plant-based food. This means that stocking the fridge with meat plays a big role in contributing to the global reactive nitrogen burden.

"We're growing meat," says Tom Fisher, professor at the University of Maryland's Center for Environmental Science's Horn Point Laboratory. "Much of the agriculture on the Delmarva Peninsula, where I am, is growing grain for the poultry industry. … People have chosen to eat meat, and they've created a market for chickens, and the poultry industry created a market for grain."

And it takes even more feed to produce beef and pork than it does chicken. The exact numbers vary depending on how resource use is estimated — but according to Erisman and other researchers, it typically takes 6 kilograms (about 13 pounds) of reactive nitrogen to produce 1 kilogram (about 2 pounds) of beef, about 3 kilograms (almost 7 pounds) for 1 kilogram of pork and about 2.5 kilograms (5.5 pounds) of nitrogen for 1 kilogram of chicken. Erisman also points out that, due to lopsided food choices, about 20 percent of the world's population consumes about 80 percent of the fertilizer.

"When it comes to food choices, frequency and portion size of animal foods and the mix of animal products can have a big effect on the end [nitrogen] footprint," says Eric Davidson, professor and

director of the Appalachian Laboratory at University of Maryland's Center for Environmental Science.

A look at the N-Print project's Nitrogen Footprint Calculator illustrates this well. According to its figures, the average U.S. nitrogen footprint for food — an estimate of all of the nitrogen involved in this food's life cycle, production through consumption — is 61 pounds (28 kilograms) per year. A vegetarian who eats only two eggs a week and limits dairy products — including cheese — to no more than 15 one-cup servings a week reduces that load to 24 pounds (11 kilograms). For non-vegetarians, if meat consumption is limited to eating only poultry (no beef or pork) four times a week (based on 7-ounce [200-gram] servings), the nitrogen footprint would decrease by about one-third even with no other changes to "average" U.S. eating patterns (eating five eggs and 26 servings of dairy and cheese a week).

STOCKING THE FRIDGE WITH MEAT PLAYS A BIG ROLE IN CONTRIBUTING TO THE GLOBAL REACTIVE NITROGEN BURDEN.

While raising livestock and poultry has a particularly large nitrogen footprint, another load comes when food is processed. "There's a lot of waste in the food processing step," Erisman explains, and food wasted means nitrogen lost because that food is not being consumed. Still more nitrogen is ultimately lost to the environment through food waste in retail and by consumers. Given that about one-third of the food produced globally each year is wasted or lost, this is significant since replacing that food means using and releasing still more reactive nitrogen. One recent estimate puts the amount of nitrogen lost to the environment because of global consumer food waste at 2.7 million metric tons (2.9 million tons) per year.

So along with increasing nitrogen-use efficiency in farming, reducing fossil fuel use and curbing urban runoff, changing

About three-quarters of reactive nitrogen in the environment comes from growing crops to feed people and livestock.

PHOTO © ISTOCKPHOTO.COM/FOTOKOSTIC

food choices and curtailing food waste can contribute significantly to easing the global reactive nitrogen burden.

LEAVING THE FARM

Still, "the single largest source [of nitrogen pollution] is from cropland," says Adam Chambers, leader of energy and environmental markets with the U.S. Department of Agriculture's Natural Resources Conservation Service. When synthetic fertilizer or manure is applied to agricultural soil but not fully taken up by plants it will enter the environment, either by volatilizing or washing off fields, he explains: When it evaporates, this nitrogen typically enters the atmosphere as nitrous oxide, a potent greenhouse gas; when more fertilizer is applied than plants can use, excess nitrogen runs off with rain and irrigation water.

2.7 million
Metric tons of nitrogen lost to the environment because of global consumer food waste

6
Kilograms of reactive nitrogen used to produce 1 kilogram of beef

2.5
Kilograms of reactive nitrogen used to produce 1 kilogram of chicken

75
Percent of the average person's nitrogen footprint attributed to food in the U.S.

Certain farming practices and methods exacerbate this runoff, says Valerie Dantoin, who teaches sustainable agriculture at Northeast Wisconsin Technical College and, with her husband, Rick Adamski, runs an organic dairy farm. When fields get too heavily tilled, soil microbes that fix nitrogen are destroyed, she explains. "The solution is perennial roots and leaves in cover crops" along with building up soil's organic matter, she says, which "encourages the microbial life of the soil." This results in slow releases of nitrogen to plants, which is more effective and efficient than synthetic fertilizers that can be easily washed away.

"THE SINGLE LARGEST SOURCE [OF NITROGEN POLLUTION] IS FROM CROPLAND." —ADAM CHAMBERS

Efficient nitrogen use — key to what's sometimes called "precision agriculture" — reduces nitrous oxide emissions, Chambers says, and also runoff to streams and ultimately to places like Chesapeake Bay, the Great Lakes and the Gulf of Mexico. Timing of fertilizer application is also key to reducing runoff. Rainstorms play a big role in this, Chambers explains. If it "rains 2 inches [5 centimeters] one night and plants weren't ready to take up the nitrogen, you can get a huge spike in emissions." Even two such events in a year can make a difference, prompting big runoffs of nitrogen — some of which also evaporates, he says.

"In our region, 70 percent of our agricultural runoff occurs in 17 days of the year," Dantoin says — during big spring rains, which typically happen at the time of year just before or just after the annual crop has been planted, when plants are not yet up and making full use of the nitrogen. The rains also come in the fall, when crops are no longer using nitrogen. To correct the problem, she says, "all we have to do is fix those 17 days." This would mean applying fertilizer at the precise time plants can make the best use of it and — to avoid excess lingering in the soil to be washed off with those big rains — not applying any more than plants can use.

Some farmers, like Dantoin and those Fisher is working with in Maryland as part of a watershed-scale experiment to reduce nutrient runoff to Chesapeake Bay, are planting cover crops and setting up drainage systems that absorb water rather than let it careen off the land. Others are using products designed to help plants absorb nitrogen fertilizers more efficiently.

These include products that work with fertilizer in ways that stabilize or inhibit loss of nitrogen to the environment, explains Greg Schwab, director of agronomy at Koch Agronomic Services, one company in this market. "It helps farmers use fertilizer more efficiently," he says — efficiency that can ultimately improve crop yield. Using fertilizer effectively and applying just the right amount at the right time is key, say Davidson and others, because such practices eliminate financially and environmentally costly waste and help crops.

There are now so many such nitrogen-efficiency products on the market that the Environmental Defense Fund has launched a program called NutrientStar to help farmers compare nitrogen management tools. Choosing correctly is important because "nitrogen is hard to manage," says Steve Sibulkin, CEO of a company called Agronomic Technology Corp that makes a nitrogen data management tool, Adapt-N. "Lots of things affect how nitrogen behaves: crops, soil type, weather," he says, so what works for one farm — or even a particular field on a single farm — might not work well elsewhere.

POLICY PERSPECTIVE

While there are enforceable limits on many nitrogen-based pollutants in the U.S. — including under the Clean Air Act and Clean Water Act — efforts to decrease nitrogen releases do not currently include specific targets for comprehensive reductions.

U.S. and European efforts to reduce nitrous oxide emissions from fossil fuel burning, however, have been remarkably effective. These measures include clean-burning engines and regulations requiring technology to reduce industrial smokestack emissions. They also include government and company policies on greenhouse gas emission reductions — some mandatory, some voluntary — that at the same time reduce harmful nitrogen releases. And with the growing recognition of agriculture's contribution to nitrogen-based air pollutants, policies are beginning to focus on these as well, but specific measures in the U.S. vary depending on farm size and location.

Policies in the Netherlands and Denmark that have effectively pushed farmers to implement measures that reduce emissions from manure — through agricultural waste containment and fertilizer application techniques — have succeeded in reducing ammonia releases by 70 percent in the Netherlands and 40 percent in Denmark, helping to significantly reduce overall reactive nitrogen releases. While there is nothing comparable in the U.S., the U.S. Department of Agriculture and Environmental Protection Agency — and some individual states, including California — have programs to help states and farmers reduce nitrogen emissions and runoff. But right now, these efforts don't yet take what might be described as a holistic approach to nitrogen releases throughout agriculture and food production.

"Denmark and the Netherlands are way ahead of the others in taking measures on nitrogen," says Erisman, but Germany, Austria, France and Italy are beginning to follow this example. Public perception of the problem, he says, is still very low, though.

"We need solutions on both ends" — at the farm scale but also on the consumer end — says Leach. "It's so critically important to talk to all the stakeholders in this, not just the producers but also the consumers," says Galloway. But one way or another, the problem "is caused by humans, by the growing of food and disposal of waste," says Fisher. Raising awareness of this issue is an important step in getting a grip on nitrogen footprints. Something to think about, perhaps, next time you contemplate a veggie versus a beef burger.

IMPACT

This story was republished at Vox, GreenBiz, Business Insider and Alternet.


ALTERNET

ENVIRONMENT

We've Changed a Life-Giving Nutrient Into a Deadly Pollutant—Can We Change It Back?

In the process of producing food, we've inadvertently filled our planet with toxic forms of nitrogen.

By Elizabeth Grossman / Ensia | April 6, 2016

53 COMMENTS

Coastal dead zones, global warming, excess algae blooms, acid rain, ocean acidification, smog, impaired drinking water quality, an expanding ozone hole and biodiversity loss. Seemingly diverse problems, but a common thread connects them: human

ELIZABETH GROSSMAN is an independent journalist specializing in environmental and science issues. The author of *High Tech Trash* and other books, her work has appeared in publications including National Geographic News and the *Washington Post*.

WRITER UPDATE: *Whether it's nitrogen runoff into water from agriculture or municipal sewer systems, or nitrogen emitted through fossil fuel burning, this pollutant continues to be very much in the news.*

A new California Nitrogen Assessment released in 2016 by the University of California, Davis, shows that agriculture is the state's largest source of nitrogen. According to the report, about half the nitrogen applied to crops is lost to the environment, and leaching of nitrogen from cropland is the biggest source of nitrogen to California's groundwater. At the same time, fossil fuel burning is the major source of nitrogen to California's atmosphere. While California is a major source of nitrogen pollution, the state and others are working to address this problem. In September 2016, the U.S. Environmental Protection Agency announced new policies aimed at curbing pollutants that include nitrogen oxides. The EPA "Cross-State Air Pollution Rule" is designed to reduce power plant emissions of nitrogen oxides across 22 states. The climate change legislation signed by California Governor Jerry Brown also aims to reduce nitrogen oxides along with greenhouse gases. Meanwhile, on the East Coast, a community in Massachusetts is working to address nitrogen emissions via septic and sewer systems, while some experts are concerned about how changes in regulations there may affect efforts to curtail Chesapeake Bay pollution. — ELIZABETH GROSSMAN

PHOTOS BY JEAN POLFUS

NATIVE KNOWLEDGE meets science-based CONSERVATION

From Canada's Far North to Australia, researchers and indigenous people pursue a more respectful relationship.

by **BEN GOLDFARB**

ORIGINALLY PUBLISHED:
MAY 2016

WHY THIS MATTERS

In this story William Housty, a member of British Columbia's Heiltsuk First Nation and director of the science and conservation program Coastwatch, says, "The hardest thing is to sit in a room with scientists who think they've discovered something, but their scientific discovery just confirms what our oral histories have talked about forever." When scientists fail to consider traditional knowledge, they overlook what could be centuries of valuable information. Beyond that, ignoring the experience of indigenous people is at best hubristic and at worst racist — two words better left in previous centuries.

In the rugged Sahtú Region of Canada's Northwest Territories, a district so remote that in winter only a single treacherous ice road connects it to the outside world, life revolves around caribou. For millennia, the Dene people lived as nomads, tracking vast herds across the Sahtú and harvesting the itinerant animals for their meat, skin and bones. Although the region's indigenous people today reside in villages, subsistence hunting remains central to diet and culture. The Dene language contains phrases for such concepts as "we grew up with caribou blood" and "we are people with caribou."

That intimate relationship did not always coexist comfortably with empirical science. Wildlife biologists had long studied caribou by swooping down in helicopters, netting them and affixing them with radio collars, a process that some Dene saw as disrespectful to creatures they considered kin. In September 2012, the Sahtú Renewable Resource Councils passed resolutions recommending that all wildlife research involve local people and respect indigenous values. Biologists could still collar the caribou, but they now had a directive to pursue more respectful, noninvasive methods as well.

The task of developing new techniques fell to a team of scientists that included Jean Polfus, a postdoctoral fellow at the University of Manitoba Natural Resources Institute. Polfus' introduction to the Northwest Territories wasn't an easy one — "it was completely dark, it was cold and a lot of the meetings happened in Dene language," she recalls — but, over the course of many conversations with community leaders, she and her local collaborators concocted a visionary project: They would study caribou populations using DNA extracted from scat. Dene hunters and trappers, who regularly cross paths with the herds during their travels on snowmobile, would collect droppings — with each sample that Polfus received earning its finder a C$25 gasoline gift card. "It's a lot cheaper per sample than collaring caribou," Polfus says.

NEWFOUND RESPECT

Although biologists and indigenous people have worked together for centuries, the relationship has tended toward friction. Scientists often looked askance at traditional knowledge, sometimes with harmful consequences for both science and indigenous livelihoods. In the 1970s, for instance, U.S. federal researchers concluded the Bering Sea's bowhead whale population was shrinking, prompting the International Whaling Commission, a global organization that manages whale conservation and whaling, to impose drastic hunting restrictions on indigenous communities that depended on the cetaceans for sustenance. Alaska Natives objected, pointing out that, while government scientists only counted whales in open water, bowheads also passed through heavy ice, deploying their massive skulls to crack open breathing holes. When the National

Marine Fisheries Service finally used native feedback to guide its surveys in the 1980s, it nearly quadrupled its whale estimate.

"The hardest thing is to sit in a room with scientists who think they've discovered something, but their scientific discovery just confirms what our oral histories have talked about forever," says William Housty, a member of British Columbia's Heiltsuk First Nation and director of Coastwatch, a science and conservation program. "That's been the biggest hump for us to overcome, to get people to think about our culture on the same level as Western science."

Rocky though the transition has been, wildlife biologists like Polfus are today pursuing more respectful and participatory relationships with indigenous people. Scientists have partnered with Aboriginal Australians to study sea turtle populations; relied on Kaxinawá hunters in the Amazon to investigate the abundance of game species like monkeys and deer; and solicited information from Alaskan Yupiks about walrus migrations. Renata Leite Pitman, a Brazilian wildlife veterinarian who's studied Central and South American fauna for 25 years, has leaned on local expertise to learn the calls, scats and tracks of the elusive forest animals she studies. "I think it's intuitive — you just learn from what the native people have always been doing," she says.

Pitman's latest collaboration involves the Waorani tribe, Ecuadorian natives

"THAT'S BEEN THE BIGGEST HUMP FOR US TO OVERCOME, TO GET PEOPLE TO THINK ABOUT OUR CULTURE ON THE SAME LEVEL AS WESTERN SCIENCE." —WILLIAM HOUSTY

ABOVE: Charles Oudzi, of Coalville Lake in the Sahtú Region of the Northwest Territories, Canada, collects caribou fecal pellets that provide noninvasive genetic information used to analyze the connectivity and relationships among different caribou populations in the region.

PHOTOS BY JEAN POLFUS

ABOVE: Waorani chief Penti Bahuia tracks an anaconda in the Amazon as part of a collaborative research project between the Waorani tribe and wildlife veterinarian Renata Leite Pitman. LEFT: Collaborative work among researchers, students and two local First Nations on clam gardens along the Canadian Pacific Coast have led to discoveries that challenge Western notions about indigenous people and serve to benefit management decisions along the coast.

PHOTO BY RENATA LEITE PITMAN

PHOTO BY MARCO HATCH

whose young men catch and release green anacondas, the world's heaviest snake, as ritual tests of manhood. Since 2014, Pitman has inserted radio transmitters into six anacondas in Ecuador and Peru to study the species' movements in the Amazon. She also trained Waorani tribe members to tag and track the snakes; indigenous technicians provide her daily updates via Skype. Pitman and her Waorani partners extracted samples from both anacondas and bushmeat, which the scientist tests for contaminants stemming from upstream oil exploration. The giant reptiles have effectively become ecological indicators whose own flesh reflects the health of the Waorani's homeland.

Pitman's tracking has not only revealed secrets of anacondas' wanderings — the snakes appear more territorial than she'd realized, for instance — it also stands to provide valuable knowledge for the Waorani, who draw considerable income from ecotourism. "They want to get benefits from taking people to see the anacondas," she says. "This could be a long-term help for the economy."

Collaborative research can yield even more surprising gains. Marco Hatch, a member of the Samish Indian Nation and a marine ecologist at Northwest Indian College in Washington state, studies the Canadian Pacific Coast's clam gardens — well-groomed intertidal terraces, surrounded by rock walls, in which coastal people have dug shellfish for thousands of years. Hatch's research, conducted in partnership with the gardens' native owners, suggests that clams grow larger and more abundant in gardens than in the wild and that other edible species, like crabs and snails, thrive on rock walls. "Nonnative beach owners can manage their beach more effectively using tools and technologies that First Nations people have developed," Hatch says.

His findings also challenge the long-held notion that the Northwest's indigenous people were strict hunters and gatherers. "Clam gardens give us these very large and undeniable modifications of the intertidal," he says. "They show the complexity of indigenous food and knowledge systems."

LOOK TO THE NORTH

Hatch and Polfus aren't the only scientists to pursue collaborative research in Canada, where a slew of court cases have acknowledged native authority in natural resource

management. That's set the stage for programs like the Heiltsuk's Coastwatch, an initiative rooted along British Columbia's Koeye River, where grizzly bears fish for migrating salmon in dense coastal rainforest. In 2007, Housty and other Heiltsuk, with help from conservation groups and scientists at the University of Victoria, set up a network of barbed-wire snares, baited with salmon scent, that snagged clumps of bear hair for DNA analysis. The monitoring program revealed the presence of a grizzly "highway" along the Koeye, and helped the Heiltsuk better manage their own relationship with the bruins — for instance, by moving their youth camps away from the most heavily trafficked areas.

Just as significant as the study's results were its guiding principles: the Heiltsuk's *Gvi'ilas,* a body of traditional laws that shape the First Nation's relationship with the natural world. Just as the Dene's cultural values led them to insist upon noninvasive caribou research, so did the *Gvi'ilas* call for unobtrusive hair monitoring. "Those very fundamental ideas formed the base of everything we did," Housty says. "One of the biggest ones was respect. If you treat bears respectfully, they'll treat you the same way."

Yet that respect isn't always reciprocated by the powers that be. According to Housty, when the Heiltsuk presented the provincial government with their map of grizzly habitat, officials shrugged off data that clashed with the province's existing maps. "So we said, to heck with the government — we'll just go right to industry," Housty recalls. The Heiltsuk presented their habitat maps to local logging companies, which proved to be more interested than was the province. "They gave a little, we gave a little, and we could show them where it was appropriate to log," Housty says.

If the Heiltsuk can't make headway with the B.C. government using hair snares and DNA analysis — tools of Western scientific research — it shouldn't come as a surprise that native knowledge still receives short shrift in many quarters. Elsewhere in British Columbia, First Nations reports of grizzly bears inhabiting coastal islands were dismissed by the government because the observer "was not a biologist"; subsequent DNA analysis showed that 10 islands hosted resident grizzlies. According to one 2008 caribou study, some scientists remain guilty of using traditional knowledge "only when it fits within current resource management models of thinking." There's a fine line between collaborating

THERE'S A FINE LINE BETWEEN COLLABORATING WITH INDIGENOUS PEOPLE AND EXPLOITING THEIR LABOR AND KNOWLEDGE.

PLAN BEE

AS BEN GOLDFARB WRITES in his piece, putting traditional knowledge to work "is on the upswing." In another 2016 Ensia story, writer Christina Selby took readers to the Kullu Valley in the Himalaya Mountains of northwestern India, the Yucatan Peninsula of Mexico and smallholder farms in Tanzania to tell a story of how conservationists are turning to traditional farmers to help with pollinator decline around the world. From diversified farming systems, to traditional beekeeping practices that help conserve forests, to beehive fences that protect property from elephants while providing pollination services, "traditional beekeeping practices in bee conservation efforts may be exactly what we need to keep our agriculture systems, forests and farmers thriving," Selby writes.

READ MORE AT **ENSIA.US/POLLINATORS**.

PHOTO BY BUDAK (FLICKR/CREATIVE COMMONS) / INSET PHOTO BY PRADEEP METHA

with indigenous people and exploiting their labor and knowledge.

The technical language of resource management can also thwart authentic cooperation. In a 2004 essay, anthropologist Marc Stevenson detailed how seemingly innocuous words like "harvest" and "quota" can dominate co-management discussions and exclude native people from decision-making. When Stevenson sat on a whale management board in eastern Canada, he observed that Inuit hunters refused to use the word "stock" to refer to belugas — the concept didn't exist in Inuktitut language. Such utilitarian terminology, warns Stevenson, may be "not only foreign, but antithetical to Aboriginal values, concepts and understandings."

TALES FROM POOP LADY

Cautionary tales notwithstanding, collaborative research is on the upswing, and Polfus' caribou scat project offers an encouraging example. Though the effort was slow to catch on — as Polfus points out, "When it's minus 40 out and you're on your Ski-Doo, who wants to stop to pick up caribou poop?" — word gradually spread. Over two years, Polfus, known locally as Poop Lady, received over a thousand scat-filled plastic bags; her army of bounty hunters included everyone from elders to 12-year-old girls.

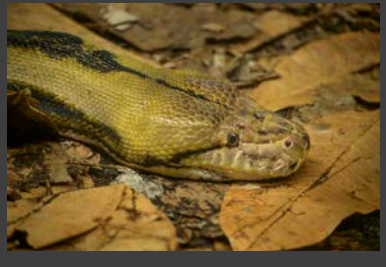
"WHEN YOU SUPPORT THE KNOWLEDGE OF PEOPLE WHO HAVE A LOT OF INCENTIVE TO KEEP CARIBOU AROUND FOR THEIR CHILDREN, THAT'S WHEN REAL CONSERVATION SUCCESS CAN HAPPEN." —JEAN POLFUS

Polfus' DNA tests revealed three genetically distinct forms of caribou — boreal woodland caribou, barren-ground caribou and mountain caribou. Although the three types generally occupy distinct habitat, they often overlap in the boreal forest, bewildering wildlife biologists who aren't sure where one subspecies' range ends and others' begin. No such confusion exists among the Dene, whose language includes separate words for all three types. Dene hunters can distinguish between caribou varieties on the basis of morphology, tracks and even behavior; woodland caribou, for instance, will loop back around on their own path to throw off predators.

That the Dene have developed different terms and hunting tactics for each type, says Polfus, suggests that the caribou diverged in the distant past. Paying heed to indigenous

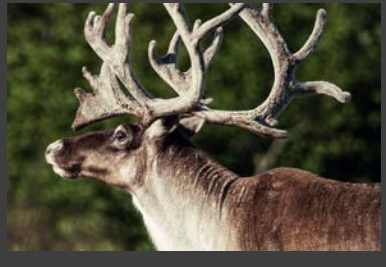
INDIGENOUS INSIGHTS AROUND THE WORLD

Working with indigenous peoples across the globe, researchers have seen many advances in conservation and scientific discovery.



ANACONDA
Working with the Waorani tribe in Ecuador, Brazilian wildlife veterinarian Leite Pitman inserts radio transmitters into anacondas to gain insights into the movements of the giant reptiles. The transmitters have provided new information not only about the snakes, but also about the larger ecosystem they and the Waorani inhabit.

GRIZZLY BEAR
William Housty, a member of British Columbia's Heiltsuk First Nation and director of Coastwatch, a science and conservation program, has — with other Heiltsuk, conservation groups and scientists at the University of Victoria — been able to better define grizzly bear habitat in British Columbia, leading to changes in the logging industry.



CARIBOU
In conjunction with the Dene people in the Sahtú Region of Canada's Northwest Territories, Jean Polfus, a postdoctoral fellow at the Natural Resources Institute at the University of Manitoba, worked to find respectful, noninvasive methods to study caribou that involve local people and respect indigenous values.

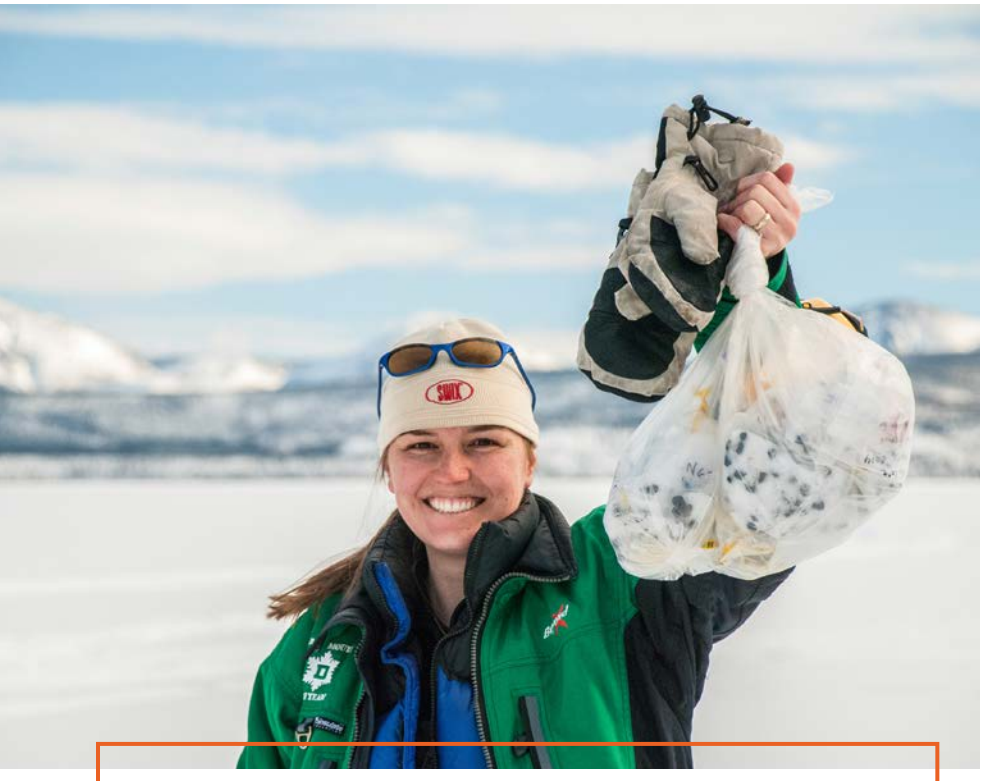


PHOTO BY JEAN POLFUS

Jean Polfus, a postdoctoral fellow at the University of Manitoba, holds a bag of caribou scat collected by indigenous Dene hunters. Polfus uses the scat as an alternative to radio collaring to study caribou populations.

language, in other words, advances science's grasp of evolutionary history and helps researchers identify subtle but crucial differences between subspecies. Authorities are already taking note: As a result of Polfus' research, the Sahtú Renewable Resources Board has pledged to use the Dene word for boreal woodland caribou, *todzı*, in all official correspondence.

In the Far North, studying caribou population ecology is anything but academic. Shale-oil development is inexorably coming to the Northwest Territories, and a better understanding of caribou ecology and population dynamics should help biologists and indigenous hunters manage both industry and wildlife.

"When you support the knowledge of people who have a lot of incentive to keep caribou around for their children," says Polfus, "that's when real conservation success can happen."

BEN GOLDFARB is a freelance environmental journalist whose work often focuses on fisheries and wildlife management. His writing has appeared in publications including the *Guardian, Scientific American, Earth Island Journal, OnEarth* and *High Country News*.

IMPACT

This story was one of our most popular Facebook posts of all time, reaching nearly 15,000 people who reacted to it 203 times and shared it 98 times. It was republished at Vox and Alternet, and has been read nearly 6,000 times at ensia.com. Quirks & Quarks, Canada's CBC Radio's weekly science program, tweeted it to its 63,000 followers.

CROWDED REFRIGERATOR © ISTOCKPHOTO.COM/ JOEY333 / FOOD WASTE PHOTO © ISTOCKPHOTO.COM/ FOTOGRAV

how can we break humanity's FOOD WASTE habit?

When it comes to reducing consumer food waste, guilt doesn't cut it. Here's what does.

by MARY HOFF

ORIGINALLY PUBLISHED:
OCTOBER 2015

It was bound to happen. When I first got the assignment to write a story on reducing consumer food waste, I was feeling just a little smug. I'm the one who wraps up breadsticks at the restaurant to take home, slurps the last bit of soup from the bowl, cuts the soft spots out of an apple rather than tossing the whole thing away. But even though I personally don't fritter food, plenty of people do — and this would be my big chance to help reduce the hefty social and environmental costs by exploring why and what we can do about it.

Then I opened my refrigerator. Pulling out what I thought was a perfectly healthy stalk of celery, I found instead the early stages of compost. On the top shelf, a cottage cheese carton disguised leftovers I had diligently squirreled away — and promptly forgotten. And then there was the ketchup. "Best if used by March 2012"? Busted.

Like it or not, when it comes to food waste, it's not just industrial farms or supermarkets or restaurants or caterers or *other people* who are to blame: It's all of us. In fact, according to *The Wall Street Journal,* more than twice as much food is wasted at the consumer level than at the retail level in the U.S.

"There's good news and bad news," says Jonathan Bloom, author of *American Wasteland: How America Throws Away Nearly Half of Its Food (and What We Can Do About It).* "The bad news is that we are pretty wasteful as individuals and families. The good news is we can be a major part of the change with food waste."

Capitalizing on that concept, government agencies, environmental organizations and other nonprofits around the world have been developing and deploying a spectrum of strategies to help consumers reduce the amount of food we waste, from simple awareness-building social media campaigns to gala events in which celebrity chefs demo innovative approaches to turning leftovers, stale bread, forlorn fruits and the like into culinary creations. In the process, they have learned much about what works — and doesn't — when it comes to reducing consumer food waste.

CONSUMER POWER

Worldwide, one out of every three bites of food produced never makes it to our mouths. Some — especially in developing countries — is lost in harvesting, storage, transportation and so on. But in developed countries, a good chunk gets tossed out after it's in the consumer's hands.

"Consumers, especially in Europe and the United States, we are the main food wasters," says Selina Juul, founder of the Danish food waste reduction campaign Stop Spild Af Mad (Stop Wasting Food), which got its start eight years ago when Juul, who emigrated to Denmark after living in Moscow during the tight times following the collapse of the USSR, decided she had had enough of the profligate attitude toward food in her new setting.

The Food and Agriculture Organization of the United Nations estimates that in North America and Europe the average individual throws out 95 to 115 kilograms (210 to 250 pounds) of food each year. In the U.S., that number is more like 290 pounds (130 kilograms), according to U.S. Department of Agriculture's Economic Research Service estimates.

THE FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS ESTIMATES THAT IN NORTH AMERICA AND EUROPE THE AVERAGE INDIVIDUAL THROWS OUT 95 TO 115 KILOGRAMS (210 TO 250 POUNDS) OF FOOD EACH YEAR.

WHY THIS MATTERS

Producing food for Earth's 7.4 billion people comes with hefty environmental costs: habitat transformed into farmland; water and energy used to grow, transport and prepare what we eat; pollution from agricultural chemicals; and more. Yet one-third of that food never makes it to our mouths. Stemming the loss can help us boost food supply to meet growing human needs while minimizing farming's environmental footprint.

Half a super-size jar of jam that was such a good deal but you likely couldn't consume in a lifetime … the apple and bag of chips prepackaged in the deli lunch … a papaya you purchased but weren't quite sure how to prepare. It all adds up.

But why is wasting food such a big deal, anyway?

For the individual, wasting food is, simply put, wasting money. "One of the things I find so odd is we're so attuned to the savings on the front end," Bloom says. "We'll change what we're going to buy based on sale items at the supermarket, but we don't ever think about the cost of food waste on the other side of the equation and how much that adds up to." On average, according to the U.S. Department of Agriculture, an American family of four throws out close to US$1,500 worth of food in a year.

Wasted food is wasted time, too. Juul says a recent survey found people spend four to five hours per month shopping for the food they end up throwing away. "You can save those five hours," she says. "That's a lot of time."

On a societal scale, many argue it's a matter of justice: Even though distribution and politics complicate the picture, from an ethical point of view there is little to argue for tossing food when others go hungry.

And from an environmental perspective, it boils down to the fact that we are literally throwing our natural resources into the trash. The implications for the planet are huge: According to a 2009 study published in the journal PLOS ONE, fully one-quarter of the water used in the U.S. goes to produce food nobody eats. The Dutch Ministry of Economic Affairs estimates that every kilogram of food produced embodies 1.3 liters (0.34 gallons) of gasoline. Even after food is thrown away, its environmental footprint continues to grow as the rotting discards generate methane, a super-potent greenhouse gas. In fact, the U.K.'s Waste & Resources Action Programme — WRAP — estimates that fully 7 percent of global greenhouse gas emissions are attributable to food waste.

FOOD LOSS AT THE CONSUMER LEVEL IN THE U.S. (2010)

Studies have found that saving money is a main motivator when it comes to reducing consumer food waste. Here's a snapshot of what Americans threw away per person in 2010:

Vegetables
$66

Meat
$62

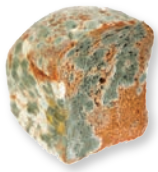
Dairy
$60

Fruit
$45

Poultry
$40

Fish & Seafood
$25

Added Fats/Oils
$22



Grain Products
$22

Added Sugars/Sweeteners
$15

Eggs
$8

Tree Nuts & Peanuts
$4

TOTAL = $369

Source: Economic Research Service/USDA.

IN THE KNOW

If wasting food has such negative consequences for ourselves, our fellow humans and our planet, why do we still do it? That's a question many consumer food waste reduction programs try to

answer as a first step in convincing people to do otherwise.

One frequent finding, mirroring my own experience, is that people are simply unaware.

"Most of us think that we don't waste much food," Bloom says. "We think, 'Oh, that's the other people, it's the other wasteful folks.' And it's really easy to think that way, because we have learned to not see our own food waste. We're sort of willfully and blissfully ignorant of how much food we are throwing away." Indeed, in a 2014 Johns Hopkins University survey of food waste awareness, attitudes and behaviors in the U.S., three-fourths of respondents said they throw away less food than the average American.

To counter this, Bloom recommends composting: Watching the scraps pile up, he says, "forces you to see what you're not using." Food diaries are another common approach to helping build awareness of food waste. Food: Too Good to Waste, a food waste reduction program spearheaded by the U.S. Environmental Protection Agency, even offers a downloadable tool consumers can use to measure their food waste on a weekly basis.

It's not just lack of awareness of how *much* we waste, however; many of us are oblivious to the personal and societal costs we incur when we waste as well. "We've become disconnected from our food and so have lost our understanding of its value — for example, all the resources, energy and time taken to get it to us," notes Emma Marsh, former head of WRAP's Love Food Hate Waste, a research-based campaign that has led the way in bringing the consumer food waste reduction message to the United Kingdom since 2007. Despite this disconnect, Marsh notes, "No one intends to waste food or gets pleasure from it. We all want to make the most of our food, but life can get in the way."

IMAGE COURTESY OF WRAP

The U.K.'s Waste & Resources Action Programme — WRAP — launched Love Food Hate Waste, a creative campaign to encourage people to use leftovers.

Food waste campaigns have been quick to pick up on the need to educate people about the problem. Virtually all include messaging intended to shock people into awareness of the magnitude of consumer food waste and the personal costs we incur when we throw food away.

"If you want to change the people, if you want to change their mentality, you need to communicate on a level they can

understand and also communicate through something that they can relate to and which can be beneficial to them," Juul says. "And saving money is very beneficial, and saving time as well."

MAKE IT EASY

Just being aware of the problem and its consequences doesn't solve the problem by itself, though. "You can't expect raising awareness or providing information to change behavior for the long term," Marsh says. "We need to offer practical solutions such as cookery classes, budgeting and planning support, better choice of pack size, storage information on pack, etc."

Often it's our routines and habits — whether we check what's already in the cupboard before we shop, what we think is the right number of bananas or buns to buy at one time, how much pasta we think we need to put into the pot — that do us in. According to I Value Food, a food waste reduction program of the nonprofit Sustainable America, one-third of Americans rarely if ever look at what's in the refrigerator or pantry before heading to the supermarket. And the FAO attributes more than half of food waste to poor planning while shopping.

Food: Too Good to Waste works to overcome this by connecting people with an entire array of tools for making it easy to break old routines and start new ones, from a shopping list template to meal planning apps.

Stop Wasting Food published a leftover cookbook and offers an online clearinghouse of ideas for consumers on ways to reduce food waste, from making a meal plan to making pancakes out of leftover mashed potatoes. (A word of warning, though, for non-Danish speakers; the Google Translate version can be a little dicey. Take this helpful hint, for example: "If your carrots are soft and hangs around with his nose, throw them in the water, then into the refrigerator and let them suck, they are just as resilient as before.")

To help reduce food waste, French supermarket chain Intermarché sold imperfect fruits and vegetables for a discount and launched an in-store and media campaign called "Inglorious Fruits and Vegetables." The effort was meant "to rehabilitate and glorify" the odd-looking foods.

PHOTO COURTESY OF MARCEL WORLDWIDE

Meanwhile, on the manufacturer and retailer end, supermarket chain REMA 1000 eliminated volume discounts in Denmark to make it less tempting for consumers to buy more food than they can use. Intermarché, a French supermarket, gathered odd-looking produce into a special section and sold it at a discount. Several years ago British grocer Tesco started offering "buy one, get one free — later" rather than the more common "buy one, get one free now" deals to help reduce consumer food waste due to over-purchasing.

Consumer waste that occurs in restaurants, cafeterias, banquets and other places outside of the home has been addressed by campaigns that try to instill new habits as well. In Italy, where taking leftovers home is considered poor taste, some restaurants have been working to get patrons to change their perception and encouraging them to save what they don't finish. In Denmark, Stop Wasting Food has distributed more than 50,000 doggy bags to restaurants free of charge to help the cause. In the U.S.,

THE FAO ATTRIBUTES MORE THAN HALF OF FOOD WASTE TO POOR PLANNING WHILE SHOPPING.

many colleges have opted to forgo trays in their cafeterias to make it harder for students to take too much food. According to the Natural Resources Defense Council, on some campuses this one seemingly small change has reduced food waste by more than one-fourth.

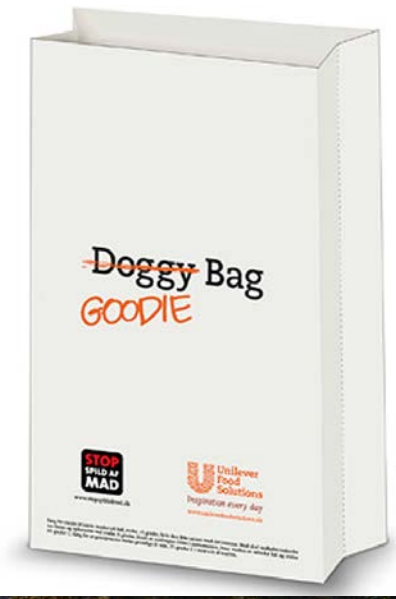
MINIMIZING MISINFORMATION

Misinformation and insufficient information is also a problem. As a result, a number of food-waste-reduction campaigns have focused on quashing misinformation and providing accurate information about how to handle food.

Improving knowledge about how to store food offers one big opportunity for reducing food loss due to spoilage. Food: Too Good to Waste provides a food storage guide, and Love Food Hate Waste has produced a "Best Before Date" series of video spoofs on television matchmaking shows as well as food ditties by comedian-poet Kate Fox to help consumers make good choices about food storage. Knowing when food is really a goner is important as well: Is it OK to use an onion after it sprouts? The unmoldy half of a moldy cucumber? Meat that's turned brown, or cheese that's turned green? Packaged food that's past its "sell by," "best before" or "use by" date? A 2014 survey of U.S. consumer food waste found that worry about food poisoning was one of the top reasons people throw food away. And in the U.K, the Department for Environment, Food & Rural Affairs recommended against using "sell by" and "display until" labels because they erroneously led consumers to think food was no longer safe to eat.

According to Bloom, one of the most challenging misperceptions may be how we view scarcity and abundance. "We want to have plenty of food because for millennia as a species we haven't been able to just go out to the store and buy plenty," he explains. "There still is that slight feeling of not necessarily knowing where the next meal is coming from." To the children and grandchildren of the Great Depression or other tight times, buying and preparing more food than is needed can be a sign of everything from love to having "made it." Love Food Hate Waste is working to counteract quantity misperceptions with free portion planning tools to help cooks prepare appropriate amounts of food. Other strategies include simply using smaller plates, which can provide the sense of abundance while reducing the temptation to overserve.

Noting that amount of food wasted correlates with demographic factors such as household size, age and employment status, Love Food Hate Waste reminds us that an important part of any campaign is to figure out the target audiences and their specific interests, needs and limitations. Food: Too Good To Waste also underscores the importance of engaging consumers with messages and op-



TOP: Stop Wasting Food's cookbook, which offers creative recipes for turning leftovers into fresh meals, quickly sold out after it was published several years ago. The organization also distributed doggy/goodie bags to help legitimize the practice of bringing home uneaten food from restaurants. BOTTOM: I Value Food offers online instructions for hosting a gourmet dinner made from less-than-prime ingredients in a dumpster as a way to showcase creative strategies for reducing food waste.

PHOTO BY ANDREW HINDERAKER / IMAGES COURTESY OF STOP WASTING FOOD MOVEMENT DENMARK

portunities often, rather than taking a "one and done" approach.

COOL AND COMPETITIVE

As in many things, though, turning the trend has a lot to do with making it cool. Juul, for example, places a high premium on avoiding food shaming and instead focusing on engaging people with edgy, upbeat messaging; a vast social media presence; a lively TEDx talk; and a make-it-cool-to-conserve approach. "What is really important is to deliver a positive message," she says. "If you have a negative message, like 'the big, bad supermarkets' or 'the big, bad consumers,' they won't listen."

I Value Food offers consumers a way to turn about-to-be-wasted food into a party with instructions for hosting a Salvage Supperclub. In a similar vein, Love Food Hate Waste plays off the "foodie" trend, focusing on food's value as a source of pleasure and a creative outlet — encouraging people to take an unusual approach to preparing ugly or leftover food, for instance. With its Foodwise campaign, Australia-based Do Something! provides recipes from celebrity chefs using leftovers.

Competitions are a popular tool, too. The Hong Kong Environmental Protection Department's Food Waste Reduction program, for example, encourages members of the public to upload photos of their empty restaurant plates to a special Facebook page for a chance to win a prize. Love Food Hate Waste initiatives include poster contests and school-based races to reduce waste.

ENCOURAGING TRENDS

Clearly there is no shortage of initiatives to educate and inspire consumers to keep food out of the trash. But do they work?

Making cause-and-effect connections between the various strategies these campaigns employ and the amount of food wasted is difficult. But concurrent trends are encouraging.

For example, communities participating in Food: Too Good to Waste saw a reduction in preventable food waste of 11 percent to 48 percent by weight. Avoidable household food waste in the U.K. has dropped 21 percent since the Love Food Hate Waste program began in 2007. A 2013 survey showed that half of Danes reported reducing their food waste over the previous year, and food waste has declined 25 percent in Denmark over the past five years.

Juul attributes that success to a variety of campaign strategies by Stop Wasting Food, including getting the attention of media, engaging via social media, avoiding alignment with a particular political ideology and using a variety of messages to avoid tiring people out. But, she says, ultimately it all boils down to one simple thing: convincing consumers that reducing food waste is simple and worthwhile.

"The main message for consumers is, 'Start doing something on your own because it is so easy,'" she says. "It is so easy to go to the kitchen, see what you already have in your fridge, use your leftovers and be creative. It will really save you so much time, so much money — it's a win-win situation, and it's also good for the environment."

"THE MAIN MESSAGE FOR CONSUMERS IS, 'START DOING SOMETHING ON YOUR OWN BECAUSE IT IS SO EASY.'" —SELINA JUUL

IMPACT

This story has been viewed some 24,000 times. It was republished at United Nations University's Our World magazine, Quartz and GreenBiz, among other outlets, and was the subject of a live interview at WTIP radio.

MARY HOFF has more than two decades' experience working to improve understanding, appreciation and stewardship of our environment. Her work has been published in *Discover, Science World, National Geographic Explorer* and *PLoS Biology,* among others.

SOREK DESALINATION PLANT PHOTO COURTESY OF IDE TECHNOLOGIES / FILTRATION © ISTOCKPHOTO.COM/TERRY J ALCORN

making peace with WATER *in the* MIDDLE EAST

Will desalination unite longtime adversaries in a common cause?

by ROWAN JACOBSEN

ORIGINALLY PUBLISHED:
JULY 2016

Ten miles south of Tel Aviv, I stand on a catwalk over two concrete reservoirs the size of football fields and watch water pour into them from a massive pipe emerging from the sand. The pipe is so large I could walk through it standing upright, were it not full of Mediterranean seawater pumped from an intake a mile offshore.

"Now, that's a pump!" Edo Bar-Zeev shouts to me over the din of the motors, grinning with undisguised awe at the scene before us. The reservoirs beneath us contain several feet of sand through which the seawater filters before making its way to a vast metal hangar, where it is transformed into enough drinking water to supply 1.5 million people.

We are standing above the new Sorek desalination plant, the largest reverse-osmosis desal facility in the world, and we are staring at Israel's salvation. Just a few years ago, in the depths of its worst drought in at least 900 years, Israel was running out of water. Now it has a surplus. That remarkable turnaround was accomplished through national campaigns to conserve and reuse Israel's meager water resources, but the biggest impact came from a new wave of desalination plants.

Bar-Zeev, who recently joined Israel's Zuckerberg Institute for Water Research after completing his postdoc work at Yale University, is an expert on biofouling, which has always been an Achilles' heel of desalination and one of the reasons it has been considered a last resort. Desal works by pushing saltwater into membranes containing microscopic pores. The water gets through, while the larger salt molecules are left behind. Microorganisms in seawater quickly colonize the membranes and block the pores, and controlling them requires periodic costly and chemical-intensive cleaning. But Bar-Zeev and colleagues developed a chemical-free system using porous lava stone to capture the microorganisms before they reach the membranes. It's just one of many breakthroughs in membrane technology that have made desalination much more efficient. Israel now gets 55 percent of its domestic water from desalination, and that has helped to turn one of the world's driest countries into the unlikeliest of water giants.

Driven by necessity, Israel is learning to squeeze more out of a drop of water than any country on Earth, and much of that learning is happening at the Zuckerberg Institute, where researchers have pioneered new techniques in drip irrigation, water treatment and desalination. They have developed resilient well systems for African villages and biological digesters that can halve the water usage of most homes.

The institute's original mission was to improve life in Israel's bone-dry Negev Desert, but the lessons look increasingly applicable to the entire Fertile Crescent. "The Middle East is drying up," says Osnat Gillor, a professor at the Zuckerberg Institute who studies the use of recycled wastewater on

WHY THIS MATTERS

Desperate drought in the Middle East in the early 2000s depleted the Sea of Galilee and groundwater supplies, forcing rural residents of failed farms to flee to cities and settle in shantytowns from which the seeds of Syrian unrest sprouted. As desalination technology comes online, there is much hope that turning water shortage to water abundance will help to quell violence and heal political divides in the region — as well as provide a hopeful model for other parts of the world threatened with destabilization due to increasing water stress.

crops. "The only country that isn't suffering acute water stress is Israel."

That water stress has been a major factor in the turmoil tearing apart the Middle East, but Bar-Zeev believes that Israel's solutions can help its parched neighbors, too — and in the process, bring together old enemies in common cause.

Bar-Zeev acknowledges that water will likely be a source of conflict in the Middle East in the future. "But I believe water can be a bridge, through joint ventures," he says. "And one of those ventures is desalination."

"I BELIEVE WATER CAN BE A BRIDGE, THROUGH JOINT VENTURES. AND ONE OF THOSE VENTURES IS DESALINATION." —EDO BAR-ZEEV

DRIVEN TO DESPERATION

In 2008, Israel teetered on the edge of catastrophe. A decade-long drought had scorched the Fertile Crescent, and Israel's largest source of freshwater, the Sea of Galilee, had dropped to within inches of the "black line" at which irreversible salt infiltration would flood the lake and ruin it forever. Water restrictions were imposed, and many farmers lost a year's crops.

Their counterparts in Syria fared much worse. As the drought intensified and the water table plunged, Syria's farmers chased it, drilling wells 100, 200, then 500 meters (300, 700, then 1,600 feet) down in a literal race to the bottom. Eventually, the wells ran dry and Syria's farmland collapsed in an epic dust storm. More than a million farmers joined massive shantytowns on the outskirts of Aleppo, Homs, Damascus and other cities in a futile attempt to find work and purpose.

And that, according to the authors of "Climate Change in the Fertile Crescent and Implications of the Recent Syrian Drought," a 2015 paper in the *Proceedings of the National Academy of Sciences,* was the tinder that burned Syria to the ground. "The rapidly growing urban peripheries of Syria," they wrote, "marked by illegal settlements, overcrowding, poor infrastructure, unemployment, and crime, were neglected by the Assad government and became the heart of the developing unrest."

PHOTOS BY ANDREW LAVIN

Edo Bar-Zeev, a scientist with the Zuckerberg Institute for Water Research, is working to improve desalination technology.

PHOTO © ISTOCKPHOTO.COM/ECLIPSE_IMAGES

SUPER SAVERS

WHEN IT COMES TO strategies for saving water, desalination is just the tip of the iceberg in the thirsty Middle East. Summarizing key points from his 2015 book *Let There Be Water: Israel's Solution for a Water-Starved World*, businessman, activist and writer Seth M. Siegel shared 12 strategies for moving from water scarcity to abundance with Ensia readers — ranging from creating a culture that respects water, to charging consumers realistic prices, to measuring and monitoring water use.

READ ALL ABOUT THEM AT **ENSIA.US/WATERSOLUTIONS**.

1.5 million
Number of people whose drinking water needs can be met by the Sorek desalination plant

55
Percent of Israel's domestic water that comes from desalination

1/3
The cost of water produced from desalination today relative to the 1990s

300 million
Number of people worldwide who get water from desalination

Similar stories are playing out across the Middle East, where drought and agricultural collapse have produced a lost generation with no prospects and simmering resentments. Iran, Iraq and Jordan all face water catastrophes. Water is driving the entire region to desperate acts.

MORE WATER THAN NEEDED

Except Israel. Amazingly, Israel has more water than it needs. The turnaround started in 2007, when low-flow toilets and showerheads were installed nationwide and the national water authority built innovative water treatment systems that recapture 86 percent of the water that goes down the drain and use it for irrigation — vastly more than the second-most-efficient country in the world, Spain, which recycles 19 percent.

AND THE COUNTRY FACES A PREVIOUSLY UNFATHOMABLE QUESTION: WHAT TO DO WITH ITS EXTRA WATER?

But even with those measures, Israel still needed about 1.9 billion cubic meters (2.5 billion cubic yards) of freshwater per year and was getting just 1.4 billion cubic meters (1.8 billion cubic yards) from natural sources. That 500-million-cubic-meter (650-million-cubic-yard) shortfall was why the Sea of Galilee was draining like an unplugged tub and why the country was about to lose its farms.

Enter desalination. In 2005 the Ashkelon desalination plant provided 127 million cubic meters (166 million cubic yards) of water. In 2009 the Hadera plant put out another 140 million cubic meters (183 million cubic yards). And now Sorek: 150 million cubic meters (196 million cubic yards). All told, desal plants can provide some 600 million cubic meters (785 million cubic yards) of water a year, and more are on the way.

The Sea of Galilee is fuller. Israel's farms are thriving. And the country faces a previously unfathomable question: What to do with its extra water?

WATER DIPLOMACY

Inside Sorek, 50,000 membranes enclosed in vertical white cylinders, each 4 feet (1 meter) high and 16 inches (41 centimeters) wide, are whirring like jet engines. The whole thing feels like a throbbing spaceship about to blast off. The cylinders contain sheets of plastic membranes wrapped around a central pipe, and the membranes are stippled with pores less than a hundredth the diameter of a human hair. Water shoots into the cylinders at a pressure of 70 atmospheres and is pushed through the membranes, while the remaining brine is returned to the sea.

Desalination used to be an expensive energy hog, but the kind of advanced technologies being employed at Sorek have been a game changer. Water produced by desalination costs just a third of what it did in the 1990s. Sorek can produce 1,000 liters (almost 300 gallons) of drinking water for 58 cents. Israeli households pay about US$30 a month for their water — similar to households in most U.S. cities, and far less than Las Vegas (US$47) or Los Angeles (US$58).

The International Desalination Association claims that 300 million people get water from desalination, and that number is quickly rising. IDE, the Israeli company that built Ashkelon, Hadera and Sorek, recently finished the Carlsbad desalination plant in Southern California, a close cousin of its Israel plants, and it has many more in the works. Worldwide, the equivalent of six additional Sorek plants are coming online every year. The desalination era is here.

What excites Bar-Zeev the most is the opportunity for water diplomacy. Israel supplies the West Bank with water, as re-

THE DOWNSIDES OF DESAL

IF DESALINATION IS such an amazing source of freshwater, why isn't it more common? In addition to the challenges related to biofouling Rowan Jacobsen mentions in this piece, the technology faces two other big challenges: energy use and brine disposal. As writer Brian Bienkowski pointed out in an earlier Ensia story, desalination plants can use up to 10 times as much electricity as conventional treatment plants to produce a given quantity of drinking water. And the super-salty wastewater that's left after drinking water is extracted can harm habitat if indiscriminately released. Numerous strategies are being tested around the world to reduce these downsides, including pretreating water before it enters the desalination system, using renewable energy to power the plants and extracting potentially useful salts from effluent before discharging into the environment.

quired by the 1995 Oslo II Accords, but the Palestinians still receive far less than they need. Water has been entangled with other negotiations in the ill-fated peace process, but now that more is at hand, many observers see the opportunity to depoliticize it. Bar-Zeev has ambitious plans for a Water Knows No Boundaries conference in 2018, which will bring together water scientists from Egypt, Turkey, Jordan, Israel, the West Bank and Gaza.

Even more ambitious is the US$900 million Red Sea–Dead Sea Canal, a joint venture between Israel and Jordan to build a large desalination plant on the Red Sea, where they share a border, and divide the water among Israelis, Jordanians and the Palestinians. The brine discharge from the plant will be piped 100 miles (160 kilometers) north through Jordan to replenish the Dead Sea, which has been dropping a meter (3 feet) per year since the two countries began diverting the only river that feeds it in the 1960s. By 2020, these old foes will be drinking from the same tap.

On the far end of the Sorek plant, Bar-Zeev and I get to share a tap as well. Branching off from the main line where the Sorek water enters the Israeli grid is a simple spigot, a paper cup dispenser beside it. I open the tap and drink cup after cup of what was the Mediterranean Sea 40 minutes ago. It tastes cold, clear and miraculous.

The contrasts couldn't be starker. A few miles from here, water disappeared and civilization crumbled. Here, a galvanized civilization created water from nothingness. As Bar-Zeev and I drink deep, and the climate sizzles, I wonder which of these stories will be the exception, and which the rule.

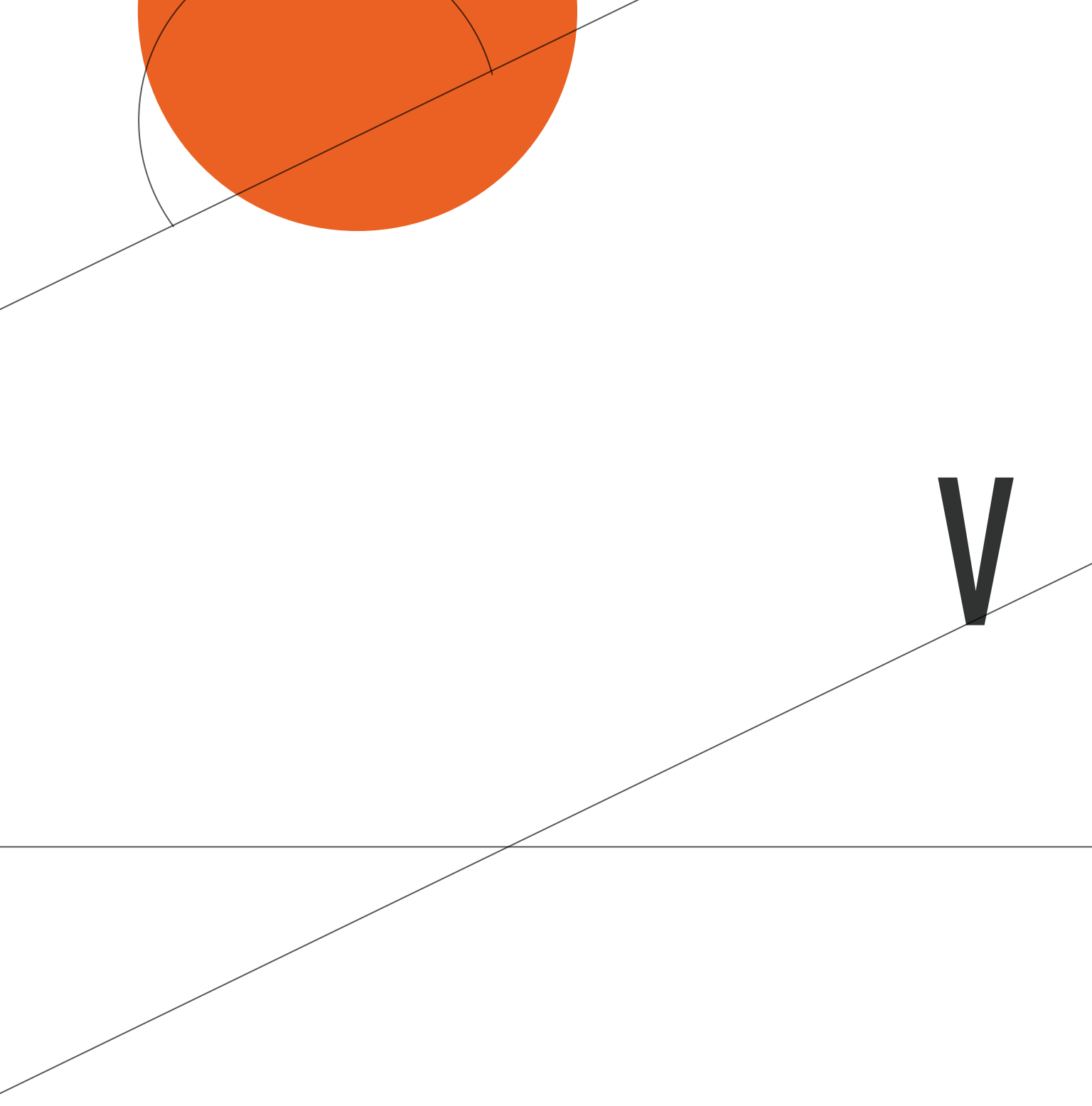
IMPACT

This piece was republished by Scientific American and FERN's Ag Insider, among other outlets. The Financial Express, India's primary daily business news and opinion media source with more than 20 million page views per month, used it as the basis for an opinion piece encouraging India to increase its investment in desalination. And the California Academy of Sciences has included it in its Education Center materials for teachers.

ROWAN JACOBSEN is the award-winning author of *Fruitless Fall, The Living Shore* and other books. He is a frequent contributor to *Outside, Harper's, Orion* and other magazines, and his work has been anthologized in *Best American Science and Nature Writing* and elsewhere.

WRITER UPDATE: *This story of Israel's recent successes with desalination technology touched thought leaders worldwide. I've rarely had a story go viral the way this one did. It circled the globe on social media and was reprinted in several countries. Both the scientist I profiled and I received multiple interview requests. The* Deccan Chronicle *in Hyderabad, India, asked me to write a piece about how Israel's situation might apply to that country. Clearly, water security is on everybody's mind.*

Although most commenters were highly encouraged by the piece, it also stirred up a hornet's nest — or perhaps "troll's nest" is a better way to word it. A vocal minority considers desalination unacceptable because of the energy required. That's an important consideration; desalination is certainly far more energy-intensive than getting your water from, say, natural rivers. But for places in the world suffering acute water stress, spending your energy to quench people's thirst seems wise. — ROWAN JACOBSEN



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VOICES

OVER THE PAST YEAR, dozens of experts from around the world challenged conventional ways of thinking and offered innovative insights and ideas through essays shared in Ensia's Voices section. A new publishing partnership with the academic journal Elementa allowed us to help leading researchers share their game-changing perspectives with a broader audience. Topics ranged from distributed electricity and how human health and conservation are intertwined to the need for a global treaty on plastics, the implications of the gene-editing tool CRISPR for agriculture and much more. The three pieces we share here reflect that wide variety. Food systems researcher Maywa Montenegro argues that the conversation around GMOs is much too narrow — and the potential consequences much too large to continue to be so. Author Jonathon Porritt says that instead of portraying Earth in 2050 as a hellhole, we should envision a place we would love to live, then figure out what it will take to get there. Finally, Ensia Mentor Program participant Kayla Walsh — who wrote her op-ed fresh off returning from COP 21 in Paris in late 2015 — explains why designating climate-displaced persons as "climate refugees" is such an important step in ensuring a planned, orderly transition for the millions who will be forced to move in the coming decades.

TO BUILD A BETTER FUTURE, WE MUST IMAGINE IT

Instead of portraying Earth in 2050 as a hellhole, let's envision — and create — a world we would love to inhabit.

by **JONATHON PORRITT**

ORIGINALLY PUBLISHED:
MAY 2016

WHY THIS MATTERS

Science tells us that optimists and pessimists respond differently to challenges. In a 2012 interview with The Atlantic, psychologist Michael Scheier observed: "[Optimists are] problem solvers who try to improve the situation. … Pessimists, on the other hand, tend to deny, avoid and distort the problems they confront, and dwell on their negative feelings." Meanwhile, Martin Seligman, director of the University of Pennsylvania's Positive Psychology Center, has defined optimism as "reacting to problems with a sense of confidence and high personal ability." So, if we actually want to do something about the environmental problems we face, science seems to support the value of starting with a hopeful vision of a future we can not only live with, but thrive in.

Just as I was putting pen to paper for this piece I was amused to receive an invitation from a wonderful organization called "Julie's Bicycle" to an event with the compelling title: "How to be a COPtimist: Culture, Creativity and COP21."

Optimism regarding the state of the planet in the face of climate change is in understandably short supply these days. Most of those who know the science (really know the science) see optimism as an illusionist's bolt-hole. And most of those who've followed things at more of a distance feel very jaundiced at the failure of today's political establishment and the increasingly offensive greed of today's business elites.

But without hope (which I prefer to optimism), it's next to impossible to persuade people to stir themselves into action rather than sitting on the sidelines rehearsing all the different ways there are of saying, "I told you so."

It was that psychological impasse that set me on the trail of what became *The World We Made,* published in 2013. My conviction — now and as I wrote the book — is very simple: Instead of portraying the future Earth as a polluted, overpopulated hellhole, we must show it as a place where we would all love to live: exciting, aspirational, high-tech, fair and hopeful.

BUT WITHOUT HOPE (WHICH I PREFER TO OPTIMISM), IT'S NEXT TO IMPOSSIBLE TO PERSUADE PEOPLE TO STIR THEMSELVES INTO ACTION RATHER THAN SITTING ON THE SIDELINES.

The World We Made is told through the words of Alex McKay, a history teacher looking back from 2050, trying to understand how we got from the world as it is today to a much more compelling world in which:

- 90 percent of energy comes from renewable sources and 30 percent of electricity from solar power

- standard tech devices are computing at the same rate as the human brain
- nanotechnology, 3-D printing and biomimicry have transformed the world of manufacturing
- personal genomics allow everyone to manage their own health, live longer and healthier lives, and die when they want to
- there are still rich and poor, but the rich are poorer but happier, and the poor are richer in so many ways.

The point of *The World We Made* is that we pretty much have all the technological firepower we need to move from being inherently and hopelessly unsustainable today, to a more or less sustainable world by 2050. When I try and persuade skeptics that this is not just a pipe dream, my favorite analogy is that of Pearl Harbor. Until Japan attacked the United States, most of the manufacturing base in the U.S. was focused on consumer goods. Within nine months, much of this productive capability was converted to making the weapons of war. For instance, not one private car was produced between 1942 and 1945.

Without this kind of positive vision, we become more and more disempowered. Yet most environmental problems (apart from species extinction) are theoretically reversible if and when we get our act together. People often cite our relative success in restoring the ozone layer over the last 25 years

THE POINT OF THE WORLD WE MADE IS THAT WE PRETTY MUCH HAVE ALL THE TECHNOLOGICAL FIREPOWER WE NEED TO MOVE FROM BEING INHERENTLY AND HOPELESSLY UNSUSTAINABLE TODAY, TO A MORE OR LESS SUSTAINABLE WORLD BY 2050.

ILLUSTRATION BY BENJAMIN CURRIE

or so as a measure of what we can do when we put our minds to it.

Climate change, however, is a very different story, not least because there is indeed a point where it becomes all but impossible to slow increases in average temperatures. Which brings us neatly back to the 21st session of the Conference of the Parties in Paris — COP 21 — at the end of 2015.

for every country to do everything in its power to limit the average temperature increase by the end of the century to no more than 2 °C (3.6 °F) — and then, even more remarkably, to aim for an even lower threshold of 1.5 °C (2.7 °F).

You may think the difference between 2 °C and 1.5 °C doesn't sound like much. However, the difference is massive. Forget about targets and deadlines and so on,

FOR ALL THE PROBLEMS OF TODAY'S MARKET ECONOMY, MARKETS ARE POWERFUL DRIVERS OF CHANGE. JUST LOOK AT THE ASTONISHING UPTAKE OF SOLAR TECHNOLOGIES ACROSS THE WORLD AS PRICES HAVE COME CRASHING DOWN OVER THE LAST FEW YEARS.

By near-universal agreement, this was a pretty extraordinary event where, for the very first time, world leaders seriously got their heads around the threat of runaway climate change. They confirmed the need

and just think about carbon budgets, the metric climate scientists prefer. Here's what 1.5 °C means from a carbon budget point of view: Scientists have calculated that we can put no more than 650 billion metric tons

(720 billion tons) of carbon into the atmosphere if we want to stay below that 1.5 °C threshold. Since the mid-19th century, we've already put 550 billion metric tons (610 billion tons) into the atmosphere,

MAKING THE FUTURE

TURNS OUT Jonathon Porritt's not alone in positing that we need to first imagine the future we want before we can get ourselves there. In her 2010 TED talk, game designer and future forecaster at the Institute for the Future Jane McGonigal described the meaning behind this sign in the institute's Palo Alto, California offices:

"[I]t expresses our view of how we should try to relate to the future. We do not want to try to predict the future. What we want to do is make the future. We want to imagine the best-case scenario outcome, and then we want to empower people to make that outcome a reality."

Today we are simultaneously facing some of the hardest challenges the world has ever seen, and it's easy to think it's too late to make the changes we need in order to thrive on a healthy and vibrant planet. But a little bit of imagination could go a long way to providing us with just the road map we need to get to the planet we want.

leaving a residual "budget" of just 100 billion metric tons (110 billion tons). At the moment, we emit about 10 billion metric tons (11 billion tons) per year. Which means, putting it as starkly as people need to hear it, our remaining budget will be all used up in just 10 years' time.

I doubt that a single world leader understood the implications of that in Paris. But they will by 2020. Every nation, rich or poor, will by then understand the imperative of moving toward an ultra-low-carbon economy as fast as possible.

Take transport, for starters. What would that look like in practice? By 2030, working together, governments and city mayors will have to have eliminated new sales of all petrol and diesel vehicles. Almost all vehicles (buses, cars, taxis, vans, trucks, etc.) will need to be either electric or hydrogen-powered. Absolute priority will need to be given to cycling and pedestrian infrastructure.

For the first time in a very long time, the air people breathe will then be unpol-

EVERY NATION, RICH OR POOR, WILL BY THEN UNDERSTAND THE IMPERATIVE OF MOVING TOWARD AN ULTRA-LOW-CARBON ECONOMY AS FAST AS POSSIBLE.

luted. Thousands of deaths and hundreds of thousands of hospital admissions will have been avoided. Streets will be safer; kids will play outside across areas zoned primarily for people, not for cars. Suburbs will be "re-greened," with more space set aside for trees, parks, city farms and mini-market gardens.

That was the kind of alternative I mapped out in *The World We Made* — for transport, energy, manufacturing, farming, water, waste and so on. And practically everything I pointed to at

THE ENEMY OF HOPE IS NOT DESPAIR, BUT INDIFFERENCE.

the time really has started to emerge in practice — including the Pope becoming one of the world's outstanding leaders in advocating for a "just transition" to an ultra-low-carbon society.

For all the problems of today's market economy, markets are powerful drivers of change. Just look at the astonishing uptake of solar technologies across the world as prices have come crashing down over the last few years. Just look at the speed with which the coal industry is now heading into a death spiral, unable to cope with competition from gas and renewables.

And just look at the way Elon Musk's crusading drive to get a US$35,000 Tesla into the market by the end of next year has revolutionized people's expectations of the future of the car industry — with giants like Toyota and GM now intent on matching Tesla every step of the way.

The enemy of hope is not despair, but indifference. Post-Paris, we have a chance to change the "mood music" about the extraordinary benefits of a genuinely sustainable world, pointing out not only that it's absolutely necessary to move in that direction, but that to do so will be both exciting and desirable. That's what we mean by COPtimism!

JONATHON PORRITT, co-founder of Forum for the Future, is a writer, broadcaster and commentator on sustainable development. He has served as director of Friends of the Earth and co-chair of the Green Party, among other roles.

THE MOST IMPORTANT THING WE CAN DO

TO DIG DEEPER into *The World We Made*, Ensia asked Jonathon Porritt why he wrote the book, what's already started to change and what more he hopes people will take from it.

ENSIA: Have people been grabbing onto some of the ideas from the book and saying, "I want to run with this"?

PORRITT: Quite a lot of the ideas in the book have already started to happen. With artificial meat, for instance, there has been incredible progress over the last year. People are now starting to talk about breakthroughs on artificial photosynthesis. And the speed of change on solar technologies is just breathtaking to me.

ENSIA: What would you like people to do after reading *The World We Made*?

PORRITT: The most important thing we can do now is not to give into temptation to spend all of our engaged minutes learning everything that's going wrong and focusing on the slow sliding away into the apocalypse. We've got to use our available advocacy time and capacity to persuade people that good and exciting things are there and are available. What I'd like is for people to say, "Yeah, OK, I've got it. Let's grab a little bit of that and make that happen in our community, whether it's a community farm, or renewable energy, or we're going to think about this differently."

READ THE REST OF THE INTERVIEW AT **ENSIA.US/PORRITT**.

IT'S TIME FOR A NEW GMO CONVERSATION

An honest discussion of genetically modified organisms must move beyond narrow concepts of human health to the wider social and environmental impacts of engineered crops.

by **MAYWA MONTENEGRO**

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WHY THIS MATTERS

The debate around GMOs has become polarized to a point where opposing sides often don't bother to listen to each other, much less actually hear one another. In this piece, Maywa Montenegro attempts to get past the narrow constraints of the usual discussion around GMOs, which tends to focus solely on safety for human consumption, to extend the conversation to include broader social and ecological concerns. In the process, she clearly states that she is not anti-GMO, acknowledging that "many (probably most) GMO crops will be safe to eat," while accepting the fact that even with that admission there is still room for healthy and productive dialogue around the issue.

The GMO debate is one from which I've kept a purposeful distance.

For one thing, it's an issue that has already garnered more than its fair share of attention. For another, when you consider that many domesticated crops resulted from seed irradiation, chromosome doubling and plant tissue culture — none of which is genetically engineered — the boundaries of "natural" are more porous than they initially appear.

But I study seed science and policy, in which genetically engineered organisms — more often referred to as genetically modified organisms, aka GMOs — are pervasive, so it's an issue I cannot ignore. Most recently, the director of a science communications program asked if I could engage her students on a few topics: Is there a scientific consensus on GMOs? How is the media doing when it comes to covering biotech in the food system? Where are the biases and blind spots in reporting?

Swapping emails, we discussed the retraction of a study on "golden rice," a Slate feature calling the war against GMOs "full of fearmongering, errors, and fraud," and the infamous tangle among Vandana Shiva, David Remnick and Michael Specter in the aftermath of "Seeds of Doubt," a critical New Yorker profile of Shiva's crusade against genetically modified crops. Anyone who examines these stories will appreciate the thicket of fact, interpretation and framing that makes the GMO terrain explosive.

Let me begin with a frank admission: I am a proponent of agroecology, food sovereignty, and the rights of farmers to save and reproduce their seed. But I am not anti-GMO. In agreement with my colleagues at various universities and non-governmental organizations, I believe that some GM crops could have some benefits. What I object to is a lack of complex evaluations of the technology, the overzealous selling of its benefits and the framing of cautionary skeptics as anti-sci-

ence scaremongers. The tendency to treat GMOs in isolation from their historical, social and political contexts is also of no help: The technology was developed as a tool to enhance the scope and scale of industrial agriculture. I don't argue that GMOs cannot be — and never will be — extricated from that context, but that discussion is very different from the more common debate about health benefits or risks.

Why do the merits or demerits of GMOs grab more headline space than systemic food and agriculture concerns? Can we get past what Jonathan Foley, executive director of the California Academy of Sciences, calls the "silver bullet" and reductionist thinking on this issue? As a molecular biologist turned science journalist turned social scientist, I've been puzzling over these questions for some 15 years. What I've come to realize is that GMO stories point to deeper struggles over how science is conducted, interpreted and deployed in the arena of "sustainable food."

The *New Yorker,* Slate, *National Geographic* and numerous other media outlets have been part of an unfortunate trend in which GMO skeptics are framed as anti-science wing nuts. If scientists happen to work at an NGO, the credibility of the organization is frequently assailed — as if researchers outside the academy cannot provide intelligent critiques. To the contrary, organizations such as the Union of Concerned Scientists, Center for Food Safety and Pesticide Action Network support scientists whose research offers an invaluable supplement to academic work. In fact, they often are more willing to pursue "politicized" issues than university researchers who feel to do so would threaten their credibility or "impartiality." There are benefits to this precaution (we want to be as objective as we can be) but also considerable drawbacks, because it tends to deter scientists from considering the larger societal contexts of their research. That food and agriculture researchers are expected to wear the veil of value-free science is especially unfortunate now, when agribusiness is proving phenomenally successful at marginalizing its critics.

WHY DO THE MERITS OR DEMERITS OF GMOS GRAB MORE HEADLINE SPACE THAN SYSTEMIC FOOD AND AGRICULTURE CONCERNS?

ILLUSTRATION BY ERIN DUNN

"THOUGHTFUL AND SMART"

MICHAEL SPECTER, whose *New Yorker* piece on GMOs, "Seeds of Doubt," Montenegro references early in her story, wrote a note saying it was a "very thoughtful and smart piece. There are some things I think you got wrong (philosophically, not factually), but I just wanted to say you took a horrific and complex subject and handled it beautifully."

Though there are many angles from which to look at this issue, I think three are particularly important to help us get past less consequential aspects of this technology and on to things that are having a greater impact. The first is the construction of scientific consensus around GMO safety. The second is the framing of biotech benefits, which are often exaggerated. Finally, I think it's important to discuss the increasingly murky waters of scientist-industry-media relations.

WHAT IS SAFE?

"Good science" is often said to be based on strong scientific consensus, which, in turn, is a powerful statement about the use of rigorous methods and knowledge of science. Therefore, industry has a strong stake in demonstrating the existence of scientific consensus. Most people think of such consensus as emerging purely from objective studies of the natural world. But scholars of science and society argue that consensus is also negotiated and constructed through mechanisms such as conferences, expert panels, assessments of science and policy statements by scientific societies. When expert panels are assembled, for example, who is included — and excluded — can go a long way toward shaping what consensus emerges.

One needn't search far to find media narratives suggesting that the verdict is in: The vast majority of scientists have forged robust agreement around GMO safety; there is no evidence that engineered foods are unsafe to eat. These tactics are reminiscent of those of Big Tobacco and Big Oil, but with an interesting twist. Whereas those groups primarily sought to inflate scientific doubt, in the case of GMOs we are told that the science is settled.

Yet no good scientist would be content with the "epidemiologically shabby construct that if there's no evidence something isn't safe, it must be safe," Tim Wise, director of the Research and Policy Program at the Global Development and Environment Institute at Tufts University, points out. Scientific consensus on GMO safety simply doesn't exist.

A well-known 2011 peer-reviewed report attempted to survey all studies available in international scientific journals on human safety impacts of GMOs. The researchers found that about half of animal-feeding studies conducted in recent years found cause for concern. The other half didn't, and as the researchers noted, "most of these studies have been conducted by biotechnology companies responsible for commercializing these GM plants."

Importantly, this assessment — comprehensive as it was — only recognized the toxicological health risks to humans of ingesting GM foods. It did not analyze broader environmental and social impacts, which is where my primary concerns lie. These include overusing GMO-compatible herbicides, promoting the development of herbicide-resistant weeds and degrading habitats for organisms such as monarch butterflies. Monoculture cropping frequently associated with GMOs brings a host of other concerns: loss of biological pest control (requiring more pesticides), reduced soil fertility (requiring more fertilizer), and strain on nutrition and food security when traditional crop varieties are displaced by GM varieties or contaminated by their pollen. And the combination of GM crops with patent protection has resulted in concentrated seed industry control that has not only diminished public breeders' and farmers' access to germplasm, but also reduced crop genetic diversity, boosting vulnerability to environmental change.

Opportunity costs of pursuing GMOs should be a concern, too. Biotech tends to be expensive, and money spent there is not spent on research and development elsewhere. According to a University of California, Berkeley, review, over the past century, the U.S. Department of Agriculture has devoted less than 2 percent of its budget

to agroecological and organic agriculture.

"Safety," in sum, has been narrowly defined as human nutritional health, excluding many important safety dimensions and ignoring impacts on the larger agricultural, social and ecological systems. These, to me, are far more frightening than any "frankenfood."

Lately, a few studies have begun to consider these broader dimensions, with troubling results. In March 2015, the International Agency for Research on Cancer, an agency of the World Health Organization, reviewed the health effects of the herbicide glyphosate (aka Roundup). The IARC found that the chemical, which is designed to kill weeds without harming GM glyphosate-resistant crops, should be classified as "probably carcinogenic," meaning animal studies have demonstrated a definite link between cancer and exposure to glyphosate. Subsequent appraisals in 2016 by another arm of the WHO have interpreted the data differently, concluding that glyphosate is "unlikely to pose a carcinogenic risk to humans from exposure through the diet." But gone missing in this assessment is risk incurred through non-dietary forms of exposure, including for farmers and rural communities.

When such studies have been done, there is limited but growing evidence of harm to humans — mostly for farm workers who are more highly exposed to glyphosate. In addition, as a growing range of toxicological studies are demonstrating, high exposure levels may not be as important as once thought, as low doses of chemicals, including pesticides, are being demonstrated as detrimental — not to mention the potential effects of compounding exposure to multiple chemicals. In August 2015, the *Guardian* reported on a possible link between human birth defects and pesticides applied to GM crops in Hawaii. The Fund for Investigative Journalism–sponsored article underscored that scientists don't yet have epidemiological data, but connecting the dots between incidence and exposure, researchers indicated ample cause for concern.

In the words of 300 scientists in a joint statement published in the journal *Environmental Sciences Europe* in January 2015, "…the totality of scientific research outcomes in the field of GM crop safety is nuanced; complex; often contradictory or inconclusive; confounded by researchers' choices, assumptions, and funding sources; and, in general, has raised more questions than it has currently answered."

"SAFETY," IN SUM, HAS BEEN NARROWLY DEFINED AS HUMAN NUTRITIONAL HEALTH, EXCLUDING MANY IMPORTANT SAFETY DIMENSIONS AND IGNORING IMPACTS ON THE LARGER AGRICULTURAL, SOCIAL AND ECOLOGICAL SYSTEMS.

EXAGGERATED BENEFITS

A second issue is hyperbole. Despite the fact that over the past 25 years, classical plant breeding in both the U.K. and the U.S. has generally been subordinated to molecular biological methods in terms of resources and attention, biotech advances have not materialized as initially prophesied.

Take yield, for example. Testifying before the National Academies of Sciences in September 2014, North Carolina State University crop scientist Major Goodman observed that it's actually classical cross-breeding that continues to set the yield bar. In corn, he said, transgenics have made a roughly 5 percent gain in yields over the past 18 years, while standard breeding produces an estimated 1 percent yield gain annually.

Conventional breeding also appears to be outperforming genetic engineering in the race to develop crops that can maintain productivity in the midst of drought, extreme temperatures, salty soils and shifting pest regimes. A September 2014 *Nature* news article describes the work of researchers from the International Maize and Wheat Improvement Center, or CIMMYT, in Mexico City and the International Institute for Tropical Agriculture in Ibadan, Nigeria, around the use of non-GMO methods to develop drought-resistant corn varieties in 13 African countries. In field trials, these varieties are matching or exceeding yields from nonresistant crops under good rainfall — and yielding up to 30 percent more under drought conditions. The project already has 153 varieties in trial stages, and other seeds are already well beyond trial stage, enabling some 3 million smallholder farmers in Africa to increase yields by an average of 20 to 30 percent.

Meanwhile, Monsanto, CIMMYT and other researchers are still hoping to get a transgenic drought-tolerant seed trait to Africa by 2016 at the earliest. Even then, Monsanto's drought-tolerant seeds have been shown to increase yield only about 6 percent in the U.S., and only under moderate drought conditions. Direct comparisons are always tricky, of course, but as the *Nature* article put it: "Old-fashioned breeding techniques seem to be leading genetic modification in a race to develop crops that can withstand drought and poor soils."

I don't doubt that next-generation biotech methods — such as genomic editing — will slowly make inroads where current biotechnologies come up short. But complex gene-environment interactions and traits defined by multiple genes — including yield and drought resistance — are reminding scientists that living systems are tough nuts to crack. The major successes

of GM to date have all been single-gene tweaks, sometimes called low-hanging fruit. However, as Goodman told the academy, "They're not low-hanging fruit. They were things that were picked up off the ground."

The media often makes GM skeptics sound as though they are ignoring a gold mine of benefits — or worse, depriving Africans, Latin Americans and Southeast Asians of biotech solutions to hunger. But to date, roughly 99 percent of GM acreage has gone to industrial soy, canola, cotton and corn for which the principal end uses are biofuels, industrial animal feed, oils and ingredients for processed foods. In Foley's words, "While the technology itself might 'work,' it has so far been applied to the wrong parts of the food system to truly make a dent in global food security." (For more on this topic, see anthropologist Glenn Davis Stone's "Golden Rice: Bringing a Superfood Down to Earth.")

Of course, there are exceptions: virus-resistant papaya and summer squash have had local benefits, and cassava has been engineered for resistance to brown-streak disease, answering many critics' concerns that biotech will ignore regionally important smallholder crops. Yet even examples that are laudable in one sense (bye-bye, streak disease) require a hard look at ecological factors (why is streak a problem in the first place?) and the political and socioeconomic implications of an engineered solution. For example, as several West African countries prepare to allow GM cowpea to enter their markets, scientists are raising concerns over effects on the informal seed sector, traditional barter and gift practices, and local economies. What is at stake is only partly about GMOs per se, since modified seeds might cross-pollinate with traditional cowpea. It is also about using engineered seeds, alongside favorable marketing, intellectual property and biosafety laws, to open food systems to private sector development without participation or consent from local people.

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MUDDIED WATERS FOR THE MEDIA

So where does the media come in? To me, the *Guardian's* Hawaii story and others like it (e.g., Michael Moss's 2015 *New York Times* expose of the U.S. Meat Animal Research Center) illustrate the importance of in-depth reporting. The agri-food space is not an easy beat, with the waters muddied by industry public relations campaigns, conflicting studies and heightened intermingling of science with corporate interests. Witness Eric Lipton's 2015 *New York Times* investigative report detailing efforts by Monsanto, Dow and other companies to enroll scientists as spokespersons for GMOs to achieve "the gloss of impartiality and weight of authority that come with a professor's pedigree." The organic industry was also implicated, and a finger pointed to Charles Benbrook for receiving support from companies like Stonyfield Organic. However, *Times* readers (in the comment section) and academics (on email listservs) immediately bristled. It was an attempt, they said, to create a balanced profile without discussing the disproportionate nature of the practice: The biotech industry side has invested vastly more resources than the alternative side in corralling scientific support. In addition, Benbrook has consistently disclosed his backing publicly, whereas many of the industry affiliations are only coming to light because NGOs and journalists are requesting records via the Freedom of Information Act.

While the *Times* story helpfully ignited a conversation over FOIA and transparency, it left underexplored the extent of industry-research relations. The few scientists named in the piece only hint to a larger

READER COMMENT

THIS PIECE STARTED A LENGTHY ONLINE DIALOGUE in the comments section, including this excerpted comment from Paul Vincelli, a professor in the Department of Plant Pathology at the University of Kentucky. To add your own voice to the discussion, go to **ensia.us/gmos**.

"Nice contribution. Good points and good leads to some literature I had not seen. I'd like to share a few points (hopefully briefly). You may be correct: Perhaps we scientists sometimes are 'over-the-top' in our defense of genetic engineering (GE). In fairness, many of us

network of economists, consultants, lobbyists, industry executives and prestigious academics with a deep history of producing peer-reviewed publications, influencing U.S. Department of Agriculture regulatory policy and working to defuse public concern over GMOs. Hardly a better example can be found than the Cornell Alliance for Science, formed in 2014 with a US$5.6 million grant from the Bill & Melinda Gates Foundation to Cornell University to "depolarize" the debate over GM foods. Soon after, I saw an alliance job posting indicating the work would entail outreach to groups that "may not be well informed about the potential biotechnology has for solving major agricultural challenges." A colleague of mine joked that this sort of depolarization amounts to loading up one side with more ammunition.

Scientists aren't the only ones being enlisted in the GMO wars. Another strategy, according to a report published in 2015 by U.S. Right to Know, Friends of the Earth and author Anna Lappé, is the grooming of front groups that appear to be independent media sources and are frequently quoted in the press without reference to their industry ties. These groups include the Alliance to Feed the Future (which produces Common Core–compliant curricula on healthy food for public schools) and the U.S. Farmers & Ranchers Alliance (whose stated goal is "to enhance U.S. consumer trust in modern food production to ensure the abundance of affordable, safe food," and whose partners include the animal pharmaceutical company Elanco, biotech giant Monsanto, and chemical companies DuPont, Dow and Syngenta). Lappé estimates that such third-party coalitions spent US$126 million from 2009 to 2013 "to shape the story of food while presenting the veneer of independence."

Such public relations strategies are not new, but it's notable that they've surged at precisely the time when chemical-intensive farming, antibiotic use in livestock and genetic engineering are under intense public scrutiny. Journalists now need to critically evaluate not only the claims of bona fide scientists, farmer coalitions and hunger organizations, but also those made by deceptively named front groups. Some researchers may not even recognize the powerful sway of funding and sponsorships at institutional levels, or the politics of persuasion in elite inner circles. As New York University molecular biologist Marion Nestle argues, a substantial body of literature exists on industry-funded science — much of it looking at the effects of pharmaceutical industry funding of medical professionals. This literature suggests that industry-sponsored research tends to produce findings favoring the sponsor's interests. Such conflicts are "generally unconscious, unintentional, and unrecognized by participants," but they are nonetheless there.

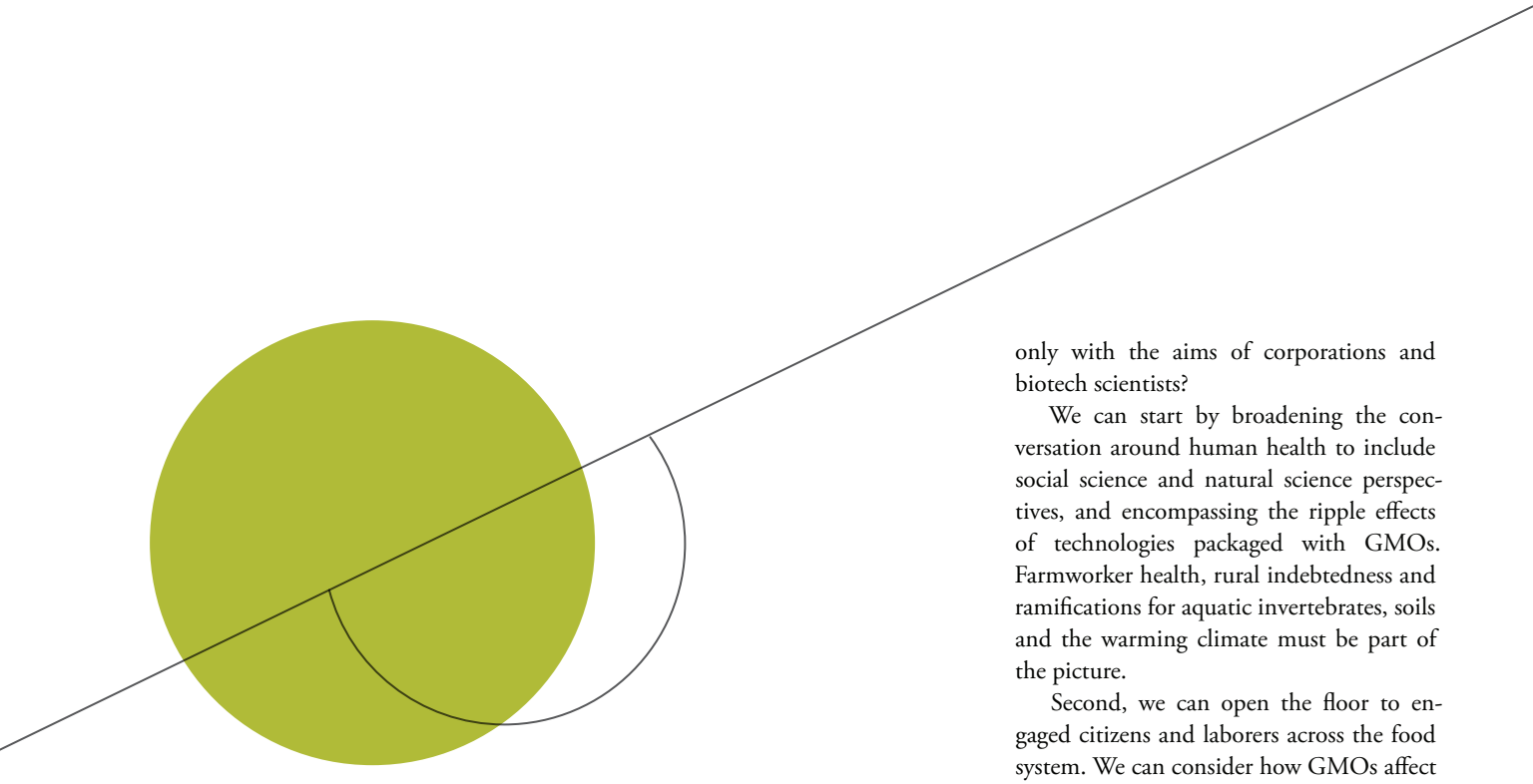
99
Percent of GM acreage that has gone to industrial soy, canola, cotton and corn

2
Percent of the U.S. Department of Agriculture's budget devoted to agroecological and organic agriculture over the past century

What I would like to pull out from this picture is something more subtle than corporate money corrupting impartial science. The key is learning to recognize that no science exists in a cultural vacuum. The very fact that

WHAT ARE THE CONDITIONS UNDER WHICH GMOS MIGHT WORK MORE EFFECTIVELY? CAN THEY BE COMPATIBLE WITH THE NEEDS OF FARMERS, EATERS AND THEIR COMMUNITIES, NOT ONLY WITH THE AIMS OF CORPORATIONS AND BIOTECH SCIENTISTS?

perceive questionable challenges to the very legitimacy of GE as a suite of tools for crop improvement. These challenges are often based on 'cherry-picking' or misinformation, and I cannot stress enough that this deprives the public of the valid, informed choice that it deserves. To your credit, you don't exclude a role for GE, used wisely. Too bad you are so far away — I would enjoy buying you a cup of coffee and sharing ideas. Not every scientist favorable to GE is part of a science-industry media machine. ... Also, I don't see GE as the only answer. It is merely a suite of tools, to be used as the breeder sees fit to achieve breeding goals. If a non-GE technique gets us there, fantastic! In this context, I also second your point about the value of participatory research. As a plant pathologist, I see vast potential for GE help with crop disease control."



certain scientific fields (such as molecular biology) are seen as more legitimate than others (such as organic farming and agroecology) grows out of longer-running social and political histories, institution-building and internal struggles for validation. "Fact" is far more densely layered than meets the eye.

What we do know is that since the 1940s, when World War II pesticide, herbicide and fertilizer technologies dovetailed with revolutions in hybrid seed and patenting, agriculture has increasingly moved toward simplified, intensive monoculture to supply multinational food companies with a steady supply of interchangeable ingredients. Surplus production has fended off the Communist Menace, underwritten the expansion of military-strategic interests under the guise of food aid and extended the market reach of input suppliers, commodity traders, food processors and retail giants to economies from Papua to Plano.

It should come as no surprise, then, that science and technology conducive to these developments has gained clout among certain governments, industry leaders and funding agencies. When those actors have the power to invest in particular research directions, build educational programs and forge science policy advisory networks, one paradigm — e.g., simplified farming systems + biotechnologies = feed the world — can easily gain traction over another. What comes to appear "normal" papers over what scholars Sheila Jasanoff and Brian Wynne call the co-production of science and political order that shores up the legitimacy of each.

This phenomenon is extraordinarily important for journalists to appreciate because it helps us see how reporting on food means not just weighing objective science against crank science, but teasing through science's sociopolitical contexts. Unless journalists are willing to tread into this space, polarization of the GMO debate will continue, and journalists will be helping ascribe wingnut status to anyone who challenges the status quo.

GMOS, IN SUM, POINT US TO DEEPER ISSUES THAT UNDERLIE THE ENTIRE FOOD SYSTEM.

BUILDING A BETTER GMO

What are the conditions under which GMOs might work more effectively? Can they be compatible with the needs of farmers, eaters and their communities, not only with the aims of corporations and biotech scientists?

We can start by broadening the conversation around human health to include social science and natural science perspectives, and encompassing the ripple effects of technologies packaged with GMOs. Farmworker health, rural indebtedness and ramifications for aquatic invertebrates, soils and the warming climate must be part of the picture.

Second, we can open the floor to engaged citizens and laborers across the food system. We can consider how GMOs affect not just yields, but also farmers' margins of return, food cultures and communities. We should listen to experiences of Bt cotton growers in India, Roundup Ready farmers in Iowa and academics who remind us that many things once considered safe — DDT, PCBs, BPA and thalidomide, to name a few — later showed "scientific consensus" to be more fragile than popularly perceived.

We also need better regulatory oversight. Many (probably most) GMO crops will be safe to eat, but some could be harmful. What should we do about those without a robust regulatory system? Labeling is one important prong of such a system; not surprisingly, it's being fought tooth and nail by industry. Other regulatory pegs include putting the burden of proving safety onto GMO developers, supporting long-term epidemiological studies and removing the bullying tactics of international trade regimes that pressure countries to deregulate their markets in favor of GM production and imports.

Finally, I would like to see GM research and development moved into the public sphere. Decoupling profit interests from R&D could open up a realm of possibilities: GMOs adapted for agroecological systems instead of monocultures, GMOs developed through participatory plant breeding, GMOs available to all under open-source seed licenses. As a concrete start, we can reevaluate the 1980 Bayh-Dole Act, which allows universities to own and commercial-

ize inventions made with federal funding — including granting exclusive licensing of GMO innovations to the private sector. While Bayh-Dole was intended to speed the flow of science into the marketplace "for the public good," backward pressure from industry onto university administrators and faculty has come to profoundly shape the direction of crop and agricultural science. Land-grant universities, strapped by shrinking state budgets, are increasingly pushed to conduct research that leads to patentable outcomes of resale value to industry. Private funding of land-grant schools has been outpacing federal funding for decades.

GMOs, in sum, point us to deeper issues that underlie the entire food system. A nonreductionist evaluation of GMOs can push us toward thinking about effects at multiple scales and time spans. Such an evaluation can get us to think deeply about who benefits from technologies, who controls their availability and access, and who makes such decisions. We get to think about the entanglements of politics, the media and public interest in shaping scientific validity and "consensus." In short, we are invited to think socially and ecologically — indeed agroecologically — about the utility and value of engineered seeds.

If GMOs can survive such scrutiny and emerge as a beneficial tool, I'm certainly not anti-GMO. Let's hope I won't be labeled a wing nut.

IMPACT

This story has been viewed nearly 20,000 times at ensia.com, with readers spending on average more than eight minutes reading it. It was also republished by Business Insider, PRI and Quartz, where nearly 78,000 readers have seen it. Meanwhile, Michael Pollan tweeted the piece to his 515,000 followers, calling it "important and brilliant." Offline, a number of professors have begun including the piece in class syllabi.

MAYWA MONTENEGRO is a Ph.D. candidate in environmental science, policy and management at UC Berkeley, with a master's degree in science writing from MIT. Her research focuses on seeds, agroecology and food system diversity, with writings on these topics and more appearing in *Gastronomica, Earth Island Journal, Seed Magazine, Grist* and the *Boston Globe*.

WRITER UPDATE: *Scarcely a week goes by when some new development in science, law or business does not spark reinvigorated GMO debate. As I write this, experts are arguing the merits of a new pesticide study out of Iowa State University based on the most detailed GM corn and GM soy data ever assembled. Meanwhile, the German chemical company Bayer has just offered US$66 billion to buy out agribusiness giant Monsanto, the latest in a string of deals that could also see the births of Syngenta-ChemChina and Dupont-Dow — all companies with significant investments in GM technology. If U.S. and EU regulators allow the mergers to take place, it will mean nearly 60 percent of the world's seeds and 70 percent of agricultural chemicals are controlled by just three companies. And as the U.S. Department of Justice considers the legality of BayerSanto (MonBayer?), social movements across Europe, the U.S., Asia, Africa and Latin America are convening in the Hague for the Monsanto Tribunal, a symbolic trial that will use international human rights and criminal law to try the company for crimes including "ecocide."*

The intensity of the "GMO wars" has only been deepened by gene editing using CRISPR-Cas9 technology. Since I wrote this essay in 2015, gene editing has exploded into public attention, raising fresh questions about how society should define, regulate and apply biotechnologies. With advocates and critics entrenched in seemingly intractable postures, CRISPR has become a Trojan horse to some and, to others, a tool of epic possibilities — feeding the world with word processor precision.

With CRISPR applications already underway, we don't yet have robust social and ecological criteria with which to evaluate genetic engineering — or any form of crop improvement. A much-anticipated report from the National Academies of Sciences, Engineering, and Medicine released in 2016 looked at a range of health, environmental and socioeconomic impacts of GM crops. It highlighted pressing needs, such as more public transparency and regulatory oversight. Very importantly, it found no evidence that GM crops in the U.S. yield more than their non-GM counterparts, casting doubt on the feed-the-world hypothesis. But even this study seemed to largely miss its own point. Its recommendations often did not match the subtle and qualified scientific findings buried deep in the 388-page report, and its narrow take on individual "food safety" fell far short of wider societal concerns: for example, how do herbicides affect the safety of farmworkers and food workers? What is the relationship of GE use to crop genetic diversity? What are the long-term impacts on peasant and indigenous seed systems? Not least, how "safe" is it for just three companies to control most of the world's commercial seed? I look forward to more holistic appraisals of the technologies we deploy in and around our crops, at local to global scales. Stay tuned.
— MAYWA MONTENEGRO

THE MOVE CLIMATE-DISPLACED PEOPLE REALLY NEED

The designation "climate refugee" is key to ensuring an orderly transition for the millions who will be forced from their homes in the decades ahead.

by KAYLA WALSH

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WHY THIS MATTERS

As Kayla Walsh writes in this piece, in 1985 the United Nations Environment Programme estimated that 30 million people had been displaced by environmental catastrophes. Looking forward to 2050, some estimates say 150 million to 300 million people could be at risk of displacement. Recent years have seen much strife as countries figure out ways to deal with newcomers at their doors.

We can either take a proactive approach to future migrations, figuring out, as best we can as an international community, what to do before more people are uprooted against their will, or we can stumble from crisis to crisis, leaving displaced people feeling unwelcome and residents of receiving countries confused and often angry — with neither group satisfied with the outcome.

Undoubtedly, the climate agreement achieved at COP 21 in 2015 deserves recognition as the world's first multilateral accord to curb climate change. But the final document failed to address the tens of millions of climate refugees expected to arrive at our collective doorsteps by 2050.

Governments such as China and Mozambique have already started displacing certain populations in anticipation of climate changes. But many vulnerable countries, such as Bangladesh, whose people will most likely need to move, lack the resources to relocate entire populations to a new region or nation. Bangladesh is being ravaged by flooding, cyclones, storm surges, salination, erosion, rising seas and more. Of the country's 64 districts, at least 24 are already producing climate-displaced people. At the same time, India is building a 2,500-mile (4,000-kilometer) barbed wire fence along the Bangladeshi border to dissuade migrants.

It's difficult to predict how many people will be displaced around the world in years and decades to come. In 1985 the United Nations Environment

Programme estimated that 30 million people had been displaced by environmental catastrophes. In 1995, British environment and development consultant Norman Myers estimated that 200 million people or more could be at risk of displacement by 2050, with 26 million from Bangladesh alone. More recent estimates of the number of "environmental migrants" to be expected by 2050 range from 150 million to 300 million.

Whatever the numbers, it is vital that refugees not be viewed as enemies at the gate, but as agents adapting proactively to climate anomalies beyond their control. In fact, it is in the world's best interest — not just the refugees' — to start considering human mobility as a climate adaptation tool under an international political framework. Using migration as an adaptation strategy will help the world avoid crises such as that occurring in Europe and elsewhere, where refugees fleeing Syria, in part due to climate-related anomalies that contributed to and escalated instability, have been met with a wide range of responses, from acceptance to hostility. Instead, future migrations could ensure climate refugees the right to a safe and planned transition in which they have a voice to advocate for themselves.

DEBATING THE DEFINITION

In order to accomplish this, it's imperative that climate refugees receive the protections granted under international law to most other refugees. Environmental scientists and academics define climate refugees as people who can no longer guarantee safety or a secure livelihood in their own countries because of drought, soil erosion, desertification, sea-level rise or other environmental issues. But this is an academic definition, not a legal one.

THE REALITY IS THAT CLIMATE DISPLACEMENT IS A FORM OF PERSECUTION.

Under international law, climate refugees are not refugees at all. The word "refugee" gives asylum seekers legal status under the 1951 Geneva Convention Relating to the Status of Refugees. But that definition only grants human rights protections to persons fleeing political persecution. Since climate refugees, as currently defined, are not fleeing political persecution, this convention can rarely protect them. The United Nations High Commissioner for Refugees tends to use the term "climate displaced persons" instead. Some support the term "climate migrants," but this is problematic as well because "migrants" implies people move willingly.

But the reality is that climate displacement is a form of persecution, because globally, wealthy nations have contributed the bulk of greenhouse gases, and developing nations have suffered most of the consequences. As François Gemenne, researcher on environmental geopolitics and migration governance at Sciences Po, an international research university in France, put it at a side event at COP 21, "Most humans are the victims, not the agents, of climate change, so we should consider [climate change] a form of political persecution. … [C]limate change is just another form of violence we inflict upon them."

Legalizing the term "climate refugee" under some sort of global governance system such as that of the United Nations Framework Convention on Climate Change is our best bet to close the legal gap in which climate-displaced people around the world have no name and no safety net in international policy-making. The term "climate refugee" gives human rights protections, legitimizes migration as an adaptation strategy and makes climate change grounds for political persecution.

ILLUSTRATION BY KELSEY KING

NOT THE USUAL SUSPECTS

ALTHOUGH MIGRATION due to climate change impacts is most often thought of as an issue that will most affect people living in the developing world, the U.S. and other developed countries will also have to deal with people moving due to the world changing around them. In 2016, media attention turned to the Biloxi-Chitimacha-Choctaw Native American tribe on the Isle de Jean Charles off the coast of Louisiana, where 98 percent of the island's land has been lost to the sea. *The New York Times* and National Geographic called tribe members the first climate refugees in the U.S. and chronicled their story, which includes "$48 million for Isle de Jean Charles … the first allocation of federal tax dollars to move an entire community struggling with the impacts of climate change," the *Times* wrote. "We don't have time," tribal chief Albert Naquin told National Geographic. "The longer we wait, the more hurricane season we have to go through. We hate to let the island go, but we have to. It is like losing a family member. We know we are going to lose it. We just don't know when." Meanwhile, in an op-ed in *The LA Times*, Victoria Herrmann, president and managing director of the Arctic Institute, wrote about residents of Newtok, Alaska, Washington's Olympic Peninsula, and "thousands more from along America's most fragile shorelines [who] will embark on a great migration inland as their homes disappear beneath the water's surface."

WHO'S IN CHARGE?

Countless organizations are working creatively to fill this legal void. The Council of Europe Parliamentary Assembly's Committee on Migration, Refugees and Population lobbies for adding a "right to healthy and safe environment" as part of the Europe Convention of Human Rights. Other groups, like the Nansen Initiative — launched in 2012 by Norway and Switzerland to build a consensus on principles for domestic, regional and international policy-making on cross-border migration — wants a nonbinding protection agenda based on international cooperation, standard treatment of climate refugees and funding mechanisms for resettlement.

At another side event in Paris, Walter Kaelin of Nansen said that these topics are just "too sensitive" for the COP 21 international negotiations. Apparently he was right. In the Paris agreement, the UNFCCC politely refused to use any term for climate refugees and tucked the issue into its ambiguous "Loss and Damage" clause. Unfortunately, this clause doesn't accomplish what all small island nations hoped it would; it merely suggests implementing a task force to "develop recommendations for integrated approaches to avert, minimize and address displacement related to the adverse impacts of climate change." For this and other reasons Gemenne says, "I'm not sure if we should hope to see migration policed by the UNFCCC framework."

REFUGEE PERSPECTIVES

The issue is complicated, though, because many climate refugees don't want to be labeled as such. To these people, becoming a refugee means losing agency and becoming a marginalized victim. At COP 21, Anote Tong, then-president of Kiribati, a vulnerable small island nation, said, "I always cringe when someone says [climate refugee]."

Kiribati developed a "migrating with dignity" policy to facilitate planned migrations. As Koko Warner of the Institute for Environment and Human Security at United Nations University put it during a panel discussion in Paris, "whether people stay or go, it needs to be dignified." But not all transitions will be smooth, especially when they are due to rapid-onset disasters,

IN ORDER TO ACHIEVE PLANNED MIGRATIONS, THE WORLD MUST ADOPT A LEGAL DEFINITION FOR THE USE OF THE TERM "CLIMATE REFUGEES."

To be fair, world leaders have shown more political will to address this issue now than ever before. In opening speeches at COP 21, most world leaders emphasized the links between climate change and security. In the wake of the tragic Paris terrorist attacks in November 2015, President François Hollande of France said, "What is at stake at this climate conference is peace." Many scholars and politicians support the idea that issues related to climate change are partly to blame for the current situation in Syria, including German chancellor Angela Merkel, who has allowed more than 1 million Syrian refugees to enter her country. But in order to achieve planned migrations, the world must adopt a legal definition for the use of the term "climate refugees." Without one, ambiguity and uncertainty will continue to immobilize world leaders.

so people fleeing their homes because of climate-related issues need the protection the term "refugee" carries.

Other vulnerable nations push for the legalization of the term "climate refugee" despite its negative connotations as a way

to gain human rights protections allowed to other refugees. Additionally, many small island nations see it as an opportunity to get restitution from developed countries, which they believe they deserve for bearing the unequal effects of the developed world's greenhouse gas pollution.

Meanwhile, while we debate definitions and governance frameworks, vulnerable nations are calling for immediate action. Displacement due to disasters has increased fourfold since the 1970s. Tong said at a COP 21 meeting, "Enough talk, let's have action. … We are just trying to find a way to stay above the water."

As the number of refugees grows, the world will have to adapt to this new reality. Politicians and others need to address this issue on an international scale by creating a road map allowing for migration to be used as an adaptation strategy in our rapidly changing world. Only then will migrations mature from being sudden, forced and unwelcomed tragedies to planned, dignified and pragmatic ways to adapt to a changing climate.

Editor's note: Kayla Walsh produced this piece as a participant in the Ensia Mentor Program. Her mentor for the project was Ensia senior editor David Doody.

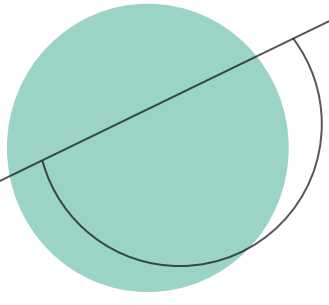
"ENOUGH TALK, LET'S HAVE ACTION. … WE ARE JUST TRYING TO FIND A WAY TO STAY ABOVE THE WATER." —ANOTE TONG

KAYLA WALSH is an environmental journalist with particular interests in social justice, sustainable development and climate policy. She received her undergraduate degree at Macalester College in St. Paul, Minnesota.

WRITER UPDATE: *Climate migrants are hard to define, which is why some people think that estimates of displacement are overblown. The fact is, climate change exacerbates political tensions, violence and persecution across the globe at a time when many political leaders are reluctant to help any displaced persons. Those who are defined as climate migrants deserve the same legal human rights protections as political refugees.*

Recently, the New York Declaration for Refugees and Migrants attempted to lay the foundation for a global compact for the safe, orderly and regular migration of refugees, and the equitable responsibilities of countries to host refugees. However, this compact still does not pay special attention to persons displaced by climate change.
— KAYLA WALSH

the YEAR



AHEAD

WHAT WILL BE the biggest challenge to address or opportunity to grasp in your field in 2017? Why? And what should we be doing about it now?

As we turned the calendar and our attention to the new year, Ensia posed those three questions to eight global thought leaders in the areas of environmental change, water resources, food and the environment, sustainable business, environmental justice, conservation, environmental health, and technology. The thoughtful answers these individuals shared provide valuable insight into where we've been, where we are and — most importantly — where we might go if we choose to let the turning of the year inspire us to pursue a healthier, more sustainable future for ourselves and our environment.

THE YEAR AHEAD

IN 2017...

INTERVIEWS *by* LISA PALMER

ENVIRONMENTAL CHANGE

PEACE AND RESILIENCE

Christiana Figueres
Former executive secretary, United Nations Framework Convention on Climate Change

A HOST OF TRENDS threatens to undermine the stability and security of our communities, including widening inequality, record youth unemployment, rapid urbanization, increasing pressure on resources, commodity price volatility and, exacerbating all of this, an increasingly unpredictable and extreme climate.

In 2015, the world came together and agreed we would not let these trends run rampant through our societies — that, instead, we would work toward a common set of positive goals. The Sustainable Development Goals, Paris climate change agreement and Sendai Framework for Disaster Risk Reduction together provided us with a common vision for a more peaceful and resilient world.

Now we need to buckle down and build it, even if we encounter unexpected resistance or challenges to our agreed goals. That means ensuring that every decision we take as a society is aligned with the goals we have set. Our fiscal and monetary policy, our infrastructure and planning decisions, our social welfare provision — all of this must point in one clear direction, so that no flank of our actions undermines the rest.

We will not be able to build more peaceful and resilient communities if in the pursuit of our objectives we run roughshod over each other's priorities and concerns. Instead, we must come together to, for example, understand what actions we take to limit temperature rise to 1.5 °C (3.6 °F) mean for how we use our land, how they can be harnessed as opportunities to reduce youth unemployment and deliver more inclusive prosperity, how they can offer opportunities to bring energy access and economic opportunity to the remotest of places through technologies such as decentralized solar. Not only is opening up this wider invitation to a world of opportunity the right thing to do — it is our best insurance against alienation, anger and violence.

ILLUSTRATIONS BY ALEKSANDAR SAVIĆ © MP ARTS

WATER PRODUCTIVITY

Betsy Otto
Director, Global Water Program, World Resources Institute

WE CONTINUE TO OVERSPEND our budget when it comes to freshwater resources globally. No country is immune; this is not just a challenge for arid regions.

Agriculture is by far the largest consumer of water, and at the same time demand for water to produce energy, industrial products, and the rapidly growing needs in cities are straining our water resources as never before. Add climate change and the situation is quite daunting.

We have no idea how much water we use relative to how much is available as a renewable supply in rivers, lakes and aquifers. The first step is to understand the relationship between supply and demand, and the impacts of freshwater use across cities, industry, power plants, and farming. WRI created the Aqueduct tool to help provide this information globally, free of charge, and it is now being widely used.

Any government or private sector enterprise can do a few things right now. One is to understand the nature of the water risks you face — too little, too much, too polluted — in specific locations, and use resources like Aqueduct's Water Risk Atlas and Global Flood Analyzer to understand supply/demand relationships and flood risks. Those in the agriculture sector can work to improve the water productivity of agriculture. A productivity gain of at least 30 percent is eminently achievable by changing farming and irrigation practices through approaches that are already well known.

We must reduce water and energy demand together, because the two are deeply intertwined. One effective approach to reducing both is to capture the methane from wastewater and use it to power treatment plants, make electricity to feed into the grid, and create compressed natural gas to run vehicles. In this way, cities can reduce energy demand and in the process free up huge volumes of water otherwise needed to cool power plants as well as reduce greenhouse gas emissions.

SUSTAINABLE BUSINESS

TRUE VALUE

Andrew Winston
Advisor, speaker and author of *The Big Pivot* and *Green to Gold*

THE BUSINESS COMMUNITY has moved a long way in recent years. There's broad acceptance that pursuing sustainability and addressing climate change are good for business. Seeing that general business case, companies have begun to invest in and build a cleaner more sustainable economy, so the biggest opportunity is to keep that momentum going. This quest may become more of a challenge in 2017 if the new administration in the U.S. is hostile to action on climate, clean energy and social justice. But the megatrends driving companies toward resilience, sustainability and clean tech are not going away — and they don't depend much on government.

For example, thanks to innovation and increasing scale, renewables are often less expensive than fossil fuels — even without subsidies. Many large companies are buying significant quantities of solar and wind power. On top of pro-climate economic trends like these, social pressure on companies to manage environmental and social issues is rising. Millennials want organizations they work for and buy from to pursue more than profit, motivating forward-thinking companies to demonstrate a commitment to a larger purpose.

Still, the quest for sustainable business faces perennial challenges. Executives feel relentless pressure for short-term results and often believe that sustainability always costs too much. But many things companies do under the banner of sustainability, like eco-efficiency, save money very quickly. Other, deeper changes in a company's operations, products and supply chains will require investment with possibly longer payback periods. So getting organizational attention for sustainability, especially in what may be a volatile political and economic environment, could still be challenging.

The solution is partly about how we tell the story and think about value. Even though many aspects of business can't be measured precisely, that doesn't mean they create no significant business value. What are improved safety, better working conditions, business resilience, employee engagement or customer loyalty worth?

So the challenge for 2017, beyond navigating a radically different U.S. political landscape, is to change our mind-set. If we demonstrate that sustainability drives value, business has an amazing opportunity to lead in the creation of a thriving, equitable world.

ENVIRONMENTAL JUSTICE

BEYOND THE USUAL SUSPECTS

Judy Hatcher
Executive director, Pesticide Action Network North America

THREE BIG NEWS ITEMS OF 2016 — the national dialogue sparked by the Movement for Black Lives, indigenous-led actions across North America to stop new oil pipelines, and the U.S. presidential election — highlight how critical it will be in 2017 to keep equity and human rights at the center of whatever good work we're doing.

The Building Equity & Alignment for Impact Initiative, launched by the Overbrook Foundation, is bringing environmental justice groups and large traditional environmental groups together. National multi-million-dollar institutions have adopted climate justice principles. Campaigns to stop oil drilling and pipelines from Canada to the Gulf Coast, led by Native peoples and communities most affected by extractive industries, have captured the imagination of millions of people. The emerging food justice movement offers Americans an opportunity to examine how separate issues — including workers' rights, public health, agriculture and conservation — are fundamentally interconnected and systemic.

The Trump presidency threatens to roll back decades of progress in protecting the natural environment, workers, residents of fence-line communities and consumers, increasing the

potential of human health harms, especially for children. If we step up our commitment to bottom-up, grassroots-led, justice-focused solutions in a proactive united front among environmentalists and with others fighting for an equitable future, we can mitigate the damage. Inside-the-Beltway groups, especially, can learn much from the multifaceted organizing happening near refineries, commercial transportation hubs, concentrated animal feeding operations, industrial-scale farms and oil pipelines, all of which offer galvanizing examples of emergent strategies that can't be ignored by policy-makers or by the media.

If we embrace the challenge and opportunity to incorporate the pursuit of justice and equity with respect to race, class and gender into efforts to protect the environment in 2017, we have the potential to exponentially expand the scope and power of the environmental movement beyond the usual suspects and to advance key agendas whatever the political climate might be. The question is, do we have the courage to change ourselves?

FOOD & THE ENVIRONMENT

UNSETTLING CONSOLIDATION

Anna Lappé
Founder, Real Food Media; Founding Principal at Small Planet Institute and Small Planet Fund; Author, *Diet for a Hot Planet*

THE FOOD SYSTEM is one of the largest forces impacting our planet's environment and people's health. The choices about what crops are grown, where and how they are produced, who gets access to that food and who makes those decisions all have global consequences.

One of the challenges to achieving a more sustainable and fair food system is corporate consolidation in the food sector. Consider the latest proposed merger between global giants Bayer and Monsanto pending antitrust approval. And remember, DuPont-Dow, Syngenta–Chem China and Monsanto-Bayer (if the mergers go through) aren't agriculture companies first — they're chemical companies.

Particularly worrisome is that these multinational corporations are focused on just a handful of commodity crops, while we know global food security comes from supporting biodiversity. We know that corporate control leads to political capture as corporations use lobbying dollars and campaign contributions to shape public policy and regulation, with enormous implications for the environment and food safety. We also know that once four or fewer corporations control more than 40 percent of a market, true competitiveness is compromised: Consumers and farmers lack real choice and fair prices. Consolidation puts food workers and small-scale farmers at risk, and it increases vertical integration, further hurting farmers' ability to compete.

To achieve greater food sovereignty, we need to embolden our regulators to take antitrust action against these mergers. We need to see these not as simply business deals for Wall Street analysts to angst over, but as deals that affect the very essence of our food system.

CONSERVATION

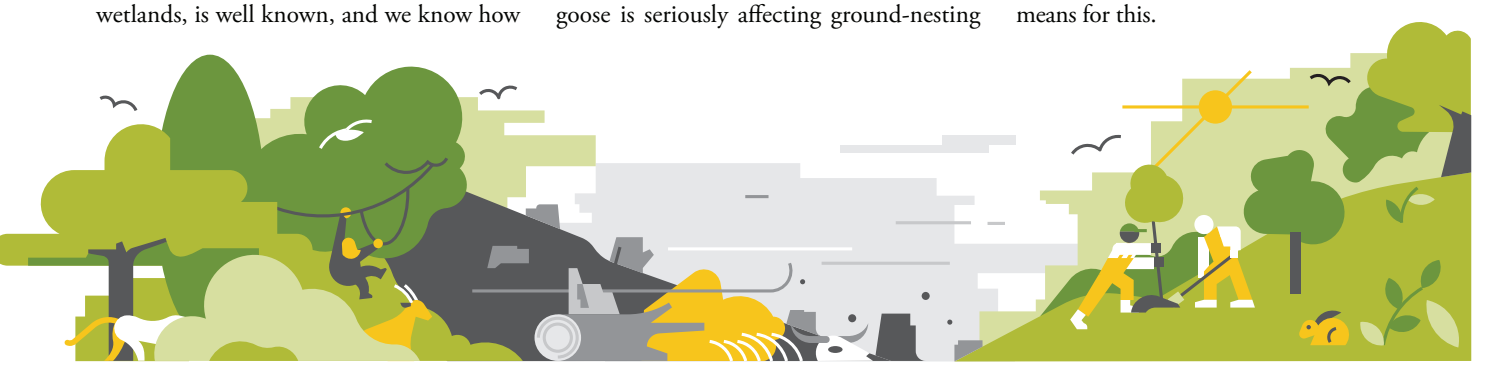
NEW SOLUTIONS

William Sutherland
Professor of Conservation Biology and Founder of Conservation Evidence, University of Cambridge

IT IS CLEARLY CRUCIAL to protect what remains of habitats and species. Alongside this, the restoration of degraded or destroyed habitats provides the opportunity to actually improve the planet both for its intrinsic importance and for the services biodiversity provides, such as storing carbon and retaining water flows.

The simple loss of habitats, such as the clear-felling of forests and the draining of wetlands, is well known, and we know how to stop it. But there are more complicated situations. Climate change makes some habitats unviable in current locations. Furthermore, invasive species, especially forest pathogens, pose serious threats to the integrity of various habitats. The upland forests of Hawaii, which I visited recently, provide one stark example. There, introduced avian malaria carried by introduced mosquitoes has restricted most endemic species to the cold damp highlands. The introduced mongoose is seriously affecting ground-nesting species. The main forest tree, the ohi'a, is dying from an introduced pathogen on one island that will surely be spread elsewhere.

What should we do about all this? Unfortunately — and this is a global problem with policy — we assume we know what to do while experience shows this results in the repetition of mistakes. While some approaches to slowing habitat loss and restoring habitat are obvious and we have the experience to carry them out, when new circumstances occur there is a need for new methods and new technologies. We need a community that innovates to make new suggestions, tests different approaches and makes the lessons learned available to others. Above all we need a global collation of the global evidence so this is available to all. Conservationevidence.com provides a means for this.



ENVIRONMENTAL HEALTH

HEALTH AND ENERGY

Jonathan Patz
Director, Global Health Institute

CONSIDERING THE PARALLEL rise in chronic diseases (like diabetes, obesity and heart disease) with trends in fossil fuel use around the globe, our greatest challenge today (and opportunity) lies at the nexus of health and energy. Much of this interlinkage can be explained across three human behavioral and related policy domains: energy, food systems and transportation/urban design.

Scientists no longer question the link between burning fossil fuels and the disruption of Earth's climate — with the myriad of adverse consequences already experienced and far more yet to come. The amazing thing, however, is that cutting emissions for climate change policy also saves lives. More than 7 million people die annually from air pollution, so this health "co-benefit" from energy policy choices is not trivial.

And food for thought: The Western diet — high in meat consumption and processed foods — harms both our health and the environment. Livestock production requires the largest fossil fuel inputs per gram of protein produced. Eating lower on the food chain for environmental reasons will also lower saturated fats in our diets and reduce the risks of stroke, heart disease and cancer.

Maybe the most direct dual benefit to our health and the planet emerges from

transportation policy. Many cities are designed for cars rather than for people. The result? 60 percent of Americans don't meet minimum daily requirements for exercise, and obesity is ranked our number one epidemic. Comparing cities with highest levels of bicycle commuting with those with lowest levels, obesity and diabetes rates are more than 20 percent lower. Smart urban design for "active transport" (walking and cycling) is therefore another double win, both for the environment and our health.

In conclusion, new policies in energy, food systems and transportation can provide us a healthy energy society, and in so doing, offer enormous health and environmental benefits for which we must not delay.

TECHNOLOGY

WE HAVE TO WANT TO

Jason Pontin
Editor in Chief and Publisher, *MIT Technology Review*

THE CHALLENGE IN 2017 existed in 1989: the civilizational challenge of climate change. Technology created the problem, and technology plausibly offers ways to ameliorate and manage it. But we have to want to solve the problem. Great civilizational challenge of that scale requires government, academia, business and ordinary people to want to solve it, and I don't think as a species we are there yet.

There will be 9.6 billion people alive on the planet in 2050 — that's 2 billion more on a world roiled by climate change; and we have no idea how to provide them with sufficient, sustainably clean energy, food and water. We have no idea how to build livable cities for that 9.6 billion. We have no idea how to offer them real, meaningful economic opportunities and some form of self-expression in what they do. Men and women of good conscience should be thinking of nothing less.

Meanwhile, two interesting technologies seem to have dropped out of the future before we are fully ready for them, politically, socially or economically. The first is CRISPR-Cas9 and the ability to edit individual nucleotides. It plausibly offers the opportunity to create new kinds of cultivars for agriculture, develop new therapeutics and make direct genetic interventions on human genome. The second is the disruption by deep learning and machine learning on a whole variety of jobs, such as medical doctors and lawyers.

I think all these things are manageable, because I am an optimist and a technologist. The first step is to admit you have a problem. And the second step for modern society is to say we are all in this together. It is the first time the human race, if it is to solve these problems, which technology has created, is going to have to think as a family, using technology rather than be used by it.

ON THE COVER

NATURE REDESIGNED

IN REMOTE PLACES, nature follows its course without interruption, but human intervention is almost always close at hand. Environmental artist Martin Hill creates and photographs ephemeral sculptures in natural landscapes to illustrate the interconnectedness of living systems. The photo featured here from Great Barrier Island, New Zealand, involves taking away elements rather than gathering and assembling them. "For me, making this body of work is my way of connecting with nature to tell the story of the transition that is now underway toward a circular economy that emulates the way nature works," Hill writes.

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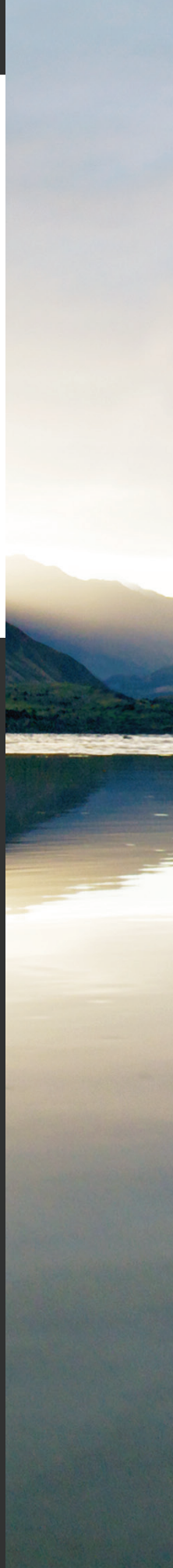

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