



how much is left?

A graphical accounting of the limits
to what one planet can provide

<< BY MICHAEL MOYER >>

WITH REPORTING BY CARINA STORRS

IF THE 20TH CENTURY was an expansive era seemingly without boundaries—a time of jet planes, space travel and the Internet—the early years of the 21st have showed us the limits of our small world. Regional blackouts remind us that the flow of energy we used to take for granted may be in tight supply. The once mighty Colorado River, tapped by thirsty metropolises of the desert West, no longer reaches the ocean. Oil is so hard to find that new wells extend many kilometers underneath the seafloor. The boundless atmosphere is now

reeling from two centuries' worth of greenhouse gas emissions. Even life itself seems to be running out, as biologists warn that we are in the midst of a global extinction event comparable to the last throes of the dinosaurs.

The constraints on our resources and environment—compounded by the rise of the middle class in nations such as China and India—will shape the rest of this century and beyond. Here is a visual accounting of what we have left to work with, a map of our resources plotted against time.

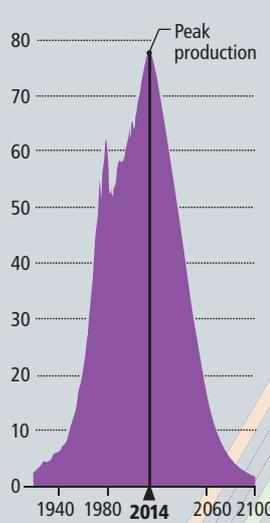
▶ Experience an interactive version of this article at www.ScientificAmerican.com/interactive

[FOSSIL FUELS]

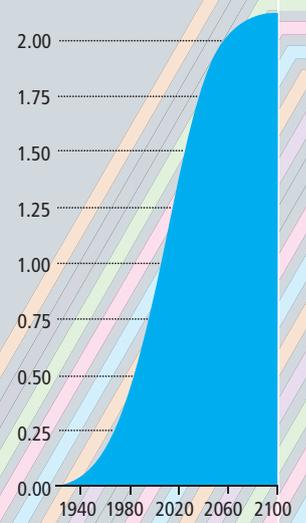
2014 >> THE PEAK OF OIL

The most common answer to "how much oil is left" is "depends on how hard you want to look." As easy-to-reach fields run dry, new technologies allow oil companies to tap harder-to-reach places (such as 5,500 meters under the Gulf of Mexico). Traditional statistical models of oil supply do not account for these advances, but a new approach to production forecasting explicitly incorporates multiple waves of technological improvement. Though still controversial, this multi-cyclic approach predicts that global oil production is set to peak in four years and that by the 2050s we will have pulled all but 10 percent of the world's oil from the ground.

World Production Rate
Million barrels per day



World Cumulative Production
Trillion barrels



[WATER]

1976-2005 >> GLACIER MELT ACCELERATES

Glaciers have been losing their mass at an accelerating rate in recent decades. In some regions such as Europe and the Americas, glaciers now lose more than half a meter each year.

Annual Change in Glacier Thickness

- Gain
- Loss
- Up to 0.25 m
- More than 0.25 m
- No data



[MINERALS]

2028 >> INDIUM

Indium is a silvery metal that sits next to platinum on the periodic table and shares many of its properties such as its color and density. Indium tin oxide is a thin-film conductor used in flat-panel televisions. At current production levels, known indium reserves contain an 18-year world supply.

[WATER]

2025 >> BATTLE OVER WATER

In many parts of the world, one major river supplies water to multiple countries. Climate change, pollution and population growth are putting a significant strain on supplies. In some areas renewable water reserves are in danger of dropping below the 500 cubic meters per person per year considered a minimum for a functioning society.

- Asia
- North Africa
- Middle East
- Europe

POTENTIAL HOT SPOTS

EGYPT: A coalition of countries led by Ethiopia is challenging old agreements that allow Egypt to use more than 50 percent of the Nile's flow. Without the river, all of Egypt would be desert.

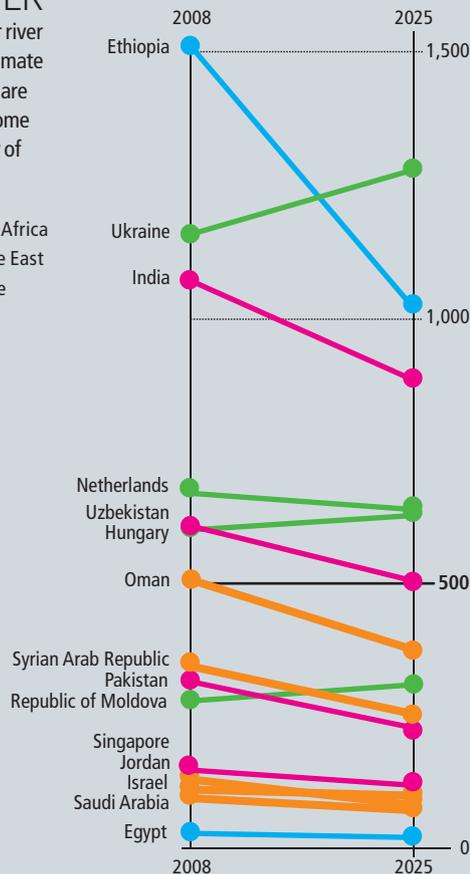
EASTERN EUROPE: Decades of pollution have fouled the Danube, leaving downstream countries, such as Hungary and the Republic of Moldova, scrambling to find new sources of water.

MIDDLE EAST: The Jordan River, racked by drought and diverted by Israeli, Syrian and Jordanian dams, has lost 95 percent of its former flow.

FORMER SOVIET UNION: The Aral Sea, at one time the world's fourth-largest inland sea, has lost 75 percent of its water because of agricultural diversion programs begun in the 1960s.

DRYING OUT

Total Renewable Water per Capita
Cubic meters per person per year



[MINERALS]

2029 >> SILVER

Because silver naturally kills microbes, it is increasingly used in bandages and as coatings for consumer products. At current production levels, about 19 years' worth of silver remains in the ground, but recycling should extend that supply by decades.

[FOOD]

>> FEWER FISH

Fish are our last truly wild food, but the rise in demand for seafood has pushed many species to the brink of extinction. Here are five of the most vulnerable.



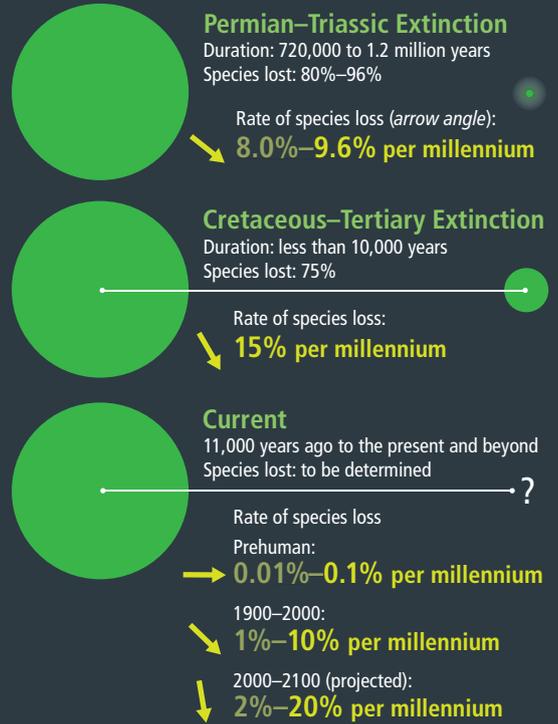
HAMMERHEAD SHARKS have declined by 89 percent since 1986. The animals are sought for their fins, which are a delicacy in soup.

JASON LEE (fish)

[BIODIVERSITY]

>> OUR MASS EXTINCTION

Biologists warn that we are living in the midst of a mass extinction on par with the other five great events in Earth's history, including the Permian-Triassic extinction (also known as the Great Dying; it knocked out up to 96 percent of all life on Earth) and the Cretaceous-Tertiary extinction that killed the dinosaurs. The cause of our troubles? Us. Human mastery over the planet has pushed many species out of their native habitats; others have succumbed to hunting or environmental pollutants. Here we compare our current extinction with its predecessors using the latest estimates of species loss per year. If trends continue—and unfortunately, species loss is accelerating—the world will soon be a far less diverse place.



[MINERALS]

2030 >> GOLD

The global financial crisis has boosted demand for gold, which is seen by many as a tangible (and therefore lower-risk) investment. According to Julian Phillips, editor of the *Gold Forecaster* newsletter, probably about 20 years are left of gold that can be easily mined.



RUSSIAN STURGEON
have lost spawning grounds because of exploitation for caviar. Numbers are down 90 percent since 1965.



YELLOWMOUTH GROUPER
may exist only in pockets of its former range, from Florida to Brazil.



EUROPEAN EEL
populations have declined by 80 percent since 1968; because the fish reproduces late in life, recovery could take 200 years.



ORANGE ROUGHY
off the coast of New Zealand have declined by 80 percent since the 1970s because of overfishing by huge bottom trawlers.

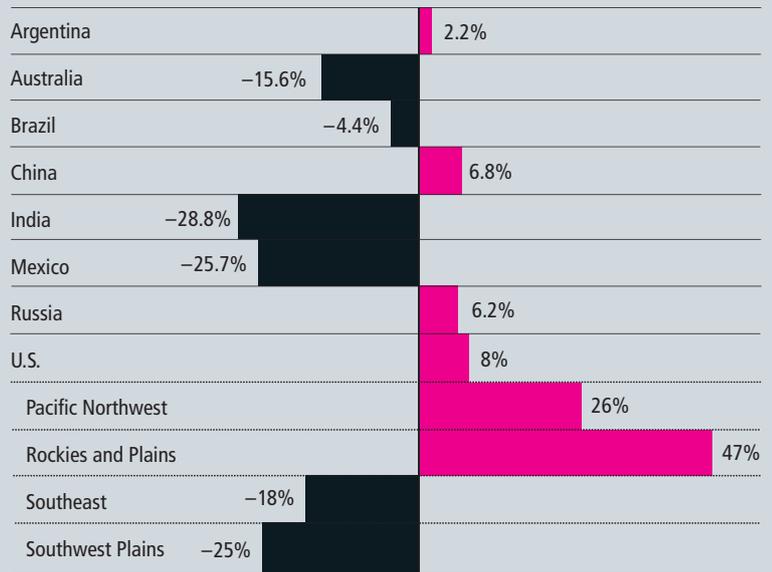
[FOOD]

2050 >> FEEDING A WARMING WORLD

Researchers have recently started to untangle the complex ways rising temperatures will affect global agriculture. They expect climate change to lead to longer growing seasons in some countries; in others the heat will increase the frequency of extreme weather events or the prevalence of pests. In the U.S., productivity is expected to rise in the Plains states but fall further in the already struggling Southwest. Russia and China will gain; India and Mexico will lose. In general, developing nations will take the biggest hits. By 2050 counteracting the ill effects of climate change on nutrition will cost more than \$7 billion a year.

The Effects of Global Warming on Agriculture

Percent change in production for the world's eight largest growers (by the 2080s)



[MINERALS]

2044 >> COPPER

Copper is in just about everything in infrastructure, from pipes to electrical equipment. Known reserves currently stand at 540 million metric tons, but recent geologic work in South America indicates there may be an additional 1.3 billion metric tons of copper hidden in the Andes Mountains.

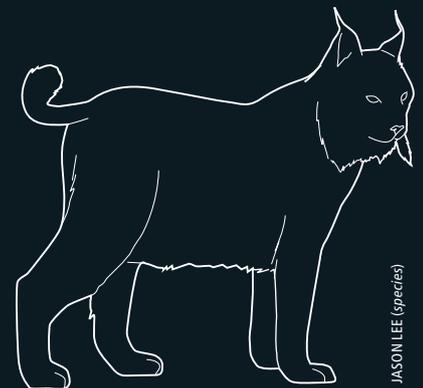
[BIODIVERSITY]

MORTAL THREATS

As the total number of species declines, some have fared worse than others [see "Our Mass Extinction," on preceding page]. Here, at the right, are five life-forms, the estimated percentage of species thought to be endangered, and an example of the threats they face.

MAMMALS
18 percent endangered

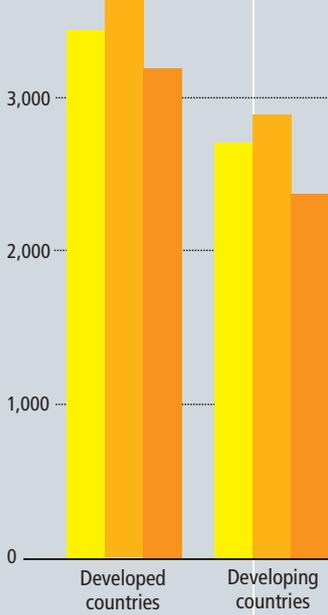
The **Iberian lynx** feeds on rabbits, a prey in short supply in the lynx's habitat ever since a pediatrician introduced the disease myxomatosis from Australia to France in 1952 to kill the rabbits in his garden.



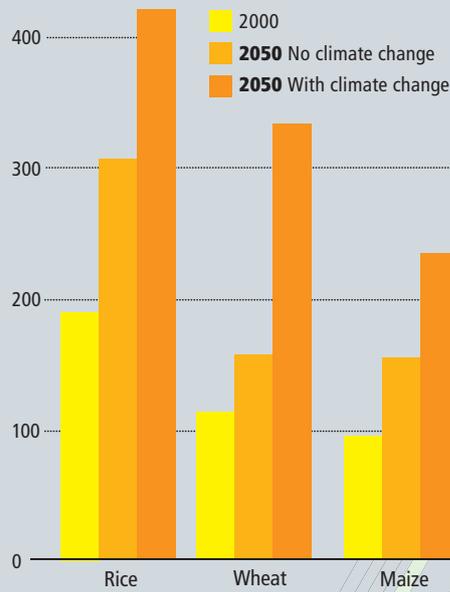
JASON LEE (Species)

2050

Daily per Capita Calorie Availability



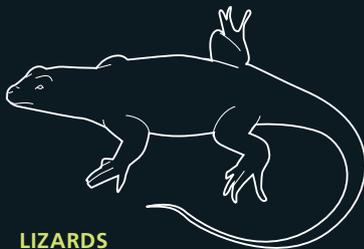
Food Prices (U.S. dollars per metric ton)



PLANTS

8 percent endangered

The **St. Helena redwood** is native to the island in the South Atlantic where Napoleon lived his last years. Its excellent timber led to exploitation; by the 20th century only one remained in the wild.



LIZARDS
20 percent endangered

The **blue spiny lizard** must retreat from the sun before it overheats; higher temperatures have cut down on the time it can forage for food.



BIRDS
10 percent endangered

The **black-necked crane** suffers from habitat loss in the wetlands of the Tibetan plateau.



AMPHIBIANS
30 percent endangered

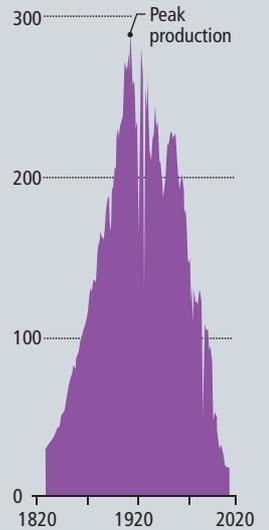
Archey's frog has been devastated by a fungal disease in its native New Zealand.

[FOSSIL FUELS]

2072 >> LIMITS OF COAL

Unlike oil, coal is widely thought to be virtually inexhaustible. Not so, says David Rutledge of the California Institute of Technology. Governments routinely overestimate their reserves by a factor of four or more on the assumption that hard-to-reach seams will one day open up to new technology. Mature coal mines show that this has not been the case. The U.K.—the birthplace of coal mining—offers an example. Production grew through the 19th and early 20th centuries, then fell as supplies were depleted. Cumulative production curves in the U.K. and other mature regions have followed a predictable S shape. By extrapolating to the rest of the world's coal fields, Rutledge concludes that the world will extract 90 percent of available coal by 2072.

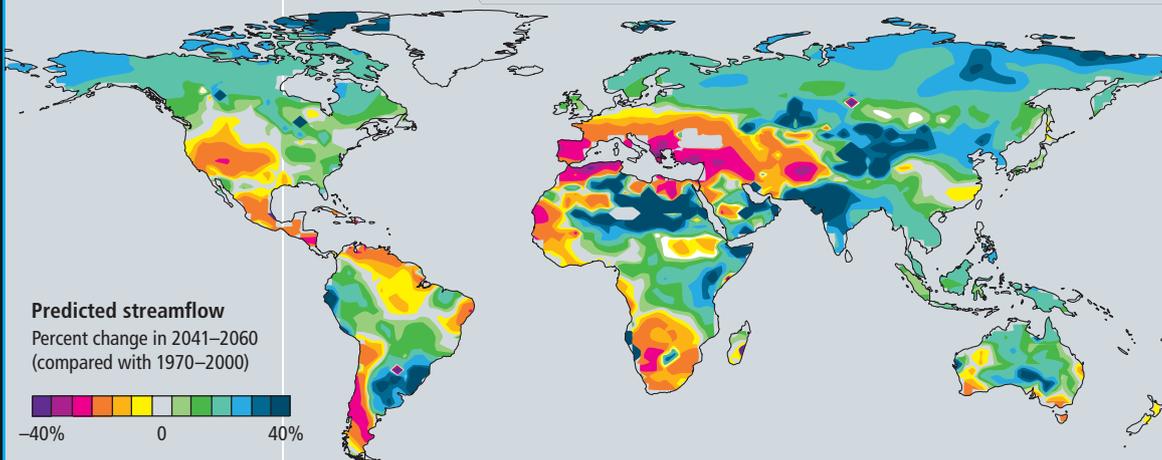
Annual Production (U.K.)
Millions of metric tons



[WATER]

2060 >> CHANGING THE COURSE OF A RIVER

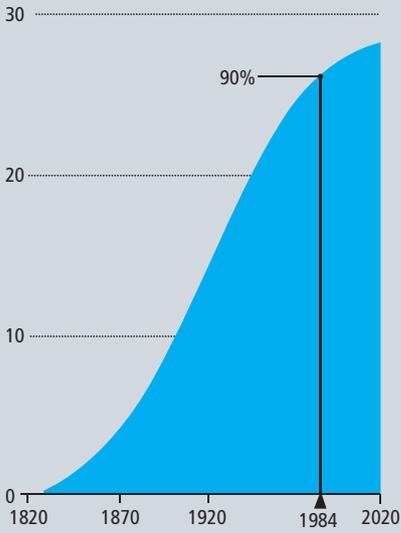
Climate change will shift weather patterns, leading to big changes in the amount of rain that falls in any given region, as well as the amount of water flowing through streams and rivers. Scientists at the U.S. Geological Survey averaged the results of 12 climate models to predict how streamflow will alter over the next 50 years. While East Africa, Argentina and other regions benefit from more water, southern Europe and the western U.S. will suffer.



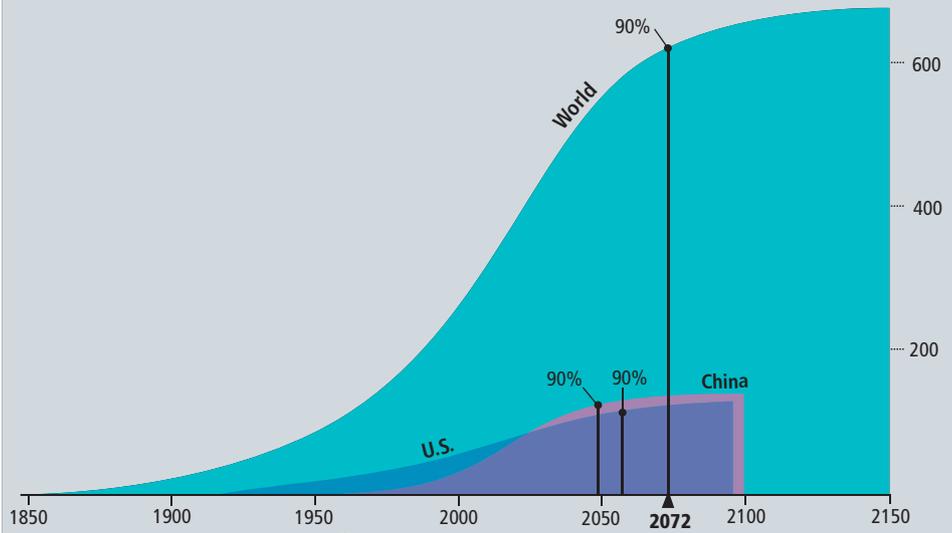
Predicted streamflow
Percent change in 2041–2060
(compared with 1970–2000)

JESSICA HUPPI (map)

Cumulative Production (U.K.)
Billions of metric tons



Projected Cumulative Production
Billions of metric tons



[WATER]

2070 >> HIMALAYAN ICE

Snow melt from the Himalayas is a prime source of water for Asia's major river valleys, including the Yellow, Yangtze, Mekong and Ganges. By 2070 ice-covered landmass in the Himalayas could decrease by 43 percent.

[WATER]

2100 >> THE ALPS

Parts of the Alps are warming so quickly that the Rhone Glacier is expected to have disappeared by the end of the century.

[MINERALS]

2560 >> LITHIUM

Because lithium is an essential component of the batteries in electric cars, many industry analysts have worried publicly that supplies won't keep up with growing demand for the metal. Still, known lithium reserves are big enough to keep us supplied for more than five centuries, even ignoring the vast supply of lithium in seawater.

[SOURCES]

WATER *Global Glacier Changes: Facts and Figures*. U.N. Environment Program/World Glacier Monitoring Service, 2008; AQUASTAT Database, U.N. Food and Agriculture Organization; "Global Pattern of Trends in Streamflow and Water Availability in a Changing Climate," by P.C.D. Milly et al., in *Nature*, Vol. 438; Nov. 17, 2005. **FOOD** *Climate Change: Impact on Agriculture and Costs of Adaptation*, by Gerald C. Nelson et al. International Food Policy Research Institute, Washington, D.C., 2009; *Global Warming and Agriculture: Impact Estimates by Country*, by William R. Cline. Center for Global Development, Washington, D.C., 2007. **OIL** "Forecasting World Crude Oil Production Using Multicyclic Hubbert Model," by Ibrahim Sami Nashawi et al., in *Energy Fuels*, Vol. 24, No. 3; March 18, 2010. **COAL** David Rutledge, submission to *International Journal of Coal*

Geology, 2010. **MINERALS** *Mineral Commodity Summaries 2010*. U.S. Geological Survey. **BIODIVERSITY** "Consequences of Changing Biodiversity," by F. Stuart Chapin III et al., in *Nature*, Vol. 405; May 11, 2000; "Quantifying the Extent of North American Mammal Extinction Relative to the Pre-Anthropogenic Baseline," by Marc A. Carrasco et al., in *PLoS ONE*, Vol. 4, No. 12; Dec. 16, 2009; "Re-assessing Current Extinction Rates," by Nigel E. Stork, in *Biodiversity Conservation*, Vol. 19, No. 2; Feb. 2010; "The Future of Biodiversity," by Stuart L. Pimm et al., in *Science*, Vol. 269; July 21, 1995; "Are We in the Midst of the Sixth Mass Extinction? A View from the World of Amphibians," by David B. Wake and Vance T. Vredenburg, in *Proceedings of the National Academy of Sciences USA*, Vol. 105, Supplement 1; Aug. 12, 2008.