NOVEMBER 2015

EXPLORER
Bill Nye's Global Meltdown
Sunday, November 1 on the National Geographic Channel

NATIONAL GEOGRAPHIC

Cool it.

The Climate Issue

thrive

Delivering seeds in Brazil

Cargill is working with The Nature Conservancy to help farmers in northern Brazil restore deforested lands and grow cocoa in the shade of the forest canopy, boosting biodiversity. In 2014, 120,000 cocoa seeds and 74,000 banana seedlings were delivered to farmers.

Awarding premiums in Indonesia

We've given $1 million to 8,800 smallholder farmers across 18 cooperatives in South Sumatra, Indonesia, awarding them for their use of sustainable harvesting methods.

Training farmers in South America

We've helped 1,000 farmers update their operations in Argentina and Paraguay with sustainable production practices—including compliance with rules limiting deforestation, reducing greenhouse gas emissions and improving labor conditions.

Benito Guerrero of The Nature Conservancy inspects a native Amazon ype tree as part of the sustainable soy program in Brazil.

150 years of helping the world ***thrive***

Seeing the forest for the trees

The world's forests are a source of abundance. They shelter biodiversity, provide food and natural resources, absorb greenhouse gases and regulate the climate. Today, the challenge is to protect our forests while working to feed 9 billion people by 2050.

For more than a decade, Cargill has been working to decrease deforestation. In Brazil, we've teamed with businesses, non-profits and others to implement the Brazilian Soy Moratorium, a voluntary effort that has helped reduce deforestation rates in the Amazon by over 80%. On the other side of the globe in Indonesia and Malaysia, we're taking steps along with other organizations to help build a sustainable global supply chain for palm oil.

And as a signatory to *The New York Declaration on Forests*, we're now united with more than 40 companies, 30 governments and dozens of civil society groups to reach big goals: halving deforestation by 2020 and ending it by 2030.

Learn more at **cargill.com/climatechange**

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Secretarybird
(Sagittarius serpentarius)
Size: Height, 90 - 137 cm (35 - 54 inches); body length, 112 - 152 cm (44 - 60 inches)
Weight: 2.3 - 4.6 kg (5.1 - 10.1 lb)
Habitat: Grasslands and grass savannas
Surviving number: Fewer than 100,000

Photographed by Anup Shah

WILDLIFE AS CANON SEES IT

Bone crusher. Thanks to lightning-quick aerial kicks and stomps forceful enough to shatter bone, the secretarybird is a master at immobilizing dangerous prey. A much more formidable hunter than its crane-like appearance would suggest, it is even capable of vanquishing the deadly black mamba, the fastest terrestrial snake in the world. But this skill makes the bird a popular pet for humans, who rob nests and raise young as protection from snakes. Meanwhile, prey is becoming harder and harder to find due to habitat degradation.

As Canon sees it, images have the power to raise awareness of the threats facing endangered species and the natural environment, helping us make the world a better place.

EOS System

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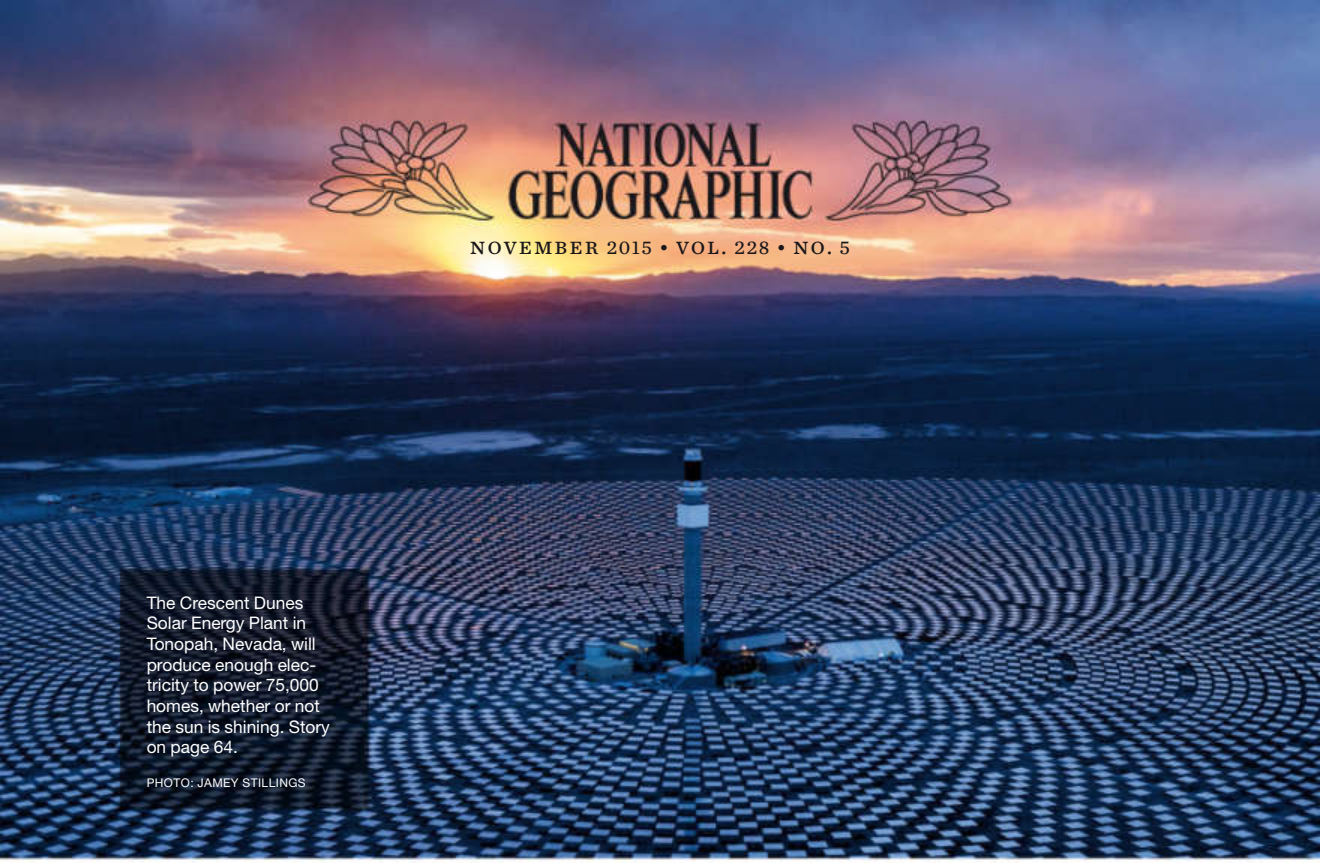
NATIONAL GEOGRAPHIC

NOVEMBER 2015 • VOL. 228 • NO. 5



The Crescent Dunes Solar Energy Plant in Tonopah, Nevada, will produce enough electricity to power 75,000 homes, whether or not the sun is shining. Story on page 64.

PHOTO: JAMEY STILLINGS

The Climate Issue

How to Fix It

On the Cover *Photo by Robert Simmon, NASA Earth Observatory/NOAA/DOD*

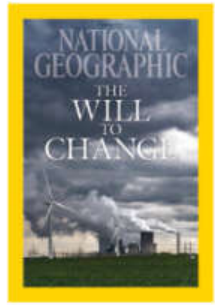
Corrections and Clarifications Go to *ngm.com/more.*

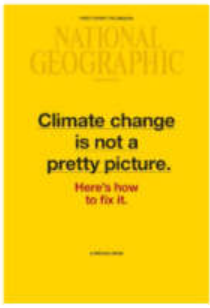
How to Live With It

Of Coverage and Covers

For some people, the subject of climate change is top of mind: They are passionately interested, want to learn everything they can, and are motivated to reduce their carbon footprint. They'll like this issue.

Then there are other folks. There are some who deny climate change is happening at all (about 25 percent of Americans in some polls) and others who feel about climate change the way I do about the tax code or car repair—they know they should care, but please, spare them the details. They also believe they can't do a thing to affect the outcome anyway. These are the people we thought about every day in putting together this month's print and digital magazine, which is devoted to exploring climate change and timed to coincide with the global climate conference in Paris.





Which of the designs would you choose: the one on our cover, or one of the four above? Cast your vote at *ngm.com/cover.*

"The problem with climate change is that it's very large, and as individuals, we seem quite small against it, so it's easy for people to feel disempowered." That's what Bill McKibben says, and he should know: He's the writer, environmentalist, and activist whose 1989 book, *The End of Nature,* introduced climate change to a general audience.

A generation later, McKibben says, he is seeing a breakthrough. Not only is the scientific evidence compelling and much discussed—2015 is expected to be the hottest year on record, with 2014 the hottest year before that—but people are finally beginning to feel like they can take action.

"We need a reasonable alternative to imagine some other future," he says. "That has become much more apparent."

Inside this issue you can see what that future might look like. Our coverage ranges from an in-depth story on how a major industrialized nation is trying to kick its coal dependency to practical guides on what you, as an individual, can do to make a difference.

Still, it's not an easy topic. To that end we're sharing a few of the dozens of tried-and-rejected versions of this month's cover. As you can see, we started out with our traditional yellow border and a literal approach—could there be a more literal representation of climate change than a man on a melting ice floe? But after much deliberation, we ended up with an eye-popping declaration on the Earth's climate imperative: Cool it.

Whatever your views on climate change, we hope this issue will be informative, entertaining, and most of all, engaging on a subject that affects us all.

Thank you for reading.

Susan Goldberg, *Editor in Chief*

Follow scientist, engineer, and comedian Bill Nye as he explores his feelings about climate change, what's gone wrong with our planet, and how we can fix it. *Bill Nye's Global Meltdown,* an episode of National Geographic's Explorer series, is hosted by Nye and airs on November 1.

PHOTO (BOTTOM LEFT): BRANDON HILL

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We believe in the power of science, exploration, and storytelling to change the world.

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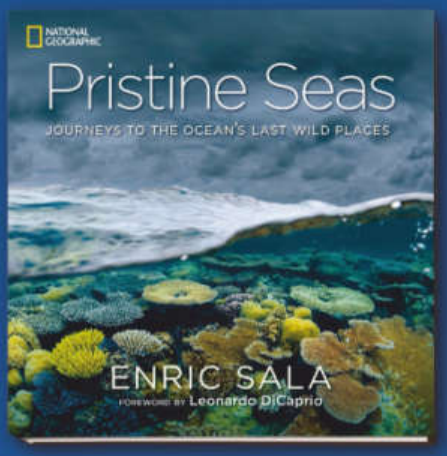
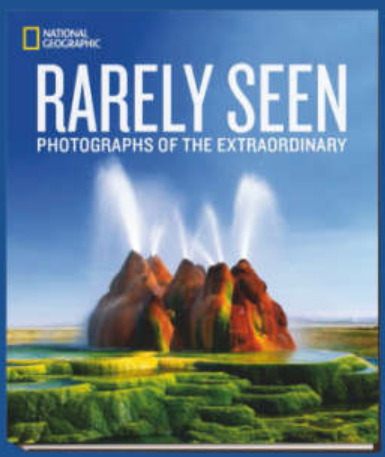
YOU WON'T BELIEVE YOUR EYES

National Geographic goes behind the scenes—underwater, in nature, and beyond—to capture the most astounding sights, revealing a world very few will have the chance to see for themselves.



Follow one man's odyssey to save the last wild places in our oceans. This incredible photographic journey presents the splendor of pristine seas untouched by man—the watery frontier that National Geographic Explorer-in-Residence Enric Sala is dedicating his life to protect.

This dazzling collection of visual wonders, shot by some of the world's finest photographers, exposes extraordinary phenomena seldom seen by human eyes—from volcanic lightning to 30,000-year-old-cave art to giant 50-ton crystals—all once-in-a-lifetime spectacles immortalized here.



NATIONAL GEOGRAPHIC

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3 Questions
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Why I'm Bullish About Earth's Future

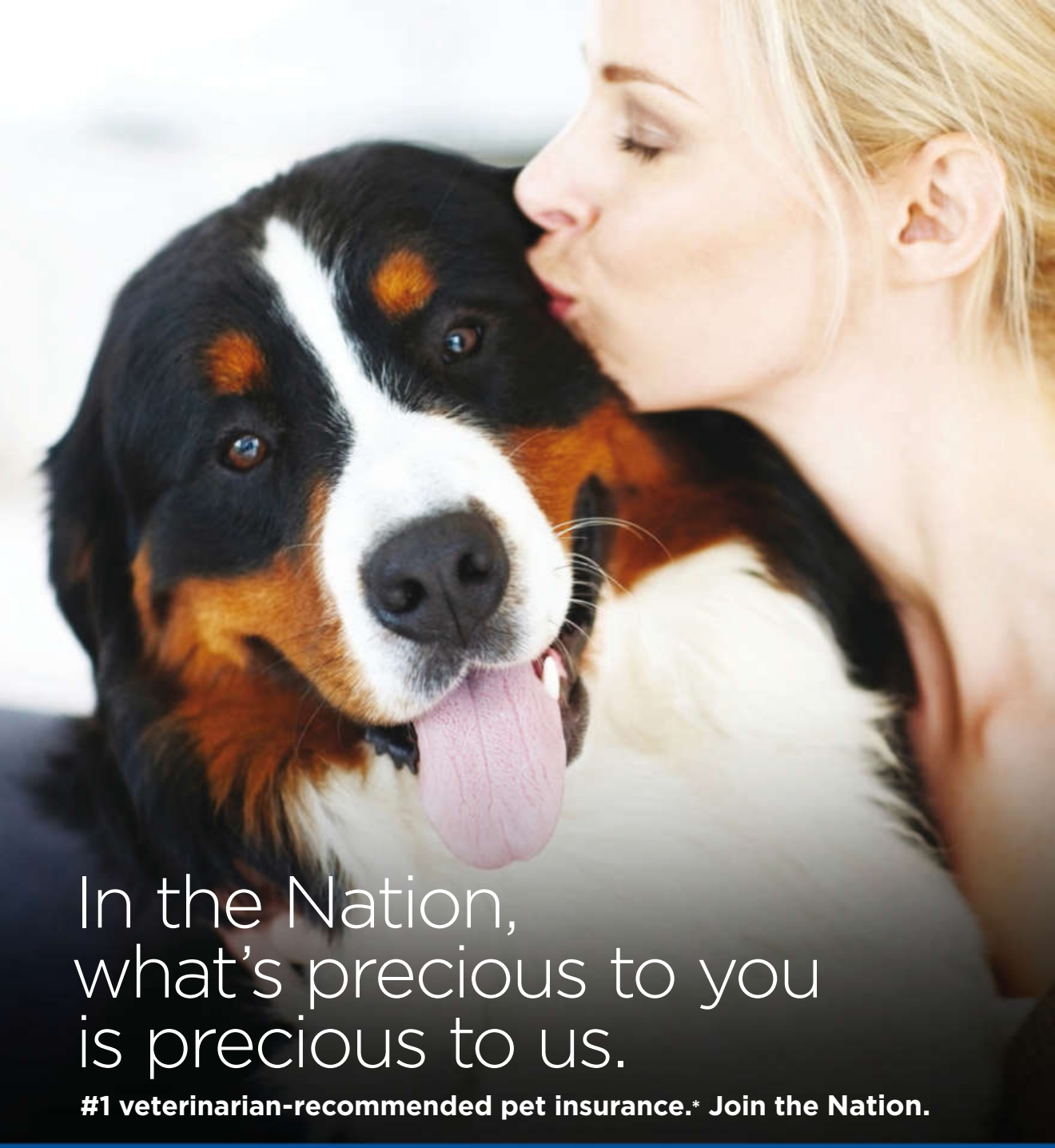
Biologist and conservationist **Thomas Lovejoy** has been working in the Amazon rain forest for 50 years. He coined the term "biological diversity" in 1980, the same year he projected that by the early 21st century the world would lose a dramatic number of species. But Lovejoy, now 74, is still optimistic about protecting the planet. And he has ideas.

Boil it down. What's the top environmental challenge?
It's a combination of people and their aspirations. If the aspirations are more like the frugal ones we had after the Second World War, a lot more is possible than if we view the planet as a giant shopping mall, which doesn't work biologically. We need to get beyond the fascination with the glitter and understand that the planet works as a biological system. Reducing our expectations is very much in our own interest.

You're in a room with the leaders of China, India, and the United States. What would you tell them?
I'd say we all have an interest in fixing this before it gets badly out of hand, and it's getting close to that. There are things we can do together. There are energy and innovation possibilities. There are biological solutions that would benefit everyone. India could offset all of its current emissions through ecosystem restoration. All those countries have a combined interest in a major international effort at restoration, and there are benefits from working on it together.

What's the future of the environmental movement?
I see a lot of new leaders coming up, although not as many as I'd like from a diversity perspective. We need to get young people upset about their future. We need to give them a sense they can make a difference. Because they're going to live with it.

PHOTO: DYLAN COULTER



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Climate Change

Assignment We asked members of National Geographic's Your Shot community to document how the changing climate is affecting where they live.

EDITOR'S NOTE

"Photographing climate change was more of a thinking-about-photography assignment. How can we use photography to express an idea and do it eloquently and aesthetically?"

Jessie Wender, senior photo editor

Brooke Whatnall
Cedar Grove, Australia

Whatnall, a paragliding instructor, finished giving lessons one morning in New South Wales, then took a glider up by himself. Flying back and forth over a field flooded by heavy rain, he noticed a cow standing near a patch of grass, ankle-deep in sky-reflecting water.

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Climate change

Meltwater gushes from an ice cap on the island of Nordaustlandet, in Norway's Svalbard archipelago. The Arctic is warming faster than any other place on Earth. At the current pace, scientists say, summer sea ice could vanish from the region this century.

PHOTO: PAUL NICKLEN


is here.

How can we power

From 7,500 feet up, the nocturnal grid of New York looks more like a circuit board than a city. The glow of LED bulbs—seen here illuminating Times Square and other parts of midtown Manhattan—accounts for the blue-violet hues.

PHOTO: VINCENT LAFORET


the planet...

Without making

Lit by morning sun, smoke from burning trees obscures the Amazon rain forest in Mato Grosso, Brazil. In recent decades nearly a quarter of the forest in Mato Grosso has been cleared for farming, releasing millions of tons of stored carbon into the air.

PHOTO: GEORGE STEINMETZ


things worse?

This year could be

LAURENCE TUBIANA THINKS SO. She's a small, elegant, white-haired woman of 63. At a press briefing in a noisy restaurant near Washington's Capitol Hill, she apologized for being incapable of raising her voice—which in a diplomat is no doubt an excellent quality. Tubiana is no ordinary diplomat: She's France's "climate ambassador," charged with the greatest cat-herding project in history. For the past year and a half she has been traveling the world, meeting with negotiators from 195 countries, trying to ensure that the global climate confab in Paris this December will be a success—a watershed in the struggle against climate change. "This notion of a turning point—that's super important," Tubiana says.

There are at least 20 reasons to fear she will fail. Since 1992, when the world's nations agreed at Rio de Janeiro to avoid "dangerous anthropogenic interference with the climate system," they've met 20 times without moving the needle on carbon emissions. In that interval we've added almost as much carbon to the atmosphere as we did in the previous century. Last year and the past decade were the warmest since temperature records began. Record-breaking heat waves are now five times as likely as they once were. A large part of the West Antarctic Ice Sheet, scientists reported last year, is doomed to collapse—meaning that in the coming centuries sea level will rise at least four feet and probably much more. We're already redrawing the map of the planet, especially of the zones where animals, plants, and people can live.

And yet there's also an unmistakable trace of hope in the air. A lot of it is still just talk. China and the United States, the two largest carbon emitters, have announced a deal to reduce emissions. Six European oil companies say they'd welcome a carbon tax. A giant Norwegian pension fund has pledged to stop investing in coal. And the pope has brought his immense spiritual authority to bear on the problem.

But the reasons for hope go beyond promises and declarations. In 2014 global carbon emissions from fossil-fuel burning didn't increase, even though the global economy was growing. We won't know for years if it's a trend, but it was the first time that had happened. One reason emissions were flat was that China, for the first time this century, burned less coal than the year

the turning point.

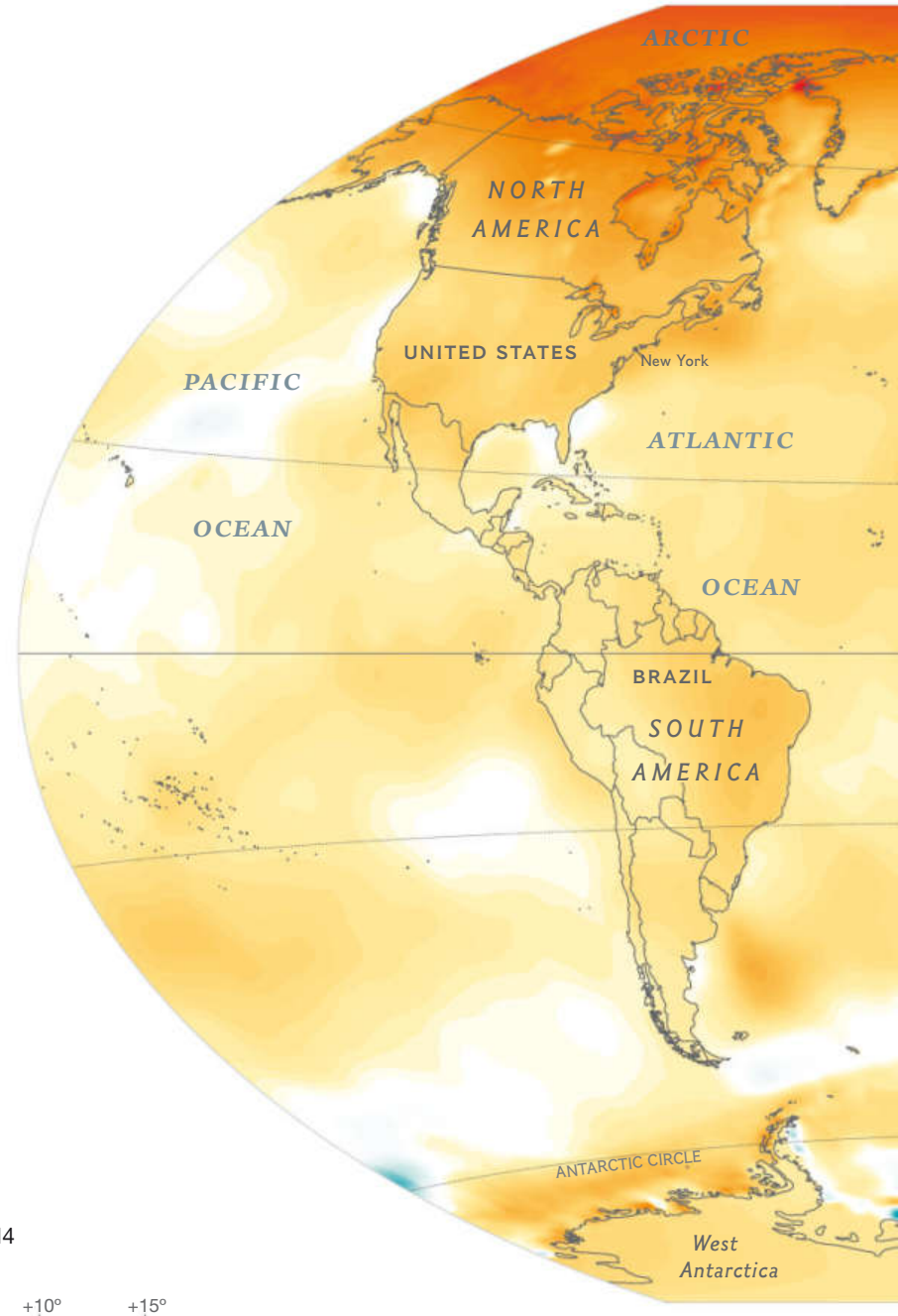
before. And one reason for that was that the production of renewable energy—wind and solar and hydropower—is booming in China, as it is in many other countries, because the cost has plummeted. Even Saudi Arabia is bullish on solar. "The world is tipping now," says Hans-Josef Fell, co-author of a law that ignited Germany's renewable energy boom. It's the kind of tipping point we want.

We've seen others. In the past half century we've created a world in which people on average live two decades longer than they did before, in which they cross oceans in a day with barely a thought, in which they communicate instantaneously and globally for barely a penny and carry libraries in the palm of their hand. Fossil fuels helped make it all possible—but by the second half of the 21st century, if a climate disaster is to be averted, we'll have to be moving forward without them. Anyone who thinks we can't complete that revolution doesn't appreciate how utterly we've already changed the world. Anyone who thinks we won't choose to complete that revolution—or at least not fast enough—well, that may turn out to be true. We're on an unprecedented adventure whose outcome can't be known and whose stakes couldn't be higher. We've lived through other global transformations, but for the first time ever we're trying to steer one, to secure a more hopeful future for the whole planet.

The late novelist E. L. Doctorow once described his writing process this way: "It's like driving a car at night—you never see further than your headlights, but you can make the whole trip that way." Fixing climate change is going to require improvisation like that. We don't have to be able to see the whole road ahead to a happy end—but we do have to believe that we can get there. That's what the negotiators will be trying to achieve in Paris. They've stopped thinking they can write a treaty that will bind every country to a specific quota for reducing emissions. Instead they're looking for a way to "send a very strong signal to the business sector," Tubiana says, to "create a self-fulfilling prophecy that the low-carbon economy is happening." When we look back at 2015 from our warmer future, we'll know if this was when the prophecy started to come true. *—Robert Kunzig*

Here's the challenge.

The Earth has warmed 1.5 degrees Fahrenheit, on average, since the late 19th century. Most of the warming has occurred since 1960, the period covered on this map. It reveals the regional variety buried in the global average: A few areas, most near the Antarctic, actually have gotten colder since 1960, while some parts of the Arctic have warmed as much as 15 degrees. Natural climate cycles



Temperature trend, 1960-2014

Change in degrees Fahrenheit

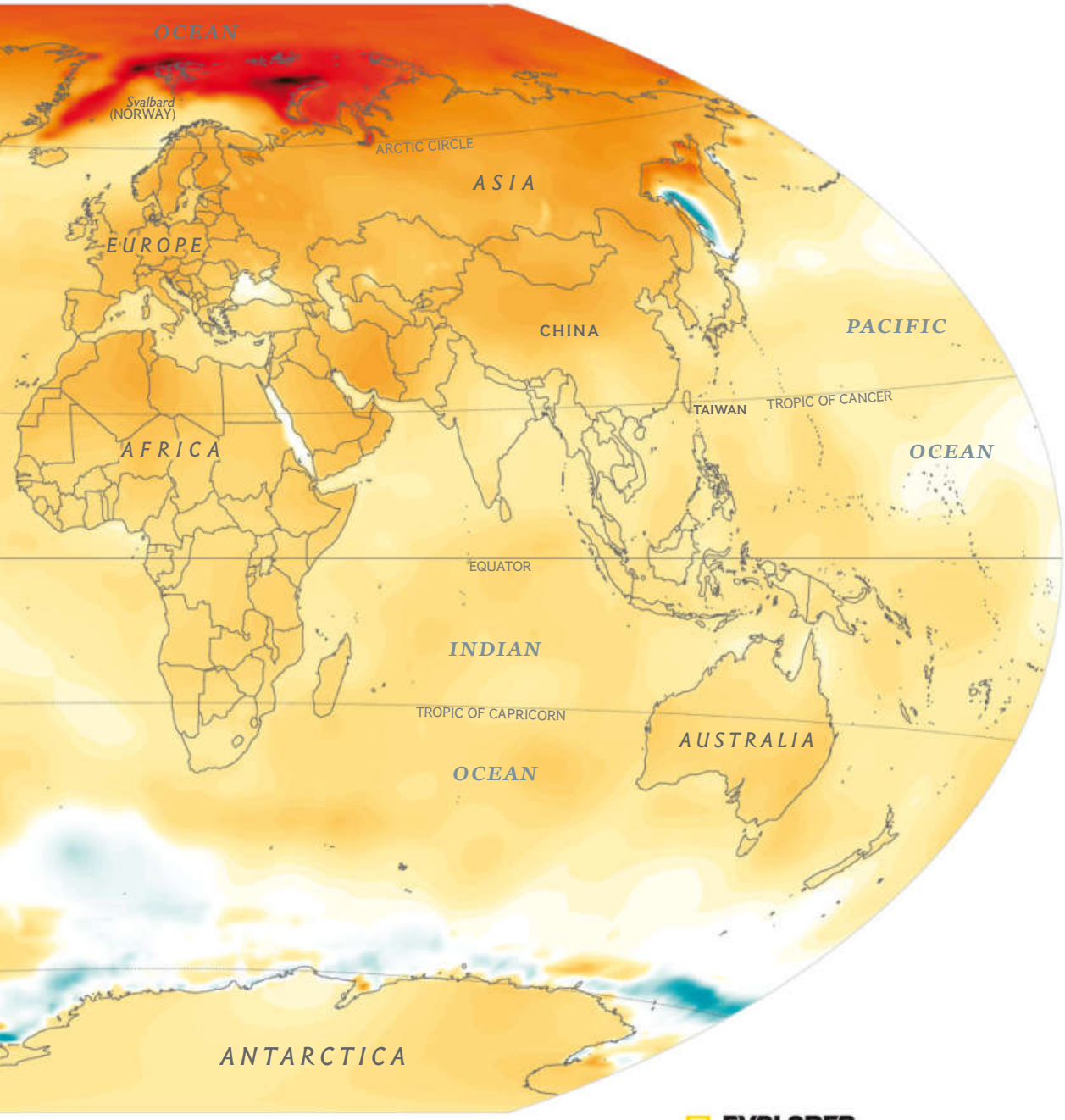
-5° No change +5° +10° +15°

Cooler Warmer

NG STAFF

SOURCES: STEVEN MOSHER AND ROBERT ROHDE, BERKELEY EARTH

explain why the warming has happened unevenly and fitfully, but not the warming trend itself, which has overwhelmed the cooling effect of the ash from volcanoes. It has coincided over the past half century with a surge in carbon emissions from our rapidly industrializing world. Finding a way to stop those emissions—and climate change—is the challenge for the next half century.



EXPLORER

Tune in November 1 to the Channel's Explorer series as Science Guy Bill Nye looks at climate change.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CLIMATE CHANGE **SURVIVAL GUIDE**

How to Fix It

Reading Henry David Thoreau's notes on when the blueberry bushes bloomed each year in Concord, Massachusetts, we see that spring there now comes weeks earlier than it did 150 years ago. Scientists attribute this in part to climate change. Thoreau, an advocate for living responsibly, might assign blame more pointedly. Since climate change is fueled by individuals, businesses, cities, and nations around the world, shouldn't solutions to it come from them?

In his 1863 essay "Life Without Principle," Thoreau issues a challenge: "Let us consider the way in which we spend our lives." A century and a half later, in a warming world, the challenge stands. —*Patricia Edmonds*

CONTRIBUTORS Text: Jeremy Berlin, Marc Gunther, Christina Nunez, Rachel Hartigan Shea, Daniel Stone, and Catherine Zuckerman
Graphics: Lawson Parker and Matthew Twombly

PHOTO ILLUSTRATION: JAVIER JAÉN

If you have type 2 diabetes

Jerry G.

PHOTOGRAPHER WITH TYPE 2 DIABETES

ACTOR PORTRAYAL

Indication and Limitations of Use

Trulicity is a once-weekly injectable prescription medicine to improve blood sugar (glucose) in adults with type 2 diabetes mellitus. It should be used along with diet and exercise. Trulicity is not recommended as the first medication to treat diabetes. It has not been studied in people who have had inflammation of the pancreas (pancreatitis). Trulicity should not be used by people with a history of severe gastrointestinal (GI) disease, people with type 1 diabetes, or people with diabetic ketoacidosis. It is not a substitute for insulin. It has not been studied with long-acting insulin or in children under 18 years of age.

Important Safety Information

Tell your healthcare provider if you get a lump or swelling in your neck, have hoarseness, trouble swallowing, or shortness of breath while taking Trulicity. These may be symptoms of thyroid cancer. In studies with rats or mice, Trulicity and medicines that work like Trulicity caused thyroid tumors, including thyroid cancer. It is not known if Trulicity will cause thyroid tumors or a type of thyroid cancer called medullary thyroid carcinoma (MTC) in people. Do not take Trulicity if you or any of your family members have ever had MTC or if you have Multiple Endocrine Neoplasia syndrome type 2 (MEN 2).

Do not take Trulicity if you have had an allergic reaction to dulaglutide or any of the other ingredients in Trulicity.

Trulicity may cause serious side effects, including:

- **Inflammation of your pancreas (pancreatitis).** If you have pain in your stomach area (abdomen) that is severe and will not go away, stop taking Trulicity and call your healthcare provider right away. The pain may happen with or without vomiting. It may be felt going from your abdomen through to your back.
- **Low blood sugar (hypoglycemia).** If you are using another medicine that can cause low blood sugar (such as insulin or a sulfonylurea) while taking Trulicity, your risk for getting low blood sugar (hypoglycemia) may be higher. Signs and symptoms of low blood sugar may include dizziness, blurred vision, anxiety, irritability, mood changes, sweating, slurred speech, hunger, confusion or drowsiness, shakiness, weakness, headache, fast heartbeat, or feeling jittery. Talk to your healthcare provider about low blood sugar and how to manage it.
- **Serious allergic reactions.** Stop taking Trulicity and get medical help right away if you have symptoms of a serious allergic reaction, such as itching, rash, or difficulty breathing.

Find out if you're eligible to pay as little as $25 for each of your first 26 prescriptions at **Trulicity.com**

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Jerry uses what's inside him to reach his goals. For his art, he uses his passion. For his diabetes, he helps his body release its own insulin.

Ask your doctor about once-weekly, non-insulin Trulicity™.

- It helps activate your body to do what it's supposed to do—release its own insulin
- It can help improve A1C and blood sugar numbers
- You may lose a little weight*

*Trulicity is not a weight loss drug.

- It's taken once a week and works 24/7, responding when your blood sugar rises
- It comes in an easy-to-use pen.† You don't need to see or handle a needle

†In a study, 94% of people said it was easy to use.

- **Kidney problems (kidney failure).** In people who have kidney problems, diarrhea, nausea, and vomiting may cause a loss of fluids (dehydration). This may cause kidney problems to get worse.
- **Severe stomach problems.** Trulicity may cause stomach problems, which could be severe.

Tell your healthcare provider if you:

- have or have had problems with your pancreas, kidneys, or liver.
- have severe problems with your stomach, such as slowed emptying of your stomach (gastroparesis) or problems with digesting food.
- have any other medical conditions.
- are pregnant or plan to become pregnant, or if you become pregnant while taking Trulicity. It is not known if Trulicity will harm your unborn baby.
- are breastfeeding or plan to breastfeed. It is not known if Trulicity passes into your breast milk. You should not use Trulicity while breastfeeding without first talking to your healthcare provider.
- are taking other medicines including prescription and over-the-counter medicines, vitamins, and herbal supplements. Trulicity may affect the way some medicines work and some medicines may affect the way Trulicity works.
- are taking other medicines to treat diabetes, including insulin or sulfonylureas.

The most common side effects with Trulicity may include: nausea, diarrhea, vomiting, decreased appetite, and indigestion. Talk to your healthcare provider about any side effect that bothers you or does not go away. These are not all the possible side effects of Trulicity. Call your doctor for medical advice about side effects.

You are encouraged to report side effects of prescription drugs to the FDA. Visit www.fda.gov/medwatch or call 1-800-FDA-1088.

Please see next page for additional information about Trulicity, including Boxed Warning regarding possible thyroid tumors including thyroid cancer.

Please see Instructions for Use included with the pen.

DG CON ISI 20APR2015

Lilly

once weekly
trulicity™
(dulaglutide) injection
0.75 mg/0.5 mL, 1.5 mg/0.5 mL

Information for Patients about Trulicity (dulaglutide):

This is a brief summary of important information about Trulicity (Trū-li-si-tee). Please read the Medication Guide that comes with Trulicity before you start taking it and each time you get a refill because there may be new information. This information is not meant to take the place of talking with your healthcare provider or pharmacist.

What is Trulicity?

Trulicity is a once-weekly, injectable prescription medicine that may improve blood sugar (glucose) in adults with type 2 diabetes mellitus, and should be used along with diet and exercise.

- It is not recommended as the first choice of medicine for treating diabetes.
- It is not known if it can be used in people who have had pancreatitis.
- It is not a substitute for insulin and is not for use in people with type 1 diabetes or people with diabetic ketoacidosis.
- It is not recommended for use in people with severe stomach or intestinal problems.
- It is not known if it can be used with long-acting insulin or if it is safe and effective for use in children under 18 years of age.

What is the most important information I should know about Trulicity?

Trulicity may cause serious side effects including possible thyroid tumors, including cancer. Tell your healthcare provider if you get a lump or swelling in your neck, hoarseness, trouble swallowing, or shortness of breath. These may be symptoms of thyroid cancer. In studies with rats or mice, Trulicity and medicines that work like Trulicity caused thyroid tumors, including thyroid cancer. It is not known if TRULICITY will cause thyroid tumors or a type of thyroid cancer called medullary thyroid carcinoma (MTC) in people.

Who should not use Trulicity?

Do not use Trulicity if:

- you or any of your family have ever had a type of thyroid cancer called medullary thyroid carcinoma (MTC) or if you have an endocrine system condition called Multiple Endocrine Neoplasia syndrome type 2 (MEN 2).
- you are allergic to dulaglutide or any of the ingredients in Trulicity.

What are the possible side effects of Trulicity?

Trulicity may cause serious side effects, including:

- **Possible thyroid tumors, including cancer**. **See** "**What is the most important information I should know about Trulicity?"**
- **inflammation of the pancreas (pancreatitis).** Stop using Trulicity and call your healthcare provider right away if you have severe pain in your stomach area (abdomen) that will not go away, with or without vomiting. You may feel the pain from your abdomen to your back.
- **low blood sugar (hypoglycemia).** Your risk for getting low blood sugar may be higher if you use Trulicity with another medicine that can cause low blood sugar such as sulfonylurea or insulin.

Signs and symptoms of low blood sugar may include: dizziness or light-headedness; blurred vision; anxiety, irritability, or mood changes; sweating; slurred speech; hunger; confusion or drowsiness; shakiness; weakness; headache; fast heartbeat; feeling jittery.

- **serious allergic reactions.** Stop using Trulicity and get medical help right away, if you have any symptoms of a serious allergic reaction including itching, rash, or difficulty breathing.
- **kidney problems (kidney failure).** In people who have kidney problems, diarrhea, nausea, and vomiting may cause a loss of fluids (dehydration) which may cause kidney problems to get worse.
- **severe stomach problems.** Other medicines like Trulicity may cause severe stomach problems. It is not known if Trulicity causes or worsens stomach problems.

The most common side effects of Trulicity may include nausea, diarrhea, vomiting, decreased appetite, indigestion.

Talk to your healthcare provider about any side effect that bothers you or does not go away. These are not all the side effects of Trulicity.

Call your doctor for medical advice about side effects. You may report side effects to FDA at 1-800-FDA-1088.

Before using Trulicity tell your healthcare provider if you:

- have had problems with your pancreas, kidneys, or liver.
- have severe problems with your stomach, such as slowed emptying of your stomach (gastroparesis) or problems digesting food.
- have any other medical conditions.
- are pregnant or plan to become pregnant, or if you become pregnant while taking Trulicity. It is not known if Trulicity will harm your unborn baby.
- are breastfeeding or plan to breastfeed. It is not known if Trulicity passes into your breast milk. You should not use Trulicity while breastfeeding without first talking to your healthcare provider.
- **are taking other medicines**—including prescription and over-the-counter medicines, vitamins, and herbal supplements. Trulicity may affect the way some medicines work and some medicines may affect the way Trulicity works.
- are taking other medicines to treat your diabetes including insulin or sulfonylureas.

Before using Trulicity, talk to your healthcare provider about low blood sugar and how to manage it.

How should I use Trulicity?

- Read the **Instructions for Use** that comes with Trulicity**.**
- Use Trulicity exactly as your healthcare provider tells you to.
- Your healthcare provider should show you how to use Trulicity before you use it for the first time.
- Trulicity is injected under the skin (subcutaneously) of your stomach (abdomen), thigh, or upper arm. **Do not** inject Trulicity into a muscle (intramuscularly) or vein (intravenously).
- **Use Trulicity 1 time each week on the same day each week at any time of the day.**
- You may change the day of the week as long as your last dose was given **3** or more days before.
- If you miss a dose of Trulicity, take the missed dose as soon as possible, if there are at least 3 days (72 hours) until your next scheduled dose. If there are less than 3 days remaining, skip the missed dose and take your next dose on the regularly scheduled day. **Do not** take **2** doses of Trulicity within **3** days of each other.
- Trulicity may be taken with or without food.
- **Do not** mix Trulicity and insulin together in the same injection.
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Do not share your Trulicity pen, syringe, or needles with another person. You may give another person an infection or get an infection from them.

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Alexander Graham Bell with his grandson Melville. Beinn Bhreagh, Nova Scotia.

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Can one person in seven billion make a difference? Despite the furor over government reports and international conferences, climate change is a problem of personal consumption. Swiss scientists say humanity could limit the effects if each person used just 2,000 watts of power a year. The average American consumes 12,000. A Bangladeshi uses 300. The challenge is conscientious reduction in the West, writes Naomi Klein in *This Changes Everything.* Lifestyle choices, such as traveling less plus better regulation and technologies will help the numbers drop.

TINY HOUSE FOOTPRINT

Since 1973 the average U.S. home has ballooned by 60 percent to 2,657 square feet. A warmer world may favor a reverse trend. Jay Shafer (at left), the California pioneer of living in tiny houses, built a lifestyle in 89 square feet (layout below)—and helped others build pint-size homes. Developers in New York City and San Francisco have created the urban equivalent: micro-apartments.

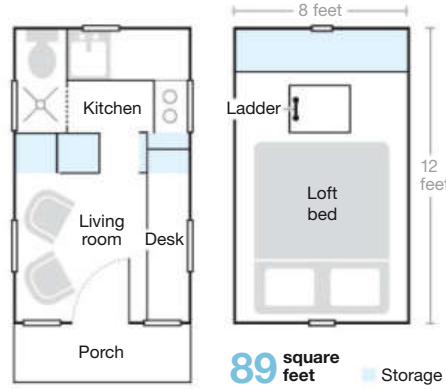
EFFICIENT LIVING

Shrinking your space doesn't mean shrinking your life. Downsizing, experts say, can bring both psychological and financial benefits. Start by getting rid of clutter. End with lower utility bills, less space to clean, and more time outdoors.

A future home's best attribute may be its **smartness,** which helps appliances conserve water and energy.

Micro-living spaces tend to work best in **urban environments,** with their existing utility hookups.

Efficiency brings **reduced living costs.** But unusual home designs can make securing land and permits hard.



Composting can divert from landfills up to 650 pounds of a U.S. household's annual food waste.

Leaving your car at home two days a week can reduce your greenhouse gas emissions an average of two tons a year.

An American household can save 1,600 pounds of CO_2 emissions a year by washing laundry in cold water.

PHOTO: JEFF MINTON. ART: ROMUALDO FAURA

BRIGHT IDEAS CAN CHANGE THE WORLD

The Institute for Climate and Sustainable Cities (iCSC) launched a fleet of electric jeepneys and created a solar-powered charging and battery-swapping station for areas devastated by Typhoon Haiyan/Yolanda. See more innovative energy projects inside. ↗

Change happens when an epic idea transforms into a real-world solution. That's why National Geographic and Shell teamed up to launch the Great Energy Challenge. A smarter energy future is possible only if all of us band together as global citizens and take an active role. Let's talk about the energy challenges we face, learn about energy innovations that work, and do more to change the way we think about and consume energy.

greatenergychallenge.com

The Great Energy Challenge

NATIONAL GEOGRAPHIC

A NATIONAL GEOGRAPHIC INITIATIVE IN PARTNERSHIP WITH SHELL

BRIGHT ENERGY IDEAS
REAL-WORLD IMPACT

GREAT ENERGY CHALLENGE GRANTEES ARE LEADING THE WAY

Enabling a world of innovation: energy solutions around the globe

National Geographic conservation fellow and renowned biologist Thomas Lovejoy leads a dream team of the world's top researchers and scientists to identify and support projects that break new ground in energy innovation and lead to real-world energy solutions. To date we have awarded 29 grants. Highlighted here are just a few.

The Great Energy Challenge

NATIONAL GEOGRAPHIC

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MASARANG FOUNDATION'S SUSTAINABLE ETHANOL PRODUCTION PROMOTES CONSERVATION IN INDONESIA

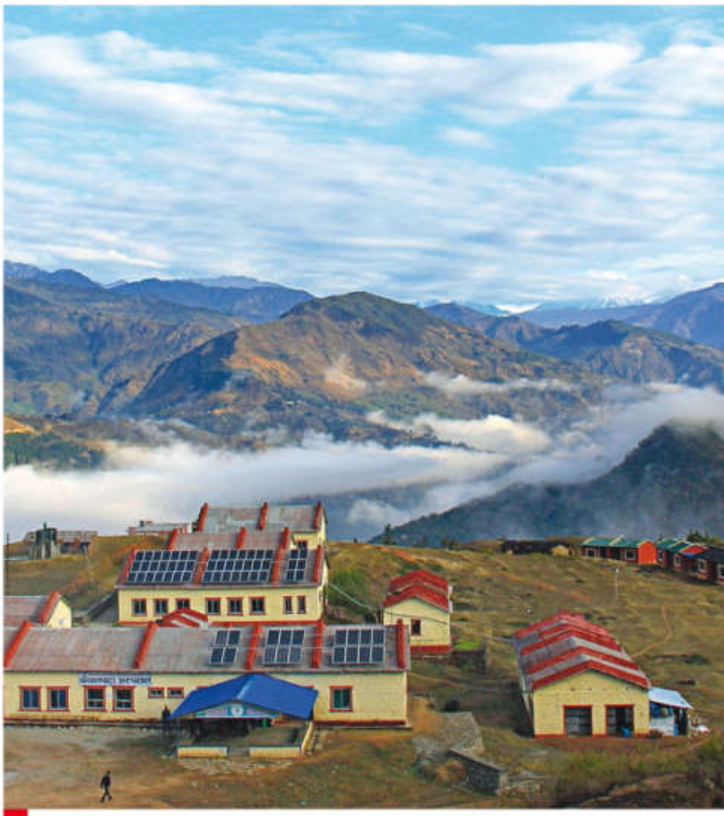
Deforestation not only threatened the native rain forests in Indonesia, but also made the country a leading greenhouse gas emitter. Working with local organizations, forester and conservationist Dr. Willie Smits developed a sustainable low-carbon method to produce ethanol from the juice of the Arenga sugar palm. Masarang Foundation's ethanol production creates jobs for locals to help alleviate poverty and avoids diverting food crops for biofuel. The process also yields premium organic sugar as a byproduct.

ECO-FUEL AFRICA EMPOWERS UGANDANS TO BECOME CLEAN ENERGY MICRO-ENTREPRENEURS

In 2010 Eco-fuel Africa created a network of farmer-entrepreneurs who turn farm waste into clean-burning fuel briquettes and organic fertilizers. Eco-fuel Africa is expanding by training other marginalized farmers and poor women to produce and sell fuel briquettes. The organization will construct 100 additional manual briquetting machines that will be essential in places where the electrical grid is unreliable. The expansion plan also includes building kiosks to sell briquettes. Mentoring and marketing support will ensure the farmers and women succeed as retailers.

SUNFARMER BOLSTERS SOLAR ENERGY DELIVERY

While solar projects have long been implemented as a viable energy solution in areas that are off the grid, maintaining solar installations to continuously provide electricity over time is still a challenge. SunFarmer is a social enterprise driving investment in rural solar projects. They provide affordable and reliable solar energy in developing countries and implement monitoring and maintenance systems to ensure reliable access to electricity to the people who need it most.



Watch the stories of these energy innovators and other visionaries whose bright ideas have been powered by grants through The Great Energy Challenge. Follow @NatGeoEnergy on Twitter and visit **greatenergychallenge.com**.

A Message From Shell

The world's population is growing and living standards are improving. To ensure that everyone can continue to progress and prosper, we will need more and cleaner energy than ever before. Put simply, our evolving world needs a multitude of bright energy ideas. Collectively, we have the will and ingenuity to develop these ideas, but we need to work together to bring them to fruition and put them into action. Experience the bright energy ideas that are shaping our future at **#makethefuture.**

A FOOTBALL PITCH'S FLOODLIGHTS POWERED BY PLAYERS

In Morro da Mineira, a favela in Rio de Janeiro, Shell converted a rundown sports ground into the world's first human-powered football pitch. Using kinetic tiles under the pitch and solar panels on the roof to power the floodlights, the pitch and the area around it became a safe haven for kids in the local community. The pitch is a real-world illustration proving the power of bright energy ideas.

See the Bigger Picture

YOU CAN HELP US TELL THE STORY OF THE FUTURE OF ENERGY

Great Energy Challenge has teamed up with National Geographic's Your Shot community to launch a series of photography assignments. Our first assignment challenged people to think about what a world without energy might look like and then capture that idea with photography. The assignment resulted in more than 8,000 images that sparked a conversation about how to meet energy demand in a world where more than a billion people live without reliable power, and how those of us who do have energy use it in our daily lives. Look for a new Your Shot Energy assignment launching soon.

Photograph by Aditya Waikul.

Be part of the solution. Take part in the challenge. Go to **greatenergychallenge.com** now.

The Great Energy Challenge

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You

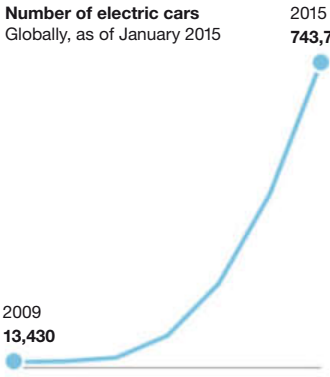
TRANSPORTATION

If you want to use the cleanest mode of transportation, nothing beats walking or biking, which create zero greenhouse gases beyond those produced making the bike and the food you eat. From there, it's far more complicated. According to the Oak Ridge National Laboratory, transit buses use more energy per passenger-mile than cars. For long distances, you're better off flying—carpooling in the sky—or, for the ultraprudent, taking a train. Calculations will change as the world's fleet shifts from fossil fuels to electric. "By 2035 there will be very few conventional gasoline or diesel cars being sold," says Dan Sperling, director of UC Davis's Institute of Transportation Studies. Global trends toward mass urbanization make infrastructure planning easier. They also raise the likelihood that more people will take trains, bikes, or their own feet to get from A to B.

TOURISM

The future of tourism might look like Iceland. The country has natural advantages such as pristine water, stunning scenery, and abundant geothermal energy. It also boasts an earth-friendly ethos—green buildings, hydrogen buses. As the number of foreign visitors has doubled since 2010, other nations have taken notice. India and Lebanon attract tourists with protected mountain ecosystems. Caribbean nations have moved to preserve reefs. The UN Environment Programme notes that money is one motivator. A cleaner environment is another.

Number of electric cars
Globally, as of January 2015

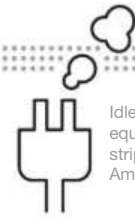


Emissions per vehicle
U.S. national average for a 100-mile trip, pounds of CO_2

"If we want to cut carbon pollution fast, moving beyond oil for transportation is an obvious strategy."

Michael Brune
executive director, Sierra Club

If meat were dropped from diets globally, the reduction in CO_2 emissions would almost equal total U.S. annual emissions.



Idle electronics, plugged in but unused, consume the equivalent output of 12 power plants. Using a power strip that you can turn on and off can save the average American home up to $200 each year.

PHOTO: SAM POLCER. SOURCE: CENTER FOR SOLAR ENERGY AND HYDROGEN RESEARCH BADEN-WÜRTTEMBERG

Businesses

In 2009, when MIT's Sloan Management Review first surveyed businesses about sustainability efforts, it found most "doing only what is necessary to meet regulatory requirements." Five years later the survey told a different story: Nearly two-thirds of companies said sustainability was at the top of their agendas, which fewer than half had said earlier. What changed? The CEOs' sense of green initiatives' worth, say Patricia and Jack Phillips, authors of *The Green Scorecard.* "Today, most (if not all) businesses recognize that climate change is a problem," they write. "Smart companies use their environmental strategy to…build competitive advantage."

BIG DATA

Many answers on climate change might lie in a cloud—the virtual one. As part of President Barack Obama's Climate Data Initiative, tech giants such as Google, Microsoft, and Amazon are lending their computational muscle to crunch data on the environment and help communities plan for an altering landscape. The results—from drought maps to sea-level charts—can help farmers manage crops or officials steer construction projects away from flood zones.

"We are guests on this planet, so conservation is important to help ensure our resources are sustained for generations to come."

Stephanie Linnartz
executive vice president, Marriott International

The hotel company has cut its greenhouse gases 12 percent since 2007 and aims to cut energy and water use 20 percent by 2020.

REPOWERING

To move toward cleaner energy without sending power plants into premature retirement, companies are making over plants, switching fuels, and boosting efficiency. Some utilities are "repowering" coal plants like this one in Newburgh, New York (left), to run on cleaner natural gas or biomass; nearly 50 units are slated for retrofits in the U.S. alone. "Repowering" is an industry term, but the concept also applies to trucks, buildings, and land. For businesses loath to see valuable assets become obsolete, it's a no-brainer. California garbage hauler Ratto Group is replacing the guts of 17 diesel trucks with electric systems that will meet state air regulations. "This gives me the ability to keep the vehicles that I currently have," says COO Lou Ratto, "and keep these things going for as long as I want to."

Per acre, microalgae can produce up to 60 times as much oil for fuel as plants that are grown in soil.

Airbus hopes to create silent, CO_2-free, hybrid-electric passenger aircraft by 2050. It's now experimenting with prototypes.

Office buildings gobble energy even when no one's at work. By 2020 spending may triple on systems that sense empty rooms and turn off lights.

ART: ROMUALDO FAURA. PHOTO: DBIMAGES/ALAMY

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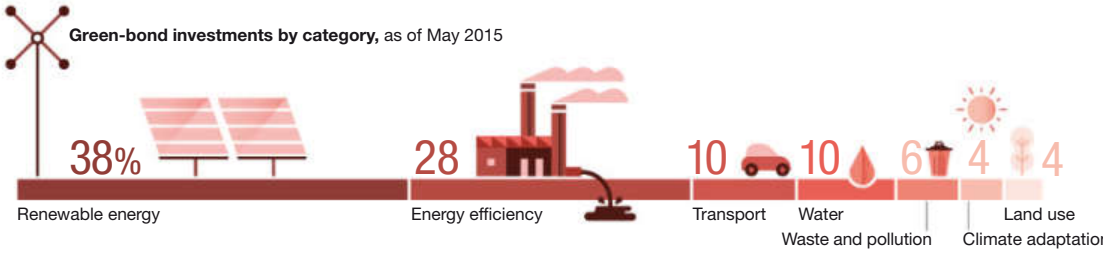
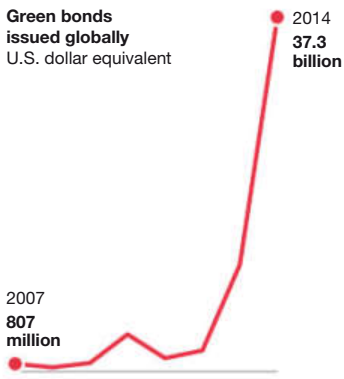
Businesses



GREEN BONDS

A warming world isn't likely to change money—but it could affect how people invest it. Banks are now offering "green bonds," which let investors link their money to environmental causes. Green bonds are similar to regular bonds, but they fund projects that mitigate climate change or help people adapt to it. "We're telling the investor exactly how the money will be used," says World Bank sustainability adviser Laura Tlaiye. Clean-energy proposals qualify, as do innovations in waste management and agricultural efficiency. In Rio de Janeiro $600 million went to improve a traffic-alleviating suburban rail network (right). Belarus borrowed $90 million to replace natural gas heating with biomass. U.S. banks have created their own green bonds; earlier this year one leading bank raised half a billion dollars to finance cities' plans for new solar capacity, wind turbines, and energy-efficient street lamps.



BATTERIES

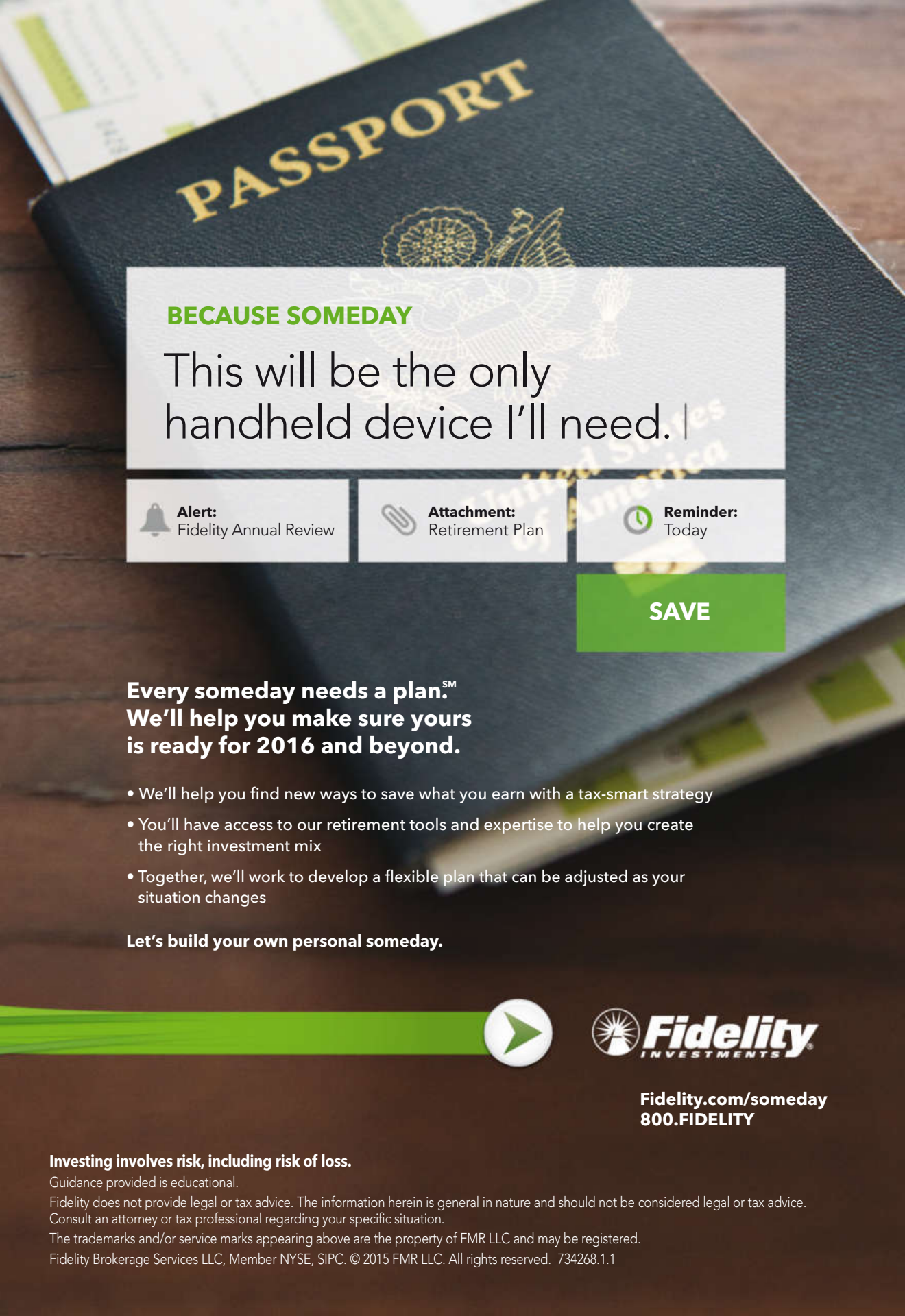
Extreme weather is a leading cause of power outages. When hospitals, transport systems, and other vital services lose juice, safety is threatened. One way to increase backup power as well as relieve our strained grid: batteries. Energy-policy analyst Todd Olinsky-Paul says two new types could help make the grid more resilient. Flow batteries, hitting the market now, provide affordable long-term storage. Lithium-ion batteries, used in electric vehicles, are good for shorter bursts of power. And then there are liquid-metal batteries. Designed by MIT electrochemist Donald Sadoway, these efficient innovations are now backed by a renewable-energy investor named Bill Gates.

A data center can use as much as 200 times more electricity than a typical office.

Hotels worldwide have joined an effort to standardize reporting of their carbon emissions and efforts to reduce them.

Levi Strauss & Co. has saved some 260 million gallons of water since 2011 by cutting use during garment production.

ART: ROMUALDO FAURA. PHOTO: ROGÉRIO REIS, TYBA. SOURCES: CLIMATE BONDS INITIATIVE; WORLD BANK



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Cities

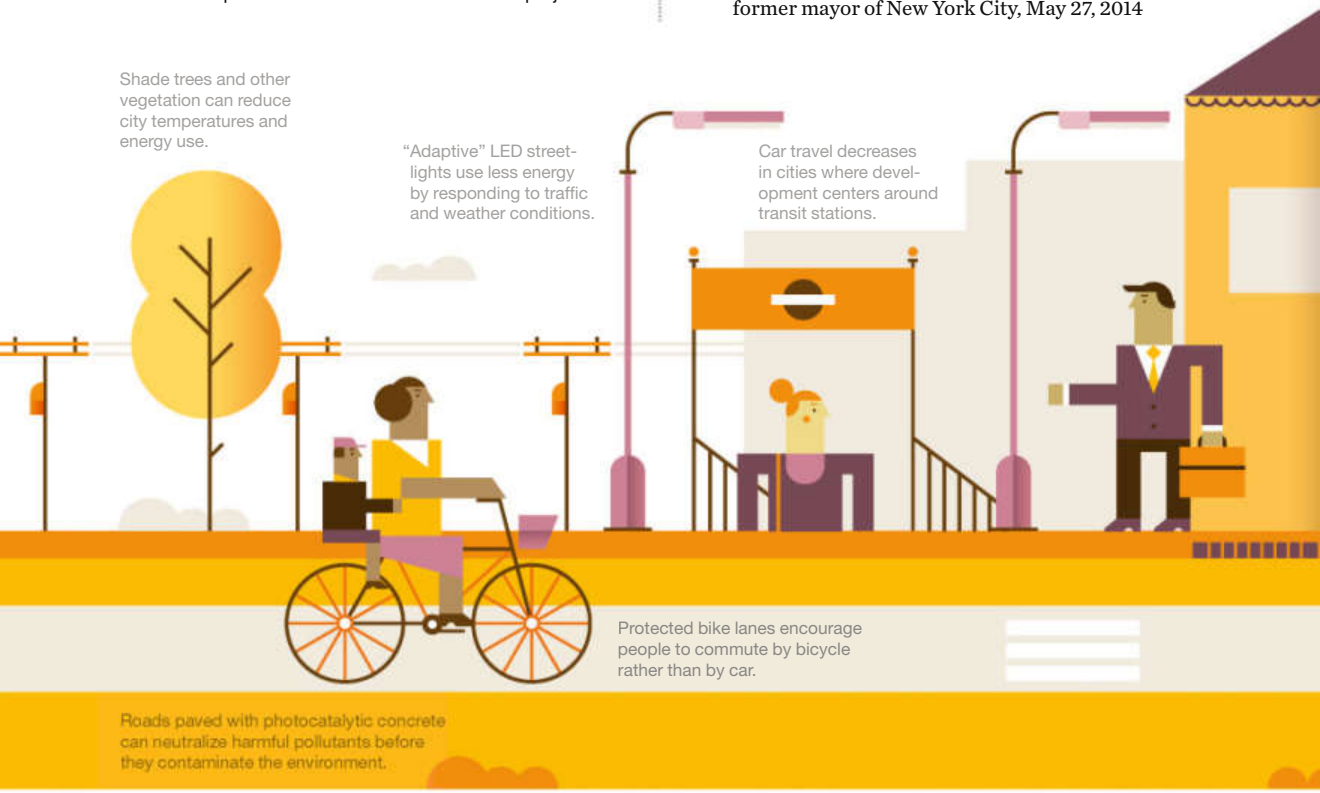
More than half the world's population lives in urban areas. By 2050 cities will likely be bursting with two-thirds of the people on the planet. Since urban areas already account for an estimated 76 percent of CO_2 emissions from energy use—and many are especially vulnerable to flooding and higher temperatures—it makes sense that city officials are taking on climate change. After all, doing so also gives them a shot at reducing pollution, improving aging infrastructure, and making their cities more attractive to residents and businesses.

SMART STREETS

Chicago has built what city officials call the "greenest street in America"—a two-mile stretch in the industrial neighborhood of Pilsen. Bike and parking lanes are paved with smog-eating concrete; sidewalks are made from recycled materials. Wind and sun power streetlights. Bioswales, thick with drought-tolerant plants, divert storm water from overburdened sewers. The spruced-up streetscape uses 42 percent less energy than it used to—and cost 21 percent less than a traditional road project.

"Mayors don't have to wait for national governments or a new global climate agreement to act. They can take action today—and increasingly, they are."

Michael Bloomberg
former mayor of New York City, May 27, 2014



London has installed more than 700 electric-car chargers throughout the city.

Georgetown, Texas, one of the fastest-growing U.S. cities, plans to be powered by renewable energy by 2017.

In Amsterdam more than a quarter of all trips in the city are made by bicycle.

GREEN BUILDINGS

Buildings are responsible for approximately one-third of all greenhouse gas emissions, a figure likely to shrink as more cities require municipal buildings to be energy efficient. Increasingly, government office buildings will have solar panels and even gardens on roofs, sensors to douse lights in empty rooms, windows lined with heat-trapping film, and energy-efficient HVAC systems.

SUSTAINABLE WATER MANAGEMENT

Despite its reputation as a water guzzler, Los Angeles is pioneering ways to capture every drop that falls from the sky. On a flood-prone block of Elmer Avenue in the east San Fernando Valley, storm water used to be funneled into drains and out to the ocean. A $2.7 million project has transformed the block into a sponge, capable of collecting enough water yearly to supply 30 families.

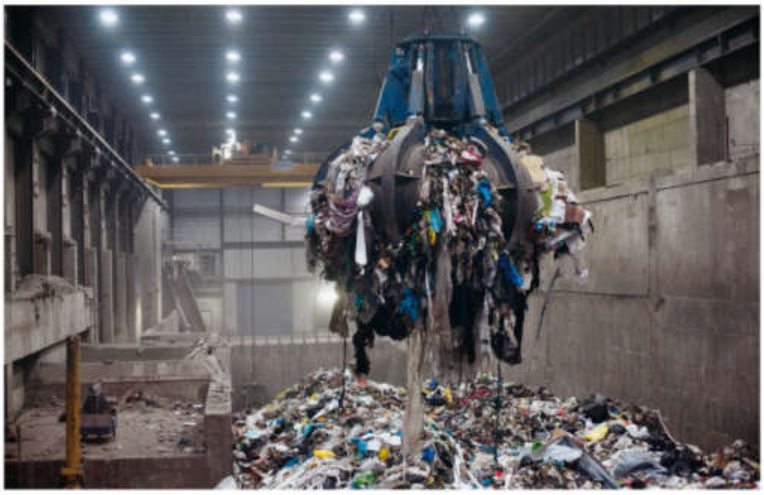
In 2014 U.S. mayors rated energy-efficient lighting as the most promising technology for reducing urban energy use and carbon emissions.

The Norwegian city of Drammen is heated almost entirely by water from the local fjord.

Most Hong Kong residents live near mass transit: 43 percent within 1,640 feet, 75 percent within two-thirds of a mile.

ART: ROMUALDO FAURA

Cities

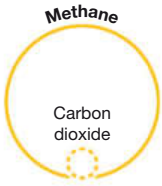


WASTE MANAGEMENT

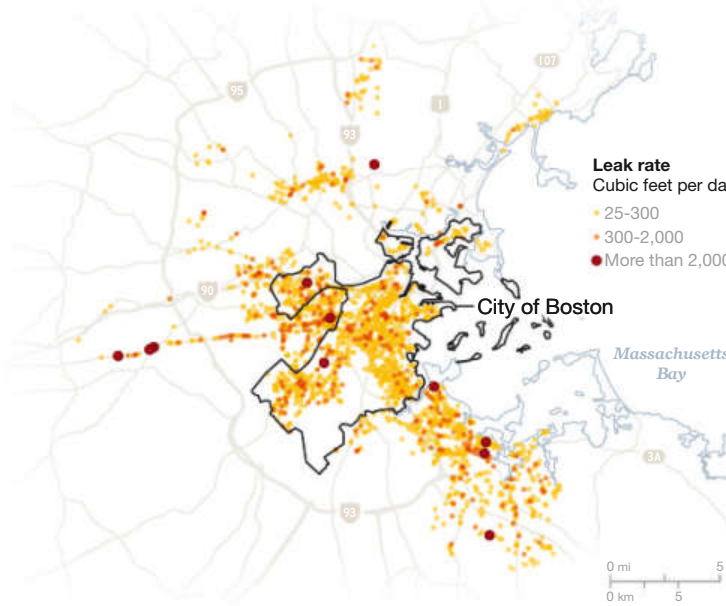
For cities, garbage is a perpetual problem. Trash stinks, it's hard to get rid of, and when it decomposes, it releases methane, a greenhouse gas. Yet waste can be a powerful resource. In Oslo, Norway, trash is burned to generate heat (left). In Durban, South Africa, landfills capture methane from the city's refuse and convert it into energy that supplies up to 6,000 houses with electricity every day. The process attacks climate change with a one-two punch: Methane doesn't escape into the atmosphere, and Durban reduces its reliance on greenhouse-gas-emitting coal.

INFRASTRUCTURE

An alarming amount of natural gas never reaches the homes it was intended to heat because it seeps out of old pipes. Utilities repair life-endangering leaks but often miss others, which can still cause trouble: The main component of natural gas is methane, a potent greenhouse gas. Fixing the pipes fixes the problem. After Indianapolis upgraded its pipes to noncorrosive materials, a methane-mapping project discovered only five leaks in the city.



Warming potential
Methane doesn't stay in the atmosphere as long as CO_2, but its impact on climate change over 100 years is 28 times greater.



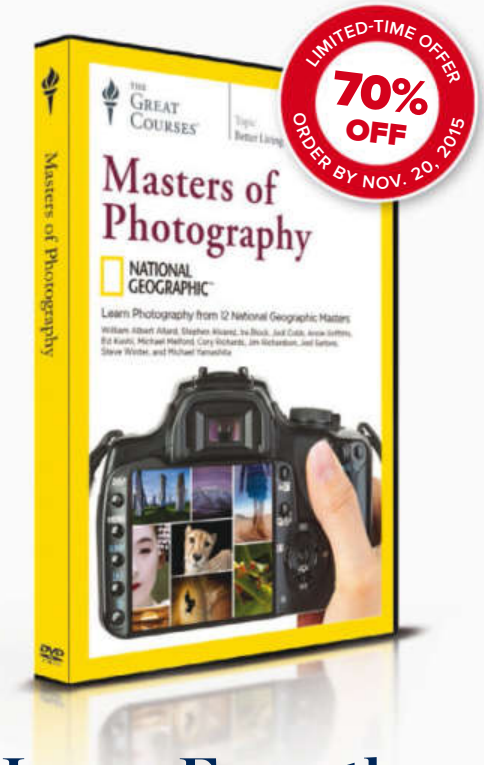
2,320
leaks detected

Greater Boston
Most of the area's pipes are more than 50 years old; nearly half of them are made of corrodible materials like cast iron.

An artificial ski slope in Copenhagen, Denmark, opening in 2017, will sit atop a power station that transforms waste into electricity for 50,000 households and heat for 120,000.

Used cooking oil was contaminating the water in Volta Redonda, Brazil, so the city began recycling it by converting it into biodiesel, which also reduces carbon emissions.

PHOTO: BRIAN CLIFF OLGUIN. MAP: EVAN APPLEGATE. SOURCE: ENVIRONMENTAL DEFENSE FUND



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Photography is an art, and the best way to learn any art form is from a master. National Geographic photographers are just that: masters at the art of photography.

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Nations

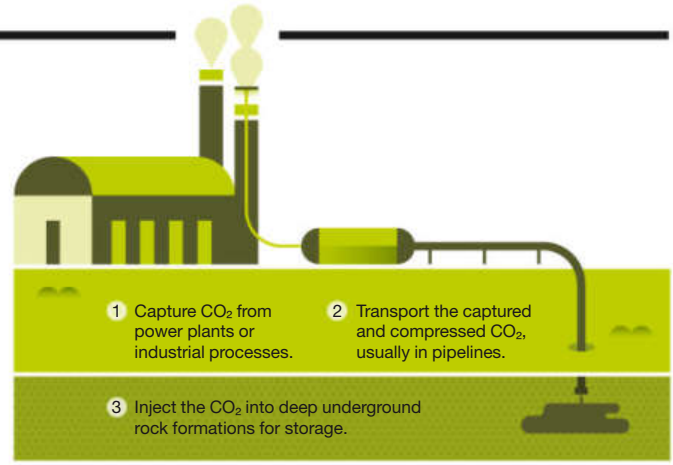
In 2014 the Intergovernmental Panel on Climate Change warned of "severe, pervasive and irreversible impacts" unless greenhouse gases are curtailed. More than 830 scientists, bringing the concerns of the 80-plus nations they call home, contributed to the report. Within their borders and on the world stage, nations wield influence that individuals, cities, and businesses cannot. Their policies can spur green innovation or stunt it, toughen pollution standards or weaken them. The fate of any accord on climate change lies in their hands.

OFFSHORE ENERGY

Solar is the "biggest tool in the toolbox" for cutting carbon, says Greg Wilson of the U.S. National Renewable Energy Laboratory. The International Energy Agency says wind power will also play a big role and could increase up to tenfold by 2050. At their peak potential, solar and wind could help us avoid some 12 gigatons of yearly carbon emissions, almost a third of the world's current total. New wind and solar technologies abound. Places short on land are using local waters for wind turbines and solar panels (like these on a pond in Japan's Kato City).

CARBON CAPTURE AND STORAGE

It's too late to keep some fossil fuels from being burned. According to one estimate, the world's existing power plants are on track to pour more than 300 billion tons of carbon dioxide into the atmosphere before they eventually shut down. That's where carbon capture and storage comes in (right). Projects in the U.S., Canada, and China are attempting to let us have our coal and burn it too by seizing carbon before it escapes into the air and storing it, usually in the ground. Capturing carbon, though, makes burning coal much less of a bargain. The cost of one pilot project in Mississippi has ballooned to more than six billion dollars.



Some 35,000 pounds of copper, 772 pounds of silver, 75 pounds of gold, and 33 pounds of palladium can be recovered from a million recycled cell phones.

In 2010, 31 percent—or 133 billion pounds—of the food available in the U.S. wasn't eaten.

All of the electricity used by the CTrain in Calgary, Canada, is purchased from renewable sources.

PHOTO: KYOCERA TCL SOLAR. ART: ROMUALDO FAURA

World

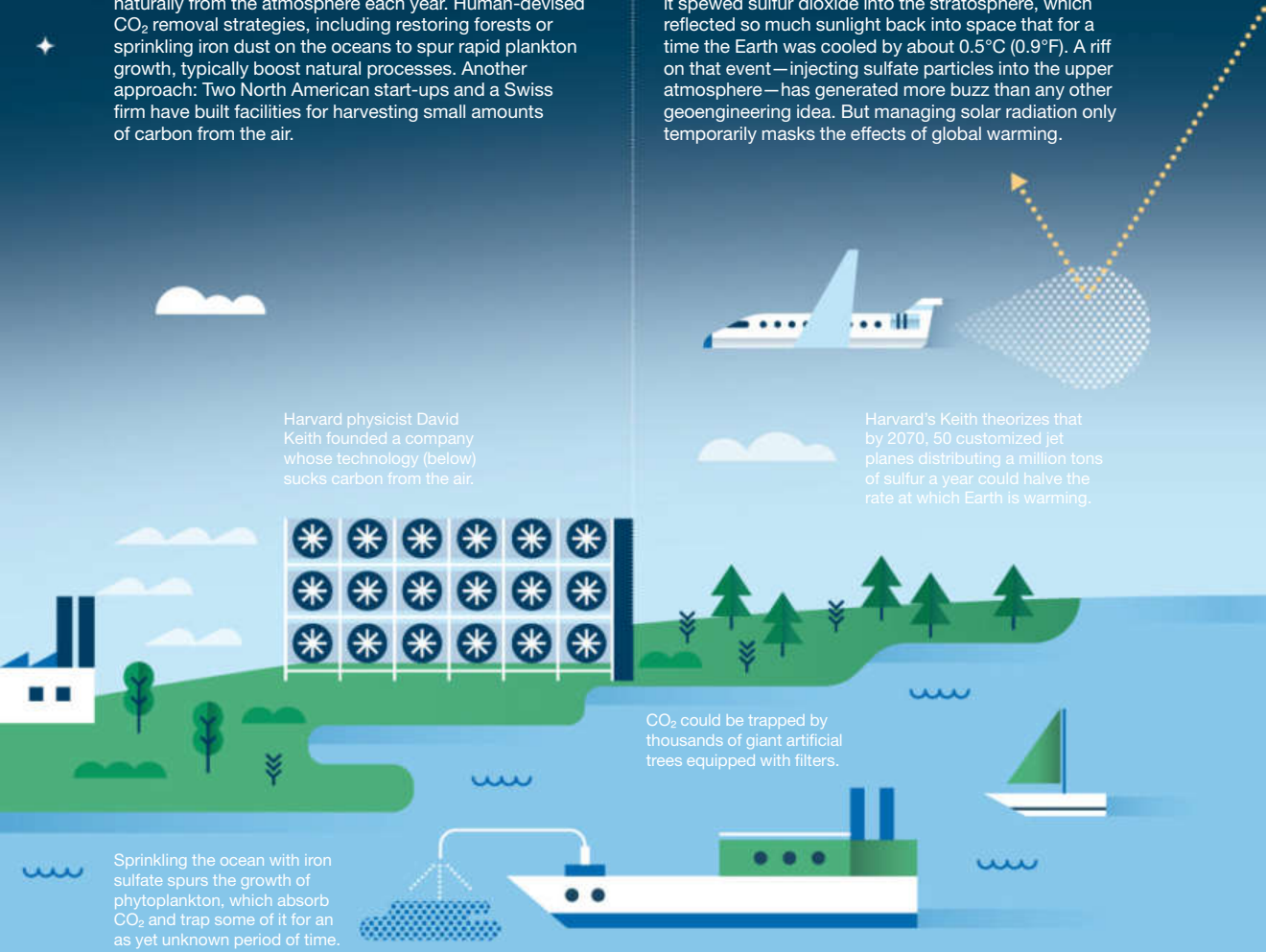
Geoengineering is a catchall term for deliberate large-scale interventions in the planetary environment that are designed to counteract climate change. As global carbon emissions rise, advocates say more research into geoengineering is needed. But hacking the planet carries unknown risks, and the politics of planetwide climate intervention would likely be complex. For starters, governments might need to agree on whether to even try cooling an overheated Earth, an extreme measure that could harm some countries while helping others.

CARBON DIOXIDE REMOVAL

Roughly half of global carbon emissions are removed naturally from the atmosphere each year. Human-devised CO_2 removal strategies, including restoring forests or sprinkling iron dust on the oceans to spur rapid plankton growth, typically boost natural processes. Another approach: Two North American start-ups and a Swiss firm have built facilities for harvesting small amounts of carbon from the air.

STRATOSPHERIC AEROSOLS

When Mount Pinatubo erupted in the Philippines in 1991, it spewed sulfur dioxide into the stratosphere, which reflected so much sunlight back into space that for a time the Earth was cooled by about 0.5°C (0.9°F). A riff on that event—injecting sulfate particles into the upper atmosphere—has generated more buzz than any other geoengineering idea. But managing solar radiation only temporarily masks the effects of global warming.



Harvard physicist David Keith founded a company whose technology (below) sucks carbon from the air.

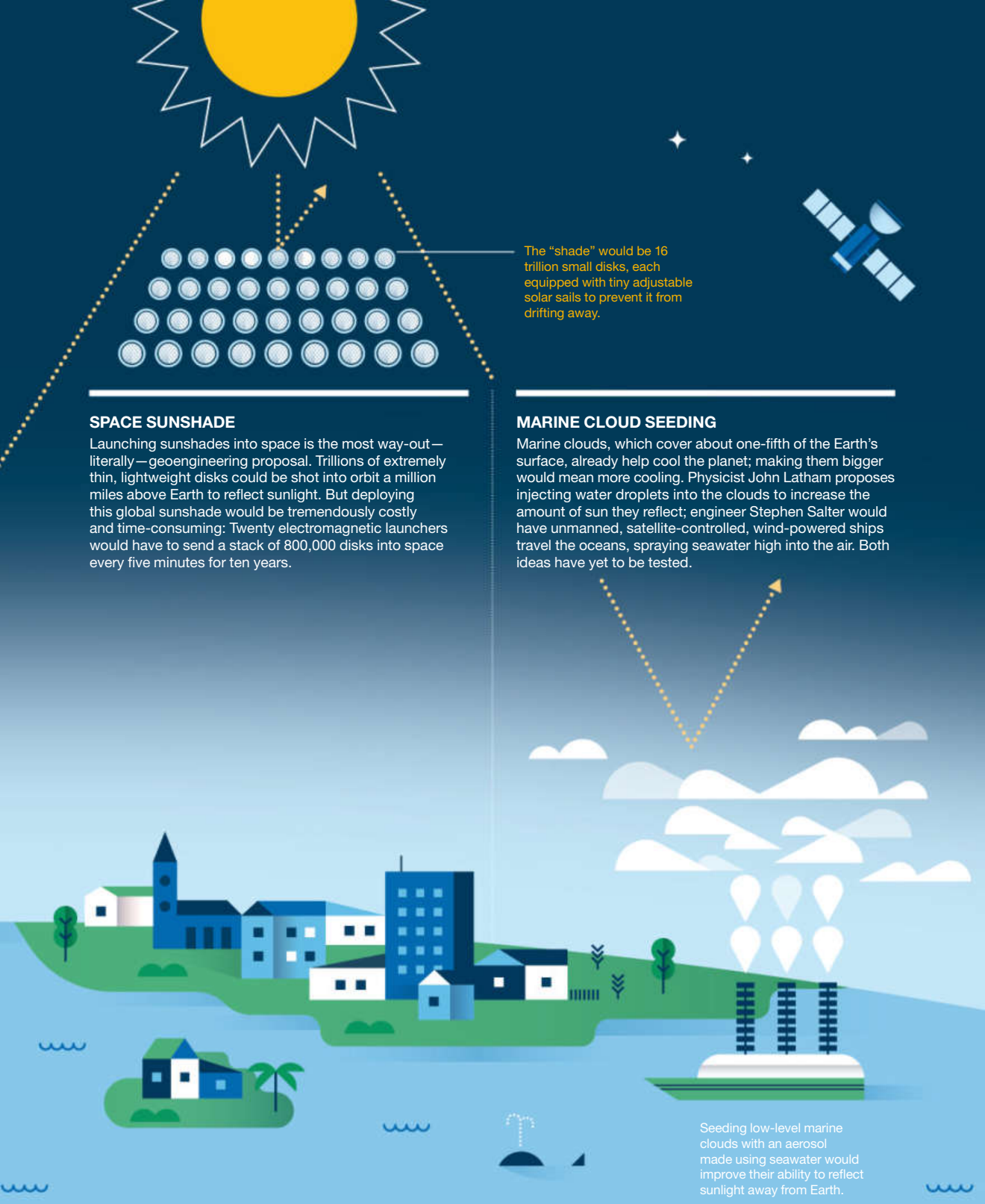
Harvard's Keith theorizes that by 2070, 50 customized jet planes distributing a million tons of sulfur a year could halve the rate at which Earth is warming.

CO_2 could be trapped by thousands of giant artificial trees equipped with filters.

Sprinkling the ocean with iron sulfate spurs the growth of phytoplankton, which absorb CO_2 and trap some of it for an as yet unknown period of time.

Pope Francis has urged people to reject the "throwaway culture" by recycling, moderating consumption, and limiting their use of nonrenewable resources.

The cost of keeping the Earth's temperature from rising more than 2°C (3.6°F) is estimated to be a trillion dollars a year through 2050.



SPACE SUNSHADE

Launching sunshades into space is the most way-out—literally—geoengineering proposal. Trillions of extremely thin, lightweight disks could be shot into orbit a million miles above Earth to reflect sunlight. But deploying this global sunshade would be tremendously costly and time-consuming: Twenty electromagnetic launchers would have to send a stack of 800,000 disks into space every five minutes for ten years.

MARINE CLOUD SEEDING

Marine clouds, which cover about one-fifth of the Earth’s surface, already help cool the planet; making them bigger would mean more cooling. Physicist John Latham proposes injecting water droplets into the clouds to increase the amount of sun they reflect; engineer Stephen Salter would have unmanned, satellite-controlled, wind-powered ships travel the oceans, spraying seawater high into the air. Both ideas have yet to be tested.

Seeding low-level marine clouds with an aerosol made using seawater would improve their ability to reflect sunlight away from Earth.

China, the U.S., and the European Union together emit the most CO_2—55 percent of the total.

Worldwide, fossil fuel subsidies may be as much as two trillion dollars, or about 2 percent of global GDP. Coal is subsidized the most.

More contraception could lower the birthrate and reduce emissions 20 percent by 2100.

ART: ROMUALDO FAURA

If You Own a Taurus Pistol
A Settlement Has Been Proposed in a Class Action Lawsuit that Alleges Safety Defects

The Settlement Provides an Enhanced Warranty, Safety Training, and a Cash Payment for Returned Pistols

The United States District Court for the Southern District of Florida authorized this notice.

Para una notificación en Español, visitar www.TaurusCarterSettlement.com

What's This About?

There is a proposed class action settlement about alleged safety defects in certain Taurus-branded pistols. This lawsuit alleges that Class Pistols (defined below) may unintentionally fire with the safety in the "on" or "safe" position, and may unintentionally fire when dropped or bumped. The Taurus Companies[1] ("Taurus") stand by the Class Pistols and deny all allegations of wrongdoing and liability.

Who's Included?

You may be a Settlement Class Member and have rights under this settlement if you are a resident or entity of the United States, Puerto Rico, U.S. Virgin Islands, or Guam and own one or more of the following Taurus-branded firearms on July 30, 2015: PT-111 Millennium; PT-132 Millennium; PT-138 Millennium; PT-140 Millennium; PT-145 Millennium; PT-745 Millennium; PT-609; PT-640; and PT-24/7 (the "Class Pistols").[2] The settlement doesn't include Taurus G2 model pistols.

What Does The Settlement Provide?

Settlement Class Members may return their Class Pistol to Taurus (with shipping paid by Taurus) and receive up to $200 per pistol, depending on the total number returned, not to exceed $30 million. The exact payment amount will be determined after the return deadline has passed and the exact number of returned Class Pistols is known. If you return your Class Pistol for a payment, it will not be returned to you even if the payment is less than you want.

Also, Taurus will provide a free, transferrable lifetime enhanced warranty that will allow owners to submit warranty claims at any time. Taurus will pay shipping and inspection costs, and will repair or replace the pistol as necessary. Taurus will also provide safety training to all Settlement Class Members. Taurus will pay for notice and administration, a class representative award of up to $15,000, and Class Counsels' attorneys' fees and costs up to $9 million, payable over 4 years.

How Do You Ask For A Payment?

You must submit a claim form and return your Class Pistol to receive a payment. Shipping is prepaid by Taurus. You can only submit a claim form *after* the settlement is finally approved and any appeals are concluded. This date is not yet known. You may register now through the website to get information about when you can submit a claim form. Visit the website to determine when you can submit a claim. If the Court approves the settlement and there are no appeals, the claims period will run from approximately February 24, 2016 until June 23, 2016.

What Are Your Other Options?

If you don't want to be bound by the settlement, you must exclude yourself by **December 14, 2015**, or you won't be able to sue, or continue to sue, Taurus about the legal claims in this case. If you exclude yourself, you can't get money from this settlement. You may object to this settlement by sending an objection by **December 14, 2015** and you may have to give a deposition. Objections and opt-outs will be public record, even if they contain the identity of Settlement Class Members. Detailed information is on the website. If you do nothing, you will still receive the lifetime enhanced warranty and safety training but will not receive a payment, and you will still be bound by the settlement.

Before money is paid, the Court will hold a Final Approval hearing on **January 20, 2016**, to consider whether to approve the settlement. You may attend the hearing, but you don't have to. The Court will also consider the request for attorneys' fees and costs and an incentive award. The motion for attorneys' fees, costs and awards will be on the website.

This is only a Summary. For detailed information, call toll-free 1-(844) 528-0180, or visit www.TaurusCarterSettlement.com, or write to Carter v. Forjas Taurus, c/o Heffler Claims Group, P.O. Box 230, Philadelphia, PA 19107-0230.

[1]The "Taurus Companies" means Forjas Taurus, S.A., Taurus Holdings, Inc. and Taurus International Manufacturing, Inc. The Taurus Companies are the Defendants in the class action lawsuit.
[2]The "PRO" series of each model is included.

www.TaurusCarterSettlement.com

IF YOU PURCHASED ONE OR MORE LOACKER QUADRATINI WAFER PRODUCTS AT ANY TIME FROM MARCH 6, 2010 TO SEPTEMBER 3, 2015, YOU MAY BE ENTITLED TO COMPENSATION FROM A CLASS ACTION SETTLEMENT.

What is the purpose of this notice? A settlement has been proposed in a class action pending in the Superior Court of the State of California for the County of Santa Clara ("Court") titled *Romero, et al. v. Loacker USA, Inc.,* Case No. 1-14-cv-274434. If the Court gives final approval to the settlement, Loacker will offer refunds to each class member (defined below) who properly and timely completes a Claim Form. The purpose of this notice is to inform you of the action and the settlement so that you may decide what steps to take in relation to it.

What is the lawsuit about? The lawsuit claims that Loacker violated certain laws by labeling and advertising its Quadratini wafer products as "All Natural" and "natural" when they contain allegedly synthetic, artificial, and highly processed ingredients, including chemical preservatives and artificial flavors. Loacker denies that it falsely advertised or marketed its products, denies all claims made against it, denies that it violated any laws, and denies that its labeling is false or misleading. *No court has decided which side is right. Both sides agreed to settle the case.*

Am I a class member? Class members include all persons in the United States who, at any time from March 6, 2010, through September 3, 2015, made retail purchases of one or more Loacker Quadratini wafer products in all sizes and flavors that were labeled "All Natural" or "natural" and contained one or more of the following ingredients: cocoa processed with alkali, sodium acid pyrophosphate, soy lecithin, and sodium hydrogen carbonate, glucose syrup, dextrose, milk powders, coffee powders, fruit powders, sugar, and coconut oil.

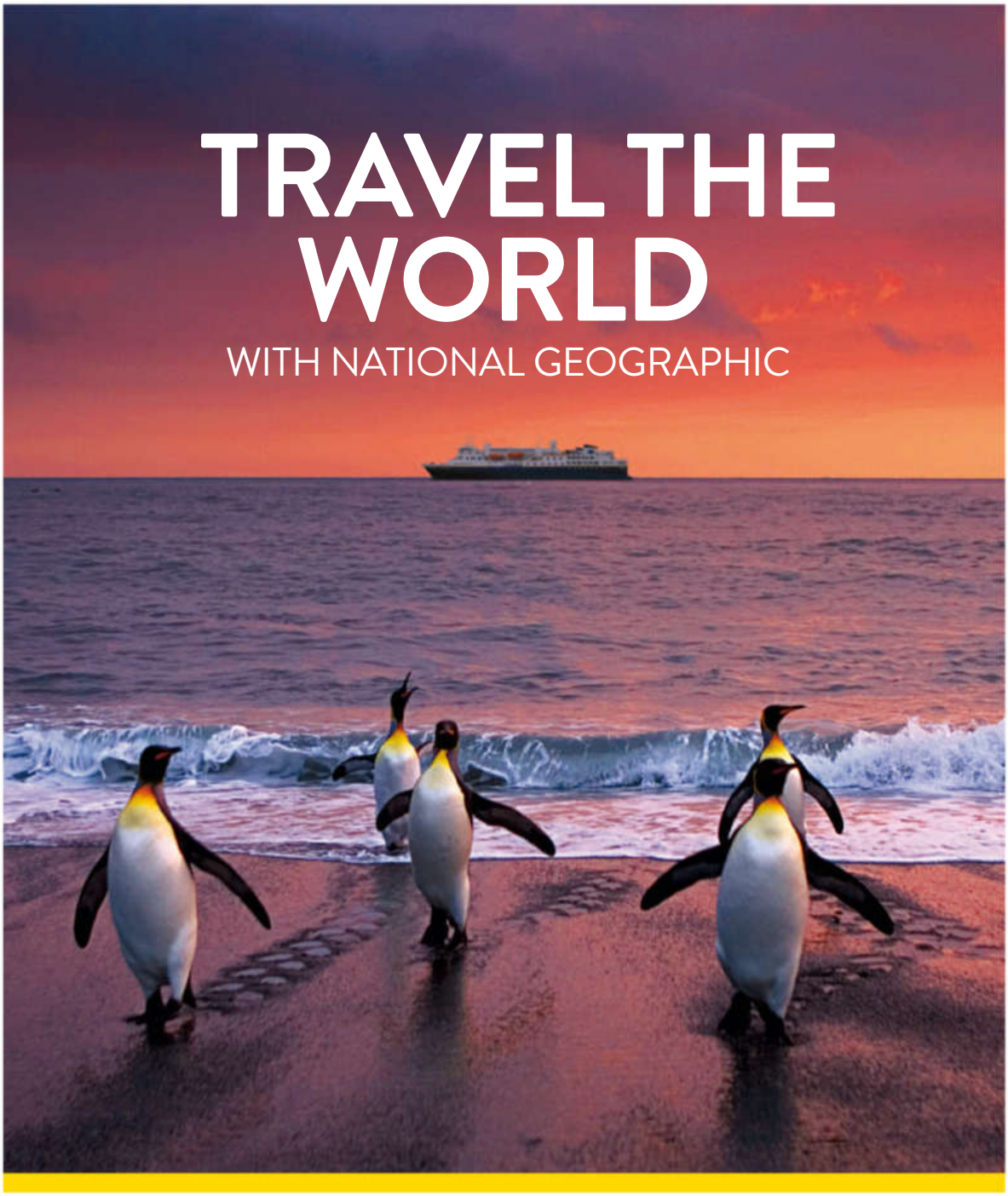
What relief does the settlement provide? In exchange for a release of claims from each class member who doesn't opt out, Loacker will create a cash settlement fund in the amount of $1,200,000. This amount is inclusive of all payments to class members who submit timely and valid claims, as well as Court-approved attorneys' fees and costs, service payments to the class representatives, and settlement administration costs. Class members with proof of purchase may receive a refund of $3.29 for each qualifying product they purchased. Class members without proof of purchase may receive a refund of $3.29 for each qualifying product they purchased up to a maximum of five (5) products. The amount of money that class members receive may ultimately be increased or decreased depending on the number of other claims that are submitted and the value of those claims.

As part of the settlement Loacker has also agreed to remove the words "All Natural" or "natural" from its labels and statements made on its website(s) representing that its Quadratini products are "All Natural" or "natural."

How do I submit a claim? To receive compensation under this settlement you must timely complete a valid Claim Form. A Claim Form is available on the Internet at the Settlement Website www.quadratiniclaims.com. The deadline to submit a Claim Form is November 30, 2015.

What are my other options? If you don't want to be legally bound by the settlement, you must exclude yourself by November 30, 2015, or you won't be able to sue Loacker over the legal claims in the lawsuit. If you exclude yourself, you cannot receive compensation from this settlement. If you stay in the settlement, you may object to it by November 30, 2015. A detailed notice available at the website below explains how to exclude yourself or object. The Court will hold a hearing on January 8, 2016 at 9:00 a.m. in Dept. 1., to consider whether to approve the settlement, a request by the lawyers representing class members for attorneys' fees and costs, and for the named plaintiffs' request for incentive awards for their services. You may ask to appear at the hearing, but you don't have to.

More information? For complete information about the settlement and its terms, to view the Settlement Agreement, related Court documents and Claim Form, and to learn more about how to exercise your various options under the settlement, visit www.quadratiniclaims.com. You may also write to the Settlement Administrator at: CPT Group, Inc., 16630 Aston, Irvine, CA 92606.



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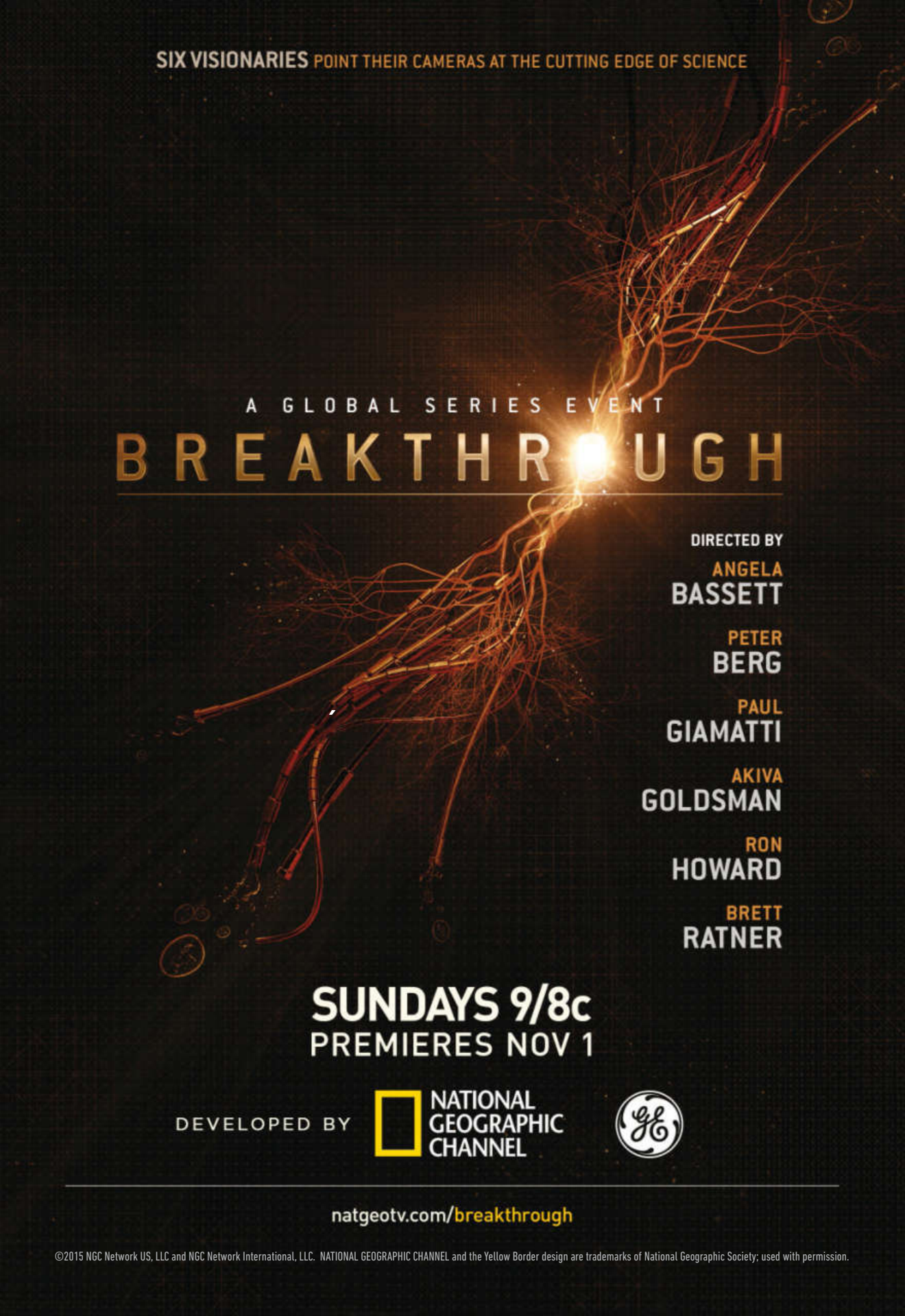


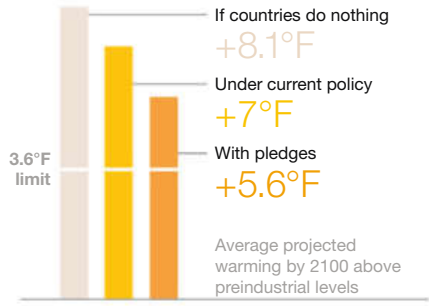
World

NATIONAL PLEDGES

When countries adopted the 1997 international treaty known as the Kyoto Protocol, they made binding pledges to reduce their greenhouse gas emissions over two decades. To monitor progress on those pledges and other climate-change efforts, a coalition of research organizations created a database called the Climate Action Tracker (CAT). This map reflects CAT's latest assessment of the major greenhouse-gas-emitting countries and a sample of minor ones, which together account for 80 percent of global emissions.

It's not always political leaders who set goals. A June 2015 lawsuit in the Netherlands—brought by a sustainable-living foundation and Dutch citizens—argued that the country's 17 percent emissions goal wasn't ambitious enough. A court ruled that it should raise that figure to 25 percent, to bolster the European Union's broader emissions reduction plan. Belgium and Norway are now facing similar lawsuits.

Talk versus action
In 2011 world governments set a goal of limiting global warming to 2°C (3.6°F). Scientists see three possible outcomes, depending on what action countries actually take.

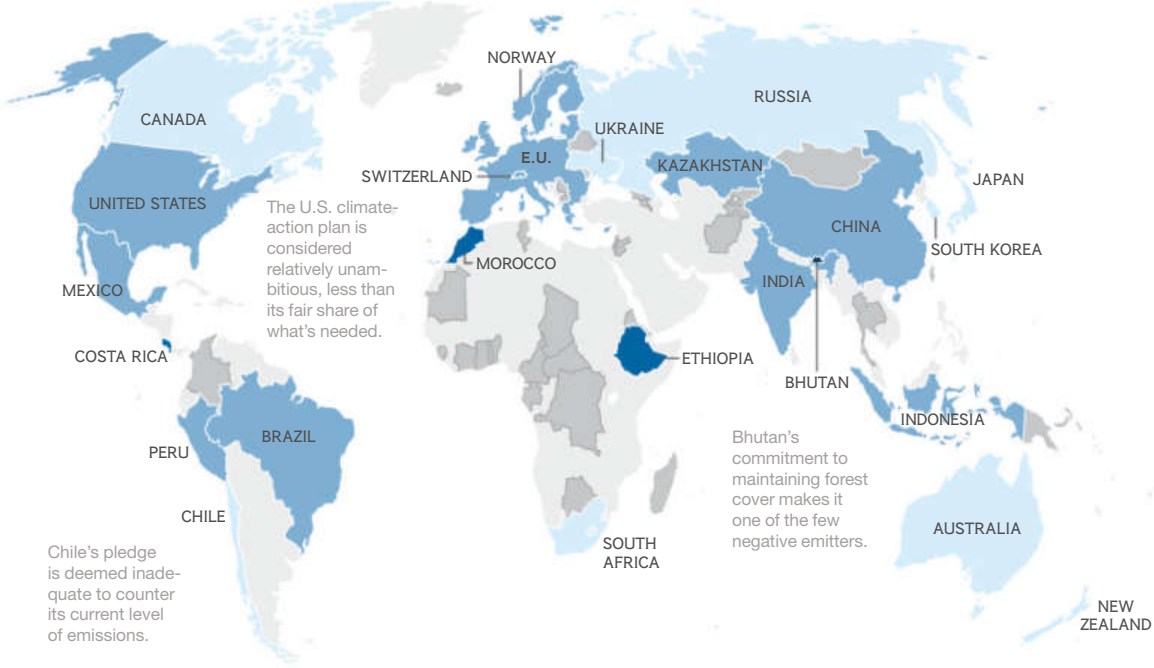


Who's keeping up?
To achieve the goal of limiting Earth's warming, climate analysts track which countries' pledges are having the most impact.

Pledges rated by CAT, ability to limit warming to 3.6°F

More than sufficient | Sufficient | Insufficient | Highly insufficient | *Not rated* | *No pledge*

Map data based on pledges made for 2020 and beyond.



NASA satellite data showed a global forest loss of 888,000 square miles from 2000 to 2012—almost three times as much as the forest that regrew.

Traditional cooking stoves use fuels such as wood, dung, and crop waste. Emissions vary depending on the fuel and the efficiency of the stove, but replacing these stoves with eco-friendly models could cut fuel and limit emissions.

SOURCE: DATA FOR CLIMATE ACTION TRACKER COMPILED BY CLIMATE ANALYTICS, ECOFYS, NEWCLIMATE INSTITUTE, AND POTSDAM INSTITUTE FOR CLIMATE IMPACT RESEARCH

THE WILL TO CHANGE

Germany's energy revolution aims to replace nukes and fossil fuels. Could it be a model for the world?

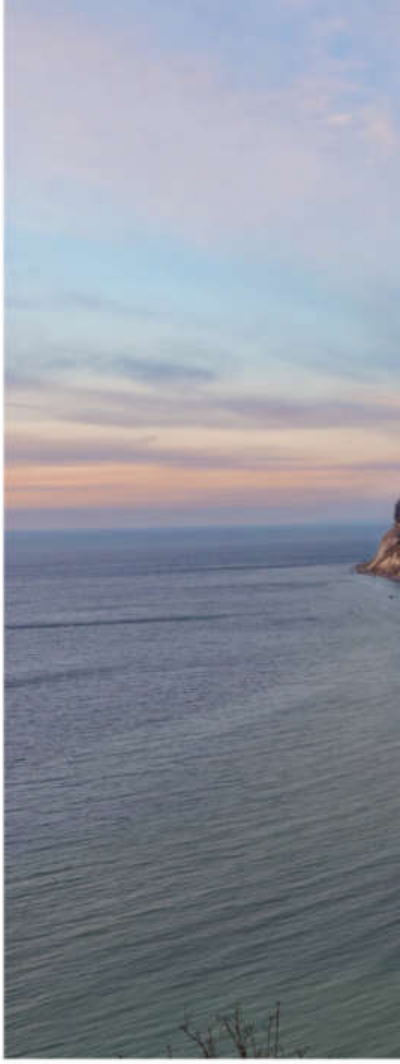
Wind turbines surround a coal-fired power plant near Garzweiler in western Germany. Renewables now generate 27 percent of the country's electricity, up from 9 percent a decade ago. Eventually they'll crowd out coal—although Germany is switching off its nuclear plants first.

Workers have been taking apart this Soviet-era nuclear power plant, near Greifswald in eastern Germany, since 1995, cleaning radioactive surfaces with steel grit (left) so the metal can be recycled. Germany plans to shut all its reactors by 2022.

A nuclear reactor at Kalkar was finished just before the 1986 explosion at Chernobyl, Ukraine—and never used. It's now an amusement park with a ride in what would have been the cooling tower. Fear of nuclear power spurred Germany's transition.

Nearly 300 feet above the North Sea and more than 30 miles from the German mainland, an engineer works on a wind turbine operated by Dong Energy. Nineteen wind farms have been built or are under construction in German waters of the North and Baltic Seas.

By Robert Kunzig
Photographs by Luca Locatelli



Hamburg knew the bombs were coming, and so the prisoners of war and forced laborers had just half a year to build the giant flak bunker. By July 1943 it was finished. A windowless cube of reinforced concrete, with seven-foot-thick walls and an even thicker roof, it towered like a medieval castle above a park near the Elbe River. The guns protruding from its four turrets would sweep Allied bombers from the sky, the Nazis promised, while tens of thousands of citizens sheltered safely behind its impenetrable walls.

Coming in at night from the North Sea just weeks after the bunker was finished, British bombers steered for the spire of St. Nikolai in the center of the city. They dropped clouds of metallic foil strips to throw off German radar and flak gunners. Targeting crowded residential neighborhoods, the bombers ignited an unquenchable firestorm that destroyed half of Hamburg and killed more than 34,000 people. Towering walls of fire created winds so strong that people were blown into the flames. Church bells clanged furiously.

The spire of St. Nikolai, which somehow survived, stands today as a *mahnmal*—a memorial reminding Germany of the hell brought by the Nazis. The flak bunker is another mahnmal. But now it has a new meaning: It has been transformed from a powerful reminder of Germany's shameful past into a hopeful vision for its future.

In the central space of the bunker, where people once cowered through the firestorm, a six-story, 528,000-gallon hot water tank delivers heat and hot water to some 800 homes in the neighborhood. The water is warmed by burning gas from sewage treatment, by waste heat from a nearby factory, and by solar panels that now cover the roof of the bunker, supported by struts angling from the old gun turrets. The bunker also converts sunlight into electricity; a scaffolding of photovoltaic (PV) panels on its south facade feeds enough juice into the grid to supply a thousand homes. On the north parapet, from which the flak gunners once watched flames rising from the city center, an outdoor café offers a view of the changed skyline. It's dotted with 17 wind turbines now.

Germany is pioneering an epochal transformation it calls the *energiewende*—an energy revolution that scientists say all nations must one day complete if a climate disaster is to be averted. Among large industrial nations, Germany is a leader. Last year about 27 percent of its electricity came from renewable sources such as wind and solar power, three times what it got a decade ago and more than twice what the

The chalk cliffs at Jasmund National Park on the Baltic have drawn tourists for centuries. The beech woods there are a remnant of the forest that once covered Germany. According to Romantic lore, the forest forged the German identity as a nature-loving people—a key inspiration for the clean-energy movement. When a quarry threatened this site in the 1920s, ranger Rico Markmann explains, "the populace didn't stand for it."

United States gets today. The change accelerated after the 2011 meltdown at Japan's Fukushima nuclear power plant, which led Chancellor Angela Merkel to declare that Germany would shut all 17 of its own reactors by 2022. Nine have been switched off so far, and renewables have more than picked up the slack.

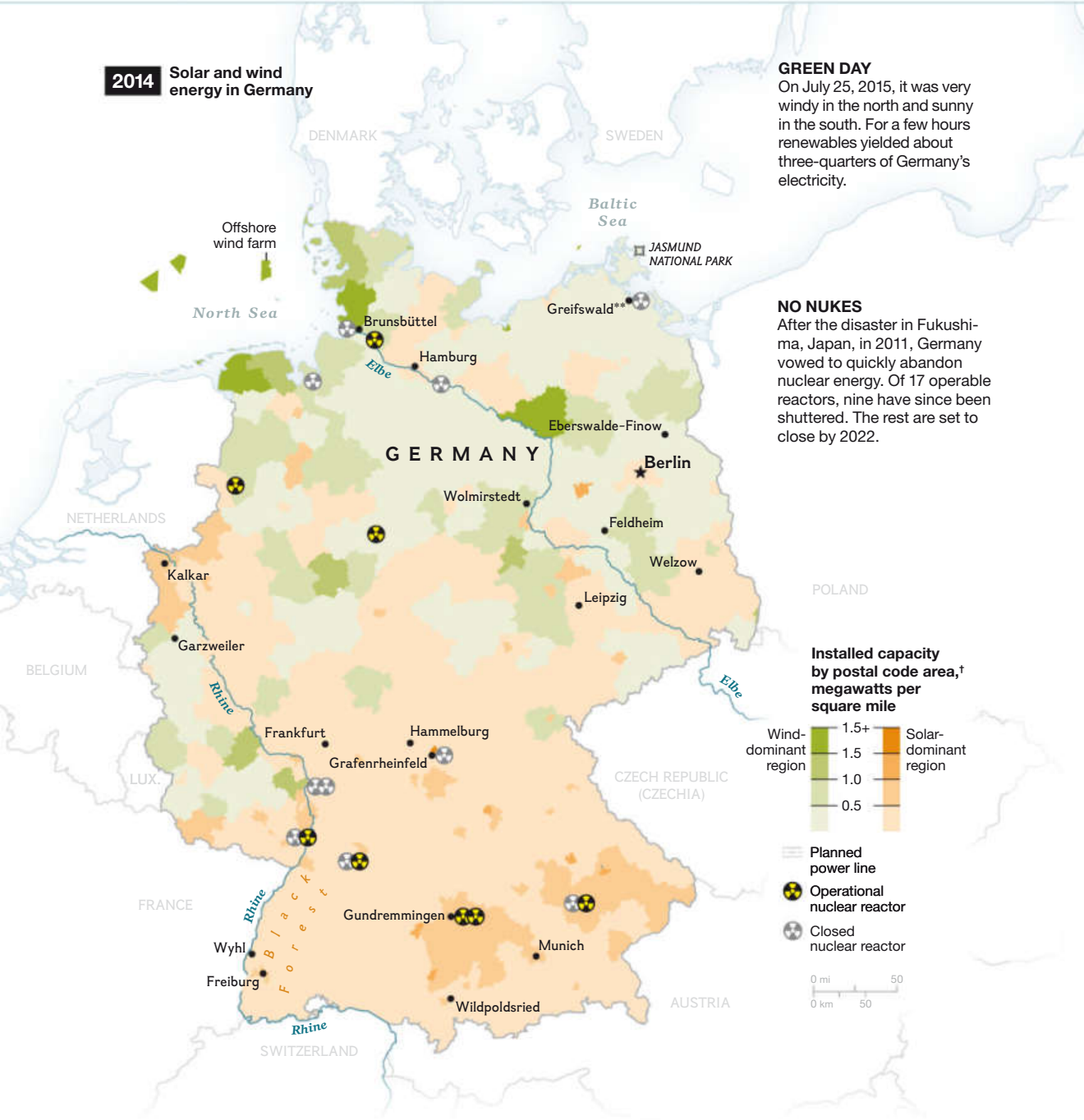
What makes Germany so important to the world, however, is the question of whether it can lead the retreat from fossil fuels. By later this century, scientists say, planet-warming carbon emissions must fall to virtually zero. Germany, the world's fourth largest economy, has promised some of the most aggressive emission cuts—by 2020, a 40 percent cut from 1990 levels, and by 2050, at least 80 percent.

The fate of those promises hangs in the balance right now. The German revolution has come from the grass roots: Individual citizens and energy *genossenschaften*—local citizens associations—have made half the investment in renewables. But conventional utilities, which didn't see the revolution coming, are pressuring Merkel's government to slow things down. The country still gets far more electricity from coal than from renewables. And the energiewende has an even longer way to go in the transportation and heating sectors, which together emit more carbon dioxide (CO_2) than power plants.

German politicians sometimes compare the energiewende to the Apollo moon landing. But that feat took less than a decade, and most

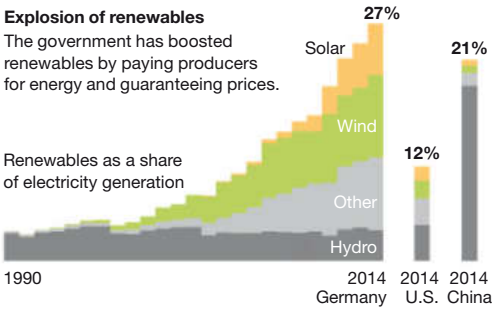
Germany's Audacious Goal

Germany has Europe's second highest consumer electricity prices, yet public support for its *energiewende*—an aggressive transition to renewable energy—is at an impressive 92 percent. The support is rooted in an eco-friendly culture, a collective desire to abandon nuclear energy, and laws that allow citizens to profit from selling their energy to the grid. Roughly 27 percent of Germany's electricity is from renewables; the goal is at least 80 percent by 2050.



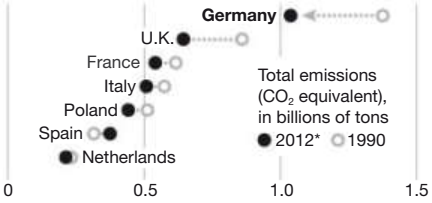
Explosion of renewables

The government has boosted renewables by paying producers for energy and guaranteeing prices.



Decline in emissions

Germany's renewable-energy surge has contributed to a 27 percent reduction in its greenhouse gas emissions.



2050

OFFSHORE PROMISE

Germany has invested heavily in energy generated by offshore wind and expects one-third of its future wind energy to come from offshore farms.

ELECTRICITY HIGHWAYS

To bring renewable power from the windy north to the heavily industrialized south, government and utilities have proposed at least two high-voltage, direct current (HVDC) power lines. Landowners and even the Bavarian government are resisting the unsightly lines. A possible compromise: running some stretches of cable underground.

*LATEST AVAILABLE DATA

**REACTOR CLOSED PRIOR TO 2011

†OFFSHORE WIND FARM AREAS ALSO SHOWN

JASON TREAT, NGM STAFF; EVAN APPLEGATE. SOURCES: FRAUNHOFER IWES, KASSEL; U.S. ENERGY INFORMATION ADMINISTRATION; GERMAN FEDERAL MINISTRY FOR THE ENVIRONMENT; EUROSTAT

Renewables are booming, but Germany's use of lignite, the dirtiest coal, hasn't declined. At Vattenfall's Welzow-Süd mine, some of the world's largest machines claw 22 million tons a year from a 45-foot-thick seam. How long will that go on? "Very long, I hope," said Jan Domann, a young engineer. "We have enough lignite."

A worker prepares a wind turbine blade for painting at a Siemens factory in Denmark. At 246 feet long, the hollow fiberglass and resin blade is nearly as long as the wingspan of the largest jetliner. A single turbine in the North Sea can supply electricity for 6,000 German homes.


1297

"It's a project for a generation, and it's hard. It's making electricity more expensive. Still, if you ask in a poll, Do you want the energiewende?, then 90 percent say yes."

Gerd Rosenkranz, political analyst

Americans just watched it on TV. The energiewende will take much longer and will involve every single German—more than 1.5 million of them, nearly 2 percent of the population, are selling electricity to the grid right now. "It's a project for a generation; it's going to take till 2040 or 2050, and it's hard," said Gerd Rosenkranz, a former journalist at *Der Spiegel* who's now an analyst at Agora Energiewende, a Berlin think tank. "It's making electricity more expensive for individual consumers. And still, if you ask people in a poll, Do you want the energiewende? then 90 percent say yes."

Why? I wondered as I traveled in Germany last spring. Why is the energy future happening here, in a country that was a bombed-out wasteland 70 years ago? And could it happen everywhere?

THE GERMANS HAVE AN ORIGIN MYTH: It says they came from the dark and impenetrable heart of the forest. It dates back to the Roman historian Tacitus, who wrote about the Teutonic hordes who massacred Roman legions, and it was embellished by German Romantics in the 19th century. Through the upheavals of the 20th century, according to ethnographer Albrecht Lehmann, the myth remained a stable source of German identity. The forest became the place where Germans go to restore their souls—a habit that predisposed them to care about the environment.

So in the late 1970s, when fossil fuel emissions were blamed for killing German forests with acid rain, the outrage was nationwide. The oil embargo of 1973 had already made Germans, who have very little oil and gas of their own, think about energy. The threat of *waldsterben,* or forest death, made them think harder.

Government and utilities were pushing nuclear power—but many Germans were pushing back. This was new for them. In the decades after World War II, with a ruined country to rebuild, there had been little appetite for questioning authority or the past. But by the 1970s, the rebuilding was complete, and a new generation was beginning to question the one that had started and lost the war. "There's a certain rebelliousness that's a result of the Second World War," a 50-something man named Josef Pesch told me. "You don't blindly accept authority."

Pesch was sitting in a mountaintop restaurant in the Black Forest outside Freiburg. In a snowy clearing just uphill stood two 320-foot-tall wind turbines funded by 521 citizen investors recruited by Pesch—but we weren't talking about the turbines yet. With an engineer named Dieter Seifried, we were talking about the nuclear reactor that never got built, near the village of Wyhl, 20 miles away on the Rhine River.

The state government had insisted that the reactor had to be built or the lights would go out in Freiburg. But beginning in 1975, local farmers and students occupied the site. In protests that lasted nearly a decade, they forced the government to abandon its plans. It was the first time a nuclear reactor had been stopped in Germany.

The lights didn't go out, and Freiburg became a solar city. Its branch of the Fraunhofer Institute is a world leader in solar research. Its Solar Settlement, designed by local architect Rolf Disch, who'd been active in the Wyhl protests, includes 50 houses that all produce more energy than they consume. "Wyhl was the starting point," Seifried said. In 1980 an institute that Seifried co-founded published a study called *Energiewende*—giving a name to a movement that hadn't even been born yet.

It wasn't born of a single fight. But opposition to nuclear power, at a time when few people were talking about climate change, was clearly a decisive factor. I had come to Germany

thinking the Germans were foolish to abandon a carbon-free energy source that, until Fukushima, produced a quarter of their electricity. I came away thinking there would have been no energiewende at all without antinuclear sentiment—the fear of meltdown is a much more powerful and immediate motive than the fear of slowly rising temperatures and seas.

All over Germany I heard the same story. From Disch, sitting in his own cylindrical house, which rotates to follow the sun like a sunflower. From Rosenkranz in Berlin, who back in 1980 left physics graduate school for months to occupy the site of a proposed nuclear waste repository. From Luise Neumann-Cosel, who occupied the same site two decades later—and who is now leading a citizens' initiative to buy the Berlin electric grid. And from Wendelin Einsiedler, a Bavarian dairy farmer who has helped transform his village into a green dynamo.

All of them said Germany had to get off nuclear power and fossil fuels at the same time. "You can't drive out the devil with Beelzebub," explained Hans-Josef Fell, a prominent Green Party politician. "Both have to go." At the University of Applied Sciences in Berlin, energy researcher Volker Quaschning put it this way: "Nuclear power affects me personally. Climate change affects my kids. That's the difference."

If you ask why antinuclear sentiment has been so much more consequential in Germany than, say, across the Rhine in France, which still gets 75 percent of its electricity from nukes, you end up back at the war. It left Germany a divided country, the front along which two nuclear superpowers faced off. Demonstrators in the 1970s and '80s were protesting not just nuclear reactors but plans to deploy American nuclear missiles in West Germany. The two didn't seem separable. When the German Green Party was founded in 1980, pacifism and opposition to nuclear power were both central tenets.

In 1983 the first Green representatives made it into the Bundestag, the national parliament, and started injecting green ideas into the political mainstream. When the Soviet reactor at Chernobyl exploded in 1986, the left-leaning Social Democrats (SPD), one of Germany's two major parties, was converted to the antinuclear cause. Even though Chernobyl was hundreds of miles away, its radioactive cloud passed over Germany, and parents were urged to keep their children inside. It's still not always safe to eat mushrooms or wild boar from the Black Forest, Pesch said. Chernobyl was a watershed.

But it took Fukushima, 25 years later, to convince Merkel and her Christian Democratic Union (CDU) that all nuclear reactors should be switched off by 2022. By then the boom of renewable energy was in full swing. And a law that Hans-Josef Fell had helped create back in 2000 was the main reason.

FELL'S HOUSE IN HAMMELBURG, the town in northern Bavaria where he was born and raised, is easy to spot among all the pale postwar stucco: It's the one built of dark larch wood, with a grass roof. On the south side, facing the backyard, the grass is partially covered by photovoltaic and solar hot water panels. When there's not enough sun to produce electricity or heat, a cogenerator in the basement burns sunflower or rapeseed oil to produce both. On the March morning when I visited, the wood interior of the house was bathed in sunlight and warmth from the conservatory. In a few weeks, Fell said, wildflowers would be blooming on the roof.

A tall man in jeans and Birkenstocks, with a bald, egg-shaped head and a fringe of gray beard, Fell has moments of sounding like a preacher—but he's no green ascetic. A shed in his backyard, next to the swimming pond, houses a sauna, powered by the same green electricity that powers his house and his car. "The environmental movement's biggest mistake has been to say, 'Do less. Tighten your belts. Consume less,'" Fell said. "People associate that with a lower quality of life. 'Do things differently, with cheap, renewable electricity'—that's the message."

From Fell's garden, on a clear day, you used to be able to see the white steam plumes of the nuclear reactor at Grafenrheinfeld. His father, the conservative mayor of Hammelburg, supported nuclear power and the local military

In a Leipzig factory partially powered by wind, BMW builds i8 and i3 electric cars with light carbon-fiber bodies—the first in mass production. German carmakers offer some electric models, but for lack of government incentives, Germans aren't buying many. "Compared to California, we're light-years behind," said BMW's Wieland Brúch.


Cleco
1628279

A sea of photovoltaic panels surrounds the runway at the Eberswalde-Finow Airport, 30 miles north of Berlin. Germany is at the same latitude as Labrador, Canada, but has installed more solar capacity than any other country. Most panels are on rooftops.

The German law drove down the cost of solar and wind, making them competitive in many regions with fossil fuels. It helped spark a worldwide boom.

base. Young Fell demonstrated at Grafenrheinfeld and went to court to refuse military service. Years later, after his father had retired, Fell was elected to the Hammelburg city council.

It was 1990, the year Germany was officially reunified—and while the country was preoccupied with that monumental task, a bill boosting the energiewende made its way through the Bundestag without much public notice. Just two pages long, it enshrined a crucial principle: Producers of renewable electricity had the right to feed into the grid, and utilities had to pay them a "feed-in tariff." Wind turbines began to sprout in the windy north.

But Fell, who was installing PV panels on his roof in Hammelburg, realized that the new law would never lead to a countrywide boom: It paid people to produce energy, but not enough. In 1993 he got the city council to pass an ordinance obliging the municipal utility to guarantee any renewable energy producer a price that more than covered costs. Fell promptly organized an association of local investors to build a 15-kilowatt solar power plant—tiny by today's standards, but the association was one of the first of its kind. Now there are hundreds in Germany.

In 1998 Fell rode a Green wave and his success in Hammelburg into the Bundestag. The Greens formed a governing coalition with the SPD. Fell teamed up with Hermann Scheer, a prominent SPD advocate of solar energy, to craft a law that in 2000 took the Hammelburg experiment nationwide and has since been imitated around the world. Its feed-in tariffs were guaranteed for 20 years, and they paid well.

"My basic principle," Fell said, "was the payment had to be so high that investors could make a profit. We live in a market economy, after all. It's logical."

FELL WAS ABOUT the only German I met who claimed not to have been surprised at the boom his logic unleashed. "That it would be possible to this extent—I didn't believe that then," said dairy farmer Wendelin Einsiedler. Outside his sunroom, which overlooks the Alps, nine wind turbines turned lazily on the ridge behind the cow pen. The smell of manure drifted in. Einsiedler had started his personal energiewende in the 1990s with a single turbine and a methane-producing manure fermenter. He and his brother Ignaz, also a dairy farmer, burned the methane in a 28-kilowatt cogenerator, generating heat and electricity for their farms. "There was no question of making money," Einsiedler said. "It was idealism."

But after the renewable energy law took effect in 2000, the Einsiedlers expanded. Today they have five fermenters, which process corn silage as well as manure from eight dairy farms, and they pipe the resulting biogas three miles to the village of Wildpoldsried. There it's burned in cogenerators to heat all the public buildings, an industrial park, and 130 homes. "It's a wonderful principle, and it saves an unbelievable amount of CO_2," said Mayor Arno Zengerle.

The biogas, the solar panels that cover many roofs, and especially the wind turbines allow Wildpoldsried to produce nearly five times as much electricity as it consumes. Einsiedler manages the turbines, and he's had little trouble recruiting investors. Thirty people invested in the first one; 94 jumped on the next. "These are their wind turbines," Einsiedler said. Wind turbines are a dramatic and sometimes controversial addition to the German landscape—"asparagification," opponents call it—but when people have a financial stake in the asparagus, Einsiedler said, their attitude changes.

It wasn't hard to persuade farmers and homeowners to put solar panels on their roofs; the feed-in tariff, which paid them 50 cents a

kilowatt-hour when it started in 2000, was a good deal. At the peak of the boom, in 2012, 7.6 gigawatts of PV panels were installed in Germany in a single year—the equivalent, when the sun is shining, of seven nuclear plants. A German solar-panel industry blossomed, until it was undercut by lower-cost manufacturers in China—which took the boom worldwide.

Fell's law, then, helped drive down the cost of solar and wind, making them competitive in many regions with fossil fuels. One sign of that: Germany's tariff for large new solar facilities has fallen from 50 euro cents a kilowatt-hour to less than 10. "We've created a completely new situation in 15 years—that's the huge success of the renewable energy law," Fell said.

Germans paid for this success not through taxes but through a renewable-energy surcharge on their electricity bills. This year the surcharge is 6.17 euro cents per kilowatt-hour, which for the average customer amounts to about 18 euros a month—a hardship for some, Rosenkranz told me, but not for the average German worker. The German economy as a whole devotes about as much of its gross national product to electricity as it did in 1991.

In the 2013 elections Fell lost his seat in the Bundestag, a victim of internal Green Party politics. He's back in Hammelburg now, but he doesn't have to look at the steam plumes from Grafenrheinfeld: Last June the reactor became the latest to be switched off. No one, not even the industry, thinks nuclear is coming back in Germany. Coal is another story.

GERMANY GOT 44 PERCENT of its electricity from coal last year—18 percent from hard coal, which is mostly imported, and about 26 percent from lignite, or brown coal. The use of hard coal has declined substantially over the past two decades, but not the use of lignite. That's a major reason Germany isn't on track to meet its own greenhouse gas emissions target for 2020.

Germany is the world's leading producer of lignite. It emits even more CO_2 than hard coal, but it's the cheapest fossil fuel—cheaper than hard coal, which is cheaper than natural gas. Ideally, to reduce emissions, Germany should replace lignite with gas. But as renewables have flooded the grid, something else has happened: On the wholesale market where contracts to deliver electricity are bought and sold, the price of electricity has plummeted, such that gas-fired power plants and sometimes even plants burning hard coal are priced out of the market. Old lignite-fired power plants are rattling along at full steam, 24/7, while modern gas-fired plants with half the emissions are standing idle.

"Of course we have to find a track to get rid of our coal—it's very obvious," said Jochen Flasbarth, state secretary in the environment ministry. "But it's quite difficult. We are not a very resource-rich country, and the one resource we have is lignite."

Curtailing its use is made harder by the fact that Germany's big utilities have been losing money lately—because of the energiewende, they say; because of their failure to adapt to the energiewende, say their critics. E.ON, the largest utility, which owns Grafenrheinfeld and many other plants, declared a loss of more than three billion euros last year.

"The utilities in Germany had one strategy," Flasbarth said, "and that was to defend their track—nuclear plus fossil. They didn't have a strategy B." Having missed the energiewende train as it left the station, they're now chasing it. E.ON is splitting into two companies, one devoted to coal, gas, and nuclear, the other to renewables. The CEO, once a critic of the energiewende, is going with the renewables.

Vattenfall, a Swedish state-owned company that's another one of Germany's four big utilities, is attempting a similar evolution. "We're a role model for the energiewende," spokesperson Lutz Wiese said cheerfully as he greeted me at Welzow-Süd—an open-pit mine on the Polish border that produces 22 million tons of lignite a year. In a trench that covers 11 square miles and is more than 300 feet deep, 13 gargantuan digging machines work in synchrony—moving the trench through the landscape, exposing and removing the lignite seam, and dumping the overburden behind them so the land can

Citizens have funded half of Germany's investment in renewable energy after a law made it profitable. Outside the village of Feldheim, visitors tour the wind park. It sells electricity to the national grid—but also supplies a local grid that makes Feldheim self-sufficient.

In 1996 the Kalkar nuclear reactor site, on the Rhine near Holland, opened as an amusement park: Wunderland Kalkar. By 2050 Germany aims to be a new kind of wonderland—an industrial country that uses half as much energy as before and gets at least 80 percent from renewables.

The euphoria hasn't lasted. Economic interests are clashing now. Some Germans say it might take another catastrophe like Fukushima to catalyze progress.

be replanted. In one recultivated area there's a small experimental vineyard. On the same rebuilt hill stands a memorial to Wolkenberg, a village consumed by the mine in the 1990s. Boulders mark the spots where the church and other buildings once stood.

It was a gorgeous spring day; from Wolkenberg, the only cloud we could see was the lazily billowing steam plume from the 1.6-gigawatt power plant at Schwarze Pumpe, which burns most of the lignite mined at Welzow-Süd. In a conference room, Olaf Adermann, asset manager for Vattenfall's lignite operations, explained that Vattenfall and other utilities had never expected renewables to take off so fast. Even with the looming shutdown of more nuclear reactors, Germany has too much generating capacity.

"We have to face some kind of a market cleaning," Adermann said. But lignite shouldn't be the one to go, he insisted: It's the "reliable and flexible partner" when the sun isn't shining or the wind isn't blowing. Adermann, who's from the region and worked for its lignite mines before they belonged to Vattenfall, sees them continuing to 2050—and maybe beyond.

Vattenfall, however, plans to sell its lignite business, if it can find a buyer, so it can focus on renewables. It's investing billions of euros in two new offshore wind parks in the North Sea—because there's more wind offshore than on and because a large corporation needs a large project to pay its overhead. "We can't do onshore in Germany," Wiese said. "It's too small."

Vattenfall isn't alone: The renewables boom has moved into the North and Baltic Seas and, increasingly, into the hands of the utilities. Merkel's government has encouraged the shift, capping construction of solar and onshore wind and changing the rules in ways that shut out citizens associations. Last year the amount of new solar fell to around 1.9 gigawatts, a quarter of the 2012 peak. Critics say the government is helping big utilities at the expense of the citizens' movement that launched the energiewende.

At the end of April, Vattenfall formally inaugurated its first German North Sea wind park, an 80-turbine project called DanTysk that lies some 50 miles offshore. The ceremony in a Hamburg ballroom was a happy occasion for the city of Munich too. Its municipal utility, Stadtwerke München, owns 49 percent of the project. As a result Munich now produces enough renewable electricity to supply its households, subway, and tram lines. By 2025 it plans to meet all of its demand with renewables.

IN PART BECAUSE IT HAS RETAINED a lot of heavy industry, Germany has some of the highest per capita carbon emissions in western Europe. (They're a bit more than half of U.S. emissions.) Its goal for 2020 is to cut them by 40 percent from 1990 levels. As of last year, it had achieved 27 percent. The European carbon-trading system, in which governments issue tradable emissions permits to polluters, hasn't been much help so far. There are too many permits in circulation, and they're so cheap that industry has little incentive to cut emissions.

Though Germany isn't on track to meet its own goal for 2020, it's ahead of the European Union's schedule. It could have left things there—and many in Merkel's CDU wanted her to do just that. Instead, she and Economics Minister Sigmar Gabriel, head of the SPD, reaffirmed their 40 percent commitment last fall.

They haven't proved they can meet it, however. Last spring Gabriel proposed a special emissions levy on old, inefficient coal plants; he soon had 15,000 miners and power plant workers, encouraged by their employers, demonstrating outside his ministry. In July the government backed down. Instead of taxing the utilities, it

said it would pay them to shut down a few coal plants—achieving only half the planned emissions savings. For the energiewende to succeed, Germany will have to do much more.

It will have to get off gasoline and diesel too. The transportation sector produces about 17 percent of Germany's emissions. Like the utilities, its famous carmakers—Mercedes-Benz, BMW, Volkswagen, and Audi—were late to the energiewende. But today they're offering more than two dozen models of electric cars. The government's goal is to have a million electric cars on the road by 2020; so far there are about 40,000. The basic problem is that the cars are still too expensive for most Germans, and the government hasn't offered serious incentives to buy them—it hasn't done for transportation what Fell's law did for electricity.

Much the same is true of buildings, whose heating systems emit 30 percent of Germany's greenhouse gases. Rolf Disch in Freiburg is one of many architects who have built houses and buildings that consume almost no net energy or produce a surplus. But Germany is not putting up many new buildings. "The strategy has always been to modernize old buildings in such a way that they use almost no energy and cover what they do use with renewables," said Matthias Sandrock, a researcher at the Hamburg Institute. "That's the strategy, but it's not working. A lot is being done, but not enough."

All over Germany, old buildings are being wrapped in six inches of foam insulation and refitted with modern windows. Low-interest loans from the bank that helped rebuild the war-torn west with Marshall Plan funds pay for many projects. Just one percent of the stock is being renovated every year, though. For all buildings to be nearly climate neutral by 2050—the official goal—the rate would need to double at least. Once, Sandrock said, the government floated the idea of requiring homeowners to renovate. The public outcry shot that trial balloon down.

"AFTER FUKUSHIMA, for a short time there was *aufbruchstimmung*—for about half a year there was a real euphoria," said Gerd Rosenkranz. Aufbruchstimmung means something like "the joy of departure"; it's what a German feels when he's setting out on a long hike, say, in the company of friends. With all the parties in Germany in agreement, Rosenkranz said, the energiewende felt like that. But the feeling hasn't lasted. Economic interests are clashing now. Some Germans say it might take another catastrophe like Fukushima to catalyze a fresh burst of progress. "The mood is bad," Rosenkranz said.

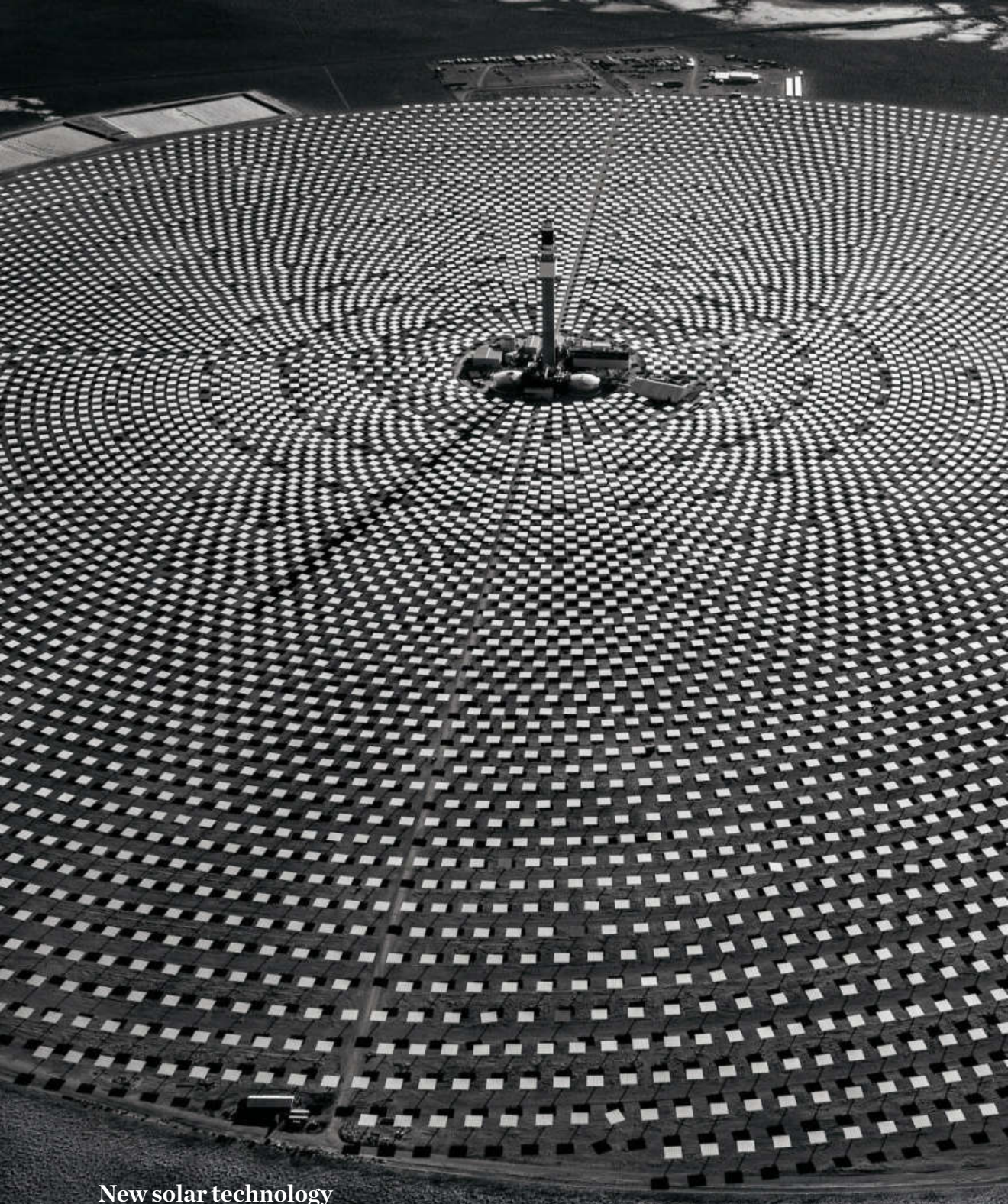
But here's the thing about the Germans: They knew the energiewende was never going to be a walk in the forest, and yet they set out on it. What can we learn from them? We can't transplant their desire to reject nuclear power. We can't appropriate their experience of two great nation-changing projects—rebuilding their country when it seemed impossible, 70 years ago, and reunifying their country when it seemed forever divided, 25 years ago. But we can be inspired to think that the energiewende might be possible for other countries too.

In a recent essay William Nordhaus, a Yale economist who has spent decades studying the problem of addressing climate change, identified what he considers its essence: free riders. Because it's a global problem, and doing something is costly, every country has an incentive to do nothing and hope that others will act. While most countries have been free riders, Germany has behaved differently: It has ridden out ahead. And in so doing, it has made the journey easier for the rest of us. □

REBECCA HALE, NGM STAFF

Photographer and filmmaker **Luca Locatelli,** who lives in Milan, is passionate about the relationship between humans and technology—and the environmental consequences of those interactions.

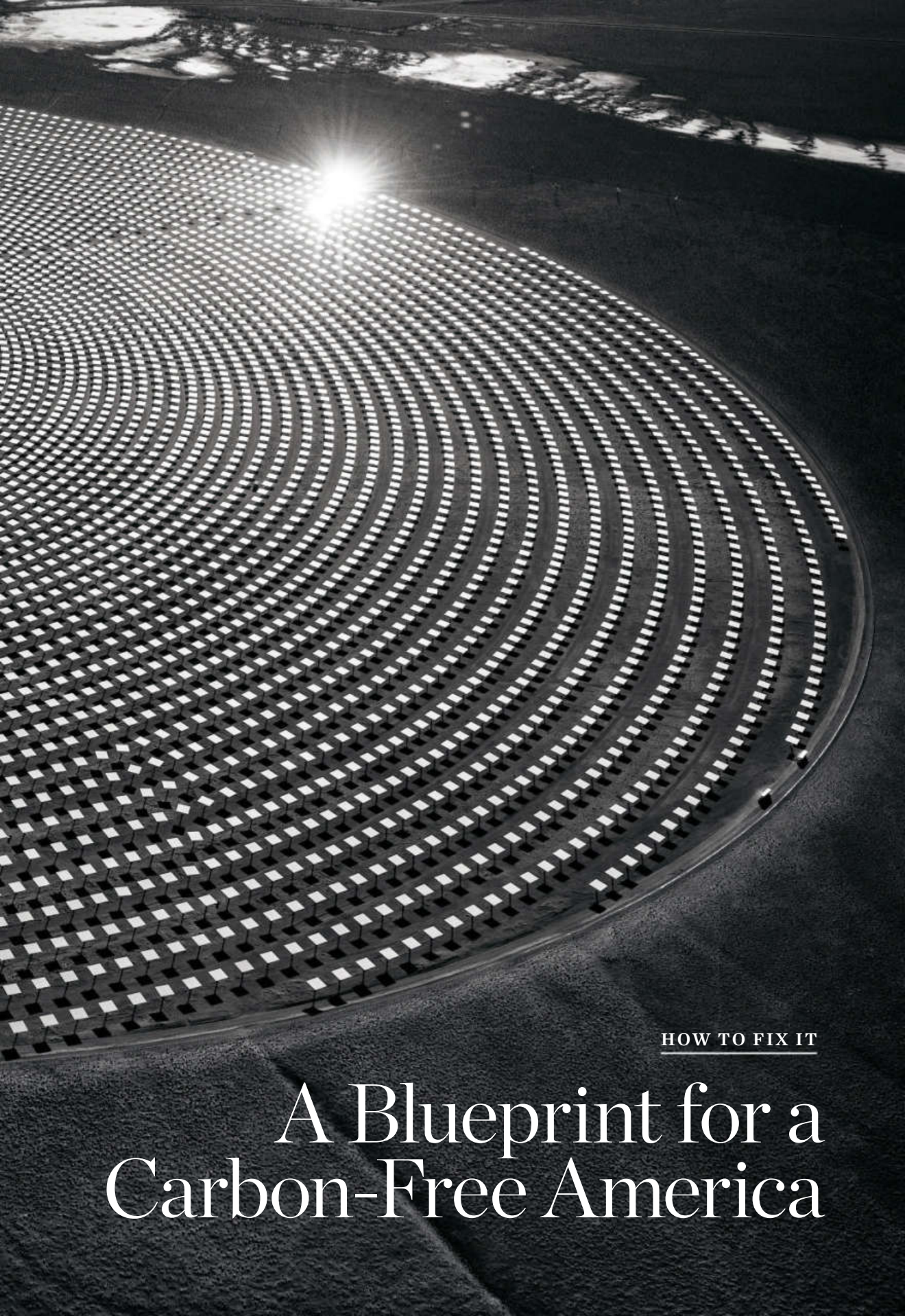
How did you prepare for this assignment? The biggest challenge was training to join the offshore-wind-park technicians. I spent three days learning to cope with hazardous situations at sea—like when a helicopter is upside down underwater, how to break a window to escape.



New solar technology

The Crescent Dunes Solar Plant commissioned this year northwest of Las Vegas uses more than 10,000 mirrors to concentrate sunlight and heat liquid salt, which can then be used day or night to generate electricity.

JAMEY STILLINGS



HOW TO FIX IT

A Blueprint for a Carbon-Free America

By Craig Welch
Graphics by Jason Treat

In just a few decades the United States could eliminate fossil fuels and rely 100 percent on clean, renewable energy. That's the bold vision of Mark Jacobson, a Stanford engineering professor who has produced a state-by-state road map of how the country could wean itself from coal, oil, natural gas, and nuclear power.

By 2050, Jacobson envisions the nation's transportation network—cars, ships, airplanes—running on batteries or hydrogen produced from electricity. He sees the breezes gusting across the Great Plains powering vast stretches of the country's middle while the blazing sun helps electrify the Southwest. He pictures New England capturing its legendary offshore winds. "There's no state that can't do this," Jacobson says.

Today only 13 percent of U.S. electricity comes from renewables. Achieving Jacobson's goal would be on par with simultaneously undertaking some of the nation's most ambitious endeavors: the Apollo program, the interstate highway system, the nuclear bomb, and the military's World War II arsenal. This transformation would cost roughly $15 trillion, or $47,000 for each American, for building and installing systems that produce and store renewable energy.

What would it take? Seventy-eight million rooftop solar systems, nearly 49,000 commercial solar plants, 156,000 offshore wind turbines, plus wave-energy and geothermal systems. Land-based wind farms would need 328,000 turbines, each with blades longer than a football field. These farms would occupy as much land as North Carolina. Of course, producing fossil fuels gnaws through land too. In the past century prospectors drilled nearly 2.5 million oil

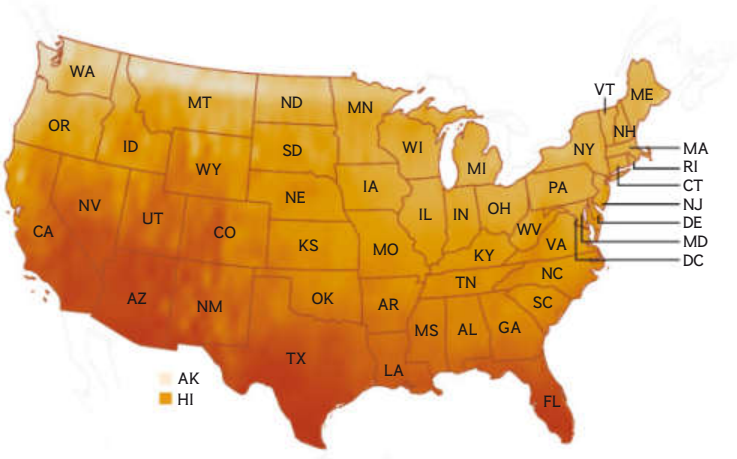
Road Map for the United States

To power the nation with wind, water, and sunlight by 2050, each state will have to focus on its most abundant source of clean energy.

SOLAR
Strong sunshine stretches across much of the southern United States, but the most intense and predictable sunlight is in the Southwest, providing the best opportunities for concentrated solar power.

Average solar radiation available
kilowatt-hours per square foot per day

0.3 — 0.6



Percentage of renewable energy needed, by source

WATER — SOLAR

3% Hydroelectric
0.4% Wave
0.1% Tidal
1.3% Geothermal

7.2% Rooftop photovoltaic (PV)
Rows of solar panels sit atop homes and commercial buildings.

30.7% Utility PV
Solar farms convert direct and diffuse sunlight into electricity using photovoltaic cells.

7.3% Concentrated solar power (CSP) plants
Industrial-scale plants use lenses or mirrors to focus sunlight and heat fluids.

and gas wells across the Great Plains of the U.S. and Canada. The wells, pads, roads, and storage facilities built in that region from 2000 to 2012 take up more ground than New Jersey. Replace fossil fuels with renewables, Jacobson suggests, and all that land could be reclaimed.

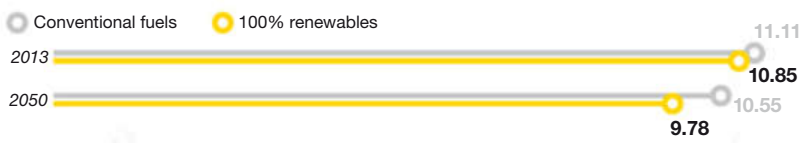
For now, he says, momentum is growing. Thanks in part to government subsidies and large-scale production, costs are falling. The amount of power generated nationwide by wind and solar increased 15-fold each between 2003 and 2013. This summer President Barack Obama moved to reduce carbon emissions from coal-fired power plants, and Hawaii committed to having all its electricity provided by renewables by 2045.

Still, many experts aren't convinced. "It has zero chance," Stephen Brick, an energy fellow with the Chicago Council on Global Affairs, says of Jacobson's plan. Political, regulatory, and social barriers are huge, especially in a nation where the energy infrastructure—and much of its political influence—is rooted in the oil, gas, and coal industries. Some critics are concerned about whether the resulting grid would be reliable. And neighborhood battles would likely erupt over wind farms and solar panels. Even outspoken scientist James Hansen, who warned Congress a quarter century ago about climate change, insists that nuclear power is essential to rid the country of fossil fuels.

Yet Jacobson's work at least offers a starting point. Scientists and policymakers may keep arguing about solutions, but as Obama points out, the nation must continue its march toward a clean-energy future—even if it's not yet clear precisely how that will look in 35 years. "If we don't do it," he said this summer, "nobody will." □

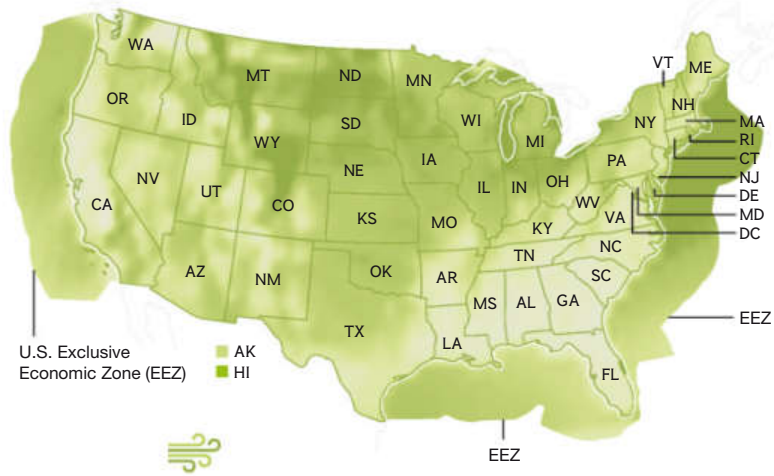
PROJECTED COSTS
Building a renewable energy system is expensive, but wind and solar require no fuel, so they're cheaper to operate over time.

Average cost of electricity* *in cents per kilowatt-hour*



WIND
The difference between wind power's average output and its peak varies dramatically. Offshore New England, the Great Plains, and the Great Lakes region offer the best potential.

Average wind-capacity factor



19.1% Offshore wind
Turbines in oceans capture strong, consistent winds.

30.9% Onshore wind
Turbines on land can transform breezes into energy in almost every state.

Detailed data not available for Alaska and Hawaii.
*Levelized cost of energy shown; capital, fuel, operations, and financing costs factored in

MAPS: EVAN APPLEGATE
SOURCE (ALL GRAPHICS AND MAPS): MARK JACOBSON, STANFORD UNIVERSITY

Reimagining America's energy future will take the kind of ingenuity, innovation, and sense of purpose we've shown before.

Economies of scale

Mass production drove down the cost of Henry Ford's Model T by 62 percent. Experts hope that growing demand for energy from wind and solar projects will have a similar effect, making the costs of each competitive with fossil fuels.

HENRY FORD COLLECTIONS

A common goal

After the bombing of Pearl Harbor, the U.S. built an arsenal of more than half a million armored vehicles, ships, and aircraft, including the B-17 Flying Fortress, made by Lockheed-Vega in California. Similarly, an arsenal of renewable energy projects could be rapidly built.

ANTHONY POTTER COLLECTION/ GETTY IMAGES

Audacious engineering

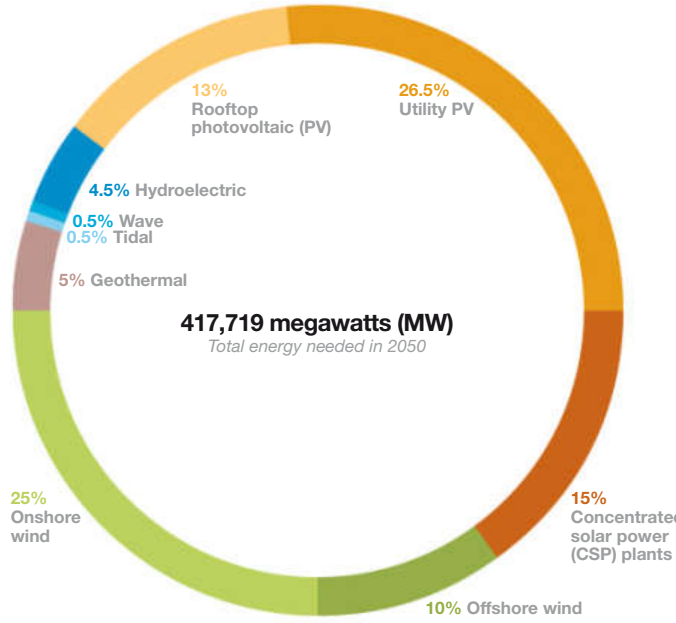
NASA scientists in Cleveland, Ohio's Supersonic Wind Tunnel prepare to test a Saturn I booster model. The 1960s' Apollo program showed that a national commitment can yield great technological feats.

NASA

A Snapshot of Six States

Stanford Professor Mark Jacobson has outlined a plan detailing how energy in the U.S. could be carbon free by 2050.

Explore how this blueprint would work in your state at *nationalgeographic.com/energyblueprint.*

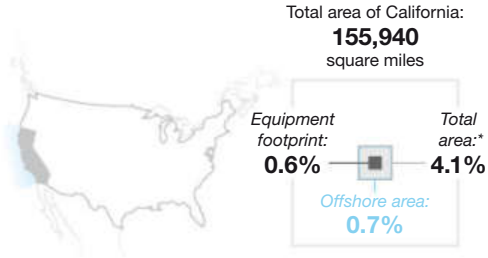


CALIFORNIA

A Wealth of Resources

OPPORTUNITIES: From rivers to ocean waves, the Golden State's natural riches offer many clean-energy options. California has set ambitious goals for renewables and is reducing regulations and costs for solar and wind projects. This could create jobs, reduce the state's severe air pollution, drive innovation, and jump-start a national movement.

OBSTACLES: Land-use battles seem inevitable, whether over raptor deaths at wind farms or the risk that solar projects pose to endangered tortoises. California, already crowded, is still growing fast, but its progressive political bent has not resulted in a commitment that comes close to eliminating fossil fuels.



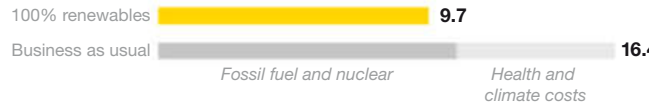
AREA NEEDED
Individual wind turbines take up little room but must be spaced far apart, so wind farms need a lot of land. Some of that land, however, could be used for farming and other purposes.

Infrastructure challenge

9.4 million+ RESIDENTIAL SOLAR PV SYSTEMS NEEDED

LESS THAN 3% OF THE NECESSARY PV SYSTEMS ARE CURRENTLY INSTALLED.

Estimated energy costs in 2050
in cents per kilowatt-hour



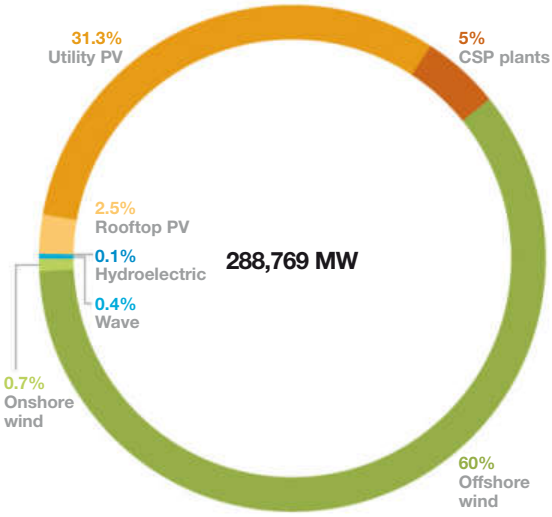
Projections for 2050

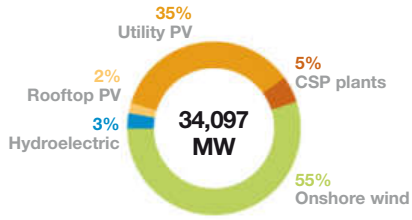
12,528
DEATHS FROM AIR POLLUTION AVOIDED, PER YEAR

$127.9 billion
SAVINGS FROM DEATH AND ILLNESS PREVENTED

$7,395
ANNUAL ENERGY, HEALTH, AND CLIMATE COSTS SAVINGS, PER PERSON

*Includes existing land and offshore projects



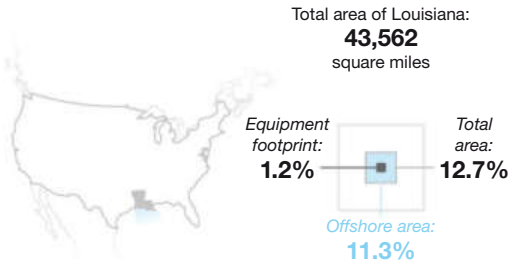


LOUISIANA

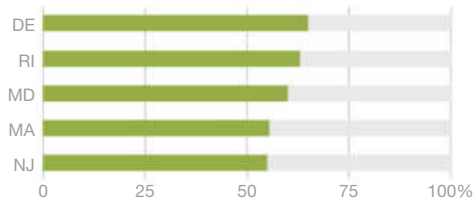
Offshore Gold Mine

OPPORTUNITIES: Gulf Coast breezes could transform Louisiana into an offshore wind haven, potentially reducing electric bills. Tens of thousands of turbines might even help protect the state from hurricanes by slowing wind speeds.

OBSTACLES: Offshore wind projects are controversial and have large up-front costs. The nation's first (in Rhode Island) won't begin operating until next year. Louisiana politics has strong ties to the oil industry.



Northeast states could rely heavily on offshore wind power.

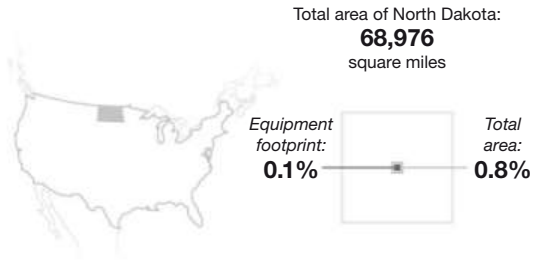


NORTH DAKOTA

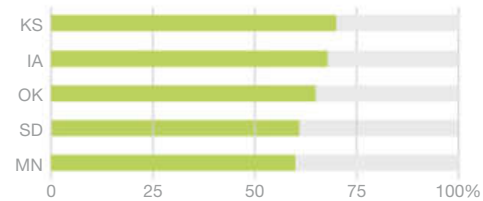
Windy Plains

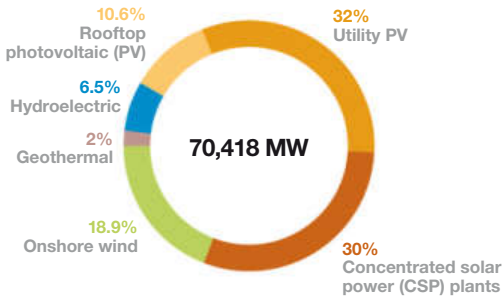
OPPORTUNITIES: The Bakken shale oil boom isn't the only energy rush here. Wind power already generates 17.5 percent of the state's electricity, and landowners are paid to allow turbines on their property. Every county has the natural breezes to support wind projects.

OBSTACLES: North Dakota's small population means its overall energy use is low, but only Wyoming, Alaska, and Louisiana consume more energy per person. Its renewable energy goal is just 10 percent.



Onshore wind power would be most dominant across the Midwest.



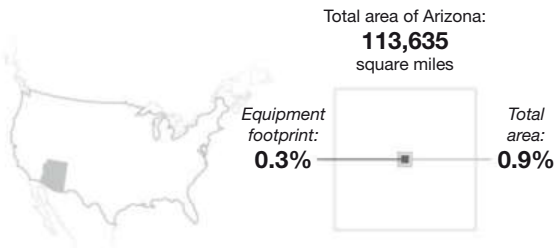


ARIZONA

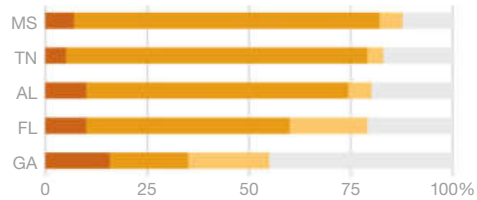
Solar Oasis

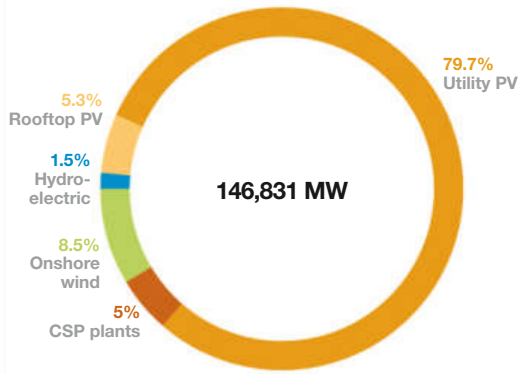
OPPORTUNITIES: Arizona is now second (behind California) in generating utility-scale solar power and could get more than 70 percent of its electricity from sunlight. Solar battery storage technology is improving.

OBSTACLES: Utilities seek and often get higher fees from homeowners who install rooftop panels. One-quarter of Arizona's electricity is used for air-conditioning—four times the national average. The state has the nation's largest nuclear power plant.



Solar power will also be crucial to meeting the Southeast's energy needs.



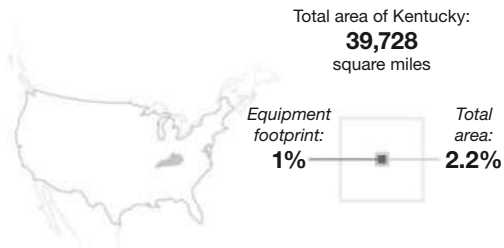


KENTUCKY

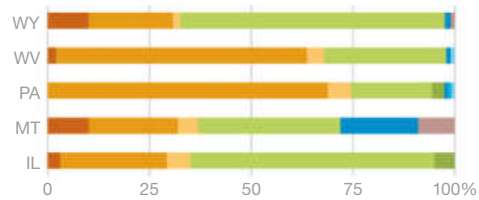
King Coal

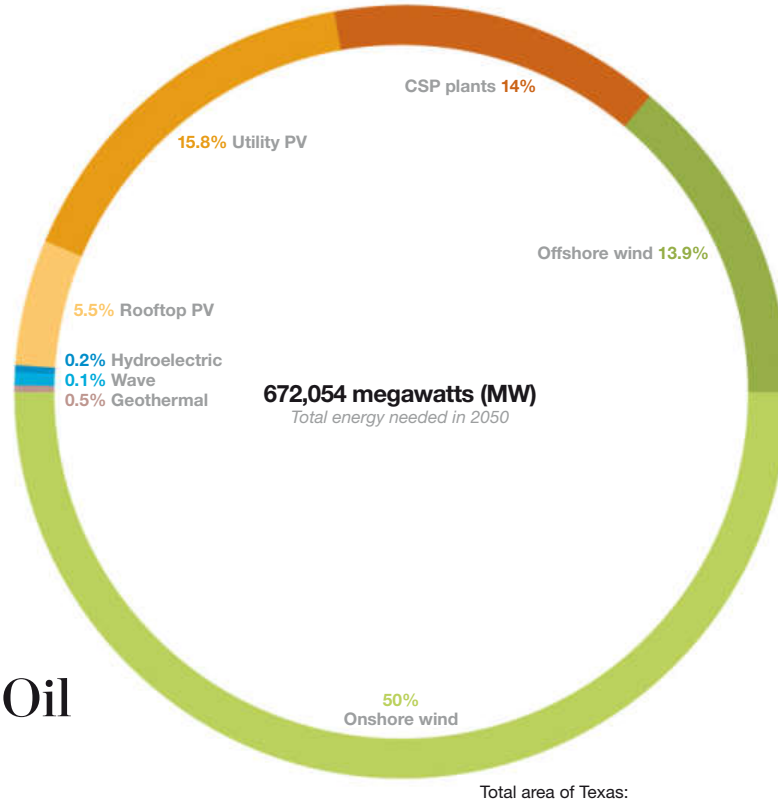
OPPORTUNITIES: Moving to 100 percent renewables would clean up one of the nation's dirtiest energy systems. Kentucky ranks first in carbon dioxide emissions per megawatt-hour of electricity.

OBSTACLES: Coal is still king in Kentucky, where it is used to supply more than 90 percent of electricity. The state has no formal goal to use more renewable energy. Hydroelectric dams generate only 4 percent of its electricity.



States that now depend largely on coal would each follow a unique path toward sustainability.



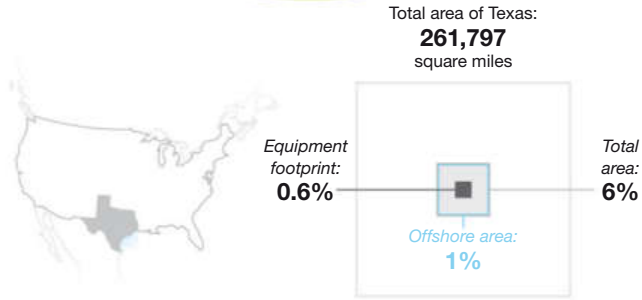


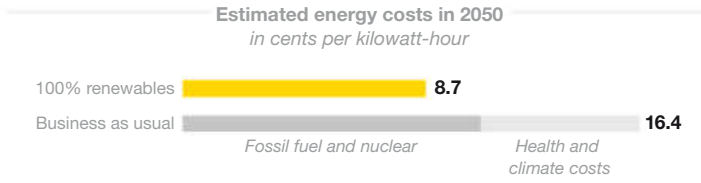
TEXAS

Big Politics, Big Oil

OPPORTUNITIES: With its coal plants and oil refineries, Texas emits more carbon dioxide than most countries—nearly twice as much as California. Ditching fossil fuels here could cut global emissions almost 2 percent. The state gets 10 percent of its power from wind turbines, and it's the national leader in wind capacity.

OBSTACLES: Lone Star politicians have led the nation in battling climate change regulations. Fossil fuels are central to the state's economy. Transitioning to renewables may lead to net job losses, unlike in most states. Utility-scale solar projects already have proved controversial because of the impact on desert landscapes.

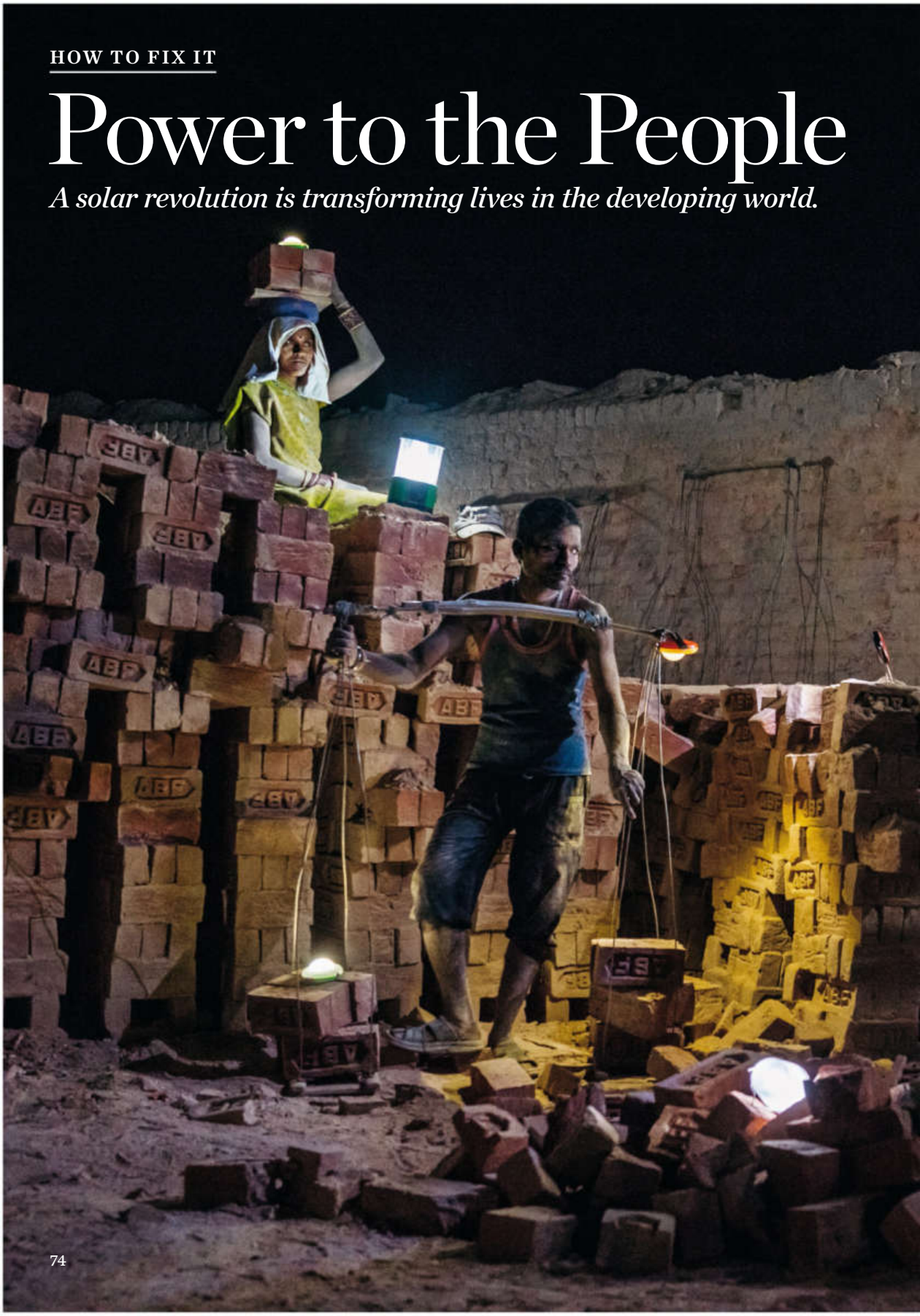




HOW TO FIX IT

Power to the People

A solar revolution is transforming lives in the developing world.



At a brick kiln in India's rural state of Uttar Pradesh, workers use solar lanterns to illuminate their paths. The developing world struggles to provide power to its people. Worldwide, about 1.1 billion people have no access to electricity.

A worker at a logging camp in Myanmar's Bago region, where elephants have been used by loggers for centuries, sits atop his 11-year-old animal. Laborers in these camps have no electricity, so they use solar lanterns before sunrise.

Ibrahim Kalungi and Godfrey Mteza, both 20, work at night in their motorcycle repair shop in Nbeeda, Uganda. The mechanics credit solar lights with enabling them to work longer hours and earn more money.

By Michael Edison Hayden
Photographs by Rubén Salgado Escudero

Prashant Mandal flips on a candy-bar-size LED light in the hut he shares with his wife and four children. Instantly hues of canary yellow and ocean blue—reflecting off the plastic tarps that serve as the family's roof and walls—fill the cramped space where they sleep. Mandal, a wiry 42-year-old with a thick black beard and a lazy eye, gestures with a long finger across his possessions: a torn page from a dated Hindu calendar, a set of tin plates, a wooden box used as a chair. He shuts down the solar unit that powers the light and unplugs it piece by piece, then carries it to a tent some 20 yards away, where he works as a chai wallah, selling sweet, milky tea to travelers on the desolate road in Madhotanda, a forested town near the northern border of India.

"My life is sad, but I have my mind to help me through it," Mandal says, tapping the fraying cloth of his orange turban. "And this solar light helps me to keep my business open at night."

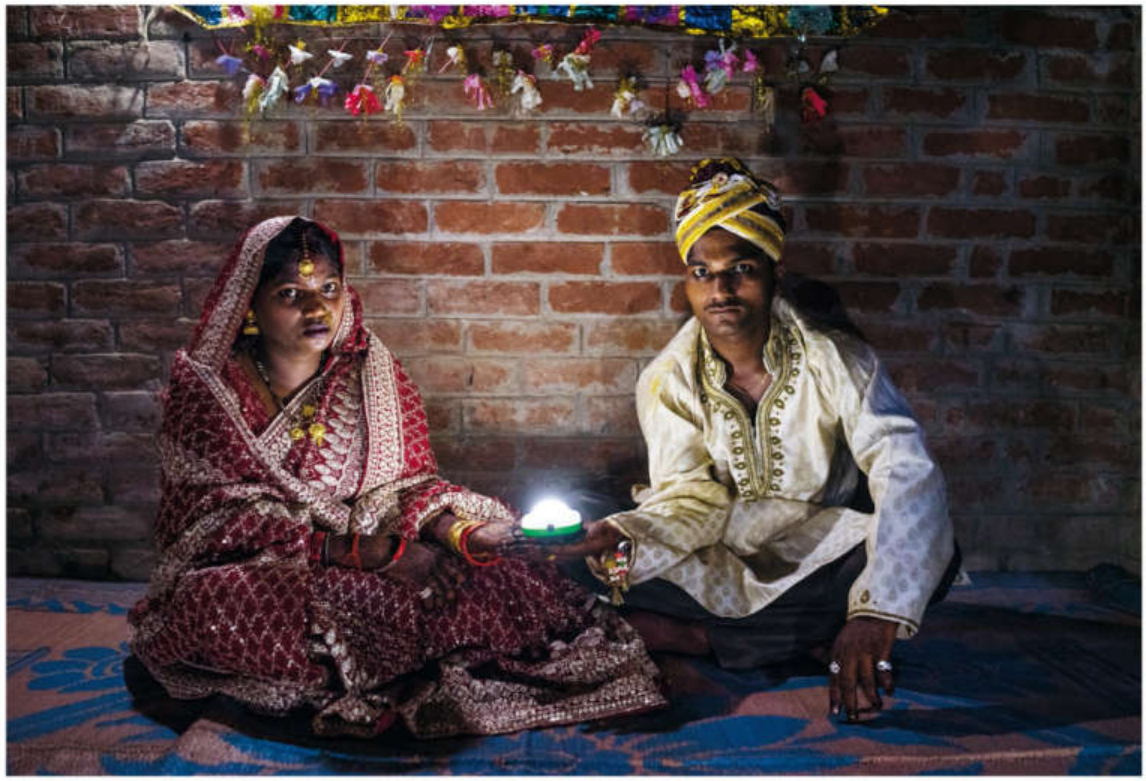
Mandal, whose home sits illegally on public land at the edge of a tiger reserve, is just a tiny cog in a surging new economic machine, one that involves hundreds of companies working aggressively to sell small solar-powered units to off-grid customers in developing nations to help fill their growing energy needs. Roughly 1.1 billion people in the world live without access to electricity, and close to a quarter of them are in India, where people like Mandal have been forced to rely on noxious kerosene and bulky, acid-leaking batteries.

Mandal's solar unit, which powers two LED lights and a fan, is energized by a 40-watt solar panel. Sun beats down on the panel, charging a small, orange power station for roughly ten hours at a time. Mandal leases the kit from Simpa Networks. A for-profit company with a name derived from the notion of "simple payments," Simpa offers subscription plans structured to fit the budgets of low-income consumers. Even so, the equivalent of roughly 35 cents a day is a massive expenditure for Mandal, who supports his family on a razor-thin budget of less than two dollars a day. Food costs money, as do schoolbooks, medicine, and tea. His middle son, who's 15, fell ill late last year, and the hospital bill plunged the family into debt exceeding $4,000.

Nevertheless Mandal says that spending 20 percent of his earnings on Simpa's services is better than living so much of his life in total darkness. "I was spending that much to recharge a battery before," he says. "I would walk about one kilometer back and forth up the road to recharge it. Sometimes battery acid would spill and burn me. One time it spilled and burned right through the fabric of my pants—all for power."

Mandal's struggle is replayed in villages in Myanmar and in Africa, where private companies are selling people solar units and panels and building solar farms. The International Energy Agency estimates that 621 million people in sub-Saharan Africa have no electricity. Because of insufficient power lines in India, only 37 percent of the nearly 200 million people in Mandal's home state of Uttar Pradesh use electricity as their primary source of lighting, according to 2011 census data. Simpa calculates that 20 million households there rely mainly on government-subsidized kerosene. Throughout the small farm towns, mobile phones are charged using tractor batteries; hundreds die of heatstroke each summer, when temperatures can soar to 115 degrees Fahrenheit; and

Holding a solar-powered lamp, Soni Suresh, 20, and Suresh Kashyap, 22, celebrate their marriage ceremony in Uttar Pradesh, where 20 million households lack electricity.



the grimy black soot released by kerosene scars human lungs. Mandal's neighbors who have electricity say that it stays on only two to three hours each day, with no alerts from the government about when the blackouts will start or end. Mandal, however, would have no viable source of power without solar because of the improvised nature of his home.

Simpa CEO Paul Needham, who used to work in Microsoft's advertising department in Washington State, lives a far more privileged life in India than Mandal could ever dream of. He has running water in his home and a near-steady flow of electricity and Wi-Fi. Originally from Vancouver, Canada, Needham moved to India in 2012 hoping to help bridge the gap between people like himself and Mandal. "In many ways India is a divided society, because after decades of rapid development, rural areas like these still lag behind major cities," he says. "Our customers can't wait for a better power grid to be built. They need power now."

Needham explains that he got the idea for his company while visiting with members of a women's rights organization in Tanzania in 2010. He saw people paying a neighbor to recharge their cell phones using a solar panel she owned. "It dawned on me that this could really be viable as a business model," he says. "Solar could be sold."

In India's rural marketplaces, sellers profited from solar for years before companies such as Simpa began offering their services to customers like Mandal. In stalls the size of closets men show off inexpensive solar units by cooling themselves under a fan. Customers drawn in by the demonstration interrogate the sellers, who show them thin red and blue wires that could connect to lightbulbs, mobile phones, or fans. These solar units, which are labeled falsely with brand names such as Rolex, Gucci, and Mercedes, cost three to four dollars—a fraction of what Mandal pays Simpa every month. The problem with

In the Jubilee Revival Church in Sango Bay, Uganda, members of the choir rehearse by solar light the night before services. Sango Bay is a small fishing village with 120 households.

these models, according to Needham and others in India's burgeoning solar services industry, is that they're poorly made and frequently fail.

Julian Marshall, a professor of environmental engineering at the University of Minnesota, says the solar-service industry has great potential to thrive and to improve people's lives in developing countries, calling it a "feel-good story." Marshall monitors air pollution inside homes of customers both on and off the grid, researching the damage inflicted by kerosene and other dirty-energy sources. Across India, fumes from kerosene lanterns combine with soot spewed by coal-burning power plants, triggering heart attacks and lung damage in many people. Marshall credits around half a dozen solar companies, including Simpa, for taking an innovative approach to sales in rural India. "The customer makes the decision to buy solar services primarily for personal financial reasons," he says. "But health and environmental benefits for the community come along with it, and I think that's great."

The chance to escape India's blistering heat is perhaps the strongest incentive for leasing a solar system. Shiv Kumar, a 20-year-old laborer in Madhotanda, makes his living gathering hay for farmers, earning less than $2.50 on the days he works. When food is scarce, he sometimes works for grain rations. The home he shares with his father and brother is concrete, with two tiny rooms that offer little ventilation. So when a sales associate from Simpa demonstrated the solar kit, it was the fan that sold him. "The kerosene lamp was dim and yellow and made me feel depressed," Kumar says, standing in the fan's breeze. "But this is the best fan I've seen."

Neel Shah, a Simpa product management leader, can attest that the challenges of bringing solar services to rural areas often stretch beyond whether people can afford them. One time men traveling on Shah's train attacked him. Another time villagers in the district of Mathura warned

Electricity is a rare luxury in Uganda. Denis Okiror, 30, began using solar lights at his barbershop in Kayunga two years ago. He says most of his customers prefer to visit him in the evening.

Shah that members of a gang, known for wearing just underwear and lubricating their bodies with oil to avoid capture, were coming that night to loot homes. The villagers apologized to Shah and escorted him to a rickshaw. Uttar Pradesh, India's most populous state—with 40 percent more people than Russia—is also its most chaotic. Gangs and violent crime are endemic, as are elected officials with criminal records.

"The solar business can be frustrating, but customers like Mandal make it worth it," says Shah, who met Mandal earlier this year after Mandal called Simpa to express his admiration. "We want to see a million people like him with light."

BACK IN MADHOTANDA, inside the tent where he sells tea, Mandal reassembles his solar unit and hangs up the lamp. The space is empty in the punishing heat of the afternoon as he stirs the tea in a metal cauldron lit by a wood fire. A few passersby will arrive by sundown, when the air cools.

Mandal wishes he could lease a second solar unit so that his children could have a more secluded place to study. But for now his priority is growing his business, a goal he believes solar power can help him achieve.

"When customers see the lights," he says, "they will come." □


NATASCHA RISSMANN

Award-winning photographer **Rubén Salgado Escudero** began his career as a 3-D video game animator. Born in Spain and now based in Myanmar, he focuses his photography on overlooked people and places.

Did the use of solar power affect your photos in this story? Solar-powered light was the only source of illumination I used in all of the portraits for this project. I wanted to work with the same type of light that is improving my subjects' quality of life so substantially.

In India's state of Odisha villagers trap fish using cone-shaped baskets and solar light. Fewer than half of Odisha's 42 million residents use grid electricity.

CLIMATE CHANGE **SURVIVAL GUIDE**

How to Live With It

Humans do not lack for advice on how to live with our circumstances. A Google search, that yardstick of ubiquity, yields more than 55 million results for "how to live with." Make it "how to live with climate change," and the results drop—to about 44,000. That's a lot of ideas. Surely we can find a few that will help us adapt to what we can't fix.

If it's true that we learn by doing, then the learning has begun. What we face is daunting: extreme heat and weather; threats to water, crops, and health. But with technology and ingenuity, Earth's custodians are finding new ways to manage our changed reality. *—Patricia Edmonds*

CONTRIBUTORS Text: Jeremy Berlin, Eve Conant, Karen de Seve, and Daniel Stone. Graphics: Lawson Parker and Matthew Twombly

PHOTO ILLUSTRATION: JAVIER JAÉN

Warming Water

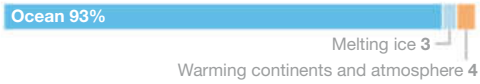
Whether it's a liquid, solid, or gas, water is vital to our planet. We depend on it for drinking and for sustaining our crops and animals, and countless species rely on freshwater ecosystems to live. The oceans help modulate CO_2 levels and maintain global temperatures while transporting nutrients and supporting marine ecosystems. As the climate changes, so will the freshwater and saltwater resources that form the foundations of our communities and economies. And as the climate changes, so will—so *must*—our relationship to water.

OCEAN

Covering 71 percent of our blue-marbled planet, the seas now absorb so much human-generated CO_2 and energy from the sun that seawater chemistry and temperatures are endangering many organisms. Changes in the marine environment affect what thrives in the water and what we can harvest from it. Sea-level shifts are altering coastlines and undermining buildings, posing risks to human life.

More moisture
Warm air holds more moisture, increasing the humidity and heat. Experts predict we'll adjust our outdoor activities to reduce heat stress.

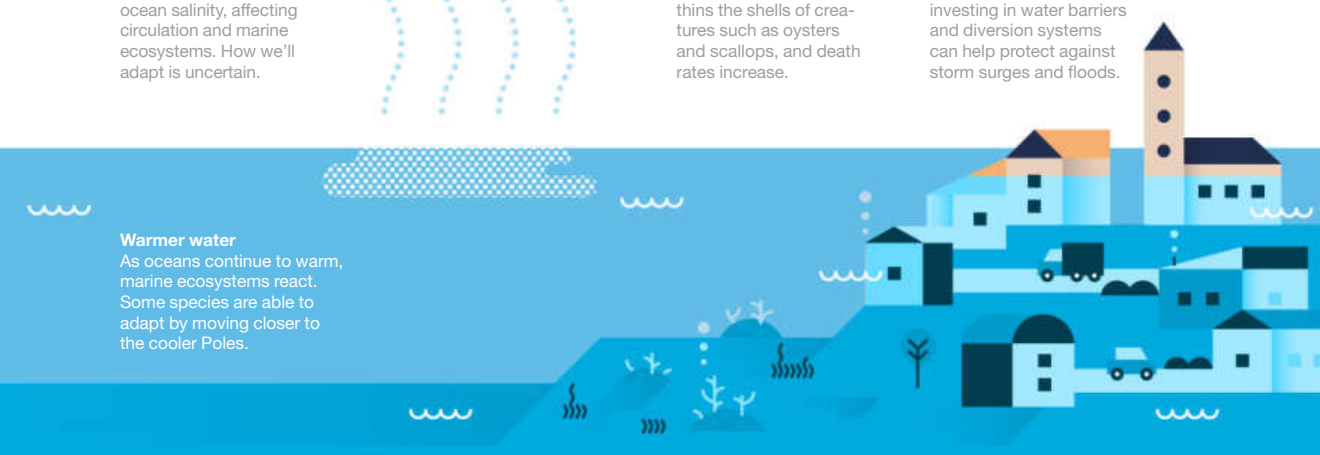
Keeping energy balanced
Earth now takes in more heat from the sun than it releases. The ocean stores 93 percent of that energy, which helps keep the planet livable by moderating temperature extremes.



Sea salt
More precipitation and ice melt will change ocean salinity, affecting circulation and marine ecosystems. How we'll adapt is uncertain.

Acidified oceans
More CO_2 makes the seas more acidic. That thins the shells of creatures such as oysters and scallops, and death rates increase.

Rising seas
Reengineering coastal infrastructure and investing in water barriers and diversion systems can help protect against storm surges and floods.



Warmer water
As oceans continue to warm, marine ecosystems react. Some species are able to adapt by moving closer to the cooler Poles.

Thirteen large U.S. airports have at least one runway at an elevation within 12 feet of the current sea level.

In New Orleans the Twin Span Bridge has been rebuilt 21 feet higher, above future storm surges.

The atmosphere can hold 7 percent more water vapor for every rise of one degree Celsius.

LAND

The dynamic interactions between climate change and freshwater resources on land are critically tied to the availability of good-quality water for human use. Today at least half the world's population relies on groundwater for safe drinking water. With projected urban growth expected to increase demand by 55 percent by 2050, we'll have to manage future water use carefully.

ICE

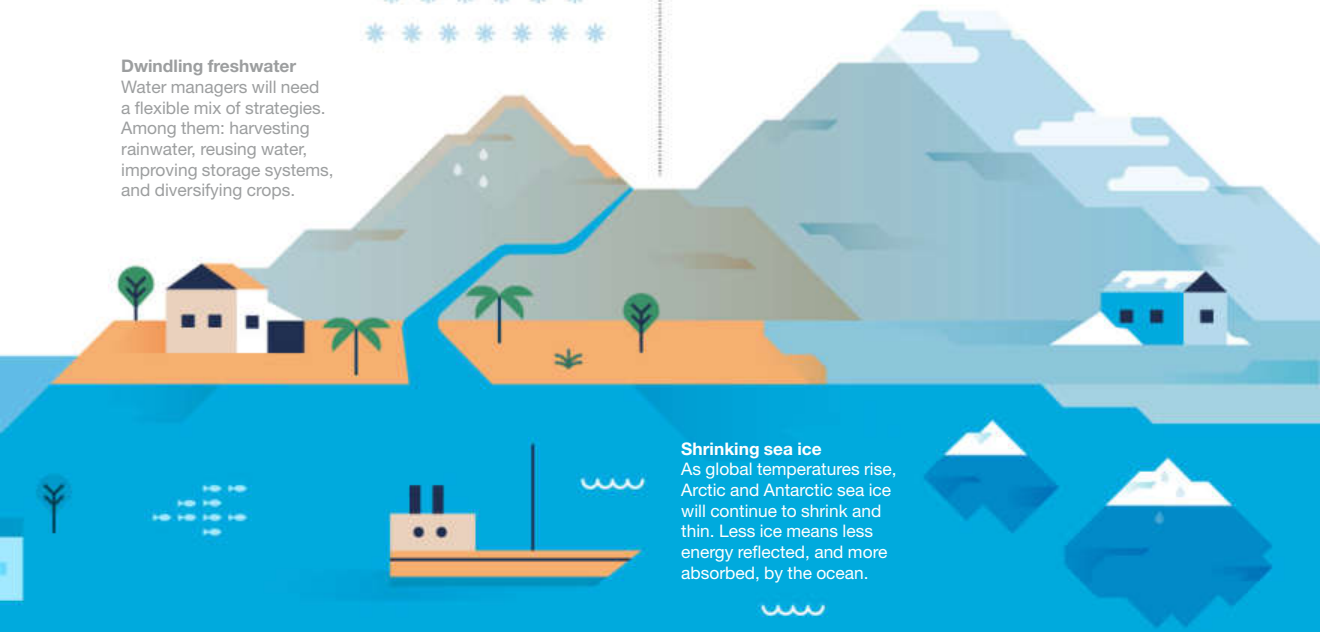
The freshwater that was once frozen in the Arctic, Greenland, Antarctica, and global alpine regions is melting and spilling into the world's oceans, streams, and soil. As more ice melts, rivers and watersheds will fill at first. But as the ice dwindles, so will the runoff—and the available freshwater. If conservation doesn't stem the problem, water-use restrictions loom.

Low snow
Springtime snow cover in the Northern Hemisphere will likely drop 10 to 30 percent by 2100, making comprehensive water management crucial.

Dwindling freshwater
Water managers will need a flexible mix of strategies. Among them: harvesting rainwater, reusing water, improving storage systems, and diversifying crops.

Unfrozen
The last ice of Bolivia's Chacaltaya Glacier melted away in 2009, leaving mountain villagers no choice but to move to cities, which now must bolster water capture and storage.

Not-so-perma frost
When permafrost thaws, land changes. People in the north rethink roads and buildings, relocate cellars that store frozen game, and move from vulnerable areas.



Shrinking sea ice
As global temperatures rise, Arctic and Antarctic sea ice will continue to shrink and thin. Less ice means less energy reflected, and more absorbed, by the ocean.

River erosion, intensified by climate change, has destroyed part of Newtok, Alaska. Water may reach the school, the village's flood shelter, by 2017.

Mangrove restoration projects dot the planet: Vietnam, Djibouti, Brazil. These efforts not only protect coastal communities from rising seas and storm surges but also help increase biodiversity and sustain livelihoods.

ART: ROMUALDO FAURA. SOURCE: IPCC

Crop Changes

Climate change may actually benefit some plants by lengthening growing seasons and increasing carbon dioxide. Yet other effects of a warmer world, such as more pests, droughts, and flooding, will be less benign. How will the world adapt? Using an aggressive climate model known as HadGEM2, researchers at the International Food Policy Research Institute project that by 2050, suitable croplands for four top commodities—corn, potatoes, rice, and wheat—will shift, in some cases pushing farmers to plant new crops. Some farmlands may benefit from warming, but others won't, says IFPRI's Ricky Robertson. Climate alone doesn't dictate yields; political shifts, global demand, and agricultural practices will influence how farms fare in the future. The winners, researchers say, will be farmers who modernize their methods and diversify their fields.

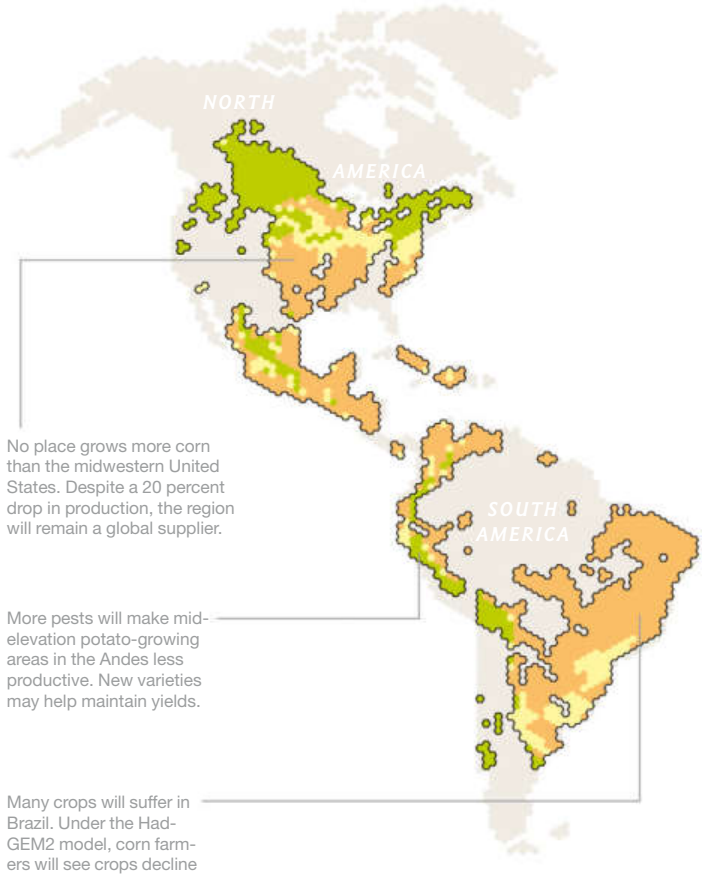
Change in potential average yields for corn, potatoes, rice, and wheat in 2050

Gain greater than 5%

0-5% gain or loss

Loss greater than 5%

Area that produced 75% of corn, potato, rice, and wheat yields in 2015

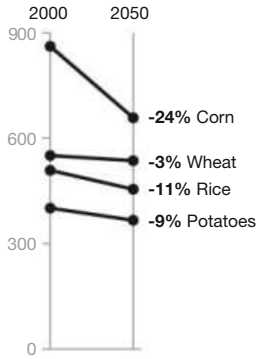


No place grows more corn than the midwestern United States. Despite a 20 percent drop in production, the region will remain a global supplier.

More pests will make mid-elevation potato-growing areas in the Andes less productive. New varieties may help maintain yields.

Many crops will suffer in Brazil. Under the HadGEM2 model, corn farmers will see crops decline by nearly 16 percent.

Global production change
Millions of tons



Climate change is likely to be most forgiving of wheat, but not enough to offset losses from other major crops.

A group of Native Americans called the Haudenosaunee Confederacy is preparing for climate change through seed banking.

Eighty percent of global deforestation is caused by agriculture.

In a warmer world, fish catches may increase up to 70 percent in some regions but drop 60 percent in the tropics and Antarctica.

CORN

Climate change will open new areas to corn (also known as maize) but will reduce production in current areas. More farmers in more places will grow it.

POTATOES

Potatoes tend to grow best in cold temperatures. In warmer climates, it may be possible to grow them farther north or higher in mountains.

RICE

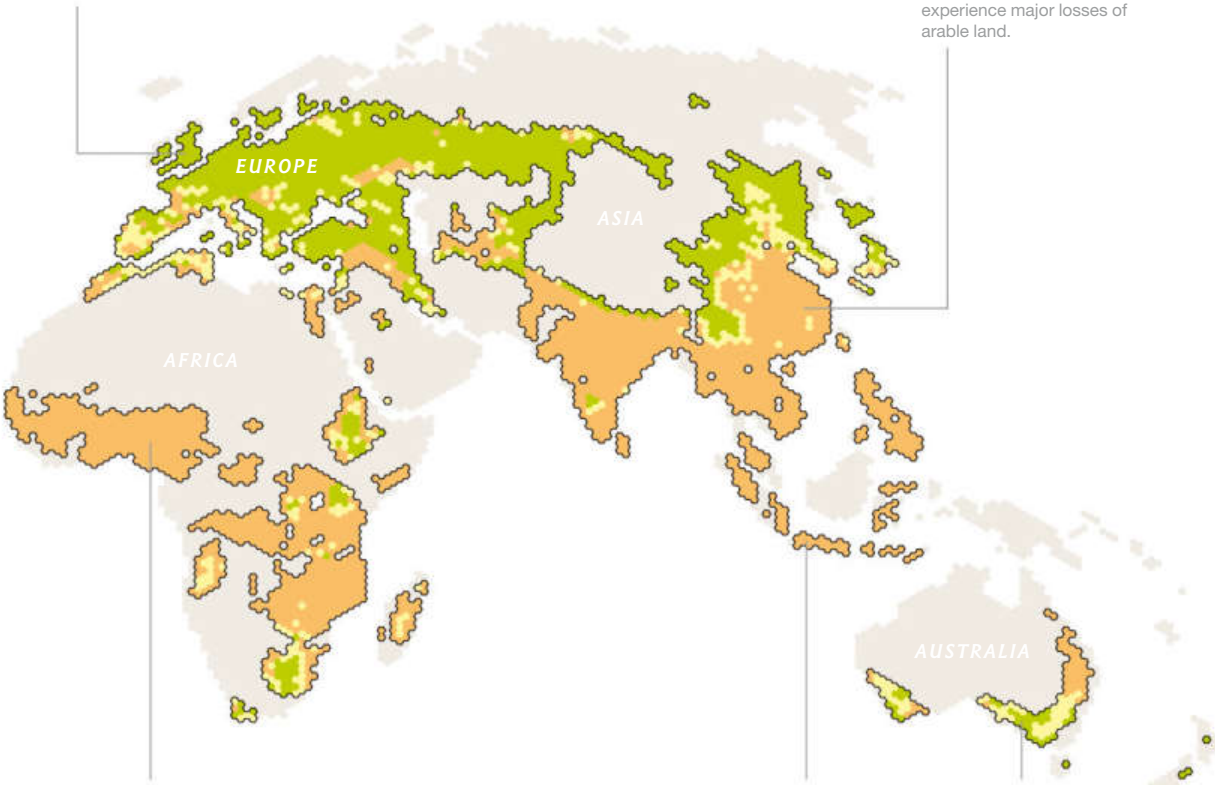
Unlike crops facing steep reductions, rice—which can grow in warm or cold—may do well. Researchers think Africa's output could double.

WHEAT

Virtually all climate scenarios show reduced wheat yields. Warmer weather globally is also likely to spur more devastating crop diseases.

Northern European potato farmers will see longer growing seasons. Fields farther south will become increasingly dry.

Changes in Asia, with its large populations and land area, will affect the most people. India and China will experience major losses of arable land.



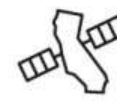
West Africa's rich soil and abundant water may support more rice. Parts of East Africa are believed to have great potential to expand production.

Indonesia's rice production will be largely spared by climate change, but corn will decline as much as 20 percent.

New parts of Australia will become arable, but droughts will require efficient farming if growing wheat is to continue.

To meet demand caused by population growth, annual world agricultural production will need to increase by 60 to 70 percent by 2050.

Women, if they had the same access to resources as men, could boost yields on their farms by up to 30 percent.



NASA satellite technology identifying California fields idled by drought can help with water allocation plans.

MAP: EVAN APPLEGATE. SOURCES: UN FOOD AND AGRICULTURE ORGANIZATION; RICKY ROBERTSON, IFPRI

High Heat

The world will feel different in 2100, when average temperatures will have risen by several degrees. Every kind of landscape that humans inhabit will be affected: urban, suburban, rural; mountains, plains, coasts. More of the developing world will acquire life-changing modern comforts. "You'll have near-universal saturation of air-conditioning" in warm climes by 2100, says economist Lucas Davis of the University of California, Berkeley. By powering those devices, though, we'll be contributing to global warming. If we can't find ways to turn down the heat, we'll find ways to adapt to it.

DEGREES OF SEPARATION

The annual mean air temperature of a city can be 4° to 11°F warmer than surrounding rural areas during the day, and 4° to 9°F warmer at night. Vegetation-rich green roofs can mitigate this urban heat-island effect, lowering the temperature by more than 5°F on the hottest days; plants also help manage excess storm water.

Vegetation can lower surface temperatures by up to 40°F, with shade and evapotranspiration.

If average temperatures rise 21°F, half the population could face unlivable conditions.

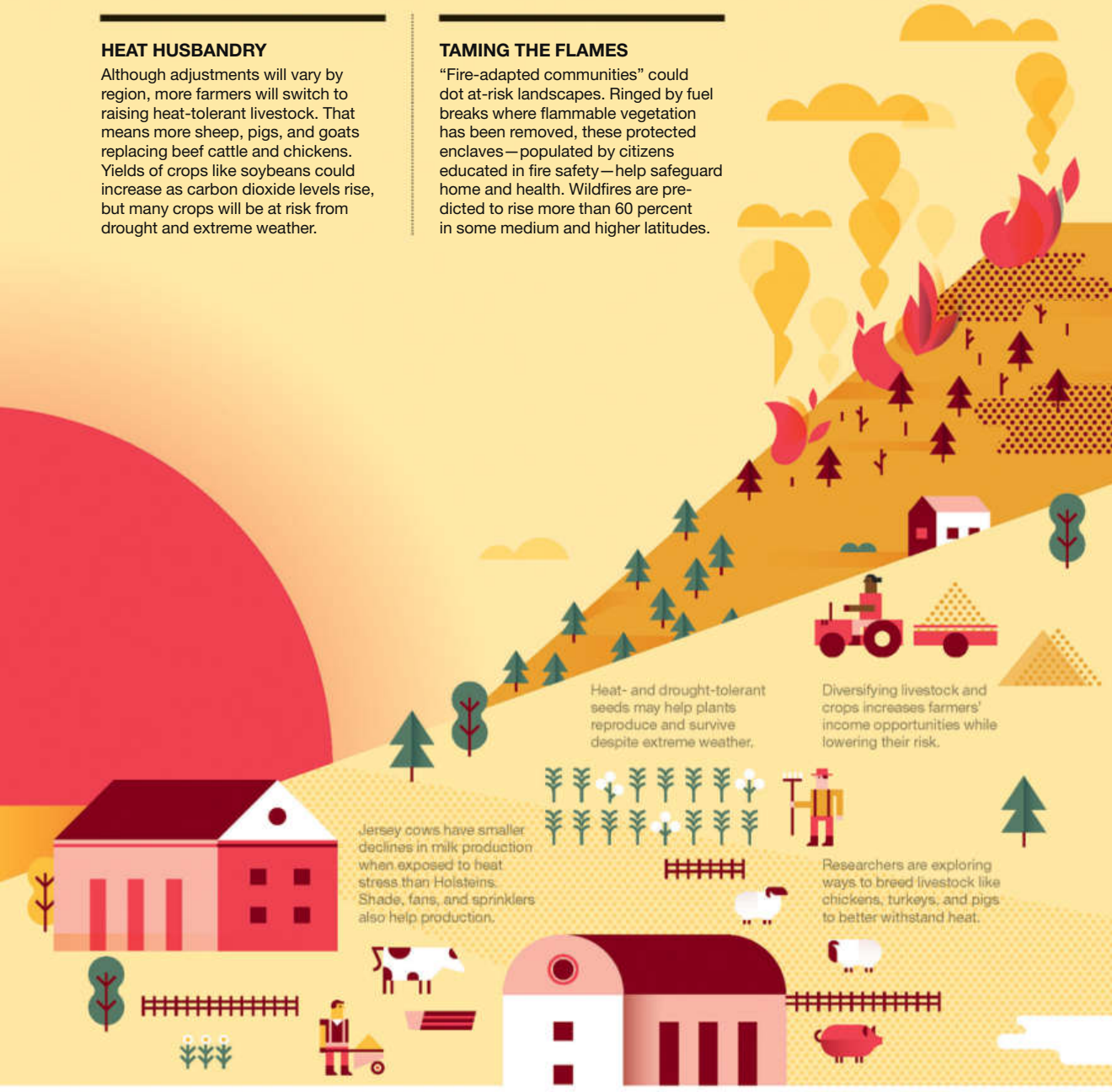
To adapt to higher temperatures, developing countries must spend $75 billion to $100 billion annually until 2050. Mitigation costs are projected to be $140 billion to $175 billion a year for the next 15 years.

HEAT HUSBANDRY

Although adjustments will vary by region, more farmers will switch to raising heat-tolerant livestock. That means more sheep, pigs, and goats replacing beef cattle and chickens. Yields of crops like soybeans could increase as carbon dioxide levels rise, but many crops will be at risk from drought and extreme weather.

TAMING THE FLAMES

"Fire-adapted communities" could dot at-risk landscapes. Ringed by fuel breaks where flammable vegetation has been removed, these protected enclaves—populated by citizens educated in fire safety—help safeguard home and health. Wildfires are predicted to rise more than 60 percent in some medium and higher latitudes.



India's potential demand for cooling is 14 times as great as the U.S. demand.

Year-round benefit: Evergreens planted on the north side of buildings block winds, lower heating bills.

Californians will endure an average of 40 to 53 extreme heat days by 2050, and 40 to 99 days by 2099. The historical average is four a year.

ART: ROMUALDO FAURA. SOURCES: MICHAEL SIVAK; CGIAR; MAX MORITZ, UNIVERSITY OF CALIFORNIA, BERKELEY; U.S. NATIONAL CLIMATE ASSESSMENT; MATTHEOS SANTAMOURIS, UNIVERSITY OF ATHENS; USDA

Wild Weather

Torrential hurricanes, devastating droughts, crippling ice storms, and raging heat waves—all are extreme weather phenomena that can claim lives and cause untold damage. Climate change influences severe weather by causing longer droughts and higher temperatures in some regions and more intense deluges in others, say climate experts. Among the most vulnerable are communities in exposed mountain and coastal regions. In those settings worldwide, citizens are adjusting to new weather realities by strengthening warning, shelter, and protection systems.

SURVIVING STORMS

A fierce cyclone hits Bangladesh about every three years. In 1991 Cyclone Marian killed 140,000. In 2007 Cyclone Sidr flattened 565,000 homes, but a warning system and fortified shelters helped limit deaths to 3,500. Today restoring coastal mangroves and hillside forests aims to stave off surging seas, landslides, and floods during future storms.

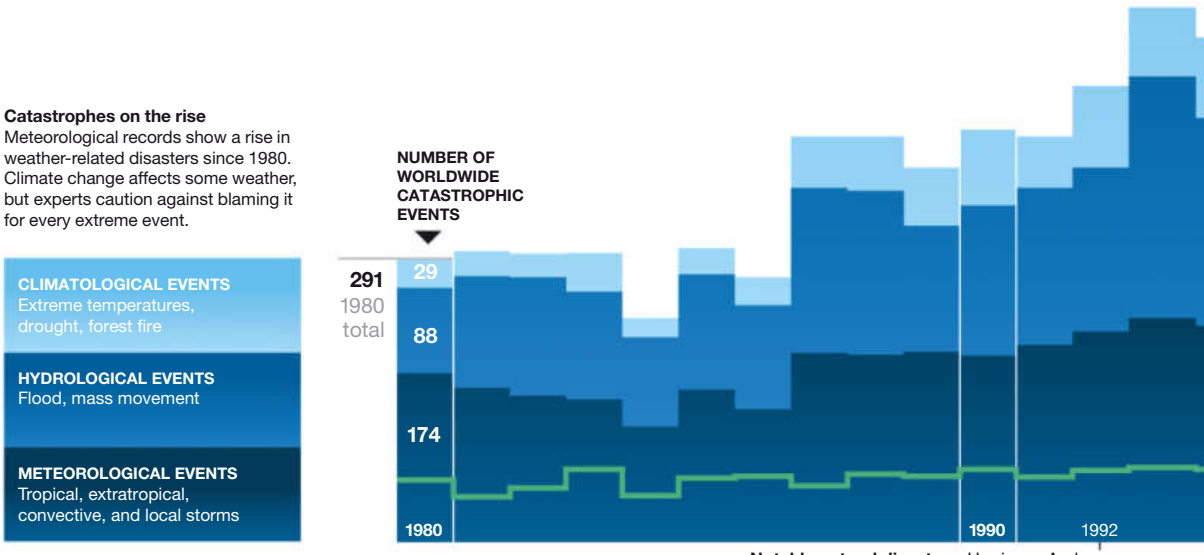
SUCCUMBING TO HEAT

The global average temperature in May 2015 was the highest on record. In India some 2,200 people perished during a ten-day heat wave when reported highs hit 113°F (45°C). To cope, the city of Ahmadabad offered potable water and cooling centers in high-risk areas and trained health aides to treat heat-related illness.

"Imagine the day we can capture the energy of a hurricane and use it to power a city that would otherwise have been destroyed."

Neil deGrasse Tyson
director of the Hayden Planetarium at the American Museum of Natural History

Catastrophes on the rise
Meteorological records show a rise in weather-related disasters since 1980. Climate change affects some weather, but experts caution against blaming it for every extreme event.



Notable natural disasters: Hurricane Andrew

In 2006 the Pets Evacuation and Transportation Standards (PETS) Act was created in the U.S. to address the needs of animal companions after a major disaster or emergency.

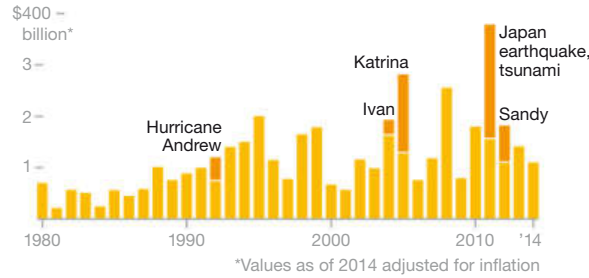
Insurance companies can adjust to climate change by raising premiums on threatened properties. But if property owners choose not to pay, the government may have to pick up the tab for damages.

RISING SEAS, RISING CONCERNS

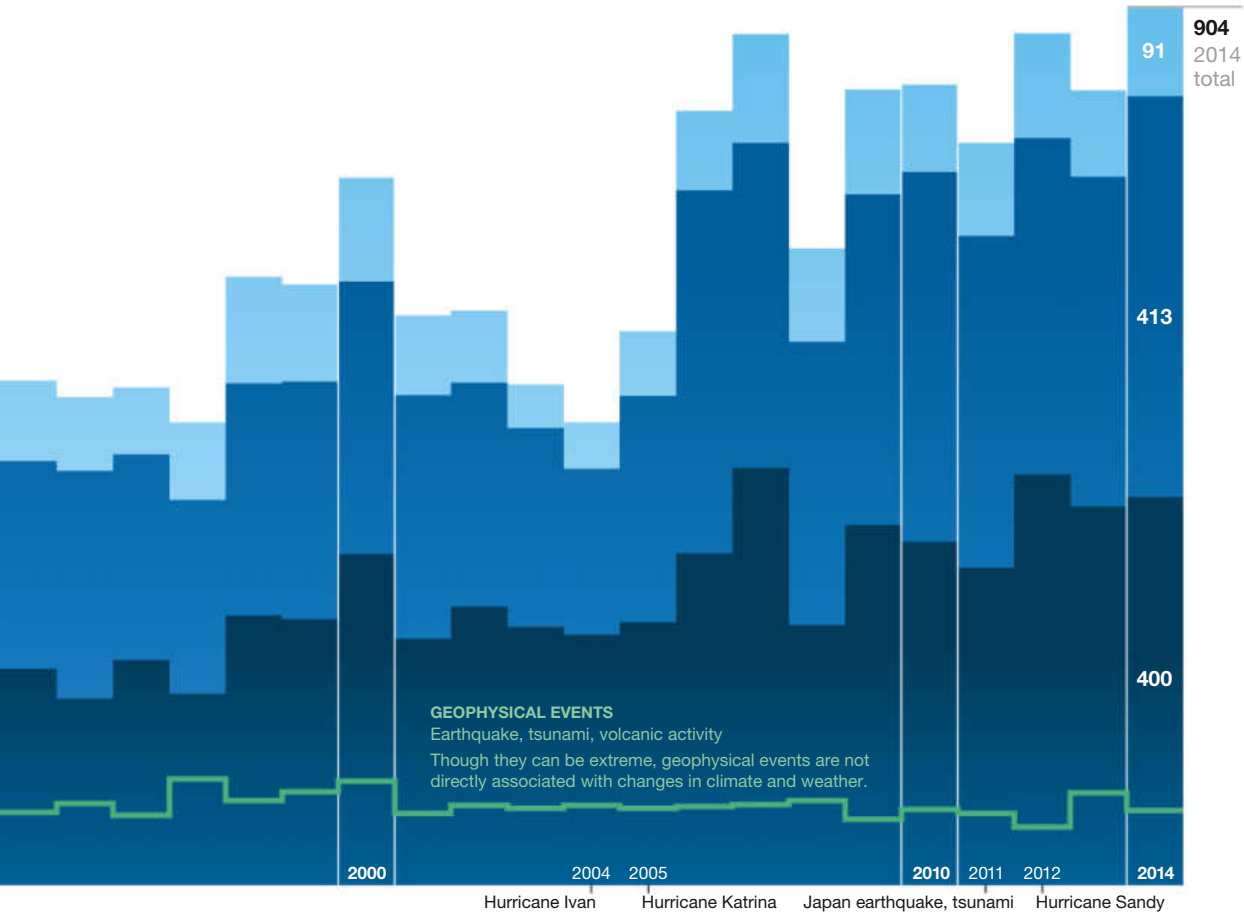
Climate change may not cause a particular storm, but rising sea levels can worsen its impact. In 2012 a nine-foot storm surge from Hurricane Sandy hit New York City at high tide, making the water 14 feet higher than normal at the tip of Manhattan. Flooding destroyed neighborhoods and beaches in outer boroughs. The sea level in this area is rising by more than an inch each decade—twice as fast as the global average—and is predicted to rise 11 to 21 inches by 2050. To prepare, the city is implementing coastal resiliency measures: A multiuse project will create more green spaces for city residents as well as a system of floodwalls, berms, and retractable barriers for enhanced storm protection.

The price of natural catastrophes

Costly storm and flood damage to burgeoning coastal infrastructure is growing. Innovations such as building floating villages and relocating vulnerable assets away from rising seas can reduce risk and losses.



*Values as of 2014 adjusted for inflation



No more than 20 percent of farmers in India are insured against crop loss.

Promising sunny weddings, a European company can set up "cloud seeding" so rain falls before the big day.

An earlier arrival of spring will lengthen the pollen season. By some estimates, pollen levels could more than double by 2040.

SOURCES: AHMADABAD HEAT ACTION PLAN 2015; BANGLADESH CLIMATE PLAN 2009; CITY OF NEW YORK; IPCC; MUNICH RE NATCATSERVICE; NOAA

Health Risks

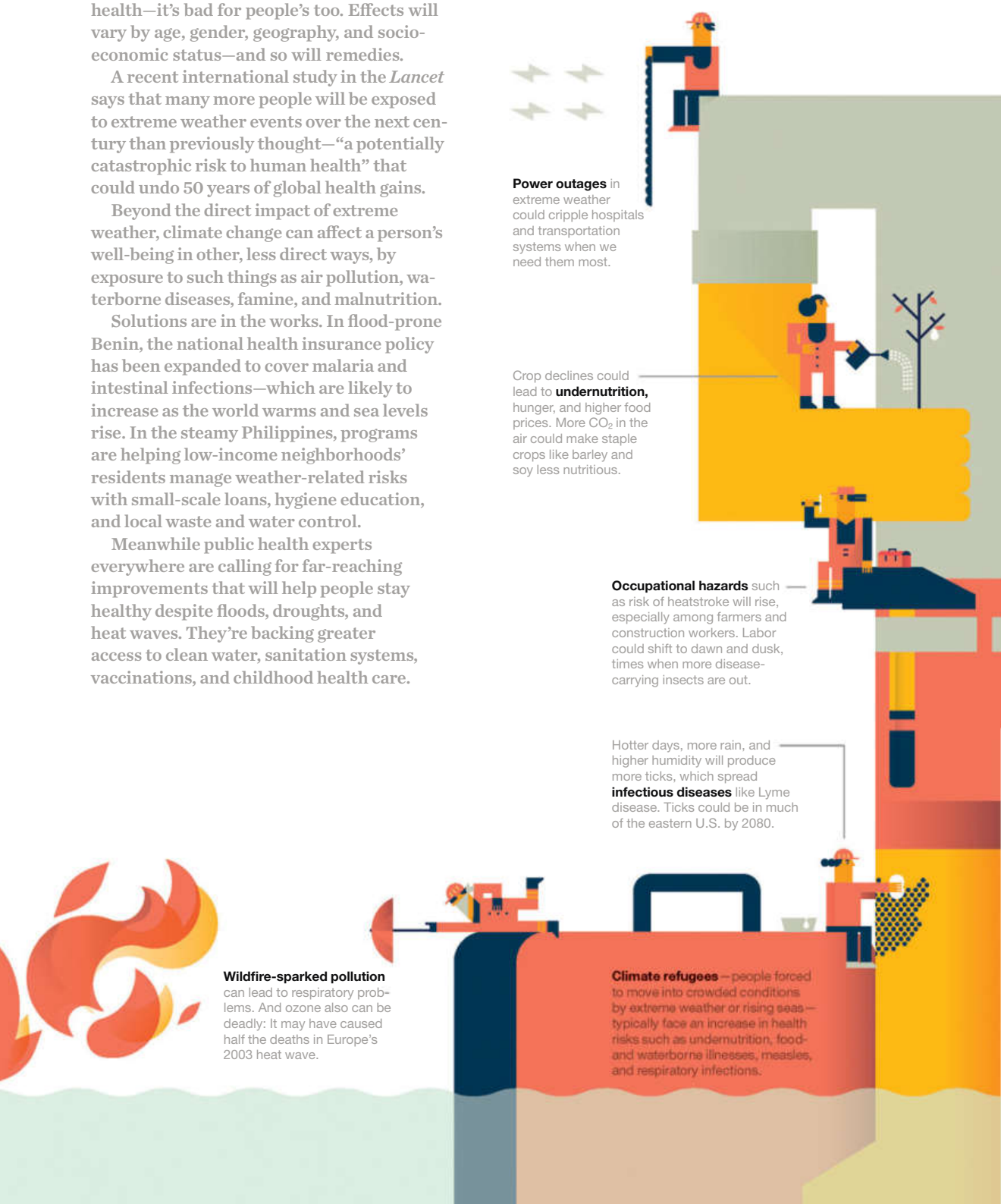
Climate change isn't just bad for the planet's health—it's bad for people's too. Effects will vary by age, gender, geography, and socio-economic status—and so will remedies.

A recent international study in the *Lancet* says that many more people will be exposed to extreme weather events over the next century than previously thought—"a potentially catastrophic risk to human health" that could undo 50 years of global health gains.

Beyond the direct impact of extreme weather, climate change can affect a person's well-being in other, less direct ways, by exposure to such things as air pollution, waterborne diseases, famine, and malnutrition.

Solutions are in the works. In flood-prone Benin, the national health insurance policy has been expanded to cover malaria and intestinal infections—which are likely to increase as the world warms and sea levels rise. In the steamy Philippines, programs are helping low-income neighborhoods' residents manage weather-related risks with small-scale loans, hygiene education, and local waste and water control.

Meanwhile public health experts everywhere are calling for far-reaching improvements that will help people stay healthy despite floods, droughts, and heat waves. They're backing greater access to clean water, sanitation systems, vaccinations, and childhood health care.



Power outages in extreme weather could cripple hospitals and transportation systems when we need them most.

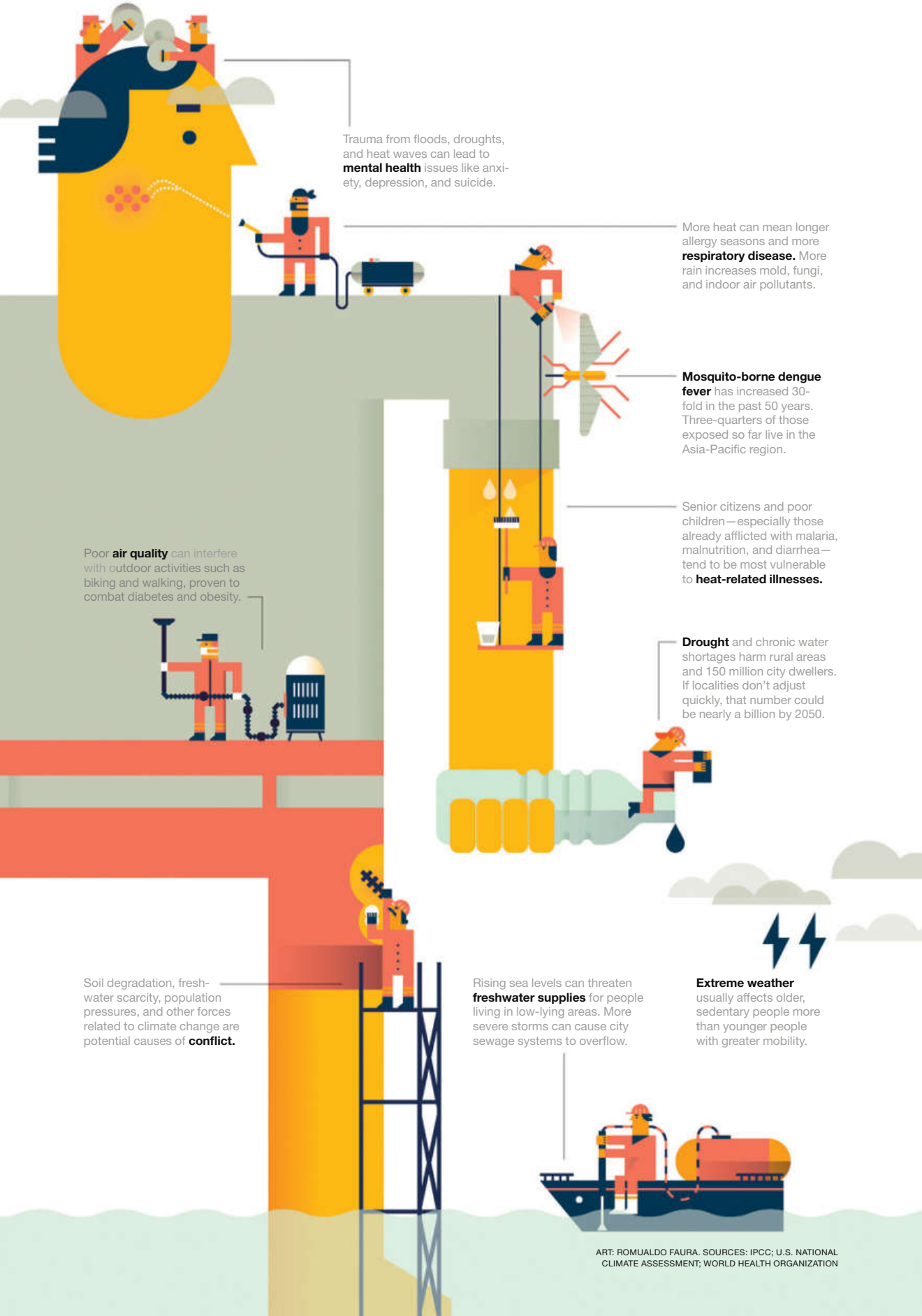
Crop declines could lead to **undernutrition,** hunger, and higher food prices. More CO_2 in the air could make staple crops like barley and soy less nutritious.

Occupational hazards such as risk of heatstroke will rise, especially among farmers and construction workers. Labor could shift to dawn and dusk, times when more disease-carrying insects are out.

Hotter days, more rain, and higher humidity will produce more ticks, which spread **infectious diseases** like Lyme disease. Ticks could be in much of the eastern U.S. by 2080.

Wildfire-sparked pollution can lead to respiratory problems. And ozone also can be deadly: It may have caused half the deaths in Europe's 2003 heat wave.

Climate refugees—people forced to move into crowded conditions by extreme weather or rising seas—typically face an increase in health risks such as undernutrition, food- and waterborne illnesses, measles, and respiratory infections.



ART: ROMUALDO FAURA. SOURCES: IPCC; U.S. NATIONAL CLIMATE ASSESSMENT; WORLD HEALTH ORGANIZATION

MELTING AWAY

For Greenland's hunters, fading sea ice could mean moving beyond a traditional way of living.

Albert Lukassen's world is melting around him. When the 64-year-old Inuit man was young, he could hunt by dog-sled on the frozen Uummannaq Fjord, on Greenland's west coast, until June. This photo shows him there in April. All the photographs for this story were taken on the fjord.

A movie projected onto an iceberg lights up the faces of two girls from the island town of Uummannaq, Nielsine (far left) and Jensigne (right), and of hunter Joas Korneliussen. The movie is *Inuk*—the tale of an Inuit boy, raised in the city, who returns to the region and discovers traditional hunting.

By Tim Folger
Photographs by Ciril Jazbec

Late one quiet November night in the village of Niaqornat, 300 miles above the Arctic Circle on Greenland's west coast, the sled dogs began to howl. No one knew for sure, but some of the villagers suspected the dogs had heard the exhalations of narwhals. The whales with the spiral unicorn tusks usually swim into Uummannaq Fjord this time of year as they migrate south. The next morning most of the community's men set out in small boats to try to bag a narwhal, as the Inuit in Greenland have done for centuries—though in this area nowadays they throw harpoons from motorboats moving at 30 knots and finish off their quarry with high-powered rifles.

That afternoon, beneath a lowering gray sky, the hunters return, dragging their boats ashore. A few more of Niaqornat's 50 residents emerge from brightly painted wooden houses and gather on the stony beach, eager to see what the boats might hold. Among them is Ilannguaq Egede, the 41-year-old manager of the village power plant. He came here nine years ago from south Greenland, where sheep farmers far outnumber whalers, to be with a Niaqornat woman he met on an Internet dating site. "I haven't caught my first narwhal yet," he says. "I'm waiting for this season."

Freeze-drying laundry hangs from a line in the village of Nuugaatsiaq, home to about 80 people who support themselves mostly by hunting and fishing. Many houses are empty. Greenland's small villages are declining as people abandon the old ways for new opportunities in larger towns to the south.

Maybe the narwhals eluded their pursuers. Or maybe they were never there and are still lingering in their summer grounds up north, not yet driven south by spreading sea ice. Whatever the reason, Niaqornat's hunters have returned with smaller prey: ringed seals, a dietary staple. Within minutes the animals have been skinned, the meat cut and carried away in plastic bags. Bite-size slices of raw liver have been handed to delighted children. Aside from some blood-stained rocks and a few severed flippers, all traces of the seals have vanished.

Something else is vanishing here too: a way of life. Young people are fleeing small hunting villages like Niaqornat. Some of the villages struggle to support themselves. And now a culture that has evolved here over many centuries, adapting to the seasonal advance and retreat of sea ice, is facing the prospect that the ice will retreat for good. Can such a culture survive? What will be lost if it can't?

On the beach Egede demonstrates what a narwhal sounds like when surfacing for air. "You can hear them breathing," he says. He takes a deep breath, holds it, and then exhales with an explosive whoosh. "Like that."

WHEN THE SEA FREEZES, the world of the north suddenly becomes larger. Horizons expand even as daylight contracts. Greenlanders, all 56,000

Now a culture that has evolved here over many centuries, adapting to the seasonal advance and retreat of sea ice, is facing the prospect that the ice will retreat for good.

of them, live their lives facing seaward, with a vast, uninhabitable interior at their backs. No roads cross the glaciers and plunging fjords that separate the scattered coastal towns. These days planes, helicopters, and fast motorboats help connect them—but traditionally, at least in more northerly places like Uummannaq, it was sea ice that brought an end to isolation and autumnal little-town blues. In winter dogsleds, snowmobiles, even taxis and fuel trucks can maneuver across what had been open water. For as long as the Inuit have been in Greenland, winter has been the time for visits, journeys, and hunts.

Of the 2,200 people who live along Uummannaq Fjord, more than half are on its namesake island, on the slopes of a 3,840-foot-high peak called Heart-Shaped (Uummannaq in Greenlandic) Mountain. The town has steep, narrow roads with cars on them; it has stores, a hospital, and bars. It's the region's commercial and social hub, the place where people in the seven outlying settlements, including Niaqornat, send their children to high school and come to shop. In Uummannaq you can work as an auto mechanic, social worker, or teacher.

In the settlements people make a living by hunting and fishing. Whale and seal meat are an important part of the diet, but their export is largely banned. The real moneymaker is halibut.

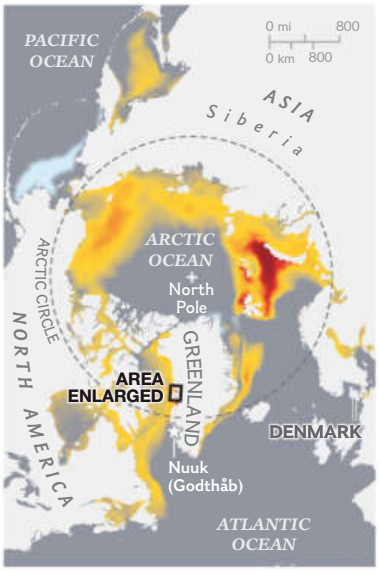
Many settlements have a fish factory operated by Royal Greenland, a government-owned company that processes and packages the halibut for export. Halibut fishing is a year-round occupation. When there's no ice, fishermen set out long lines in the fjord with hundreds of baited hooks. In the winter they cut knee-deep holes in the sea ice, sink their lines, which are hundreds of feet long, and reel in their catch with a winch. On a good day a fisherman might load his boat or dogsled with a quarter ton or more of the flat, dull-brown fish and sell them to Royal Greenland for several hundred dollars.

Although fishing provides a good income for many families, the smallest settlements wouldn't survive without generous government subsidies. Even the most remote communities have heliports, cell towers, grocery stores, clinics, and elementary schools—all subsidized by an annual block grant from Denmark, which stands at $580 million and accounts for a quarter of Greenland's gross domestic product. Greenlanders who dream of full independence from their former colonial master—right now Greenland is in charge only of its domestic policy—pin their hopes on mineral wealth and offshore oil. But the oil fields haven't been developed yet, and according to one recent study, mining would require so many immigrant workers that Greenlanders might become a minority in their own land.

CLIMATE CHANGE IS MAKING the economies of the settlements even more precarious. It has lengthened the periods in winter and spring when ice is too thick for boats to leave harbors yet not thick enough to support sleds or snowmobiles. The unsafe ice affects fishing, but it hurts the region's hunters more.

"In the 1980s we had cold winters," says Uunartoq Løvstrøm, a lean 72-year-old hunter and one of 200 residents of Saattut, a small island near the head of Uummannaq Fjord. "And ice was this thick," he says, rising from a sofa and placing his hand even with his hip. We're in the living room of his blue wood-frame home, a short, slippery walk from Saattut's harbor. On the low table between us are some polar bear claws, souvenirs from a long-ago hunt. A large flat-screen television is temporarily muted. Sled dogs nap outside in the early gloaming.

At the height of winter in recent years, says Løvstrøm, ice in the fjord might be only a foot



Change in the number of sea-ice days per year, 1979-2013

-250 0 50

VANISHING ICE
In recent decades the glaciers surrounding Uummannaq Fjord have been melting at an accelerating rate, and the number of days a year when sea ice covers the fjord has been declining.

thick. Instead of icing over in December or January and melting in June, the sea freezes in February and starts to thaw in April. The loss of ice has shortened the hunting season, in a land where wild meat helps families get by: Seal, reindeer, and whale meat fills freezers for the year. And shooting seals from boats is a poor substitute for the traditional dogsled hunt. A hunter on a sled can get off and stealthily approach his prey. On a noisy boat, he can't get as close; from a distance he must take a difficult shot at a seal coming up for air in open water.

When a hunter does bag a seal, it sinks through a surface layer of fresh glacial meltwater and floats on top of the salt water below. The hunter has to haul it up. But the glaciers flowing into Uummannaq Fjord are melting faster than ever. The freshwater layer is getting thicker, so the dead seals sink deeper. Sometimes now they're out of reach.

PEAK ICE SEASON IS STILL AT LEAST three months away on the crystalline October day when I join Løvstrøm's 66-year-old brother, Thomas, as he

JEROME N. COOKSON, RYAN WILLIAMS, NGM STAFF
SOURCE: CLAIRE L. PARKINSON, NASA GODDARD SPACE FLIGHT CENTER

The arrival of sea ice ends the winter isolation of island villages like Saattut, home to 200 people and 500 sled dogs. Freed from boats or costly air travel, residents take to sleds and snowmobiles for hunting trips and visits to relatives. No roads connect towns in Greenland, even on the mainland.

Traditionally in places like Uummannaq, it was sea ice that brought an end to isolation and autumnal blues. In winter dogsleds can glide across what had been open water.

heads out to feed his sled dogs, of which he has too many to keep in the small yard around his home. We board his 14-foot-long open boat, and after we clear the growlers—small icebergs—in Saattut's harbor, he guns the outboard motor.

To the east we can just make out a wall of white—the 200-foot-high face of a glacier flowing out from the inland ice sheet, which Løvstrøm says has retreated more than half a mile in the past decade. To the north and south, umber cliffs dusted with snow tower above the sapphire waters of the fjord. Soon we pull into one of the innumerable inlets. Keenly watching us from a bare outcrop are Løvstrøm's dogs.

Greenland's dogs are one of the world's oldest breeds, descended from animals that traveled with the Inuit when they began their journey from Siberia to Greenland a millennium ago. Almost all are kept chained as adults; they're free to roam only as puppies. They're working dogs, not pets, fierce enough to confront a polar bear and bred to find contentment harnessed to a sled pulling heavy loads over ice. They're also one of the lesser known casualties of climate change. Because of the shorter ice season, some hunters can no longer afford to keep their dogs year-round—especially given the easy availability of snowmobiles, which don't need to be fed in the off-season. Some hunters have been pushed to an extreme: They've been killing their dogs.

Neither of the Løvstrøm brothers has reached that point, and for this season they have more than enough meat for their dogs. A few days ago hunters from Saattut killed some 40 pilot whales in a single day—a windfall that will fill

A funeral procession for Johan Kristiansen winds around Uummannaq, the largest town in the fjord, with more than 1,200 residents. Greenland's population, currently about 56,000, is aging. Barring a surge in the birthrate or an influx of immigrants, it will soon begin declining.

the settlement's larders for months. Thomas has brought some of the meat for his dogs. Chunks of whale carcass as big as tree stumps and frozen as hard and smooth as lacquered wood sit on the rocks, beyond reach of canine jaws. Thomas, walking nimbly over the slick terrain, saws off stiff planks of black skin and white blubber and tosses them to the dogs, which yelp and strain against their chains.

Later that afternoon at his house, in a living room where family photos share space on the walls with old whalebone tools, Thomas talks about how Greenland has changed since his youth. "Until 1965 my family only had rowboats, no motors," he says. "My father was a great hunter. He still hunted narwhals from a kayak when he was 75 years old. Everything he needed for hunting—kayaks, tools, harpoons—he made himself."

Glancing at his grandchildren sprawled on the floor, transfixed by small screens, he says, "They're more interested in iPads and computers."

THE OLD WAYS HOLD LITTLE APPEAL for Malik Løvstrøm (no relation to the Løvstrøm brothers), a slender, 24-year-old drummer with a local band who has lived in Uummannaq all his life. His tastes run to hard rock and horror films, not seal hunting or halibut fishing. He taught himself English by listening to music,

A polar bear skin dries on a rack outside the home of Ane Løvstrøm on Saattut Island. She's one of the few women in the community with the skill to fashion boots and pants from the skin of the far north's greatest predator. Hunters prize her garments, which provide unparalleled warmth.

"The Inuit hunters have Ph.D.'s in living in nature. I think these small, remote communities can invent a sustainable future for themselves."

Jean-Michel Huctin, anthropologist

and he dreams of working as a tour guide on the cruise ships that ply Greenland's fjords in the summer. He knows he ought to move to a larger town like Ilulissat or Nuuk, but that would leave no one to care for his 80-year-old grandmother, his *aanaa,* who raised him. So he remains in Uummannaq.

On a blustery day punctuated by snow flurries, Malik, dressed in his habitual black and plugged into his tablet, takes me to his favorite spot: a high rocky hill with sweeping views of the fjord and its monumental icebergs, not yet immobilized by sea ice. Rising above us at the north end of the island is Heart-Shaped Mountain. "This is where you can listen to music and think," he says, looking across the fjord through heavy black-frame glasses. "I spend a lot of time here with my friends relaxing, watching the sun rise. In a few weeks we won't have sun here again until February 4."

He points to a name scratched on a graffiti-covered wall. "That's my best friend, who died four years ago," he says. "Suicide. Actually two people whose names are here killed themselves."

Greenland has one of the highest suicide rates in the world, with men in their late teens and early 20s accounting for most of the deaths. Researchers have proposed any number of causes: modernization (suicide numbers started to climb in the 1950s), sleep patterns disrupted by round-the-clock summer light, isolation, alcoholism. No single explanation adequately explains the ongoing national tragedy. But it is clearly emblematic of the uncertain future

Protected from the Arctic cold by polar bear fur pants and a sealskin jacket, and camouflaged by a white screen mounted on wooden skids, Albert Lukassen stalks a seal. Because the climate is warming, sea ice forms later and melts earlier than it used to, shortening the hunting season.

that awaits so many of Greenland's youths, in particular those living in far-flung settlements like the ones on Uummannaq Fjord.

Climate change is only aggravating the settlements' fundamental problem. The traditional hunting and fishing economy can't pay for access to the modern amenities that have become important to the hunters and fishers themselves, let alone to their children. Long before the sea ice disappears, such economic and social pressure might force the abandonment of the settlements. The question of what to do about them is a deeply contentious one in Greenland—as I come to appreciate one evening in Uummannaq, when I attend a *kaffemik*.

A kaffemik, one of which seems to be happening somewhere in Uummannaq almost every day, is a kind of community coffee party. Besides the usual coffee and pastries, this one features plates of whale meat—deliciously fatty both cooked and raw—fish, meats, soups, and drinks. After everyone has finished eating, a band plays Greenlandic folk music, accompanying their singing with piano, guitar, ice shaken in a glass, and a *qilaat*—a large, flat caribou-skin drum. They jam until two or three in the morning.

During a break in the music, Jean-Michel Huctin, a French anthropologist who has been studying the Uummannaq and other Inuit

Karl-Frederik Jensen tosses frozen halibut to his sled dogs. He keeps them on an uninhabited island where they needn't be chained. Less ice makes it harder for dogs to earn their keep; some hunters have killed theirs.

settlements for 18 years, gets into a lively discussion with a man from Nuuk, Greenland's capital and largest town, with more than 16,000 people. The subject is the future of places like Niaqornat and Saattut—and whether they even have one. The Nuuk man, who prefers not to be quoted by name, is ambivalent about propping up the settlements with subsidies.

"If we don't move out of isolation, we will always be conservative," he tells Huctin. "I don't want to live in a museum. I don't want to live in the old way. My son, my daughter should be part of the world." By subsidizing the settlements, he thinks, the government is providing "welfare for hunters" and slotting young people into a life of hunting and fishing rather than encouraging them to look beyond tradition.

But job opportunities in Greenland are few, Huctin retorts, and anyway what would happen to older hunters such as the Løvstrøm brothers? Should they trade their independence, give up their dogsleds, boats, and rifles for life in one of Nuuk's grim apartment blocks? The loss of the settlements, Huctin says, would be a loss for all. They're bastions of Inuit hunting culture. Somehow they should be maintained.

"The Inuit hunters have Ph.D.'s in living in nature, appreciating nature," Huctin tells me later. "This is very important, to keep this knowledge. I think these small, remote communities can invent a sustainable future for themselves. This is a people that went from subsistence hunting to Facebook in less than a century. Now they have airlines and mining companies. I'm sure they will succeed in the future."

YET SETTLEMENTS ALL OVER GREENLAND are losing population. Niaqornat's has fallen to 50, from 75 a decade ago. It came very close to being abandoned a few years back when the community's fish-processing plant shut down. Niaqornat's fishermen had to motor 40 miles to Uummannaq to sell their catch. It wasn't a tenable situation. But rather than abandon their homes, Niaqornat's residents pooled their savings and bought the processing plant. For now their community is hanging on.

Weary and frustrated after four fruitless days of seal hunting, Knud Jensen (wearing sealskin) and Apollo Mathiassen go on searching for prey in the broken ice of Uummannaq Fjord. Unlike some of his peers, Jensen, who's 15, wants to make his living as a hunter and has no desire to leave his community for a job in one of Greenland's larger towns.

And to one person at least, it has offered a new beginning. When Ilannguaq Egede became a lonely exception to Greenland's demographic trends nine years ago, moving to Niaqornat to be with the love of his life, he was willing to take any job available. For several years he emptied the town's bucket toilets. He'd call on each house daily and cart the waste to a beach, where he dumped it into the fjord. Eventually he moved on to managing the town's power plant. Along the way he found something he didn't know he'd lost: a life attuned to larger rhythms, to the passage of narwhals in the night or the wandering of reindeer in summer's perpetual light. Now even Uummannaq, with its population of 1,248, seems almost unbearably overcrowded to him.

"I like it here a lot," he says, as we walk from his office to Niaqornat's beach. "I have a home and a nice salary. I don't want to move anyplace else. And my girlfriend is here. She doesn't want to move. You can feel the freshness here, and it's open. In Uummannaq she feels closed in. There's not enough air." □

REBECCA HALE, NGM STAFF

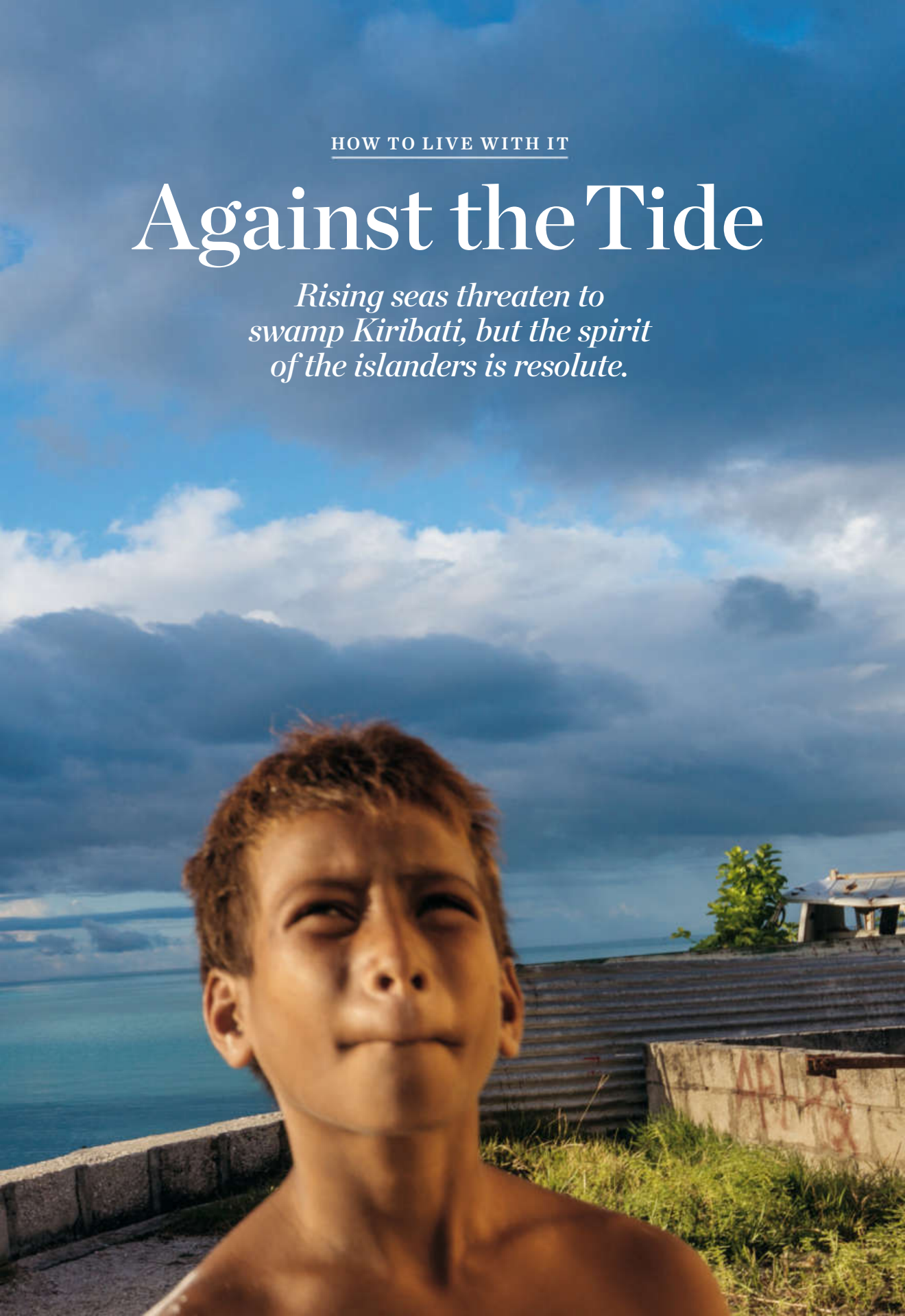
After falling in love with northern Greenland on his first trip, photographer **Ciril Jazbec** spent nearly six months in the frozen land for this assignment. There he found a new favorite food—narwhal meat.

Boys on a seawall on Tarawa atoll watch a squall approach. The warming atmosphere is predicted to bring heavier rainfall to Kiribati and other island nations in the central Pacific Ocean.

HOW TO LIVE WITH IT

Against the Tide

Rising seas threaten to swamp Kiribati, but the spirit of the islanders is resolute.



Aquaculture ponds fill a reclaimed area beside the airport on Tarawa, Kiribati's capital and its most densely populated atoll. Much of Tarawa is less than eight feet above sea level and risks being inundated as the ocean rises.

Families from Kiribati's outer atolls are flocking to South Tarawa for jobs, education, and health care, swelling the population to more than 50,000. Newcomers are often forced to live in marginal areas prone to flooding by high tides.

By Kennedy Warne
Photographs by Kadir van Lohuizen

It was the time called *itingaaro,* the dawn twilight, when the island was just waking up and the roosters were vying to out-crow each other and the angel terns were twittering their love talk in the breadfruit trees. People drifted sleepily into the lagoon to wash, splashing water on their faces, then tightening their sarongs and diving under.

The tide was full and taut like the skin of a pregnant woman. Beyond the lagoon the ocean stretched to the horizon. *Marawa, karawa, tarawa*—sea, sky, land. These are the ancient trinity of the people of Kiribati (kee-ree-bahss), the I-Kiribati. But the trinity is tilting out of balance. Mother Ocean isn't the heart of providence the people have always known. She is beginning to show a different face, a menacing one of encroaching tides and battering waves.

I-Kiribati now live with the reality of marawa rising. This is the time of *bibitakin kanoan boong*—"change in weather over many days"—the Kiribati phrase for climate change. The people live with the fear and uncertainty of those words.

How can they not feel afraid when the world keeps telling them that low-lying island countries like theirs will soon be underwater? Their own leaders have said that Kiribati—33 coral islands in an expanse of the central Pacific larger than India—is "among the most vulnerable of the vulnerable." They have predicted that Tarawa atoll, the nation's capital, will become uninhabitable within a generation.

But many I-Kiribati refuse to think of their homeland as a "disappearing island nation," its fate already out of their hands. They do not think of themselves as "sinking islanders," rather as descendants of voyagers, inheritors of a proud tradition of endurance and survival.

They believe their paradise is far from lost.

BUT IT IS SURELY SUFFERING. The sea is becoming an unwelcome intruder, eroding the shoreline and infiltrating soils, turning wells brackish and killing crops and trees. Atolls like Tarawa rely for their fertility on a lens of freshwater, replenished by rain, which floats on a saltwater aquifer. As the sea level rises—a few millimeters a year at the moment but likely to accelerate—so does the level of salt water underground, shrinking the freshwater sweet spot.

"Now we hate the sea," Henry Kaake told me as we sat in his *kiakia,* an open-sided hut on stilts used for both sleeping and chatting with friends. "Yes, the sea is good for us to get our food, but it is going to steal our land one day."

An early casualty of creeping salinity has been *bwabwai,* the prestige food of Kiribati culture, the food of feasts, a giant swamp taro that can take more than five years to mature. Some varieties reach from a person's shoulder to the ground. Sensitive to saltwater intrusion in the pits in which it's cultivated, bwabwai now cannot be grown in many areas and could eventually disappear from island cuisine.

Government and aid agencies are helping gardeners switch to other starchy crops. In a communal garden on one of Tarawa's neighboring atolls, Abaiang, I watched Makurita Teakin chop leaves into mulch and spread it around seedlings of a shallow-rooting variety of taro that doesn't need swamp conditions. Nearby, another woman watered her seedlings with fish

Bride Teiti Kiroon and groom Iannang Komi are making their home on Tarawa, despite concerns about how climate change is affecting Kiribati. Many islanders think about moving to safer countries, but they also feel wedded to their homeland and its lifestyle.

fertilizer from a can punched with nail holes.

The tide drained from the vast sand flats of Tarawa lagoon, exposing myriad miniature sand volcanoes built by ghost crabs. Adults and children, toting plastic bags and buckets, probed the sand with their fingers and scratched in the crevices of rocks with teaspoons for cockles—called *koikoi*—and sea snails. The harvesters walked far out to the water's receding edge, bending over double, sifting and scraping for a few ounces of seafood.

If they found enough cockles, they might prepare them in coconut cream, cooking them inside a coconut shell over a smoky coconut-husk fire. Coconut palm—*nii*—is there anything this tree doesn't provide? Baskets, brooms, timber, thatch, oil, fermented toddy, soap, a dark sweet syrup called *kamwaimwai*. Tree of heaven, some people call it. I-Kiribati have more than a dozen words for the stages of the fruit alone—from a young nut before the water forms to an old one with rancid flesh.

Holding fast to tradition matters for many I-Kiribati. Mwairin Timon was making coconut sennit when I met her, sitting on an old pandanus mat outside her shanty at the edge of the lagoon, rolling tufts of coconut fiber on a piece of driftwood with the palm of her hand. More than a year ago she had buried coconut husks in the lagoon, marking the place with a rock. A thousand tides had done their work, curing and softening the fibers. Now she twisted them into string the same way her grandmother would have, and her grandmother before her, all the way back to the first settlers of these atolls, who splashed ashore some 3,000 years ago.

Rain clouds darkened and moved across the lagoon, blotting out the islets of North Tarawa, the other side of wishbone-shaped Tarawa atoll. Soon they would bring relief to this side, South Tarawa, where half the nation's people live on barely six square miles of land.

It is a mercy that rainfall is predicted to

increase over the coming decades, although downpours are likely to be more extreme, causing flooding. As underground freshwater reserves are compromised by rising seas—and in Tarawa's case, heavy population pressure—harvesting rainwater from roofs may offer an alternative. On Abaiang foreign aid has provided some communities with simple systems that catch, filter, treat, and store rainfall. As long as you have freshwater, you can cope with other changes—at least for a while. How long, no one knows.

The tide turned and slid shoreward like a sheet of green glass, pushing the harvesters ahead of it. Tides are an axis of Kiribati life. So are the movements of sun, moon, and stars and the directions of wind and swell. In times past, if you understood these axes, you could calculate when to plant crops, when to fish, when to set sail in hundred-foot outrigger canoes called *baurua*. Such was the algebra of the Pacific.

How can they not feel afraid when the world keeps telling them that low-lying island countries like theirs will soon be underwater?

Fishermen knew the bait each fish preferred, whether to catch it in the day or night, and the best tactic for taking it: hook, noose, or net. But the certainties of that world are breaking down. Once reliable fishing places now yield empty lines and nets. The warming ocean is thought to be driving some fish to cooler waters.

Coral reefs are suffering as well—and worse is yet to come. As the sea grows warmer and more acidic throughout this century, reef growth is predicted to slow and even stop. Coral bleaching—when stressed corals expel the symbiotic algae that give them color and nutrients—used to happen every ten years or so. But it's becoming more frequent and eventually could happen yearly, threatening coral survival and dimming the reefs' living rainbow to a shadow.

Where reefs go, islands will follow. Atoll islands rely on deposits of sediment from corals and other marine organisms—often dumped onshore by storms—to keep their heads above water. They are like construction sites: If the materials run out, building will cease. A dead reef cannot sustain the islands it has built.

What kind of world is this, where the sea consumes its own creation?

TO MANY I-KIRIBATI it seems deeply unfair that their country's climate troubles are not of its own making. Since the 1980s Pacific leaders have scolded, cajoled, pleaded with, and tried to shame the major carbon-polluting countries over climate change. The islands are ants and the industrialized nations are elephants, declared Teburoro Tito, a former Kiribati president, speaking of the infinitesimal contribution his country has made to the planet's carbon burden.

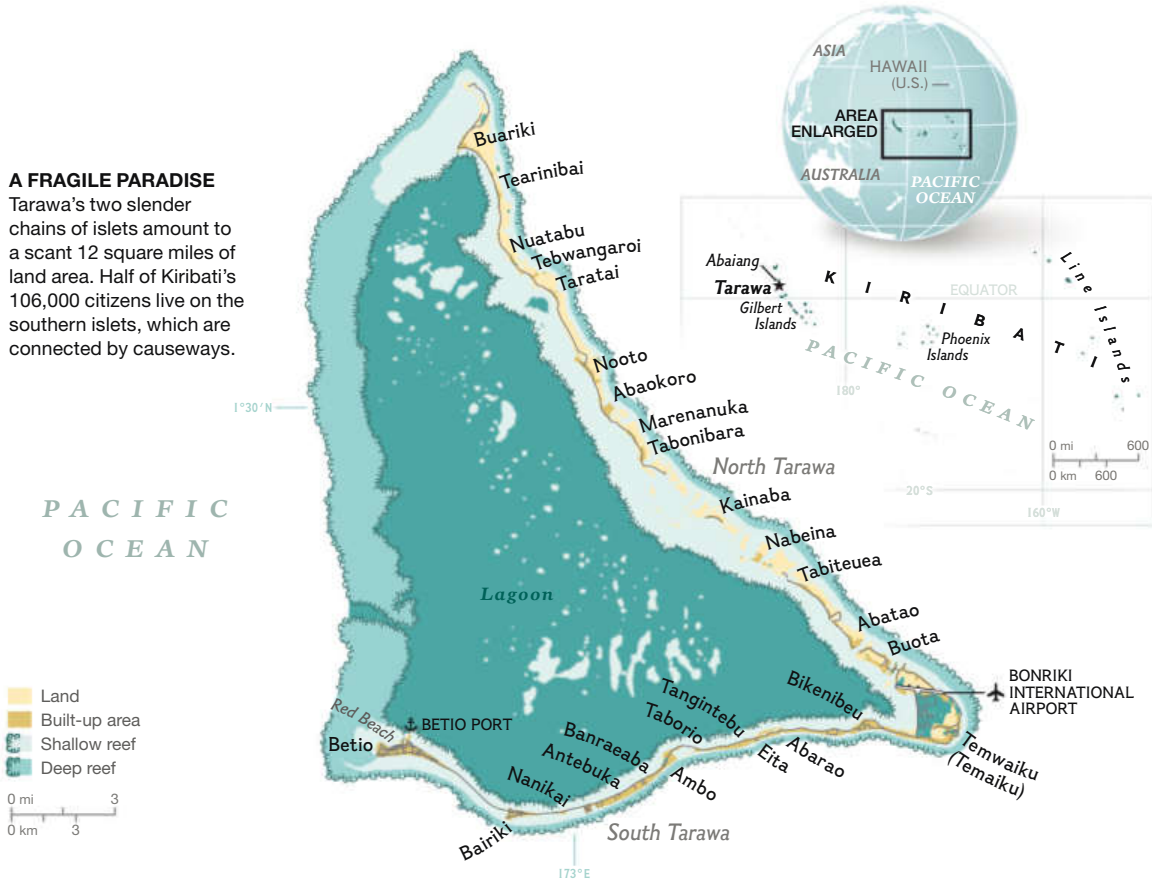
There is an aspect to the rich world's disregard that is especially hard for I-Kiribati to stomach. They are particular about respecting boundaries. Traditionally, you never took coconuts from a tree that wasn't yours. You wouldn't even take dead breadfruit leaves to light a fire without asking. Reefs had boundaries too. People knew where they were entitled to harvest.

Those protocols are still observed today. When I joined fishermen traveling from Tarawa to Abaiang, on a day so calm the clouds had blue-green bellies from the reflection of the sea, the skipper stopped the outboard motor at a certain reef and one of the crew threw hand-rolled pandanus cigarettes into the sea as offerings and a mark of respect for the owners of the territory we were crossing.

When you travel to another island for the first time, before you do anything else, you announce yourself to the place by visiting a sacred site. You make a gift of cigarettes or a few coins, and the caretaker picks up damp sand and pats it on your cheeks and ties a tendril of green vine around your head. After performing this ritual on Abaiang, the caretaker of the shrine told me, "You now belong to this island."

What do the wealthy countries know of respecting boundaries? I picture a cloud of greenhouse gases drifting toward Tarawa from over the horizon, like radioactivity from the nuclear weapons exploded in Kiribati's Line Islands after the Second World War. It doesn't seem so very different: nuclear fallout in the 20th century, climate fallout in the 21st.

The feeling of injustice is widespread on the



atolls most at risk from rising seas: Kiribati, Maldives, Marshall Islands, Tokelau, and Tuvalu. A former Tuvaluan prime minister, Saufatu Sopoaga, went so far as to compare the impacts of climate change to "a slow and insidious form of terrorism against us."

Even so, some I-Kiribati reject the rhetoric of victimhood and the implication that Pacific nations are powerless. "We are not victims," Toka Rakobu, who works for a Tarawa tourism agency, told me. "We can do something. We are not going to be a defeated people."

But can you blame politicians, including Kiribati's president, Anote Tong, for playing the global underdog? Talk of drowning islands and climate refugees has made Kiribati known around the world. Photographers and journalists have made their way to Tarawa to report from "the front line of the climate-change crisis."

Their visits tend to peak at the time of the king tides, the highest tides of the year, when the drama of waves overtopping seawalls is greatest. Early this year a king tide lifted a shipwreck off the reef at Betio, Tarawa's westernmost islet, and flung it ashore, piercing a seawall. There it has stayed. The ship has an ironic name: *Tekeraoi,* "good luck."

There is a darker irony too. The shipwreck came ashore on Red Beach, where a lower-than-expected tide stranded American landing craft during the Battle of Tarawa in 1943, leading to a bloodbath.

Stories of the Pacific's climate woes have brought a flow of sympathy and aid money to Kiribati and her island neighbors, but if you hear that message of environmental doom often enough, you might think you had no option but to leave. There is much talk now about migration. Should we stay? Shall we go? Will we be forced to relocate? If so, where? No country is flinging open its doors to climate refugees.

The questions are agonizing, not least because they bear on a sense of identity. In the Kiribati

JEROME N. COOKSON, NGM STAFF; EVAN APPLEGATE
SOURCES: GEOSCIENCE DIVISION, SECRETARIAT OF THE PACIFIC COMMUNITY; OPENSTREETMAP; UNEP WORLD CONSERVATION MONITORING CENTRE

Sandbags do little to hold back the ocean at Temwaiku, a vulnerable village on South Tarawa. In February, waves washed away this bulwark and rolled inland, leaving behind flooded homes, salty soil, and tainted wells.

Mangroves can't stop the encroaching ocean, but the trunks and roots of mature trees reduce erosion and suppress storm surges. Seedlings have been planted near Tarawa's airport to stabilize the shore of the lagoon.

language the word for "land" and "people" is the same. If your land disappears, who are you?

Yet, conversely, Pacific people are renowned for their migrations—after all, their ancestors made the entire ocean their home. In Kiribati's origin story Nareau, the Creator, was a spider, and I-Kiribati have been spinning webs ever since. Every family has relatives in New Zealand, Australia, Fiji, and farther overseas, each migration a silk strand in a net of kinship bonds.

There is sometimes an expectation that the young will leave Kiribati and the old will stay.

They do not think of themselves as "sinking islanders," rather as descendants of voyagers, inheritors of a proud tradition of endurance and survival.

But some of the young choose to live a simple life on ancestral land rather than pursue prosperity abroad. Mannie Rikiaua, a young mother who works in Kiribati's environment ministry, told me she would rather work for her own people than serve another country, despite her father's urging that she migrate to a "higher place."

"Part of me wants to go," she admitted. But then she added, as if she had made her mind up once again, "Kiribati is the best place for my sons, regardless of the threats."

She was responding to *tangiran abam,* she said, the love and longing I-Kiribati feel for their homeland. Tangiran abam has kept Kiribati's more distant atolls culturally vibrant, even as their populations shrink and Tarawa's swells. It remains a strong impulse. I heard that love of place in the sound of people singing in the lagoon at night. I saw it in the vivacious dances of schoolchildren that mimic the movements of seabirds. I heard it in the words of Teburoro Tito, when he met me between parliamentary sessions and said that, at heart, he was an island boy: "I grew out of the soil and the sand and the coral of this place. I love these islands, and I don't see any other home in the world."

TO PROTECT THAT HOME from the hungry ocean, some islanders have taken to planting mangroves, whose matrix of roots and trunks traps sediment and quells scouring waves. I joined some women who were picking ripe seedlings that dangled in bunches like string beans among the glossy green leaves of a mature mangrove stand. A few days later we planted them in a part of the lagoon that needs extra protection from king tides. It wasn't much, but there's little else islanders can do to hold on to their land except rebuild their seawalls when the waves smash them.

Mangroves might make a good national symbol, I thought: resilient trees resisting storms, binding the land. The current symbol, emblazoned on the Kiribati flag, is evocative too: *eitei,* the frigatebird, a bird of chiefs, a bird of the dance, a high flier that floats on the wind rather than fights against it. But frigatebirds must follow the schools of fish on which they feed. If the fish depart for good, will the frigatebird's forked tail still be seen scissoring Kiribati skies?

One of the mangrove planters, Claire Anterea, who works in the Kiribati government's climate adaptation program, said her people must acknowledge their role in climate change, small as it may be, and try to offset it. "We contribute less, but we still contribute," she said. "We have been eating a lot of Western food. We like noodles, we like Ox & Palm [canned corned beef]. And that food is made in factories that produce gas. We are all contributing because we want to live the Western way."

Anterea had just finished building a traditional house, powered by a solar panel. "I can't talk about climate justice overseas if I don't act right myself," she said. Even small actions have a multiplying effect, she believes. "If we work together—all the countries in the Pacific—we can maintain our islands and stay here."

On my last night in Tarawa I wanted to do something to show solidarity with my Kiribati neighbors. I am a Pacific islander too—although New Zealand's mountainous islands face nothing like the existential threat that looms for atolls where much of the land is only a few feet above sea level. Yet the "blue blood of Oceania," as Kiribati poet Teweiariki Teaero calls the Pacific, binds us as one family.

The electricity was off, not an uncommon problem, so two of my mangrove-planting

A wrecked fishing vessel serves as a diving platform for Tarawa youngsters, who grow up in, on, and always within sight and sound of the ocean. This and coming generations face tough climate challenges as warming, rising, acidifying seas threaten life on their native islands.

friends—Vasiti Tebamare and Tinaai Teaua, who run a health spa in the village of Temwaiku—suggested we take our meal to the airport runway. It is something of a tradition, on sultry nights too stifling even for a fan to relieve, for families to spread their mats on the little-used runway and eat a picnic supper. It's always cool there, with a breeze off the ocean.

We took grilled fish, rice, and fried breadfruit chips to eat and *moimoto*—green coconuts—to drink. The airfield was twinkling with flashlights and bathed in the soft murmur of conversation. We found a quiet spot, ate, talked, then lay on our backs and stared at the blazing night sky—the "belly of the eel," as I-Kiribati call the Milky Way.

I wished I could name the constellations as the early navigators did, knowing them as intimately as if they were family. They learned them by seeing the sky as the roof of a meeting-house, divided into a grid by rafters and lines of thatch. The stars rose in one quadrant, sailed across the roof, and set in another.

Master navigators knew upwards of 150 stars. You could put them anywhere in the ocean, and they would know exactly where they were. I-Kiribati might live on small islands, but there is nothing small about their sense of their place in the world. ▯

KENNEDY WARNE

New Zealand writer and editor **Kennedy Warne** has visited three of the atoll nations in his Pacific backyard that are most at risk from rising sea levels: Tokelau, Tuvalu, and now Kiribati.

What did you learn from the Kiribati people? What I wish I'd learned was the secret of their happiness. Kiribati people were once described as "princes in laughter and friendship, poetry and love." It's true: Joy is their sixth sense, and it shows in everything they do.

Who Will Thrive?

As the world warms, which animals may suffer and which may prosper isn't clear-cut.

GREATER YELLOWLEGS
Here stands an adaptable bird that so far is thriving in a changing environment. The Audubon Society reports seeing this sandpiper in high numbers on its Christmas Bird Counts, especially inland in the southern U.S. In some areas space available for these birds may double, but it's unknown if they'll fill it, and summers may become too hot to handle.
PHOTOGRAPHED AT TULSA ZOO, OK

WOODLAND CARIBOU
Already pressured by habitat loss, woodland caribou could face a food shortage. More snow and freezing rain (a result of warmer temperatures adding moisture to dry, Arctic air) crust over lichen, caribou's winter diet, making it hard to access. In summer, increasing droughts bring fires that kill the slow-growing lichen.
NY STATE ZOO AT THOMPSON PARK

AMERICAN BULLFROG
This native of North America—a voracious predator and tough competitor that spreads amphibian disease—has made its way onto other continents and spread like an army, especially in South America. It is by leaps and bounds one of the worst (most successful) invasive species on the planet. Climate change will slow its advance in some areas, but other highly biodiverse habitats will become more bullfrog friendly, meaning further raids against native species.
BENNET, NEBRASKA

ARCTIC FOX
As tundra habitat melts, this snow-loving fox will find fewer seal carcasses left on ice by polar bears and fewer lemmings—food for fox pups—whose numbers peak in the coldest winters. It may also face competition as the adaptable red fox expands north.
GREAT BEND BRIT SPAUGH ZOO, KANSAS

By Jennifer S. Holland
Photographs by Joel Sartore

Climates change. That's a fact of nature. But Earth's climate today is changing so dramatically that it's transforming land and sea, affecting all forms of life.

"There will always be a minority that manage to thrive in relatively sudden new conditions," says Thomas Lovejoy, a George Mason University conservation biologist and a National Geographic fellow. "But the vast majority will be terribly battered," if not crushed.

Higher temperatures caused by greenhouse gases are just the beginning of this ride. Next come extreme weather (including extensive drought), shifting breeding and migration seasons, and changing food availability, new disease patterns, rapid ice melt, and rising seas. Each change begets a host of others: Effects run far and wide.

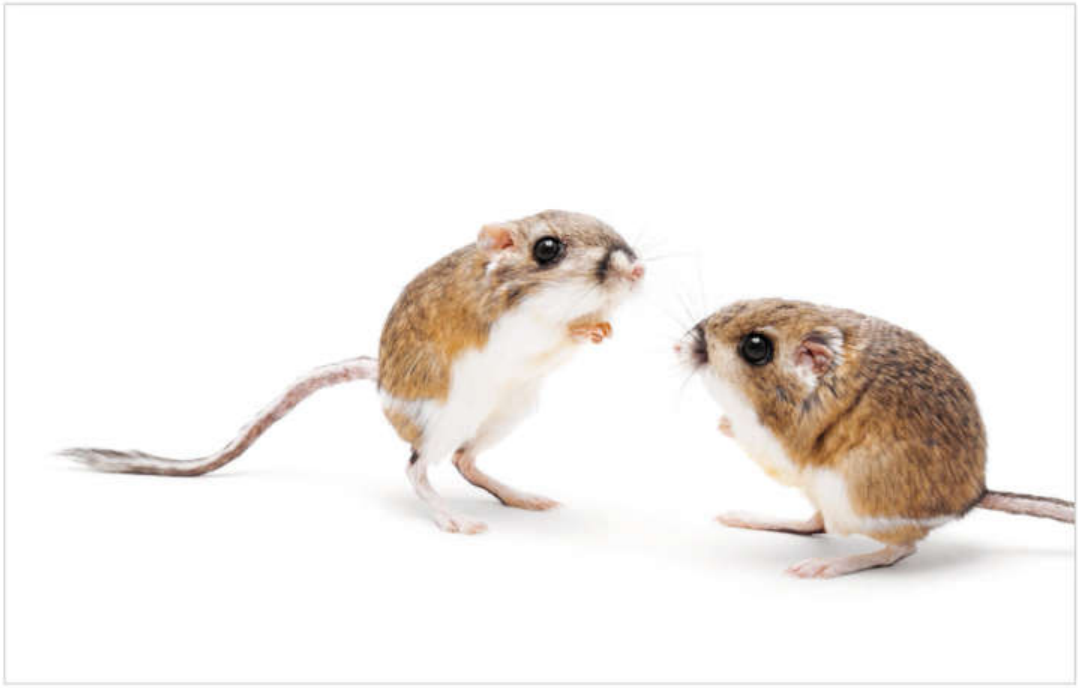
Change can be good for some—a longer spring with more food, a comfortable niche to call home, a stressful migration avoided. But as the layers build and warming continues, winners may hit new limits and lose their edge.

This isn't the stuff of the future. The effects of an altered climate are evident now.

"There's no going back," says the University of Queensland's James Watson, who directs the Global Climate Change Program of the Wildlife Conservation Society. "Everything is changing." Wildlife that's enjoyed a relatively stable climate for the past 10,000 years is being pushed and tested like never before.

And our predictions of "winners" and "losers" haven't always been spot-on, he says: "We've rarely gotten right how bad it will be. The degree of melting at the Poles and its ripple effects [on wildlife] have been staggering," for example. The sensitivity of many coral ecosystems to temperature and storms is another. "There's a lot to grapple with."

But experience and models and what we know of biology can give us a solid near-term picture. What species adapt well to rapid change?



MERRIAM'S KANGAROO RAT
This pair takes the heat in stride. In the southwestern U.S. and Mexico, kangaroo rats are already well adapted to arid conditions, and they've stayed robust during previous temperature hikes. The rodents are quick and flexible reproducers, and their diet of diverse seeds and occasional insects gives them wiggle room if some plant and bug species fizzle in the heat.
FORT WORTH ZOO, TEXAS

SPECTACLED EIDER
Specialized needs put these northern ducks at risk. In winter the birds gather in a small, cold, nutrient-rich area of the Bering Sea to dive for clams and other marine life. But as ice retreats, spectacled eiders' habitats and access to food resources in their wintering grounds are changing. Meanwhile coastal changes are altering the ducks' breeding habitat on tundra wetlands.
ALASKA SEALIFE CENTER, SEWARD

PENINSULAR PRONGHORN
Some wild pronghorn have shown marked recovery with protection, but this subspecies remains at the edge. Existing only on the Baja California Sur peninsula, fewer than a hundred wild peninsular pronghorn survive, along with a herd of captive animals used to help bolster the wild population. The ungulates are adapted to desert conditions, but further warming and reduced rainfall will affect both their winter and summer forage.
LOS ANGELES ZOO, CALIFORNIA

BULL TROUT
It's a cold-water fish in a warming world whose Rocky Mountain habitat could decline by 50 percent within 70 years, biologists say. But even if warming is extreme, some high-elevation headwater streams should remain chilly enough to support resilient populations and resist invasions by competitors. Ensuring the protection and connectivity of spawning and rearing streams is crucial for migration.
BIGHORN CREEK, BRITISH COLUMBIA

WHITE-FRONTED LEMUR
Over the next 70 years, lemur species on the island of Madagascar could lose about 60 percent of their habitat due to climate change. If climate were the animals' only foe, perhaps the white-fronted lemur could survive; climate change won't shrink its lowland and montane habitat. But other factors may—chief among them, slash-and-burn agriculture and a growing human population.
NAPLES ZOO, FLORIDA

CHINSTRAP PENGUIN
Winners turned losers: Chinstraps prefer open to ice-choked waters, so in the past 50 years of fast-melting Antarctic ice, their population boomed. But now increasing ultraviolet light exposure is killing off the algae eaten by krill (the penguins' food source), and that means less krill for penguins to share with rebounding whale populations. Soon environmental change may beat tourism as the biggest threat to chinstraps.
NEWPORT AQUARIUM, KENTUCKY

Generalists that tolerate a range of climates. Those with diverse genes and speedy reproduction (which lets helpful traits enter the gene pool fast). Those that can travel to a suitable new habitat—and that have somewhere to go. Competitive, often invasive species. Weeds.

Which do poorly? Specialists with narrow climate needs. Those already battling for survival. Small and fragmented populations, or those hemmed in by unsupportive landscapes. Animals competing with humans. Groups lacking genetic diversity. High-elevation species, island dwellers, and many coral-dependent animals. Those needing ice to survive.

We can't stop this train. But we can slow its destructive run. Restoring landscapes should be a big part of the game plan, says Lovejoy, who adds that longtime degradation of ecosystems has created a lot of the excess carbon dioxide. "A massive restoration effort could actually remove half a degree worth of potential climate change from the atmosphere before it happens."

Heading off more damage and caring for what's left must be dual priorities. "The best we can do now," says Watson, is to identify and protect key populations, "then try to stop humanity from getting in the way of their functioning." □

Joel Sartore founded the National Geographic Photo Ark in an effort to slow, or stop, the world's extinction crisis. Learn more about the project at *natgeophotoark.org.*

NATIONAL GEOGRAPHIC PHOTO ARK JOEL SARTORE

AMERICAN DOG TICK
Ticks are faring well. Climate affects a tick's life cycle, influencing the intricate dance among the arachnid, its infected hosts, and the diseases it spreads (for the American dog tick, that includes Rocky Mountain spotted fever and tularemia). But the consequences of changing climate patterns are complex and inconsistent: Disease transmission to humans may go up in some areas, down in others. Meanwhile, in the eastern U.S. certain species, like the black-legged tick, are emerging weeks early from their winter slumber to feed—and are adapting well to the new schedule.
LINCOLN, NEBRASKA

BENGAL TIGER
Wild tigers are in drastic decline, with perhaps 3,000 left. Eventually they'll need scuba gear to live in the mangrove-dominated Sundarbans of Bangladesh. A World Wildlife Fund–led study reports that a predicted 11-inch rise above sea levels from the year 2000 would destroy most tiger habitat in that region. Better news in Bhutan: As forests move upslope, tigers will likely shift with them, heading deep into northern parklands along major river valleys. Sadly, they would displace or prey on already struggling snow leopards.
ALABAMA GULF COAST ZOO

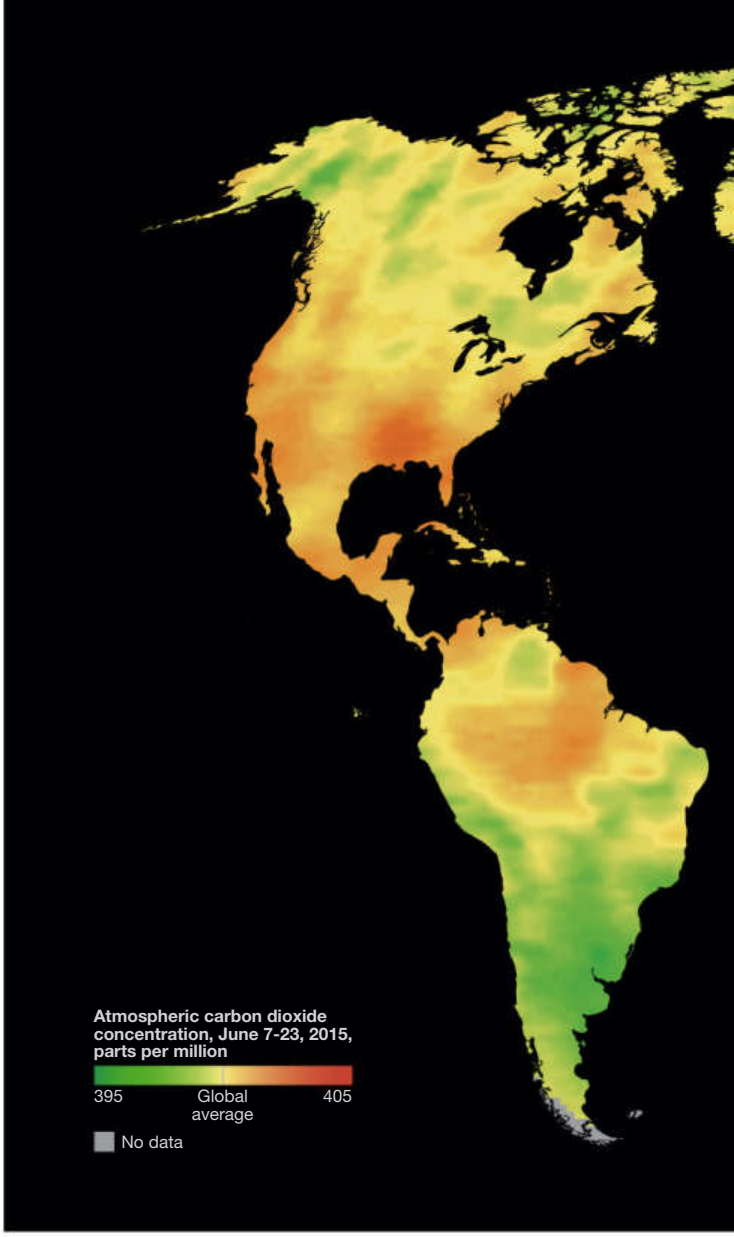
New satellite and airborne sensors won't cure the Earth. But they promise the clearest picture yet of its various ailments.

HOW TO LIVE WITH IT

Pulse of the Planet

Annual floodwaters fill the Okavango Delta, an inland oasis in Botswana, in this view from the International Space Station. High-altitude imagery and mapping are showcasing hidden details of Earth's metabolism.

NASA

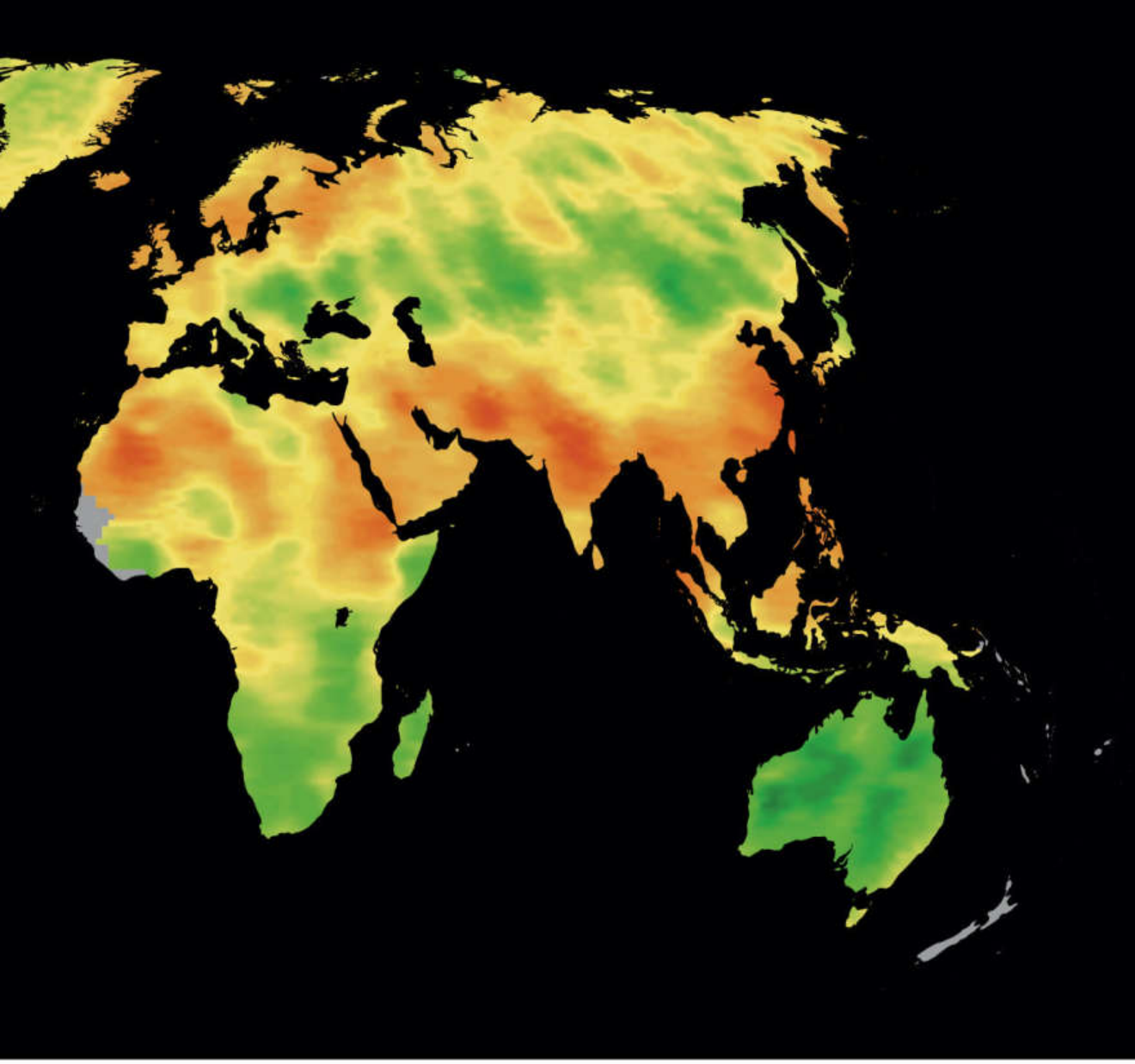


By Peter Miller

The view out the window was bad enough. As his research plane flew over groves of California's giant sequoias, some of the world's tallest trees, Greg Asner could see the toll the state's four-year drought had taken. "It looked wicked dry down there," he said. But when he turned from the window to the video display in his flying lab, the view was even more alarming. In places, the forest was bright red. "It was showing shocking levels of stress," he said.

The digital images were coming from a new 3-D scanning system that Asner, an ecologist with the Carnegie Institution for Science, had just installed in his turboprop aircraft. The scanner's twin lasers pinged the trees, picking out individual branches from 7,000 feet up. Its twin imaging spectrometers, one built by NASA's Jet Propulsion Laboratory (JPL), recorded hundreds of wavelengths of reflected sunlight, from the visible to the infrared, revealing detailed chemical signatures that identified each tree by species and even showed how much water it had absorbed—a key indicator of health. "It was like getting a blood test of the whole forest," Asner said. The way he had chosen the display colors that day, trees starved of water were bright red.

Disturbing as the images were, they represented a powerful new way of looking at the



WHAT THIS IS It's a map of atmospheric carbon dioxide over land last June, made by NASA's OCO-2 satellite. Red areas have a bit more CO_2, green areas a bit less, than the global average of 400 parts per million. **WHAT THIS TELLS US** Forests and oceans have slowed global warming by soaking up some of the CO_2 we emit. OCO-2 will shed light on where exactly it's going—and on how fast the planet could warm in the future.

planet. "The system produces maps that tell us more about an ecosystem in a single airborne overpass," Asner wrote later, "than what might be achieved in a lifetime of work on the ground." And his Carnegie Airborne Observatory is just the leading edge of a broader trend.

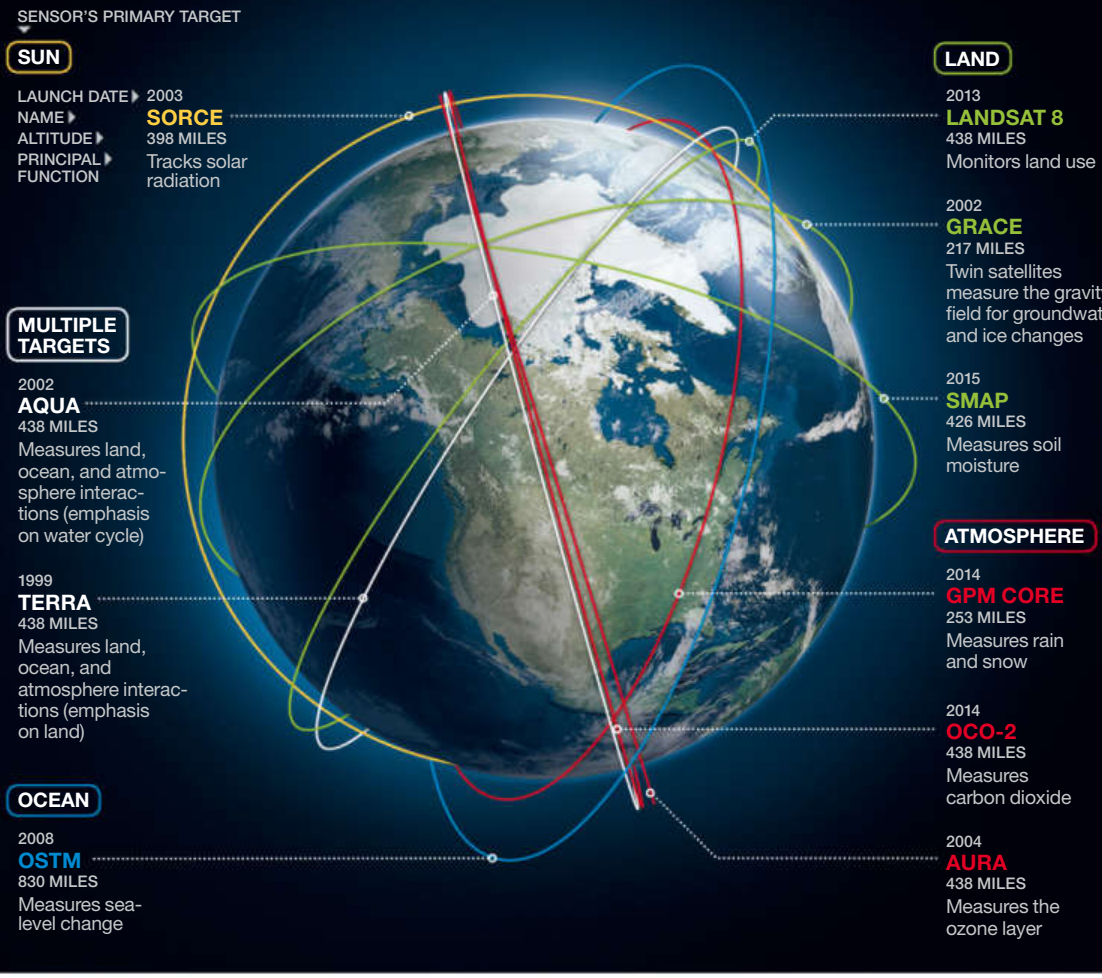
A half century after the first weather satellite sent back fuzzy pictures of clouds swirling over the North Atlantic, advanced sensors are doing for scientists what medical scanners have done for doctors—giving them ever improving tools to track Earth's vital signs. In 2014 and early 2015 NASA launched five major Earth-observing missions (including two new instruments on the space station), bringing its total to 19. Space agencies from Brazil, China, Europe, and elsewhere have joined in. "There's no question we're in a golden age for remote sensing," said Michael Freilich, NASA's earth science director.

The news from all these eyes in the sky, it has

NGM STAFF. SOURCE: NASA/JPL

Planet Probes

Earth's vital signs are monitored by a growing number of orbiting sensors. Ten of the most critical NASA-led missions, shown below, circle the globe about 16 times a day, collecting data on climate, weather, and natural disasters.



to be said, is mostly not good. They bear witness to a world in the midst of rapid changes, from melting glaciers and shrinking rain forests to rising seas and more. But at a time when human impacts on Earth are unprecedented, the latest sensors offer an unprecedented possibility to monitor and understand the impacts—not a cure for what ails the planet, but at least a better diagnosis. That in itself is a hopeful thing.

WATER IS EARTH'S LIFEBLOOD, and for the first time, high-flying sensors are giving scientists a way to follow it as it moves through every stage of its natural cycle: falling as rain or snow, running into rivers, being pumped from aquifers, or evaporating back into the atmosphere. Researchers are using what they've learned to predict droughts, warn of floods, protect drinking water, and improve crops.

In California the water crisis has turned the state into something of a laboratory for remote-sensing projects. For the past three years a NASA team led by Tom Painter has been flying an instrument-packed aircraft over Yosemite National Park to measure the snowpack that feeds the Hetch Hetchy Reservoir, the primary source of water for San Francisco.

Until now, reservoir managers have estimated

MONICA SERRANO, NGM STAFF; TONY SCHICK. SOURCES: STEVEN E. PLATNICK AND CLAIRE L. PARKINSON, NASA GODDARD SPACE FLIGHT CENTER

the amount of snow on surrounding peaks the old-fashioned way, using a few gauges and taking surveys on foot. They fed these data into a statistical model that forecast spring runoff based on historical experience. But lately, so little snow had fallen in the Sierra Nevada that history could offer no analogues. So Chris Graham, a water operations analyst at Hetch Hetchy, accepted the NASA scientists' offer to measure the snowpack from the sky.

Painter's Twin Otter aircraft, called the Airborne Snow Observatory, was equipped with a package of sensors similar to those in Greg Asner's plane: a scanning lidar to measure the snow's depth and an imaging spectrometer to analyze its properties. Lidar works like radar but with laser light, determining the plane's distance to the snow from the time it takes the light to bounce back. By comparing snow-covered terrain with the same topography scanned on a snow-free summer day, Painter and his team could repeatedly measure exactly how much snow there was in the entire 460-square-mile watershed. Meanwhile the imaging spectrometer was revealing how big the snow grains were and how much dust was on the surface—both of which affect how quickly the snow will melt in the spring sun and produce runoff. "That's data we've never had before," Graham said.

Painter also has been tracking shrinking snowpacks in the Rocky Mountains, which supply water to millions of people across the Southwest. Soon he plans to bring his technology to other mountainous regions around the world where snow-fed water supplies are at risk, such as the Himalayan watersheds of the Indus and Ganges Rivers. "By the end of the decade, nearly two billion people will be affected by changes in snowpacks," he said. "It's one of the biggest stories of climate change."

WITH LESS WATER flowing into California's rivers and reservoirs, officials have cut back on the amount of water supplied to the state's farmers, who typically produce about half the fruits, nuts, and vegetables grown in the U.S. In response, growers have been pumping more water from wells to irrigate fields, causing water tables to fall. State officials normally monitor underground water supplies by lowering sensors into wells. But a team of scientists led by Jay Famiglietti, a hydrologist at the University of California, Irvine, and at JPL, has been working with a pair of satellites called GRACE (for Gravity Recovery and Climate Experiment) to "weigh" California's groundwater from space.

The satellites do this by detecting how changes in the pull of Earth's gravity alter the height of the satellites and the distance between them. "Say we're flying over the Central Valley," Famiglietti said, holding a cell phone in each hand and moving them overhead like one satellite trailing the other. "There's a certain amount of water down there, which is heavy, and it pulls the first satellite away from the other."

At a time when human impacts on the planet are unprecedented, technology offers a chance to truly understand them.

The GRACE satellites can measure that to within 1/25,000 of an inch. And a year later, after farmers have pumped more water out of the ground, and the pull on the first satellite has been ever so slightly diminished, the GRACE satellites will be able to detect that change too.

Depletion of the world's aquifers, which supply at least one-third of humanity's water, has become a serious danger, Famiglietti said. GRACE data show that more than half the world's largest aquifers are being drained faster than they can refill, especially in the Arabian Peninsula, India, Pakistan, and North Africa.

Since California's drought began in 2011, the state has been losing about four trillion gallons a year (more than three and a half cubic miles) from the Sacramento and San Joaquin River Basins, Famiglietti said. That's more than the

Forest

WHAT THIS IS The Carnegie Airborne Observatory made this image of rain forest in Panama with a lidar device that probes the trees' shape and a spectrometer that charts chemical composition.

Carbon dioxide uptake

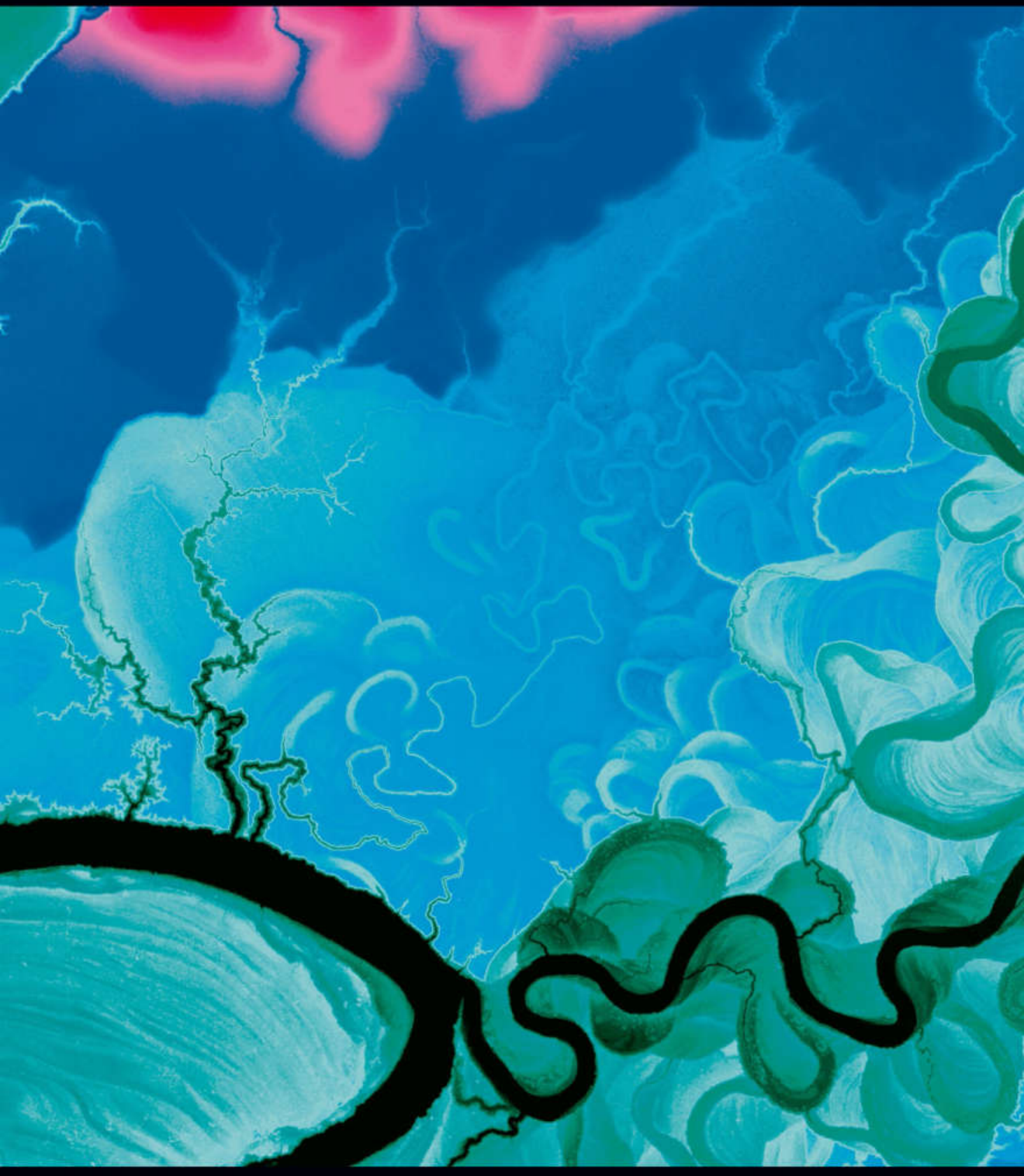
Slow — Fast

WHAT THIS TELLS US The technique allows Carnegie's Greg Asner and his team, flying at 7,000 feet, to identify individual trees from their chemical signatures—and even to say how healthy they are. The reddish trees here (the colors are arbitrary) are growing the fastest and absorbing the most CO_2.

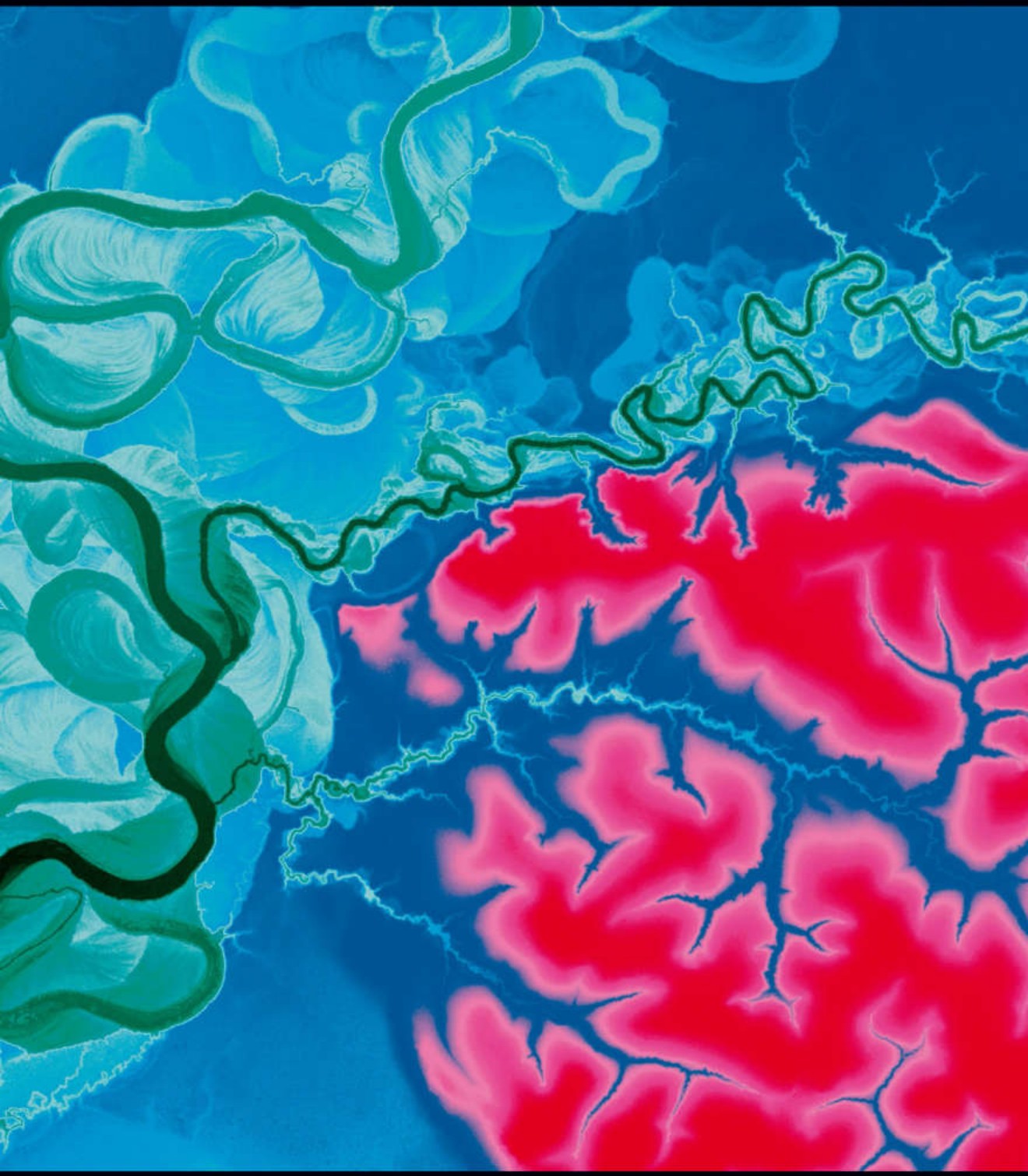
GREGORY ASNER, CARNEGIE INSTITUTION FOR SCIENCE

Water

WHAT THIS IS It's an image of the Tambopata River in eastern Peru made by the scanning lidar—a laser ranging device that works like radar—aboard the Carnegie observatory.



WHAT THIS TELLS US The area in this image is actually covered with rain forest. Some lidar pulses penetrate the forest and reflect off the ground, revealing the subtle topography—red is a few feet higher than blue—and faint, abandoned river channels that have shaped the forest and helped create its rich biodiversity.



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Land

WHAT THIS IS NASA's Aqua satellite captured these visible-light images of California and Nevada on March 27, 2010 (left), the most recent year with normal snowfall, and on March 29, 2015 (right).

WHAT THIS TELLS US After four years of drought, the snowpack in the Sierra Nevada—a crucial water reservoir for California—is just 5 percent of the historical average. Snow has virtually vanished from Nevada. And west of the Sierra, in the Central Valley, much of the fertile farmland is fallow and brown.

NASA (BOTH)

No one gets a better look at how we've transformed Earth—and conquered night—than astronauts on the space station. The view here is to the north over Portugal and Spain. The green band is the aurora.

annual consumption of the state's cities and towns. About two-thirds of the lost water has come from aquifers in the Central Valley, where pumping has caused another problem: Parts of the valley are sinking.

Tom Farr, a geologist at JPL, has been mapping this subsidence with radar data from a Canadian satellite orbiting some 500 miles up. The technique he used, originally developed to study earthquakes, can detect land deformations as small as an inch or two. Farr's maps have shown that in places, the Central Valley has been sinking by around a foot a year.

One of those places was a small dam near the city of Los Banos that diverts water to farms in the area. "We knew there was a problem with the dam, because water was starting to flow up over its sides," said Cannon Michael, president of Bowles Farming Company. "It wasn't until we got the satellite data that we saw how huge the problem was." Two sunken bowls had formed across a total of 3,600 square miles of farmland, threatening dams, bridges, canals, pipelines, and floodways—millions of dollars' worth of infrastructure. In late 2014 California governor Jerry Brown signed the state's first law phasing in restrictions on groundwater removal.

AS EVIDENCE HAS MOUNTED about Earth's maladies—from rising temperatures and ocean acidification to deforestation and extreme weather—NASA has given priority to missions aimed at coping with the impacts. One of its newest satellites, a $916 million observatory called SMAP (for Soil Moisture Active Passive), was launched in January. It was designed to measure soil moisture both by bouncing a radar beam off the surface and by recording radiation emitted by the soil itself. In July the active radar stopped transmitting, but the passive radiometer is still doing its job. Its maps will help scientists forecast droughts, floods, crop yields, and famines.

"If we'd had SMAP data in 2012, we easily could have forecast the big Midwest drought that took so many people by surprise," said Narendra N. Das, a research scientist at JPL. Few people expected the region to lose about $30 billion worth of crops that summer from a "flash drought"—a sudden heat wave combined with

NASA

unusually low humidity. "SMAP data could have shown early on that the region's soil moisture was already depleted and that if rains didn't come, then crops were going to fail," Das said. Farmers might not have bet so heavily on a bumper crop.

Climate change also is increasing the incidence of extreme rains—and SMAP helps with that risk too. It can tell officials when the ground has become so saturated that a landslide or a downstream flood is imminent. But too little water is a more pervasive and lasting threat. Without moisture in the soil, a healthy environment breaks down, as it has in California, leading to heat waves, drought, and wildfires. "Soil moisture is like human sweat," Das said. "When it evaporates, it has a cooling effect. But when the soil is devoid of moisture, Earth's surface heats up, like us getting heatstroke."

DESPITE ALL THE CHALLENGES to Earth's well-being, the planet so far has proved remarkably resilient. Of the 37 billion metric tons or so of carbon dioxide dumped into the atmosphere each year by human activities, oceans, forests, and grasslands continue to soak up about half. No one knows yet, however, at what point such sinks might become saturated. Until recently, researchers didn't have a good way to measure the flow of carbon in and out of them.

That changed in July 2014, when NASA launched a spacecraft called the Orbiting Carbon Observatory-2. Designed to "watch the Earth breathe," as managers put it, OCO-2 can measure with precision—down to one molecule per million—the amount of CO_2 being released or absorbed by any region of the world. The first global maps using OCO-2 data showed plumes of CO_2 coming from northern Australia, southern Africa, and eastern Brazil, where forests were being burned for agriculture. Future maps will seek to identify regions doing the opposite—removing CO_2 from the atmosphere.

Greg Asner and his team also have tackled the mystery of where all the carbon goes. Prior to flying over California's woodlands, they spent years scanning 278,000 square miles of tropical forests in Peru to calculate the forests' carbon content.

At the time, Peru was in discussions with international partners about ways to protect its rain forests. Asner was able to show that forest areas under the most pressure from logging, farming, or oil and gas development also were holding the most carbon—roughly seven billion tons. Preserving those areas would keep that carbon locked up, Asner said, and protect countless species. In late 2014 the government of Norway pledged up to $300 million to prevent deforestation in Peru.

> ***The spectrometer view would be like "Star Trek technology": We'd be able to see and name individual trees from space.***

Within the next few years NASA plans to launch five new missions to study the water cycle, hurricanes, and climate change, including a follow-up to GRACE. Smaller Earth-observing instruments, called CubeSats—some tiny enough to fit into the palm of a hand—will hitch rides into space on other missions. For scientists like Asner, the urgency is clear. "The world is in a state of rapid change," he said. "Things are shifting in ways we don't yet have the science for."

Within the next decade or so the first imaging spectrometer, similar to the ones used by Asner and Painter, could be put into Earth orbit. It would be like *"Star Trek* technology" compared with what's up there now, Painter said. "We've orbited Jupiter, Saturn, and Mars with imaging spectrometers, but we haven't had a committed program yet for our own planet," he said. The view from such a device would be amazing: We'd be able to see and name individual trees from space. And we'd be reminded of the larger forest: We humans and our technology are the only hope for curing what we've caused. ◻

Hanging in the Balance

When astronauts took the now famous photos, they saw a view like this: a foreground slice of moon to one side of Earth. When the photos were published, some were tipped so the moon formed a horizon below the "Earthrise." Ultimately, the angle wasn't what mattered. Once we beheld our home from space, our perspective was forever changed.

Those early whole-Earth views—this one from 1969's Apollo 11 mission—lent urgency and inspiration to a worldwide environmental movement. In the decades since, astronauts, satellites, and scientists have sharpened our view of the planet with revealing pictures and a vast library of observations. Every day we learn more about Earth's atmosphere, water, land—and our impact upon it. The health of a tiny blue planet is at risk. What will we do with what we know? *—Dennis Dimick*

PHOTO: NASA

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