DK

800 MILLION
PEOPLE WORLDWIDE ARE UNDERNOURISHED

AIR POLLUTION KILLS MORE THAN
3 MILLION
PEOPLE EACH YEAR

CITIES CONSUME
75%
OF THE WORLD'S NATURAL RESOURCES

200 SPECIES OF PLANTS, INSECTS, BIRDS, AND MAMMALS BECOME EXTINCT EVERY 24 HOURS

# HOW WE'RE F***ING UP OUR PLANET

## THE FACTS visually explained

SEA LEVEL HAS RISEN BY
7 INCHES
IN THE LAST 100 YEARS

Tony Juniper

Content previously published as *What's Really Happening to Our Planet?*

# HOW WE'RE F***ING UP OUR PLANET

TONY JUNIPER

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# 1 Drivers of Change

# 2 Consequences of Change

# 3 Bending the Curves




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**Dr. Tony Juniper** CBE is an internationally recognized campaigner, writer, sustainability adviser, and environmentalist. For more than 30 years, he has worked for change toward a more sustainable society at local, national, and international levels. A regular speaker and participant at international conferences and symposia, he has also authored and coauthored numerous books about our changing environment, including multi-award-winning best sellers.
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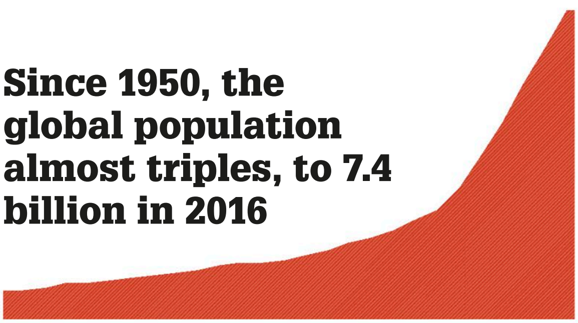
Madeleine Juniper

# Introduction

**In recent decades, the face of planet Earth has been changed forever. The effects of population and economic growth, coupled with rising demand for resources and environmental impacts, have left their mark. These trends and their repercussions now raise vitally important questions about the future of the world and how we can successfully manage and sustain it.**

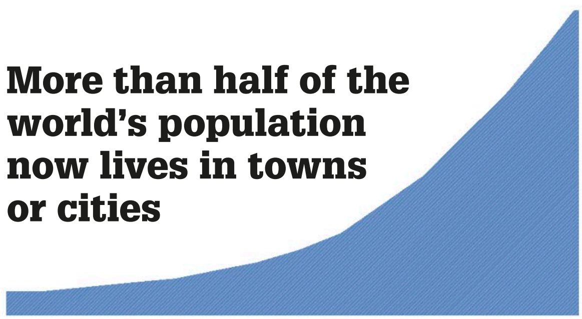
Understanding the scale and scope of the changes, and the connections between them, is vital to make sense of our modern world and anticipate where it is headed next. The implications touch all areas of our lives, from business and finance to politics and economics, and from science and technology to behavior and culture.

**Since 1950, the global population almost triples, to 7.4 billion in 2016**



POPULATION EXPLOSION

**More than half of the world's population now lives in towns or cities**

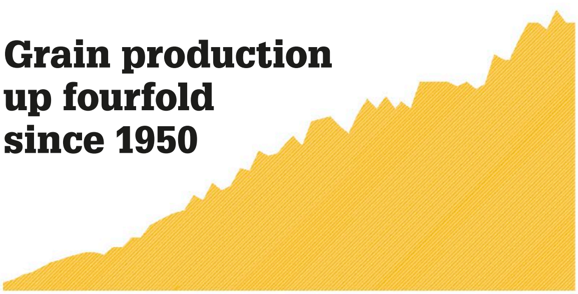


ESCALATING URBANIZATION

## Population boom

The drivers behind the ongoing shifts shaping our future are fundamental. The number of people living on Earth is rising rapidly. In 1950, there were 2.5 billion people, and today this figure has almost trebled. Going forward, the global population is expected to rise by 80 million a year—about equivalent to the population of Germany. By 2050, our number is predicted to exceed 9 billion. But the impact of people on the world arises not only from how many of us there are but also from the standard of living that people experience. This is why the rapid expansion of the global economy seen during recent decades is another fundamental driver, enabling more people to enjoy the comforts and benefits that come with increased income and consumption.

Economic growth and rising living standards have in part been fueled by rapid urbanization and the progressive shift of people from rural areas to towns and cities. During recent decades, the process that began with the industrial revolution in England during the 18th century has spread worldwide. In 2007, and for the first time in human history, more than half of the people on Earth lived in urban environments.




EXPANDING FOOD NEEDS

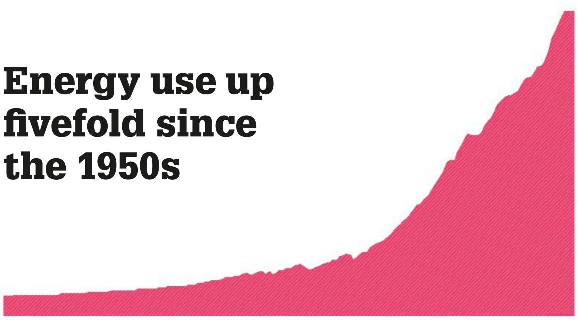

RAPID ECONOMIC GROWTH

By 2050, the proportion will be closer to two-thirds. People living in urban areas tend to be higher consumers than those in rural environments, using more energy and materials, and generating more waste. Population growth, economic development, and urbanization have converged to rapidly increase the demand for a wide range of essential resources, including energy, freshwater, food, wood, and minerals.

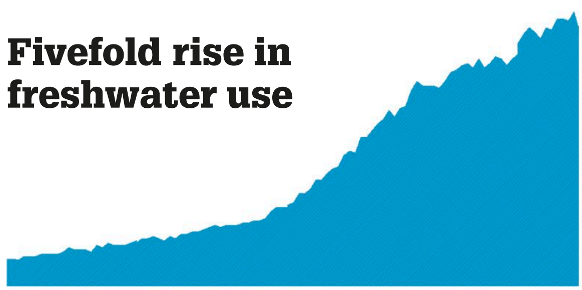
## Progress and problems

Despite concerns as to our ability to increase the supply of resources to keep pace with demand, we have so far been broadly successful and in the process most social indicators have improved. For example, billions of people have safer water supplies, the number of literate people has increased, the number of people living in abject poverty has gone down, and various health indicators, such as those relating to child mortality and contagious diseases, have improved. We are also more globally connected, with billions of people enjoying access to technology and consumer goods traded through supply chains that span the planet.

But alongside these measures of progress are a number of less positive consequences. Earth's atmosphere now has a higher




GROWTH IN FOSSIL FUEL USE



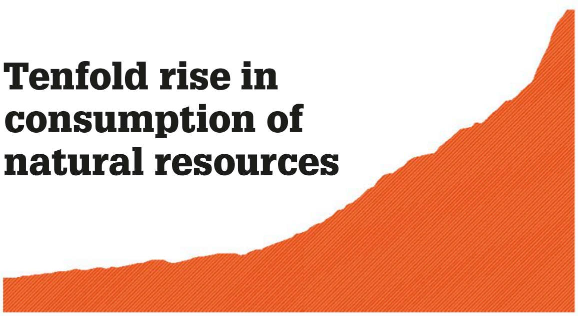

RISING FRESHWATER USE

concentration of greenhouse gases than at any time for at least 800,000 years. This is already causing climate change, leading to more extreme conditions, increased economic costs, and major humanitarian impacts. The fossil fuel combustion and forest fires driving climate change are also resulting in air pollution that kills millions of people every year.

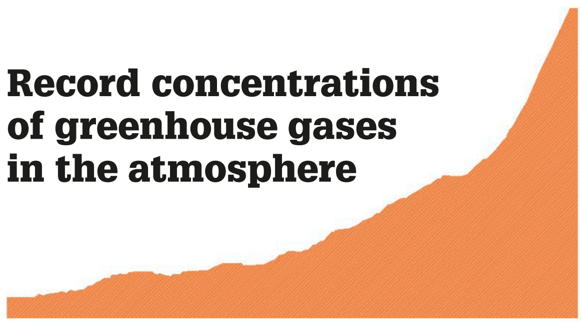
In addition, the depletion of different resources essential for human well-being is also leading toward economic and social strains. Freshwater and fish stocks are experiencing greater pressures. Soil damage is a worldwide problem, as is deforestation and the decline of species diversity. The scale of ecosystem degradation means that a mass extinction of animals and plants is gathering momentum. This could soon lead to the greatest loss of diversity since the dinosaurs were wiped out 65 million years ago. All these changes and many more will increasingly affect economic growth and development and ultimately threaten to reverse social gains.

## Saving the planet

Increased awareness of these fundamental trends has resulted in attempts to find solutions. Some of these have had a positive




RISING USE OF RESOURCES



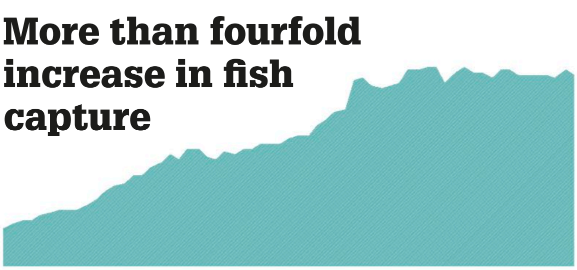

ESCALATING CARBON DIOXIDE EMISSIONS

impact, although they have been rendered more difficult to realize because of advocacy for the status quo from vested interests, political short-termism, and the corruption that diverts essential resources from environmental and development programs. The need to find ways to overcome these barriers in order to reconcile the connected social, economic, and environmental trends becomes more pressing each day.

Fortunately, there is a rich body of data, analysis, and examples to show what can be done going forward. Drawing upon this in order to lay foundations fit for the future will not be easy, but for everyone wishing to play a part in achieving positive and sustainable outcomes in the years ahead, understanding the full range of trends and developments is a vital starting point.

### Future thinking

Together with many other goals and aims, the future will be shaped by the implementation of the Sustainable Development Goals and the Paris Climate Change Agreement, both adopted in 2015. In 2020 the world will also hopefully adopt a new accord under the United Nations




TAKING FISH FROM THE SEA


GROWTH IN GLOBALIZATION

Convention on Biological Diversity to stop the mass extinction of wildlife that is now taking place. To achieve their aims of environmentally sustainable progress will require not only new levels of international cooperation, technology, and business models but also a rethinking of economics and political priorities.

To do this requires a broad understanding of the world today—and that is what this book is for. These pages provide a snapshot of what is happening on planet Earth, explaining the facts behind many of the most important issues. The most recent data and information have been used to ensure that the current trends and developments are clearly explained and understood.

The hope is that readers will find the material both accessible and inspiring, using it to enlighten and empower as together we write the next chapters of human history.

**DR. TONY JUNIPER**

## Human consumption of Earth's renewable productivity doubles

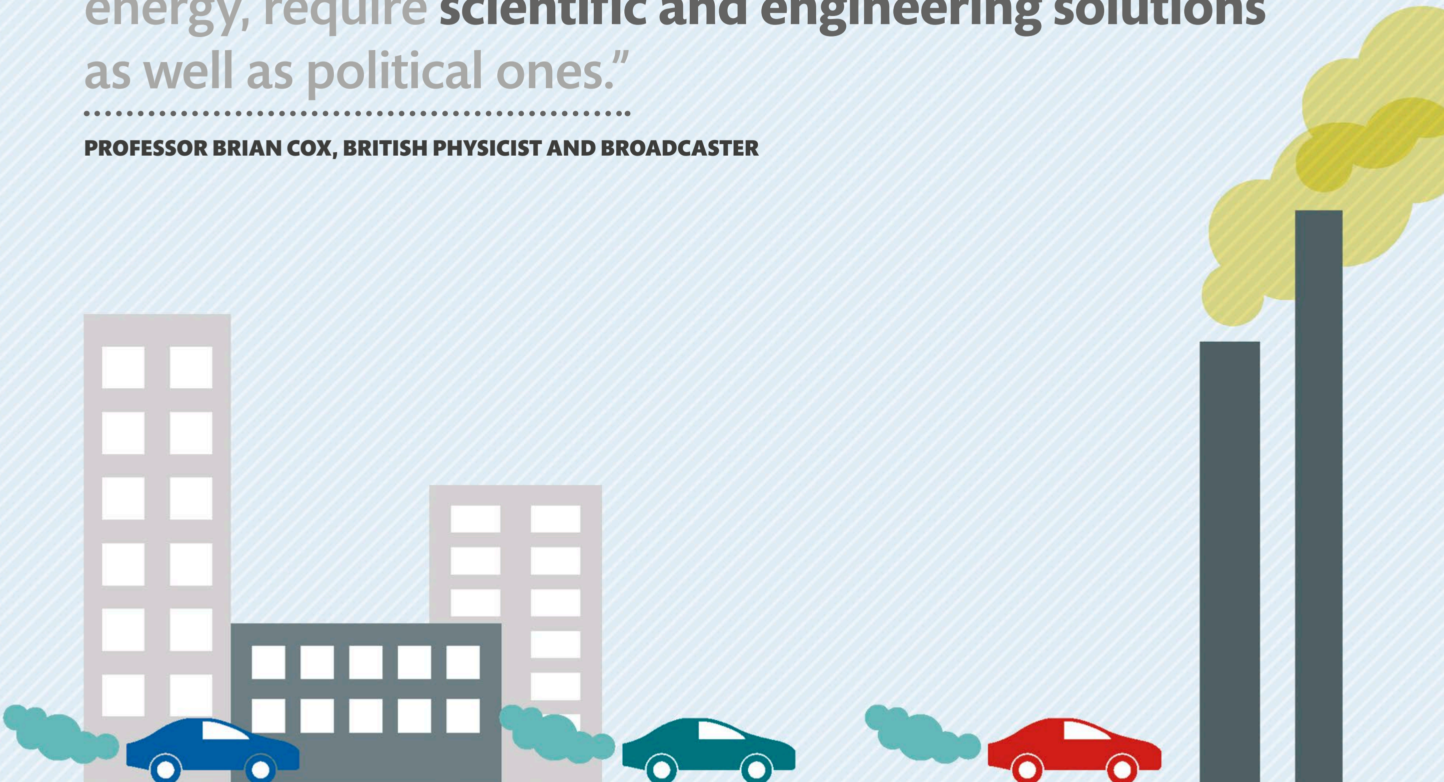
RISING LAND USE BY HUMANS

## Mass extinction of animals and plants gathers momentum

SPECIES DECLINE

"The **grand challenges of our age,** such as climate change and the ever-increasing appetite of our planet's **rapidly expanding population** for clean water and energy, require **scientific and engineering solutions** as well as political ones."

**PROFESSOR BRIAN COX, BRITISH PHYSICIST AND BROADCASTER**



**The Population Explosion**

**Economic Expansion**

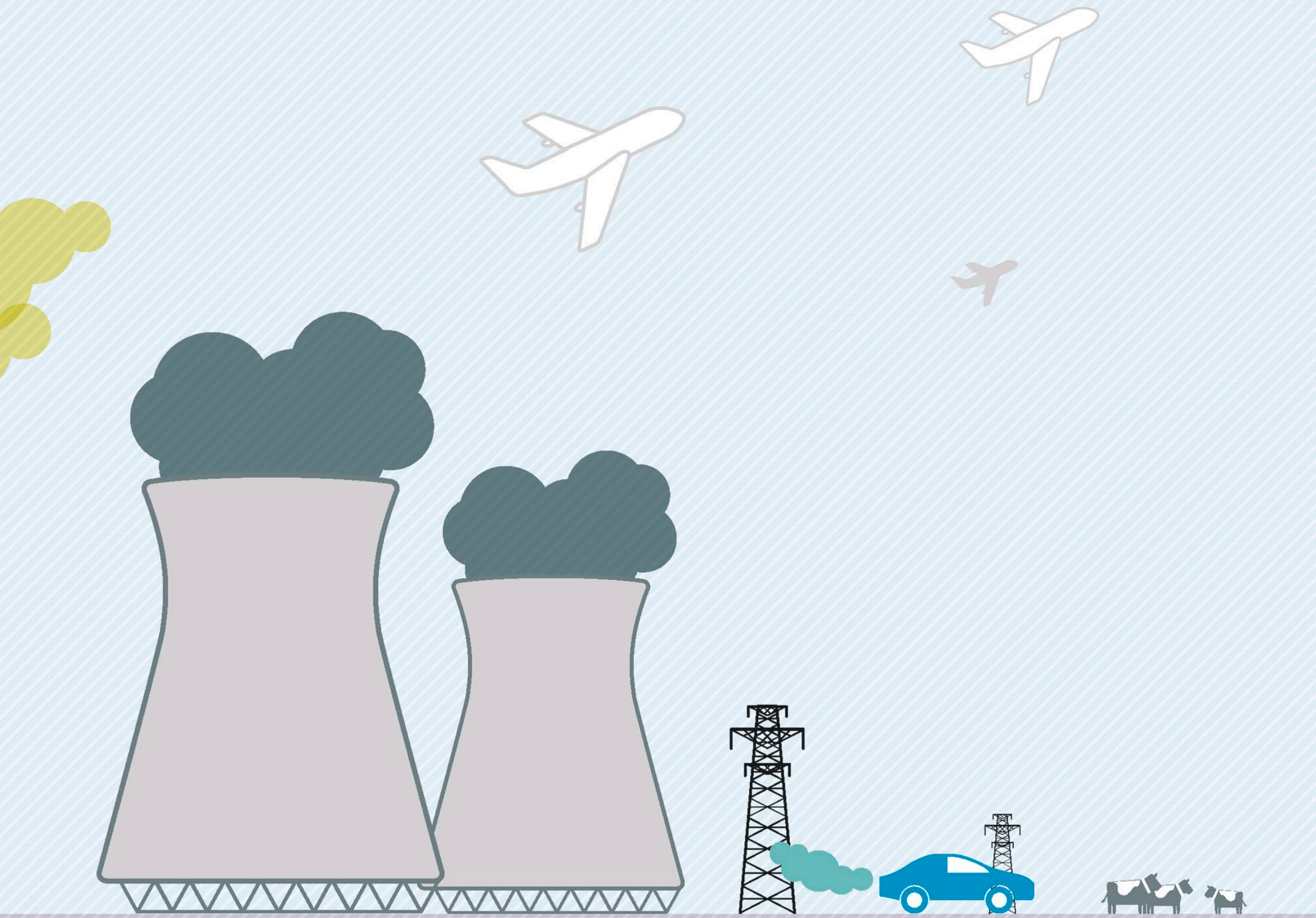
**City Planet**

**Fuel for Growth**

**Escalating Appetite**

**Thirsty World**

**Consuming Passions**



# 1 DRIVERS OF CHANGE

Rapid change is being driven by a series of powerful and interconnected trends. Working together, they are transforming humankind's impacts on the natural systems that sustain life.

# The Population Explosion

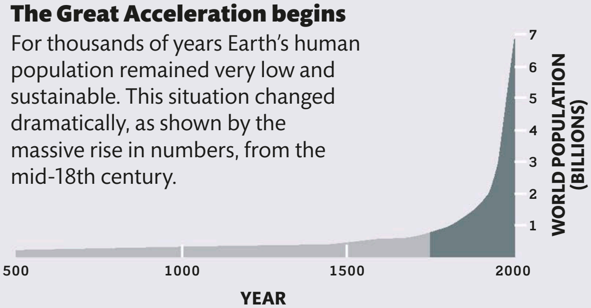
**Of all the trends shaping our changing world, the rapid increase in the human population is perhaps the most fundamental. More people create a greater demand for food, energy, water, and other resources, driving pressures on the natural environment and atmosphere. Although the rate of increase is now slowing down, human numbers rose massively during the 20th century. Our population continues to increase at a rate of over 200,000 per day, or about 80 million a year—annually adding the equivalent of the population of Germany.**

## Expanding planet

Modern population growth began around 1750, with improved food production and distribution, which lowered mortality rates during the 18th century. The 19th century introduced improved sanitation and other developments that contributed to foster better public health, and during the 20th century the growth rate accelerated at an unprecedented level. It is expected that by 2024, there will be eight billion of us on planet Earth—and by 2050, over nine billion.

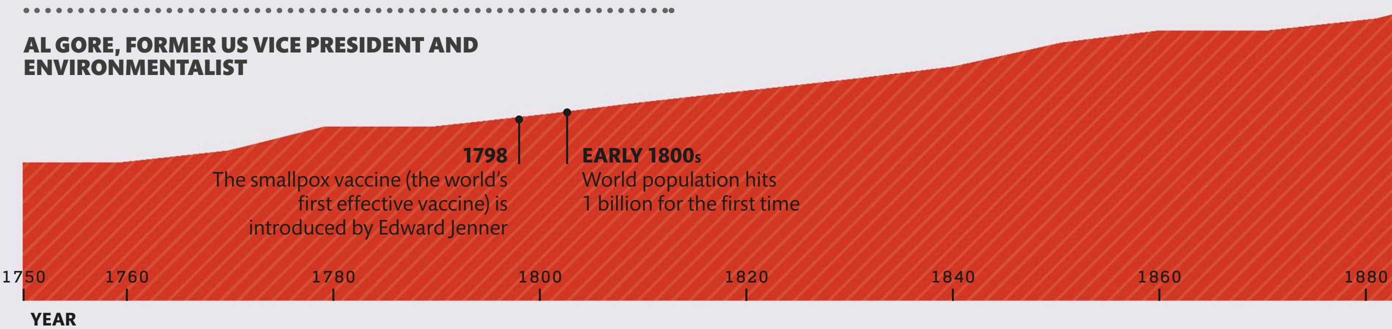
**The Great Acceleration begins**

For thousands of years Earth's human population remained very low and sustainable. This situation changed dramatically, as shown by the massive rise in numbers, from the mid-18th century.



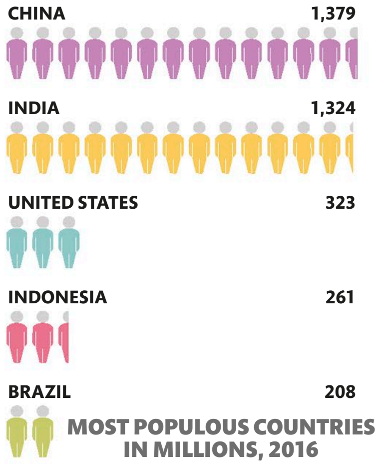

> "**Population growth** is straining the world's resources to **breaking point.**"

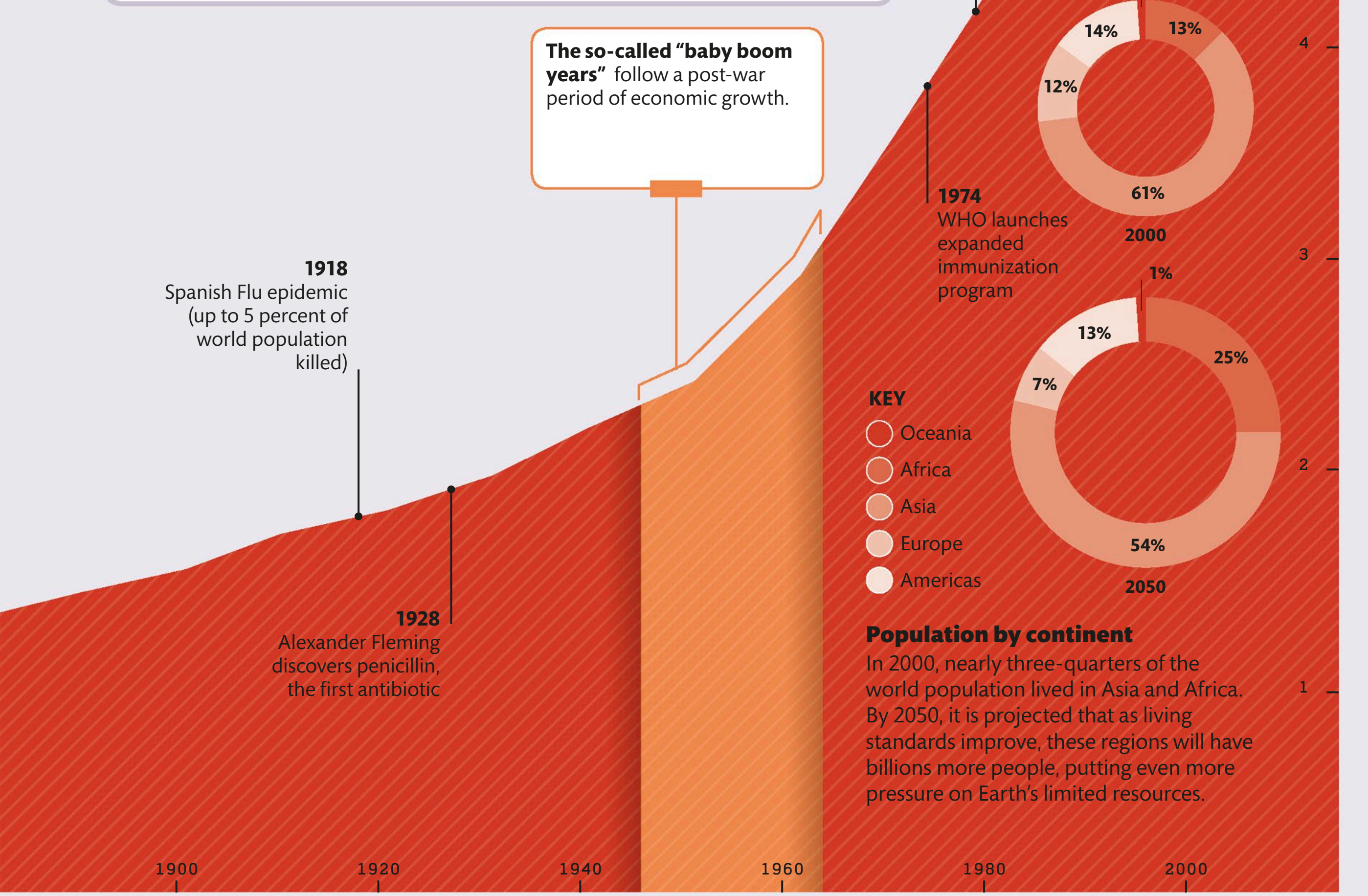
**AL GORE, FORMER US VICE PRESIDENT AND ENVIRONMENTALIST**



## AN INCREASINGLY CROWDED WORLD

In the early years of the 19th century, the world's total population passed one billion. In 1959, the population crossed the three billion mark, and 15 years later, it reached four billion. By 1987, there were five billion people on the planet, six billion in 1999, and in 2011 that figure swelled to seven billion. Today, just five countries are home to more than 3.4 billion people—nearly half of the current global total, and three times the population of Earth in the 19th century.




**Population by continent**
In 2000, nearly three-quarters of the world population lived in Asia and Africa. By 2050, it is projected that as living standards improve, these regions will have billions more people, putting even more pressure on Earth's limited resources.

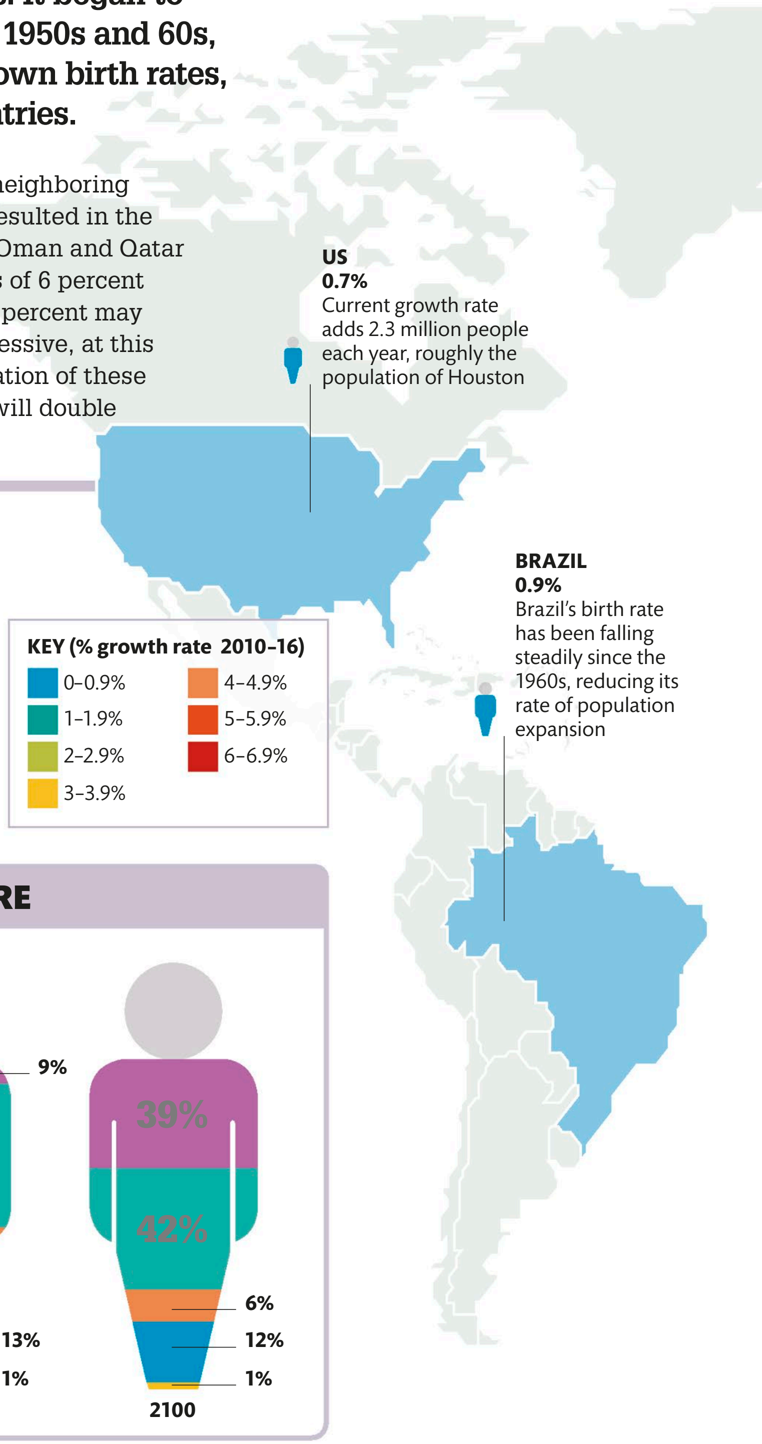
# Population Shift

**From 1800, population grew in all regions. It began to slow down in richer countries during the 1950s and 60s, as wealth, health, and education drove down birth rates, but growth continued in developing countries.**

High birth rates, improvements in medical care, and the influence and movements of migratory workers all contribute to high population growth rates around the world. In the past five years, the biggest population shift has taken place in the Middle East, where the promise of jobs as well as conflicts in neighboring countries has resulted in the populations of Oman and Qatar rising in excess of 6 percent a year. While 6 percent may not sound impressive, at this rate, the population of these two countries will double in 12 years.

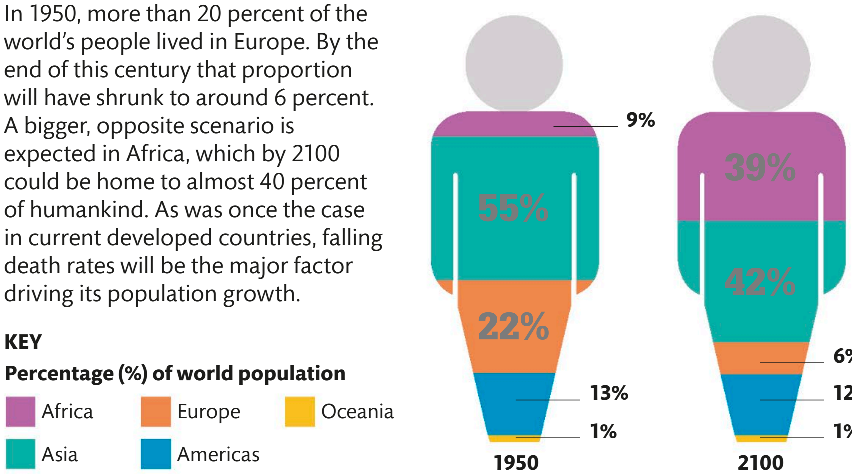
## Earth's changing profile

Populations in many of the most developed countries are now either stable or growing, primarily because of immigration. The highest percentage growth rates are currently mainly in Africa, which is why the number of people living in that continent is set to more than triple from about 1.2 billion today to more than four billion by 2100. In 2050 roughly 90 percent of the world population is expected to reside in countries currently regarded as developing (up from about 80 percent today).



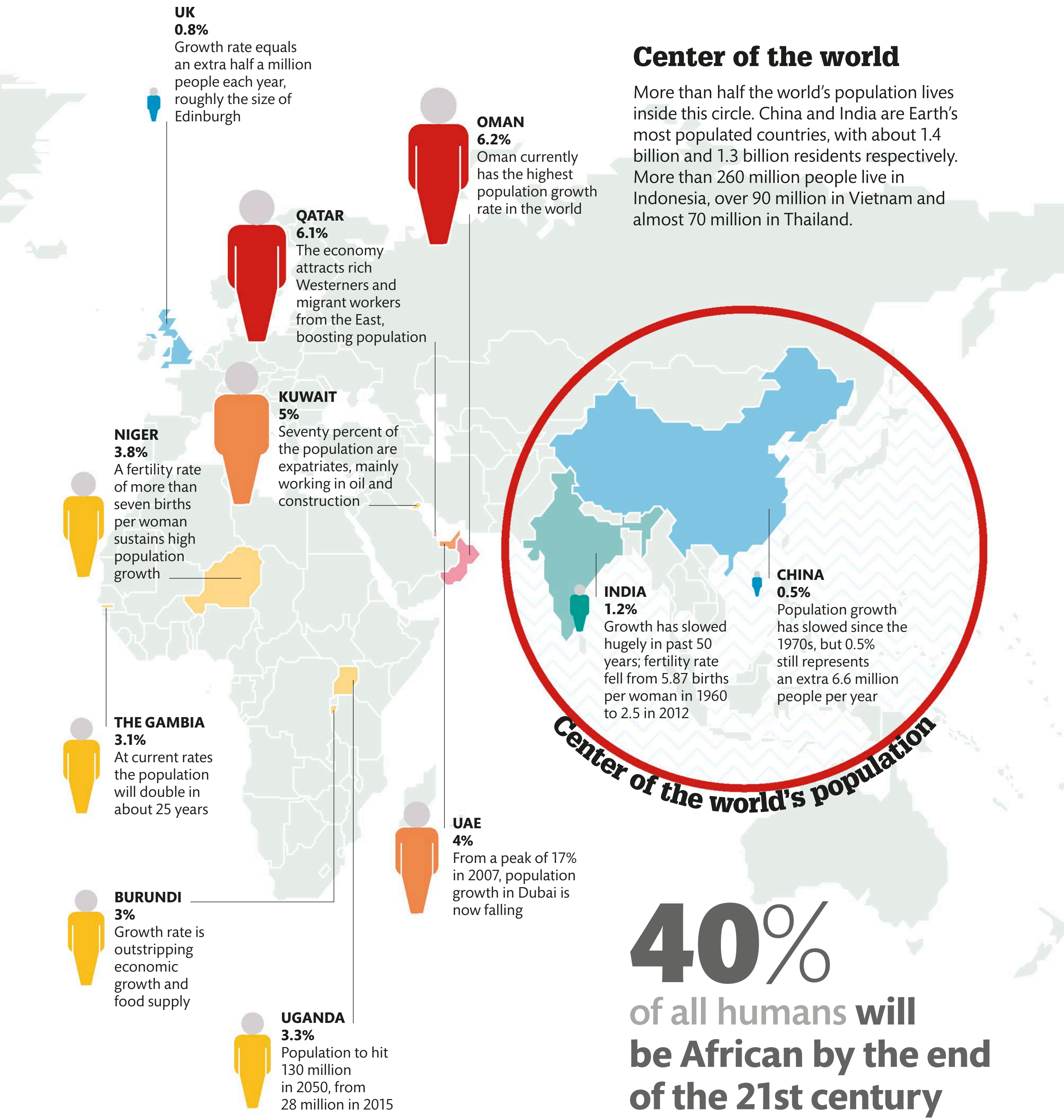

## WHO LIVES WHERE, PAST AND FUTURE

In 1950, more than 20 percent of the world's people lived in Europe. By the end of this century that proportion will have shrunk to around 6 percent. A bigger, opposite scenario is expected in Africa, which by 2100 could be home to almost 40 percent of humankind. As was once the case in current developed countries, falling death rates will be the major factor driving its population growth.



## Center of the world

More than half the world's population lives inside this circle. China and India are Earth's most populated countries, with about 1.4 billion and 1.3 billion residents respectively. More than 260 million people live in Indonesia, over 90 million in Vietnam and almost 70 million in Thailand.




**40%**

of all humans **will be African by the end of the 21st century**

# Living Longer

**Since the beginning of recorded history, young children have outnumbered those reaching old age—at least until very recently. Today, there are more people on the planet aged 65 and older than those aged five and under.**

As both the average length of life and the global proportion of older people have increased, a situation without precedent has emerged, raising many important questions we have no way of answering. For example, will the aging trend be accompanied by longer periods of good health in old age? Will there be new opportunities for different roles for older people in society? How will societies cope with a much higher proportion of retired people, many of whom will not be paying income tax?

Driven by falling fertility rates and a remarkable increase in life expectancy, population aging will continue to accelerate. Where today's employed population falls typically between the ages of 20 and 65, in future a higher proportion of healthy older people may remain employed, vying with younger workers trying to find jobs.

**SEE ALSO...**

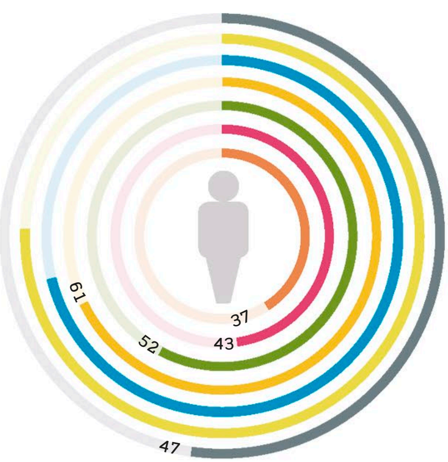
- **Slowing the rise** pp22–23
- **Better lives for many** pp102–103
- **Healthier world** pp108–109

## Life expectancy at birth

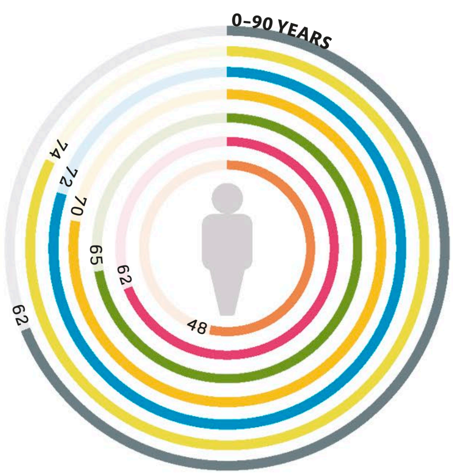
Increased life expectancy in the past 100 years reflects a shift in the principal causes of death. In the early 20th century the main causes of mortality were related to infectious and parasitic diseases. Improved public health, nutrition, and medical breakthroughs such as antibiotics and vaccines have since transformed the situation. Today, people are far more likely to die from noncommunicable illnesses such as cancer and heart disease.

**KEY**
**Life expectancy at birth (years)**

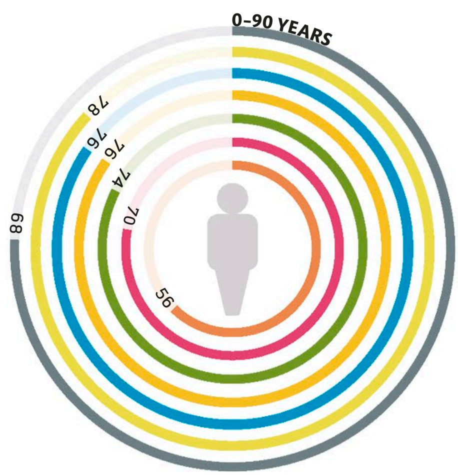
- World average
- North America
- Latin America and the Caribbean
- Europe
- Oceania
- Asia
- Africa




**1950–55**
North America and Europe exceeded the global average longevity of 47 years by the largest margins. War, disease, and malnutrition all played their parts in shortening lives.




**1980–85**
Increasingly affluent lifestyles in developed countries, and improved food security and better access to medicines elsewhere, increased average lifespans throughout most regions.

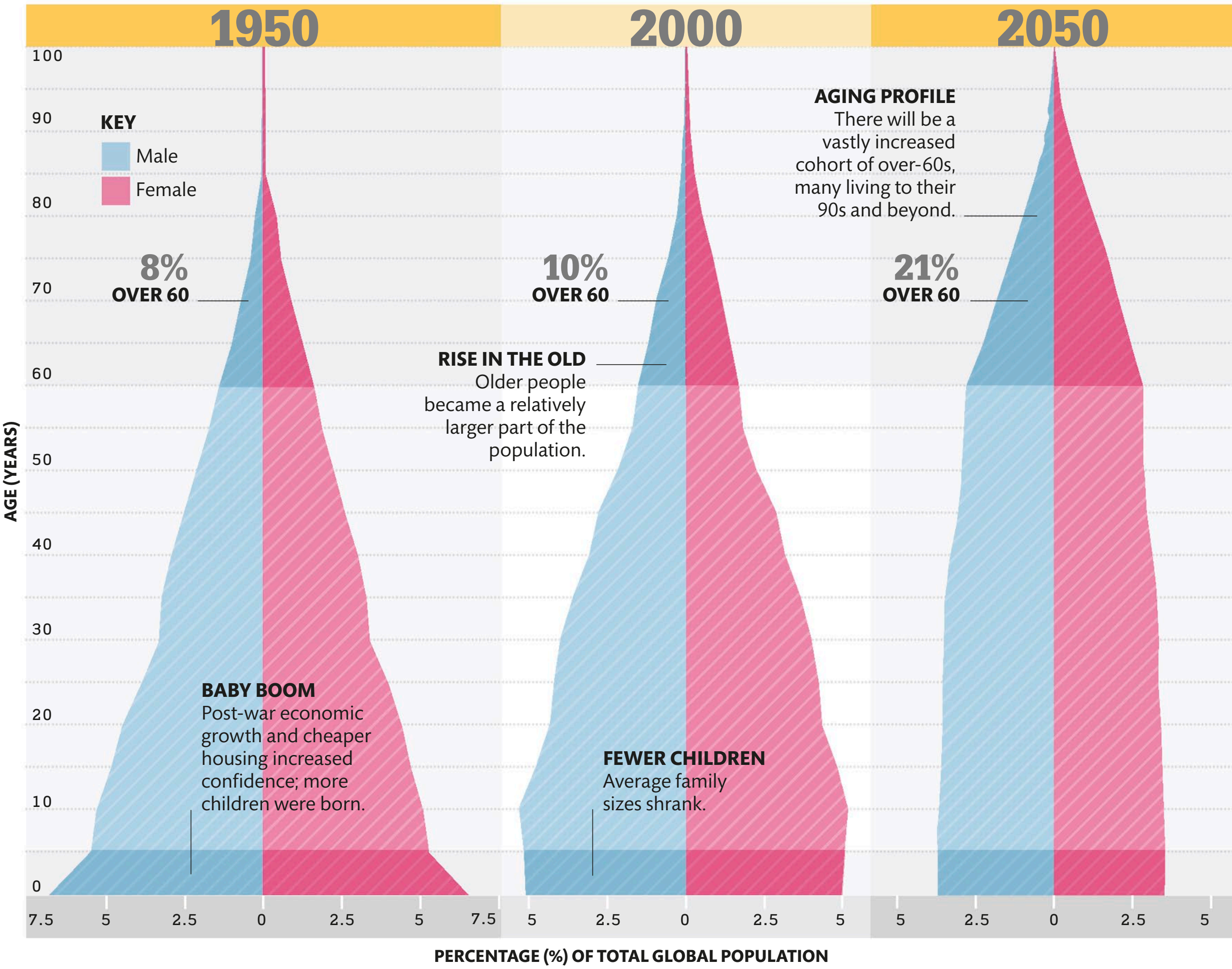



**2005–10**
Economic growth, better nutrition, and disease control achieved rising longevity worldwide. Africa still has the shortest average lifespan, as many countries remain affected by HIV/AIDS and other diseases.

## The world's population in pyramids

The shape of the global population age profile is changing rapidly. The rising proportion of people aged over 60 has caused the pyramid to become not only taller than in earlier decades but also wider at the top. Compared with the situation in 2000, the proportion of people aged 60 years or over is expected to more than double by 2050 to about 21 percent of the world total. By 2100, that proportion is expected to be about triple.

**By 2047 people aged over 60 will outnumber children**




**1950**
The global population growth curve was steep. With an increase of nearly 19 percent during the course of the 1950s, the high rate of growth persisted through the 1960s and 70s.

**2000**
The 50 years up to the new millennium saw the proportion of over-60s grow by 2 percent. Declining fertility rates and changing causes of death heralded more rapid change ahead.

**2050**
Another demographic time bomb explodes. This one is not just about the overall increase in population, but includes a simultaneous doubling in the proportion of over-60s since 2000.

# Slowing the Rise

**How best to manage population growth has been one of the most discussed and most controversial questions of modern times. But what might actually work to reduce the rate of increase?**

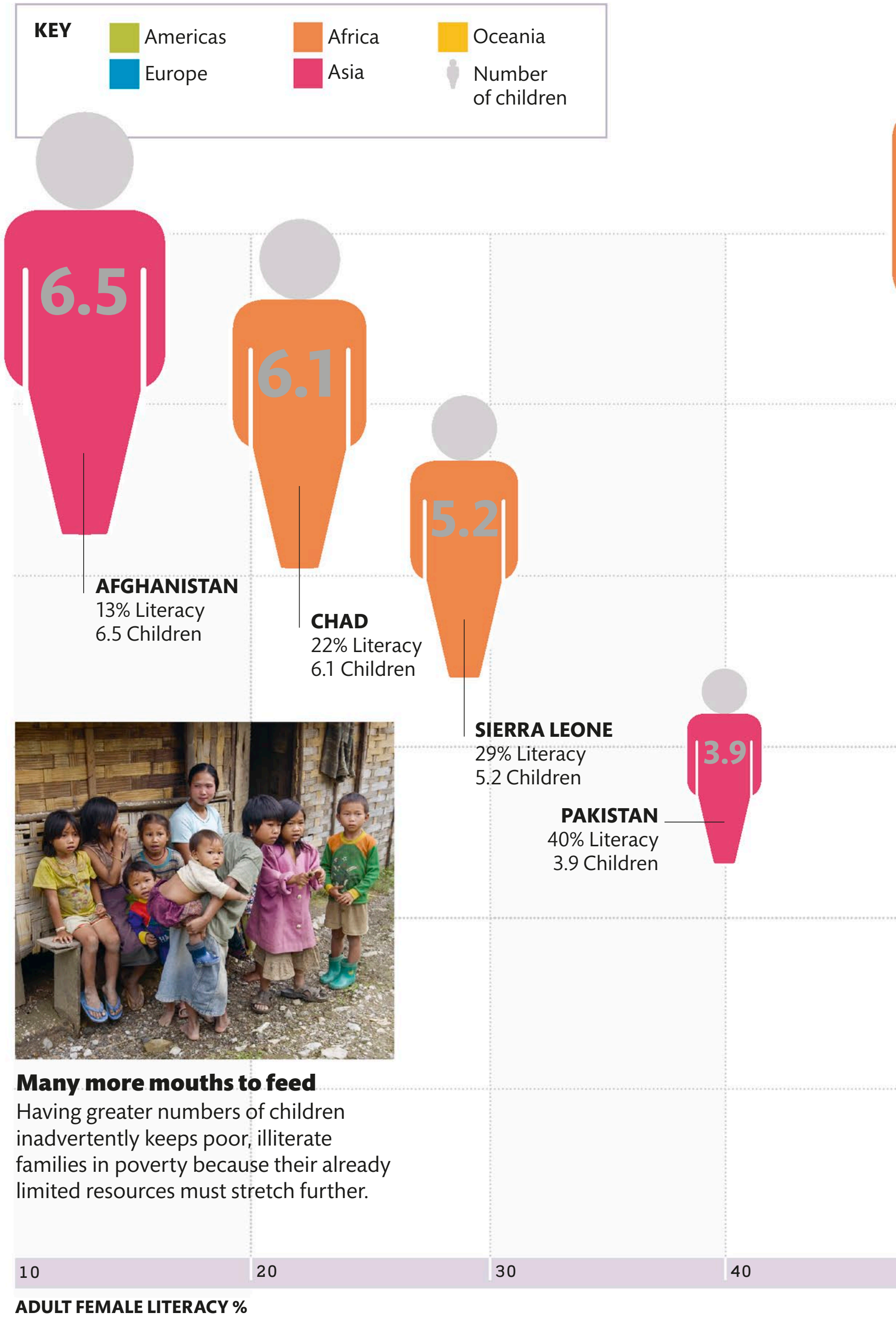
The steep population increase of the 20th century led to alarming predictions about its impact on the global environment, resources, and food supplies. While the humanitarian disaster some expected has thus far been avoided, there are still good reasons to reduce population growth.

A number of steps have been taken in pursuit of this goal, including forced sterilization (in India), greater access to contraception (many African countries), and a legal limit on family size (China, see box, right). Less controversial—and ultimately more successful—has been access to education, especially for girls and young women.

## Women's education and birth rates

Generally speaking, literate women average two children per family, while those who cannot read or write often give birth to six or more. The situation can be self-perpetuating, since female children of illiterate women are less likely to receive education themselves.

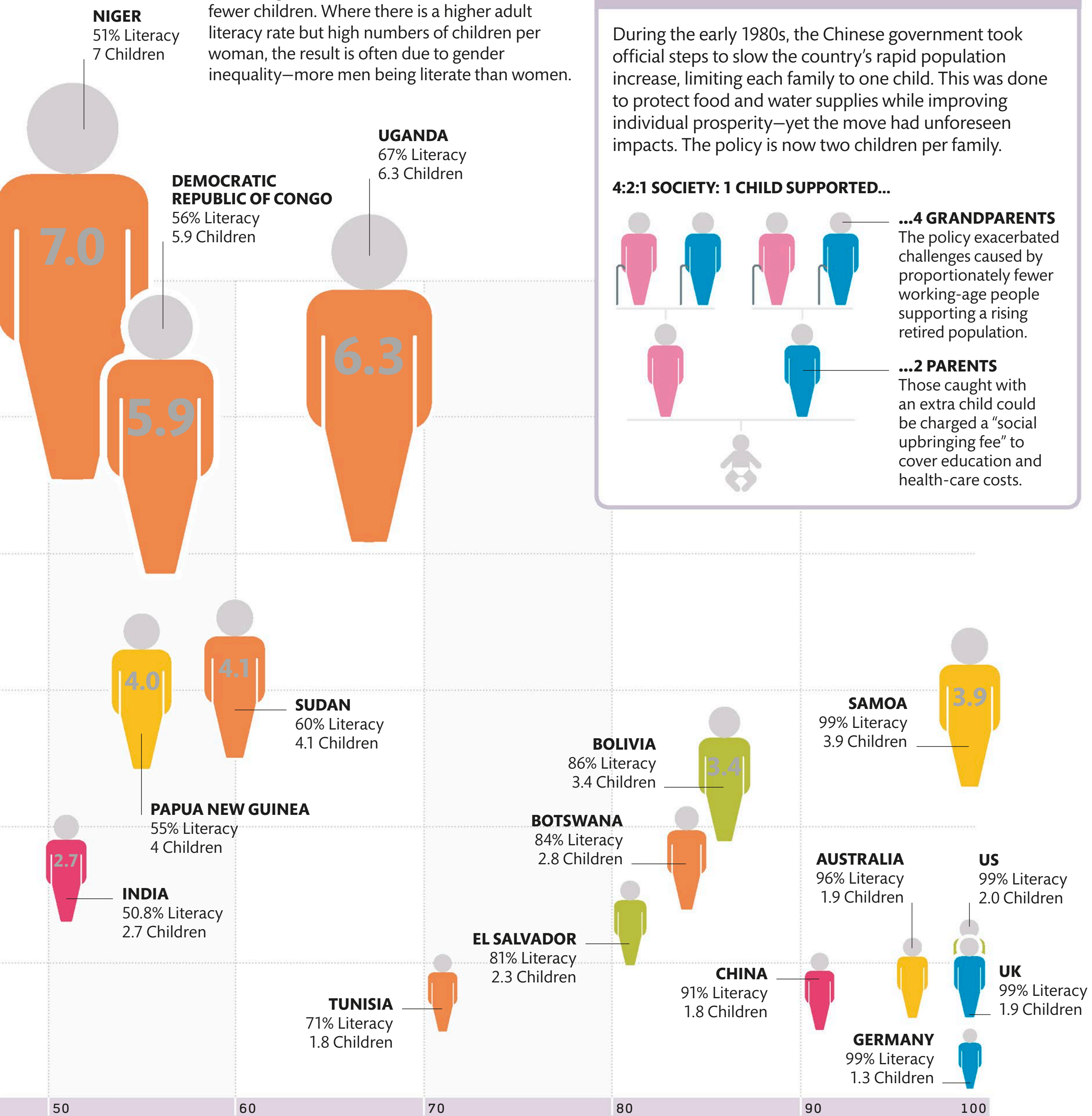
Other benefits come with greater education. For example, families of women with at least some education tend to have better housing, clothing, income, water, and sanitation. Increased access to education thus emerges as a key area for investment, bringing social, economic, and—ultimately—environmental benefits.




**Many more mouths to feed**
Having greater numbers of children inadvertently keeps poor, illiterate families in poverty because their already limited resources must stretch further.

### The literacy link

On average, women who read and write have fewer children. Where there is a higher adult literacy rate but high numbers of children per woman, the result is often due to gender inequality—more men being literate than women.




## CHINA'S ONE-CHILD POLICY

During the early 1980s, the Chinese government took official steps to slow the country's rapid population increase, limiting each family to one child. This was done to protect food and water supplies while improving individual prosperity—yet the move had unforeseen impacts. The policy is now two children per family.

**4:2:1 SOCIETY: 1 CHILD SUPPORTED...**

**...4 GRANDPARENTS** The policy exacerbated challenges caused by proportionately fewer working-age people supporting a rising retired population.

**...2 PARENTS** Those caught with an extra child could be charged a "social upbringing fee" to cover education and health-care costs.

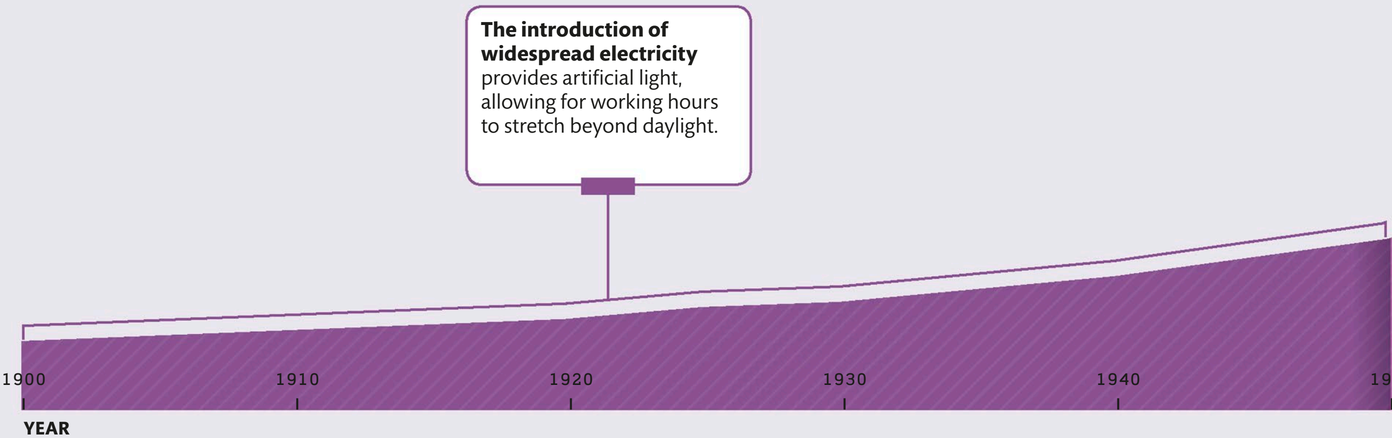
# Economic Expansion

**Since the beginning of the industrial revolution in the late 18th century the world has witnessed a period of staggering economic growth. New methods of production and innovation developed over the last 200 years have allowed for efficient use of labour and resources, producing more output per person. Increased productivity has allowed for higher incomes, better quality of life, and greatly reduced poverty worldwide. As fast-growing countries in Asia, South America, and Africa progressively industrialize, the global economy is set to grow further still.**

## A more productive world

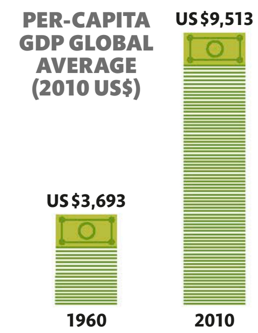
The total economic output of the world, its GDP, has been growing steadily, especially during the past 100 years. Major drivers of economic growth are increasing populations, providing more workers to produce goods and services, and more advanced technologies, allowing labor to be more efficiently utilized. Since 1950, the global economy has grown ever more rapidly, and in 2000, global economic output was 10 times its 1950 level. Even as growth has slowed with the recent global recession, economic output is at an all-time high.

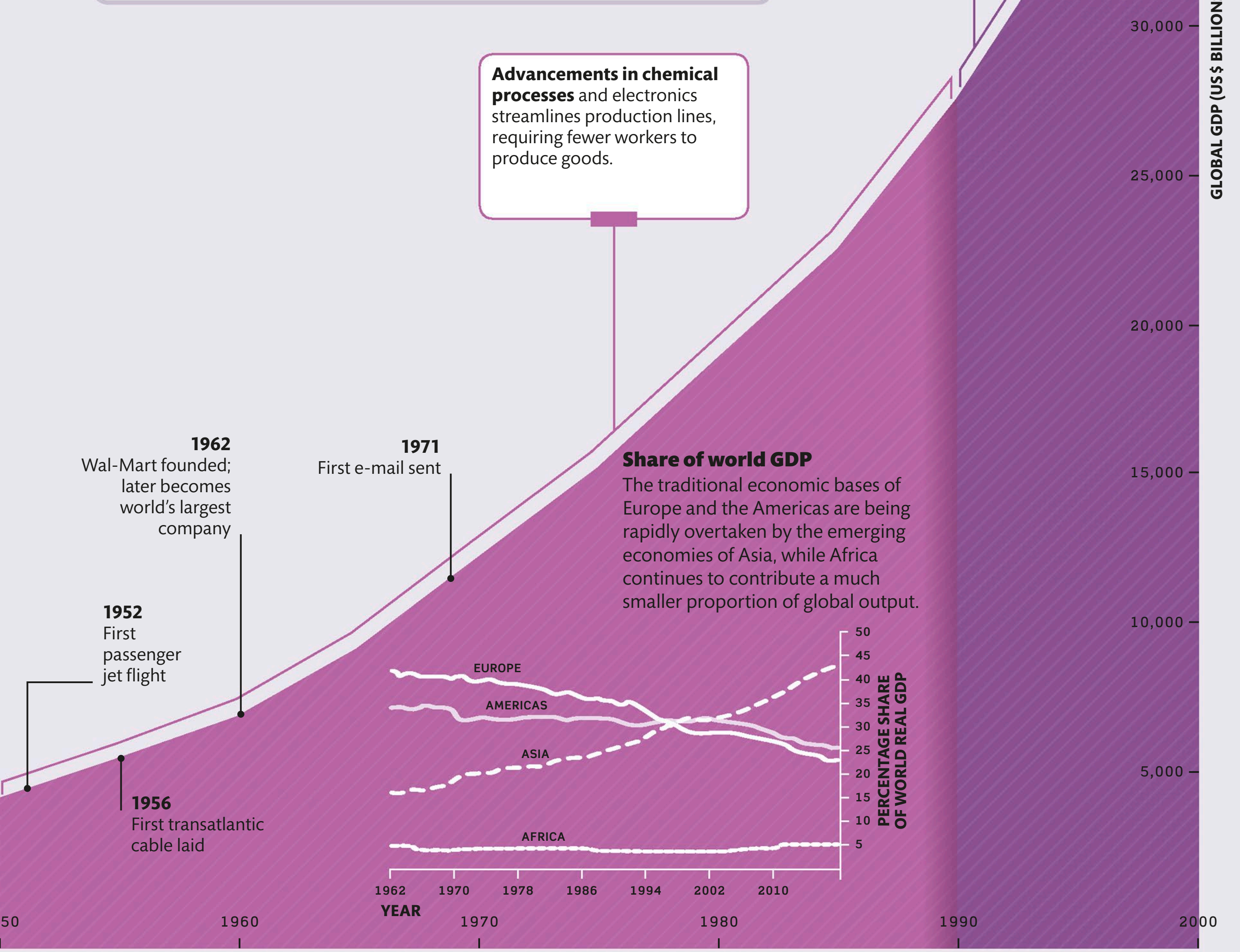
> "We have allowed the **interests of capital** to **outweigh the interests of human beings and our Earth.**"
>
> **ARCHBISHOP DESMOND TUTU, SOUTH AFRICAN SOCIAL RIGHTS CAMPAIGNER**



## INCREASING PERSONAL WEALTH

Increasing population has been one driver of economic growth, since more people requiring more goods and services leads to increased demand. However, GDP per capita has also increased, signaling an increase in productivity and wealth. In the 50 years since 1960, the amount of money in the economy per person tripled. Seen here as a global average, these gains have been unevenly distributed (see pp110–11).



# What Is GDP?

Gross domestic product, or GDP, is a measure of the output of an economy, which is defined as the total value of all the finished goods and services produced within the borders in a specific time period, usually a year. It is used to compare the relative size of economies and to judge the health of an economy over time. There are several ways in which economists measure this output—here we look at the expenditure method. This assesses the output by adding up the total amount spent by the government, individuals, businesses, and organizations in the economy.

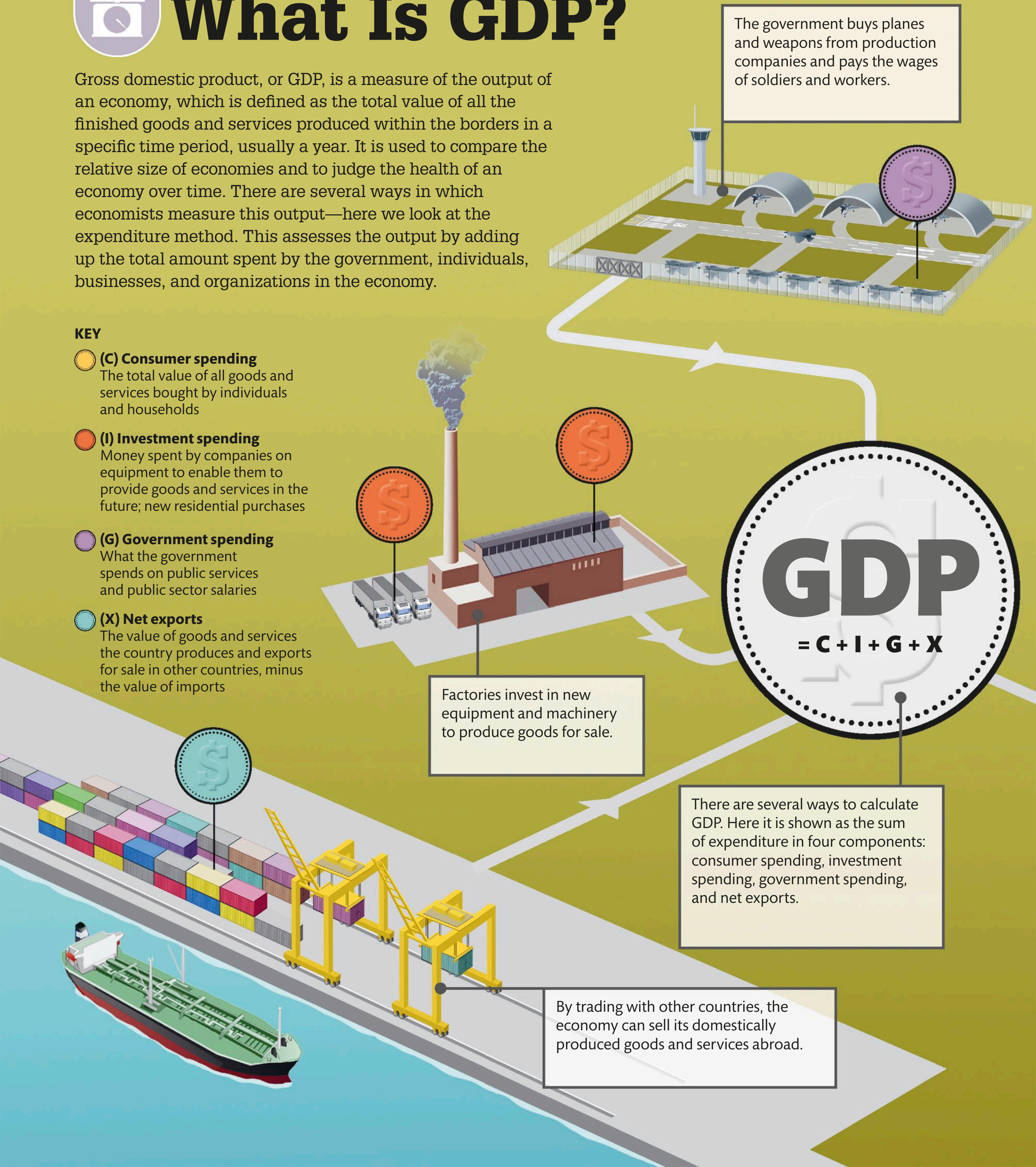
**KEY**

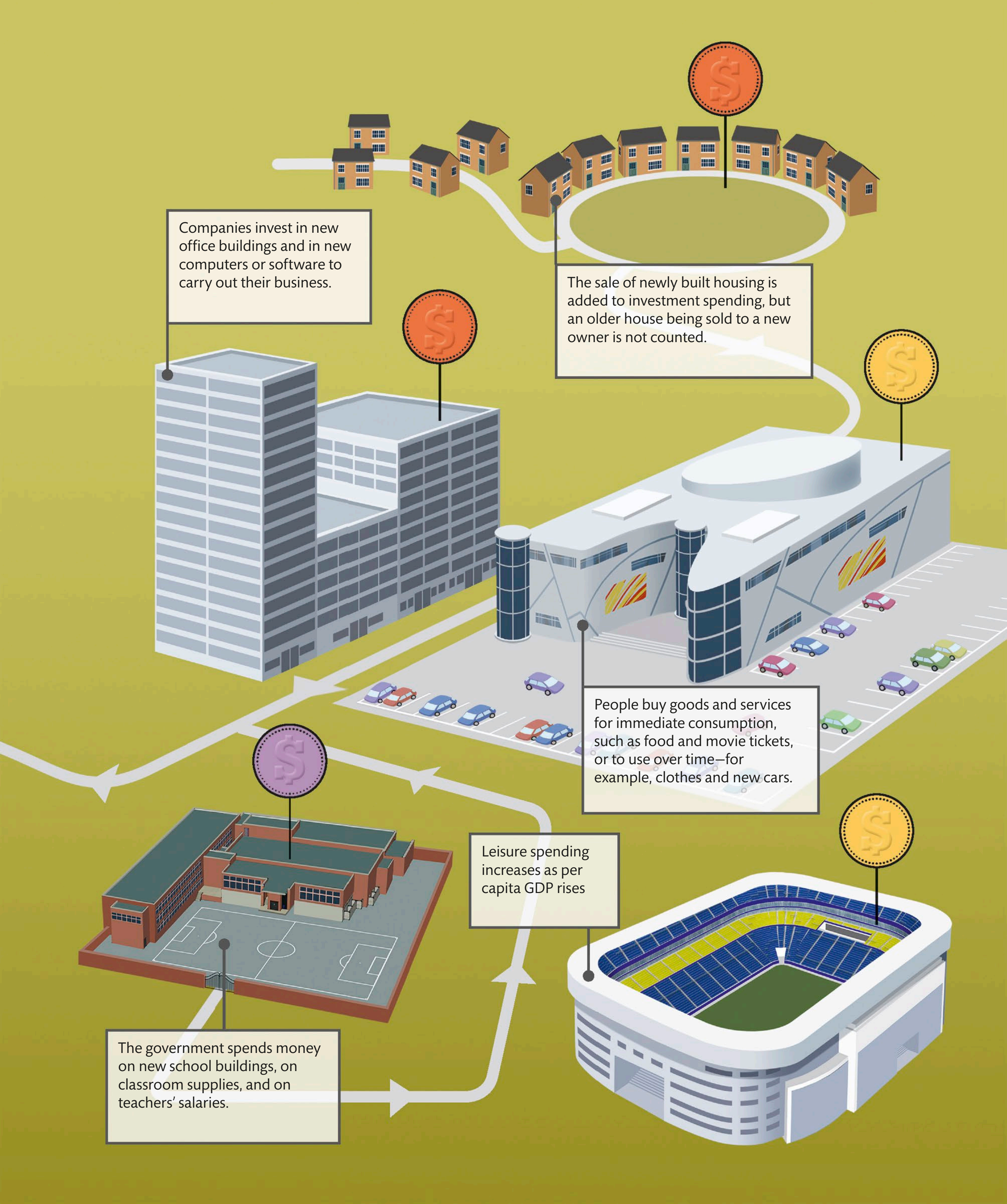
**(C) Consumer spending**
The total value of all goods and services bought by individuals and households

**(I) Investment spending**
Money spent by companies on equipment to enable them to provide goods and services in the future; new residential purchases

**(G) Government spending**
What the government spends on public services and public sector salaries

**(X) Net exports**
The value of goods and services the country produces and exports for sale in other countries, minus the value of imports




Companies invest in new office buildings and in new computers or software to carry out their business.
The sale of newly built housing is added to investment spending, but an older house being sold to a new owner is not counted.
People buy goods and services for immediate consumption, such as food and movie tickets, or to use over time—for example, clothes and new cars.
Leisure spending increases as per capita GDP rises
The government spends money on new school buildings, on classroom supplies, and on teachers' salaries.

# Richer People

**Across the world, many people are earning more money and can afford a better standard of living, but the gulf between the richest and poorest among us continues to grow wider.**

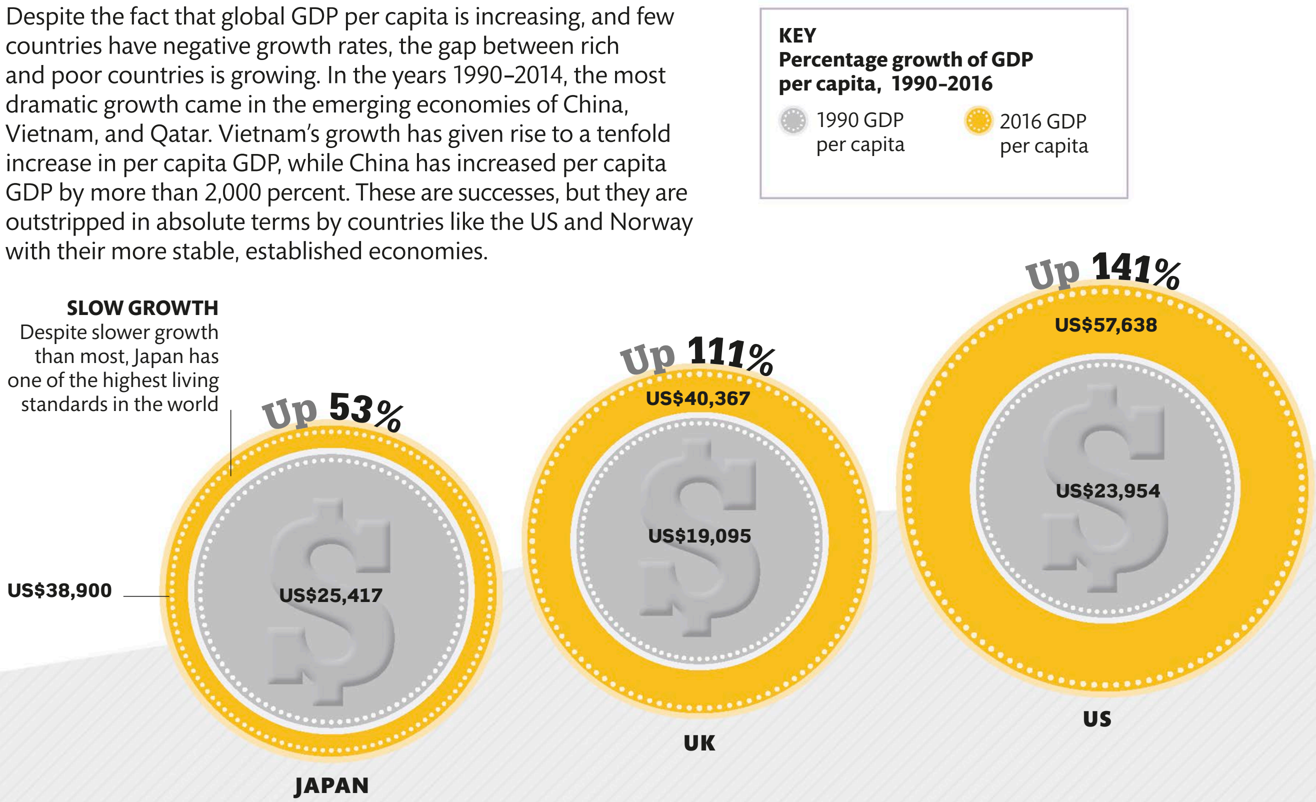
A useful way of gauging how economic growth or decline is impacting on individual quality of life in different countries is to look at gross domestic product (GDP—see pp26–27) per capita. This is the measure of a country's annual economic output divided by its population. GDP per capita figures give an indication of individual average income and quality of life, allowing for comparisons over time to see if people are generally living better or worse lives. Globally, average GDP per capita rose from US$4,271 in 1990 to US$10,804 in 2014, signaling an overall rise in household earnings. This is in part due to the rise of emerging economies—such as Brazil, Russia, India, and China—and has led to significant reductions in poverty in some of the poorest countries in the world. However, by far the biggest factor in rising average GDP during this period is the continuing growth of the world's richest economies. Established economies, such as the US and UK, may have slower growth rates but have much higher GDP per capita.


**SEE ALSO...**

- **Global power shift** pp32–33
- **Rise of consumerism** pp86–87
- **Unequal world** pp110–111

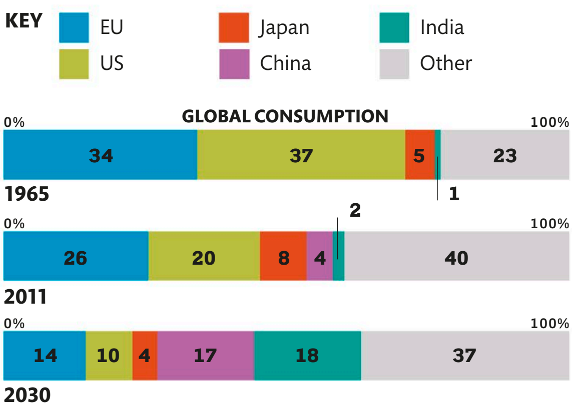

## Global inequality

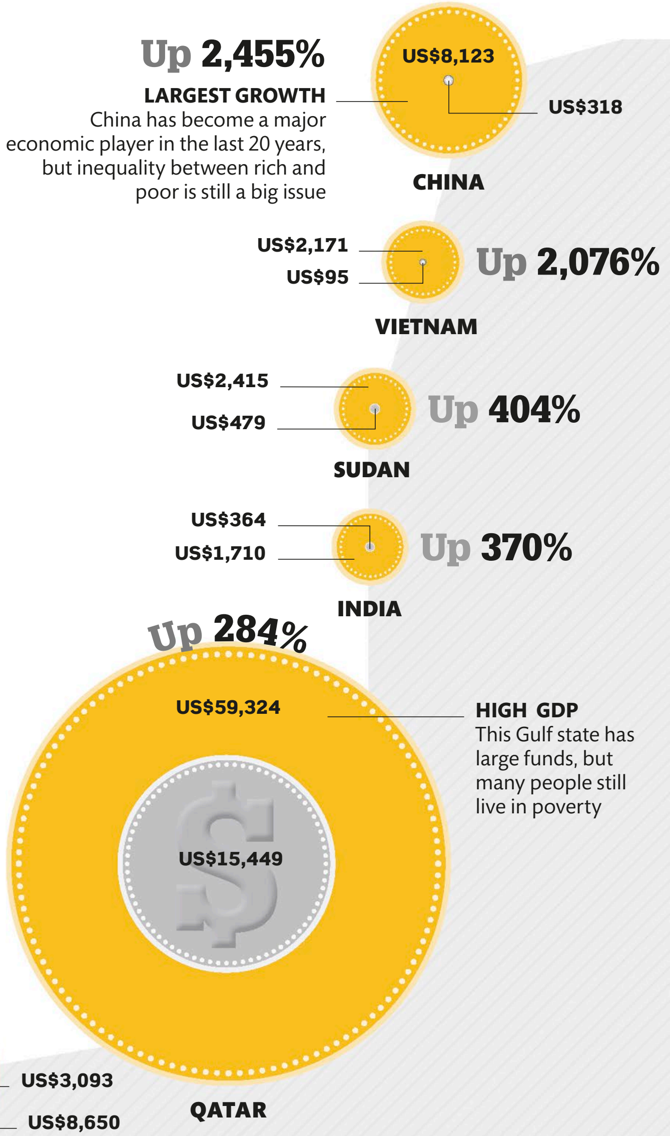
Despite the fact that global GDP per capita is increasing, and few countries have negative growth rates, the gap between rich and poor countries is growing. In the years 1990–2014, the most dramatic growth came in the emerging economies of China, Vietnam, and Qatar. Vietnam's growth has given rise to a tenfold increase in per capita GDP, while China has increased per capita GDP by more than 2,000 percent. These are successes, but they are outstripped in absolute terms by countries like the US and Norway with their more stable, established economies.



## MIDDLE CLASS WORLD

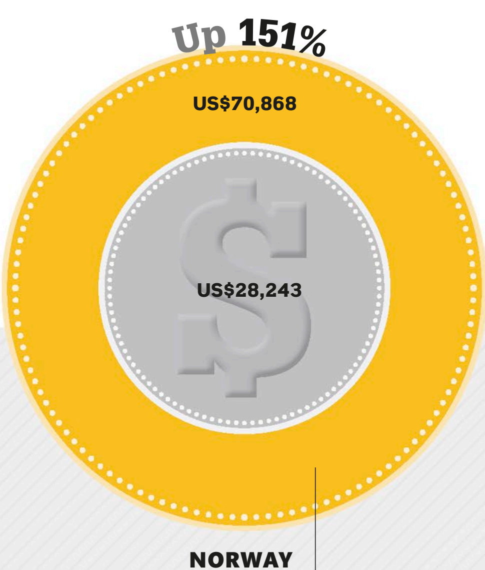
The global middle class, those with a daily spending power of US $10–100, is expanding. Around 1.8 billion people were categorized as middle class in 2009 and this is expected to rise to 4.9 billion by 2030. The influence of middle-class consumers in the developing world is growing too. By 2030, it is estimated that around 35 percent of global middle-class consumption will come from India and China.




China has become a major economic player in the last 20 years, but inequality between rich and poor is still a big issue

This Gulf state has large funds, but many people still live in poverty

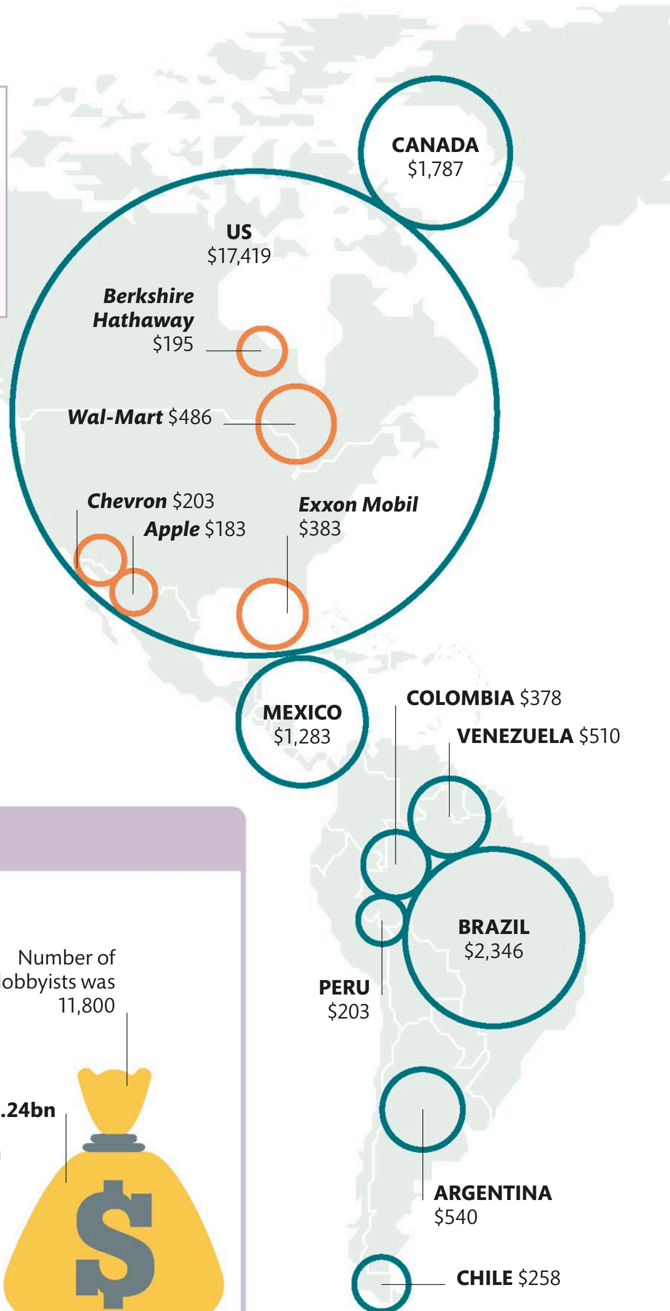

**HIGHEST GDP**
Norway's large economy is mostly due to their access to North Sea oil, which is in government ownership

**Conspicuous consumption**
While China's GDP per capita has soared, the gap between rich and poor has grown. Only a small minority can afford luxuries such as this attention-grabbing Ferrari.

# Companies vs. Nations

**The rise of global markets over recent decades has enabled a number of multinational corporations to grow larger than most countries.**

Of the top 100 economies based on GDP (see pp26–27) and revenue, 60 are countries and the rest companies. Wal-Mart, the largest public company in the world, ranks as the 28th biggest economy, just below that of Norway. Such vast economic clout gives companies power and leverage. For example, oil companies have lobbied governments against policies geared to combat global warming because of the threat posed to their businesses.

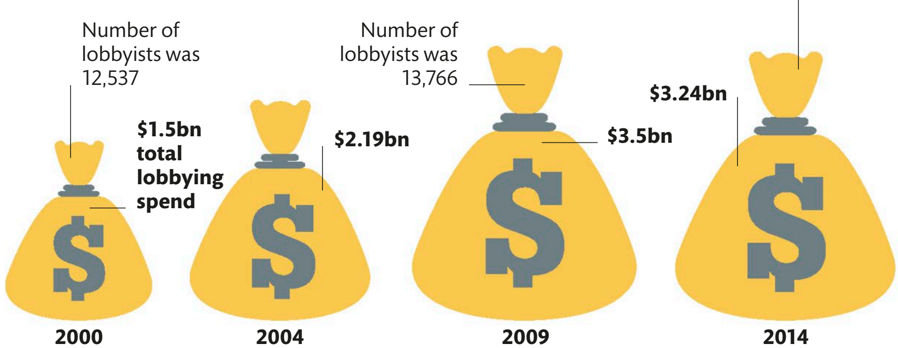


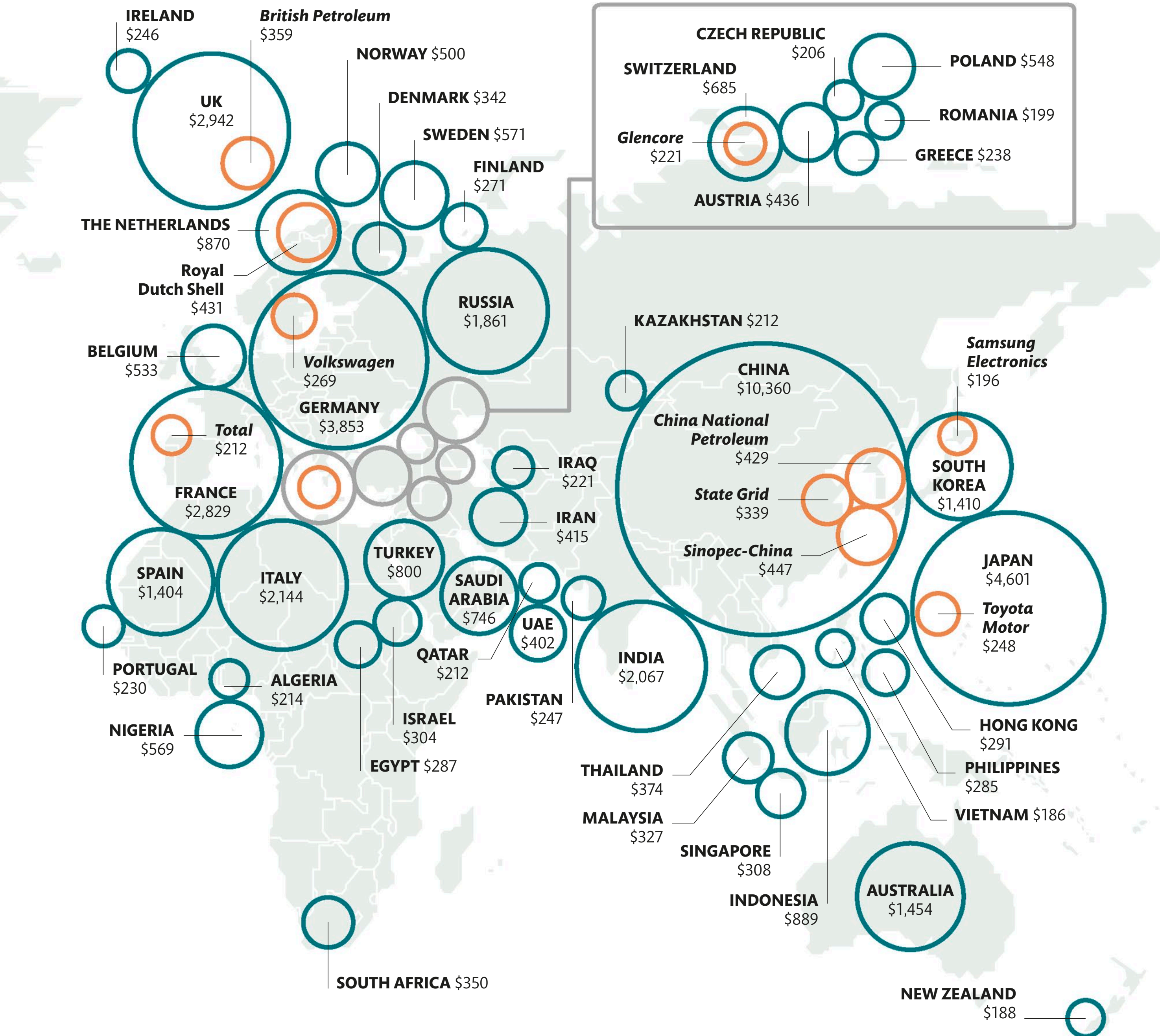

## Top money makers

This map plots the top 70 economies in the world. It compares World Bank rankings of national GDPs with the Fortune 500 list of corporations by revenue. The largest of these companies operates in the retail sector, but many of the front-runners are in petroleum refining and vehicle manufacturing—in second place on the Fortune 500 list is the Chinese oil and energy giant Sinopec, closely followed by Shell.

### POLITICAL LOBBYING

In the US, political lobbying is big business. Many corporations pay professional lobbyists to influence the decisions of politicians. In 2014, almost 12,000 registered lobbyists were working to influence 535 members of Congress.



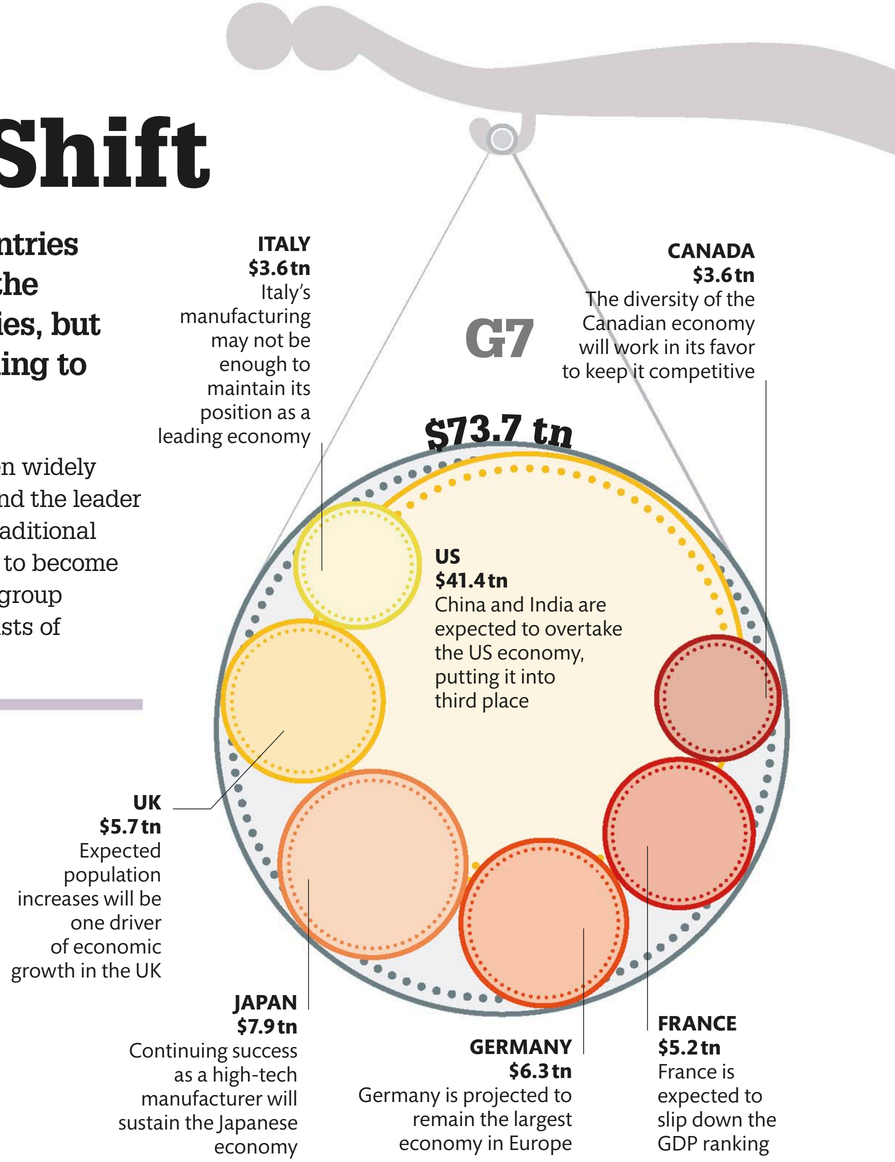



**The annual turnover of Wal-Mart ($486 billion) is almost twice the size of Pakistan's GDP ($247 billion)**

# Global Power Shift

**For the past 40 years, seven countries (the G7) have been accepted as the world’s most important economies, but emerging economies are beginning to overtake them.**

Since the late 19th century, the US has been widely accepted as the world’s largest economy and the leader in terms of output and innovation. Other traditional economic powerhouses joined with the US to become the Group of 7, or G7, in the 1970s. The E7 group (or “Emerging 7”), identified in 2006, consists of the most important developing economies.

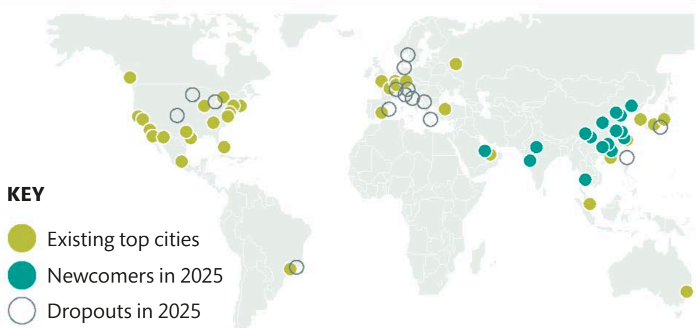



## Growth of the E7

By 2050, the G7 economies are expected to be greatly overtaken by the seven emerging economies of the E7. In China, the reform of socialist economic policies and rapid expansion of manufacturing capabilities has led to huge economic expansion, which is predicted to continue. By 2050, India will also overtake the US and become the world’s second largest economic power. The G7 economies will continue to grow but at a much slower rate than their emerging counterparts.

## THE WORLD’S RICHEST 50 CITIES

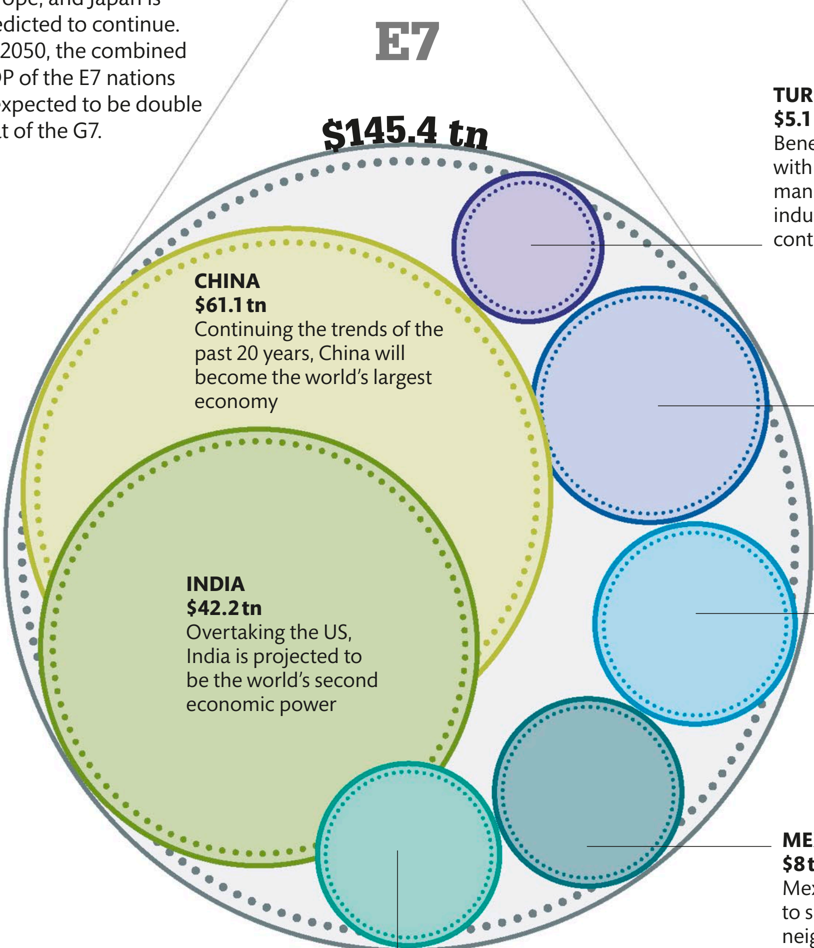
The economic rise of the East is well illustrated by forecasts of where we will soon find the world’s richest cities. In 2007, eight of the richest 50 cities ranked by annual GDP were in Asia. By 2025, this is predicted to rise to 20. More than half of Europe’s top 50 cities are expected to drop off the list entirely, as will three in North America, creating a new landscape of urban economic power.



2050

## The **EU and US's share** of world GDP is expected to **fall from 33%** in 2014 **to around 25%** by 2050

**Tipping the balance**
An economic power shift away from the established advanced economies in North America, Western Europe, and Japan is predicted to continue. By 2050, the combined GDP of the E7 nations is expected to be double that of the G7.



# Trading Benefits

**Trade has been a powerful driver of economic growth around the world for centuries. Countries described as major traders have larger economies than the smaller trading nations.**

Trade enables countries to make the most of their natural and human resources. Modern transportation is now so fast and efficient that even perishable foods and flowers can be harvested in southern Africa and sold in European supermarkets within days. The use of instant Internet communications means that many services are no longer restricted by location. These technological advances have resulted in a boom in the value of international trade.

## World trade

The majority of international trade (measured here as total exports) takes place among the richest countries. They benefit from efficient infrastructure and supportive treaties and are able to produce goods of high value. The ease of trade and transportation today means that almost any product or service is available across the world.

### TRADE VERSUS AID

Some experts believe international aid should be reduced in favor of investment in trade with poorer countries to support their development.

***Trade***

- Establishes a partnership rather than a one-way dependent relationship
- Fosters development of industry and infrastructure in poorer countries
- Can leave countries heavily dependent on powerful foreign countries

***Aid***

- Provides relief and support in a crisis
- Can be used to encourage policies for sustainable development
- Foreign aid can leave economies unequipped and dependent on assistance

### Least developed countries

The 48 least developed countries, as set by the UN, are impeded in trade by a lack of infrastructure and supportive government. Goods and services of low value are often traded here.

**IMPORTS**
Lack of manufacturing capacity in many poorer countries prevents them from participating in key global markets. These nations must import manufactured goods, such as vehicles and medicines.

**EXPORTS**
The leading exports of many less developed countries are often natural resources, used abroad to produce manufactured goods. Tourism brings in income as a service export.

**LABOR**
The countries concentrated on extracting raw materials may suffer from so-called "Dutch disease," whereby exporting raw materials is at the expense of jobs in more stable or lucrative manufacturing industries.


# 90% of world trade is carried by **the shipping industry**

## Developed countries

Trade agreements and open borders often make it cheaper for groups of richer countries to trade together. Good infrastructure and communication links ensure that trade is easy to conduct.

**IMPORTS**
Food, raw materials, and machinery are all imported regularly to produce manufactured goods. Rich countries can afford to import basic goods and services, allowing them to specialize in high-value industries.

**EXPORTS**
The highest-value exports of many developed countries are consumer electronics and vehicles. Services are exported in the form of financial services and travel, as well as the tourism industry.

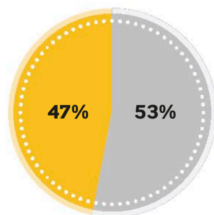
**LABOR**
Many large economies, such as China and the US, produce large amounts of consumer goods for export. This supports millions of skilled jobs in these countries.

## American agreement

The US is the world's largest international trader, with trade valued at more than $3,900 billion in 2014. With the North American Free Trade Agreement (NAFTA), the US's biggest partner is Canada. A third of US exports go to Canada and Mexico.

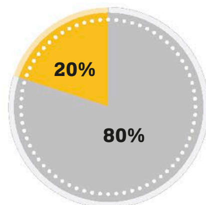
**KEY**
Imports
Exports

**CANADA**
Trade with Canada is vital for both economies, and the two countries share the highest-value trade relationship in the world.



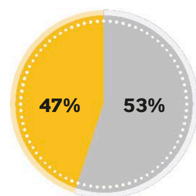
$660 BILLION

**CHINA**
The US's largest source of imports come from China. Exports are also growing rapidly, making China the third biggest market for US goods and services abroad.



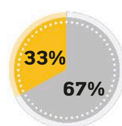
$590 BILLION

**MEXICO**
The third member of the NAFTA, Mexico has cheaper labor and production costs. This means many consumer goods are exported to the US.



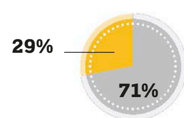
$534 BILLION

**JAPAN**
Imports from Japan are almost exclusively manufactured goods, with cars and electronics the most popular items.



$201 BILLION

**GERMANY**
The US's largest European trading partner is Germany, known for exporting high-quality consumer goods.



$173 BILLION

# World Debt

**Government debt exerts a huge influence on political policy. The drive to generate surplus and repay debt leads to fewer measures geared to meeting environmental and other sustainable development goals.**

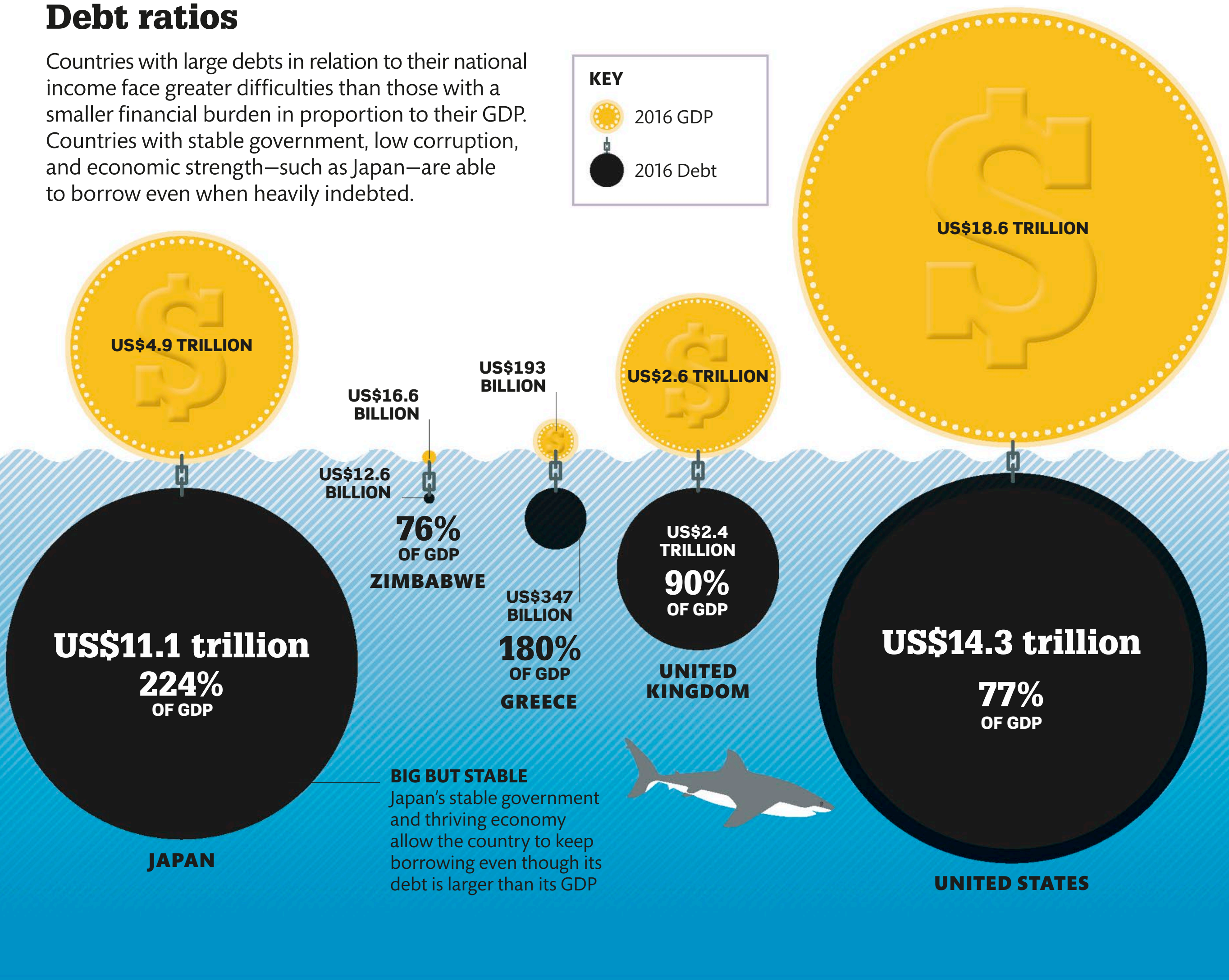
Governments often raise money by issuing bonds that are bought by private banks and other financial institutions. The money is used to invest in public services and build infrastructure. Creditors are repaid with interest, as long as the country remains solvent. When spending exceeds tax receipts and finance to repay debts dries up, governments often prioritize economic growth, cut spending, and downgrade long-term plans. The 2008 global financial crisis revealed the impact of debt on environmental goals as low carbon energy programs were cut back.


**SEE ALSO...**

- **What is GDP?** pp26–27
- **A sustainable economy** pp200–201


## Debt ratios

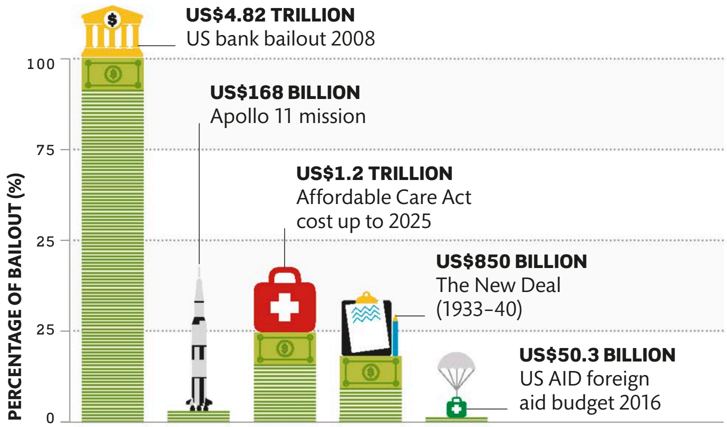
Countries with large debts in relation to their national income face greater difficulties than those with a smaller financial burden in proportion to their GDP. Countries with stable government, low corruption, and economic strength—such as Japan—are able to borrow even when heavily indebted.

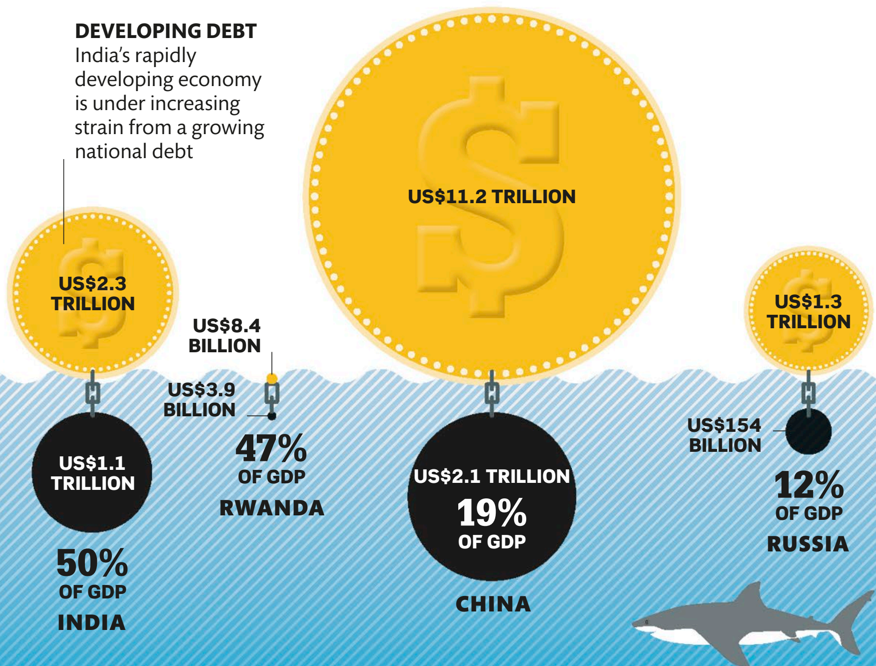



**BIG BUT STABLE**
Japan's stable government and thriving economy allow the country to keep borrowing even though its debt is larger than its GDP

## Bailing out banks

Following the financial crisis of 2008, the US government provided bailouts of $4.82 trillion to financial companies. This became public debt and has placed a huge burden on the US economy. The scale of the bailout is revealed by comparing it with other government-backed programs. In 2015 dollar-equivalent terms, the bailout would fund President Obama's Affordable Care Act for 40 years. Even the Apollo Program that took people to the Moon cost a tiny fraction of the 2008 bailout.




Global public debt reached more than **US $57 trillion** by 2015.

## THIRD WORLD DEBT

During the 1980s, excess borrowing, reckless lending, and rising interest rates led to a Third World debt crisis. Nations across Latin America, Africa, and Asia defaulted on repayments. The creditor banks in the West, rich countries' finance ministries, and global institutions pressed for reforms to promote growth and reduce spending. These included calls for the increased export of natural resources and cutting back on social programs.

LUMBER EXPORTS FROM BRAZIL

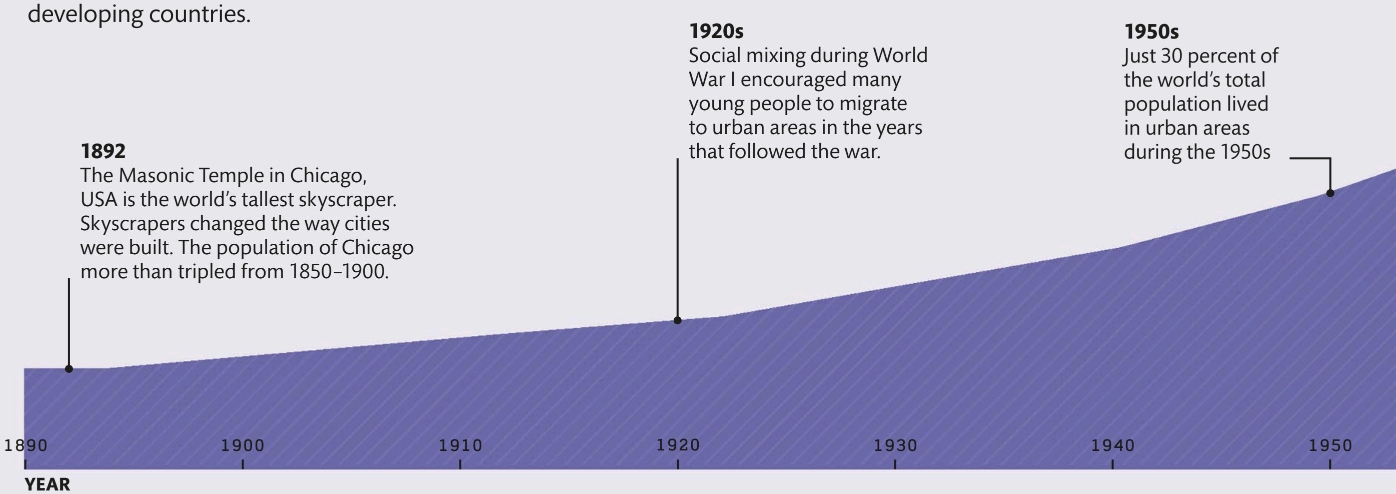
# City Planet

**The first organized urban centres were founded over 10,000 years ago. They arose in parallel with agricultural advances that enabled farmers to produce the food surpluses required to feed the new urban populations. Urbanization gathered pace with the Industrial Revolution and the intensive agriculture that enabled farmers to produce more food. Urban migration continues to increase, but so do concerns about its sustainability. By 2050 new urban capacity equivalent to 175 times the size of London will be needed to accommodate town and city dwellers.**

## Rural-to-urban shift

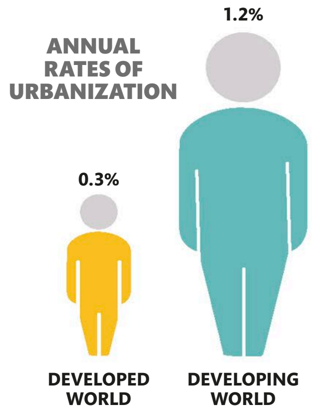
In 1800 about two percent of the world's population lived in urban areas. Over time, millions of people who once farmed have moved to urban areas in search of better lives, or have been forced to move because of falling incomes. In 2007, for the first time, more than half of us lived in towns and cities. Continuing population growth and urbanization are projected to add 2.5 billion people to the world's urban population by 2050. This works out as about 180,000 people every day, mostly in fast-growing developing countries.

> **"In many cities** the strain on both infrastructure (housing, water, sewerage, transportation, electricity supply) and **the quality of life ... is becoming unbearable."**
>
> **GEORGE MONBIOT, UK WRITER AND CAMPAIGNER**



## UNEVEN URBANIZATION

In some countries, urban growth is nearly double the rate of overall population increase, particularly in the urban areas of less developed regions. Europe, North America, and Oceania have all experienced stable rates of urbanization in the last 15 years, while South America has witnessed continuously decreasing rates. Africa and Asia, meanwhile, are responsible for bringing the developing world's average up in recent years, with Africa expected to be the fastest-urbanizing region from 2020 to 2050.

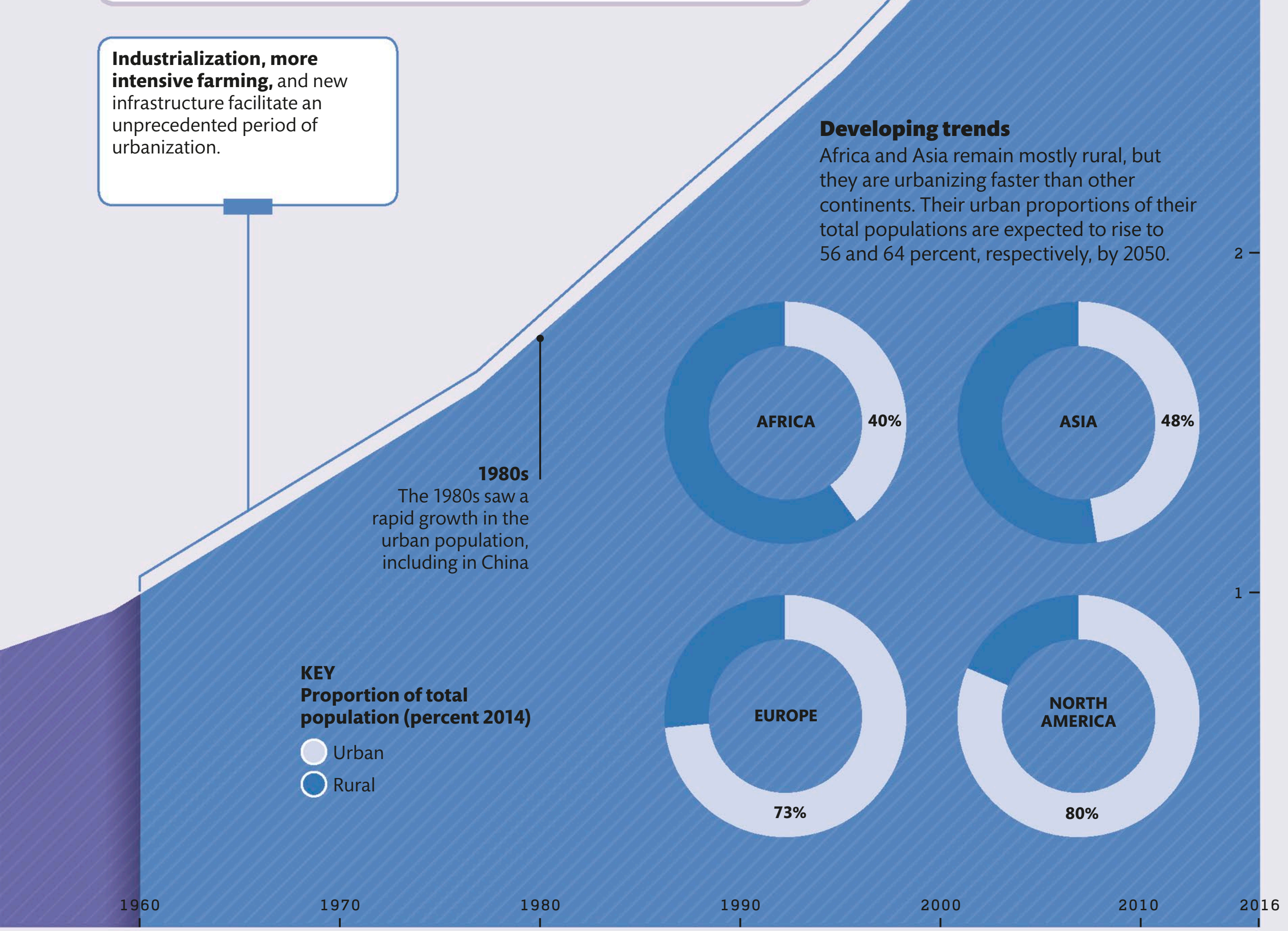



**2007**
In 2007 the historic point was reached when more than half the world's population lived in towns and cities.

**Industrialization, more intensive farming,** and new infrastructure facilitate an unprecedented period of urbanization.

**Developing trends**
Africa and Asia remain mostly rural, but they are urbanizing faster than other continents. Their urban proportions of their total populations are expected to rise to 56 and 64 percent, respectively, by 2050.

**1980s**
The 1980s saw a rapid growth in the urban population, including in China



# The Rise of Megacities

**The past 25 years have seen a huge growth in the number of megacities—cities with a population of more than 10 million. In 1950, there was only one in the world—New York City. By 1990, there were 10. This number has more than tripled to 31 today.**

In recent decades, the centers of world urbanization have shifted from the developed countries of Japan, North America, and Europe to the developing nations of Asia, Africa, and South America.

This shift is reflected in the United Nations projection that by 2030 there will be another 10 megacities, all of which are in developing countries. These new megacities are anticipated to be Lahore, Hyderabad, Bogota, Johannesburg, Bangkok, Dar es Salaam, Ahmanabad, Luanda, Ho Chi Minh City, and Chungdu.

Africa is experiencing rapid urbanization. For example, Kinshasha, in the Democratic Republic of the Congo, will see its population rise from 200,000 in 1950 to a projected 20 million in 2030, up from arouond 12 million in 2016. Some megacities will be poorly prepared for such rapid growth, placing great strain on natural resources, food, and transport.

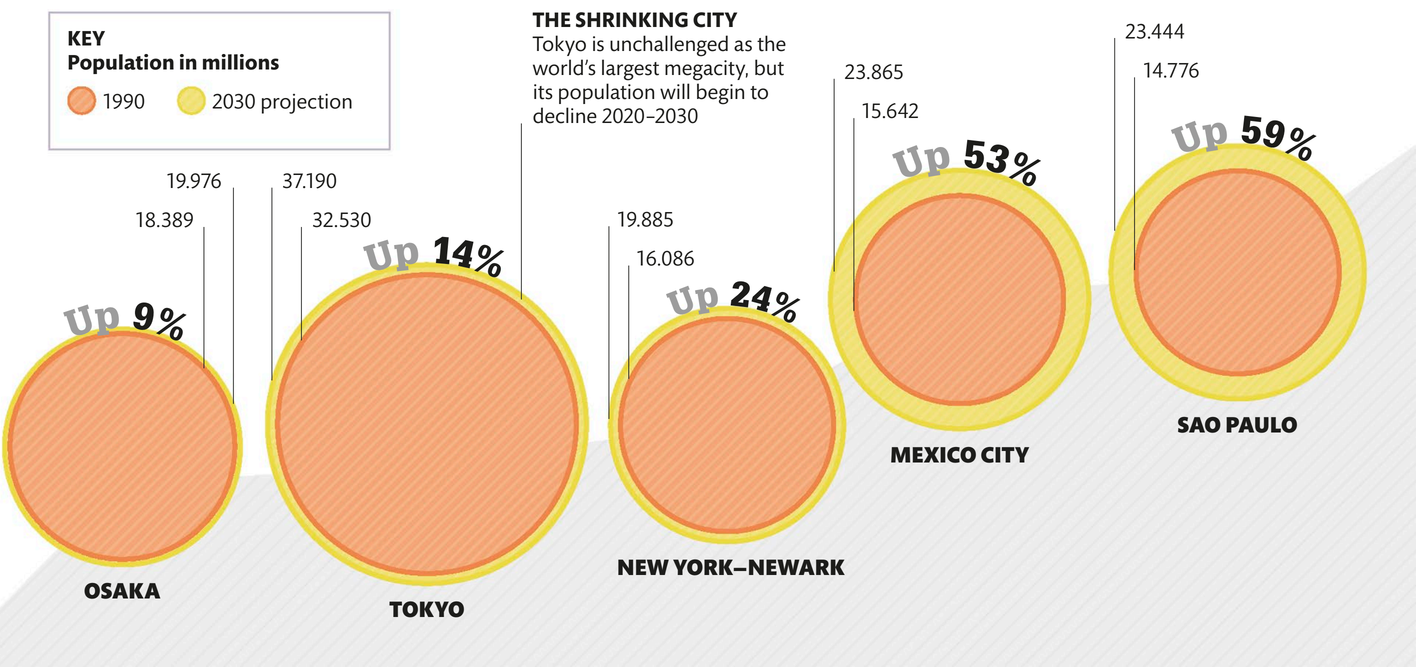

**SEE ALSO...**

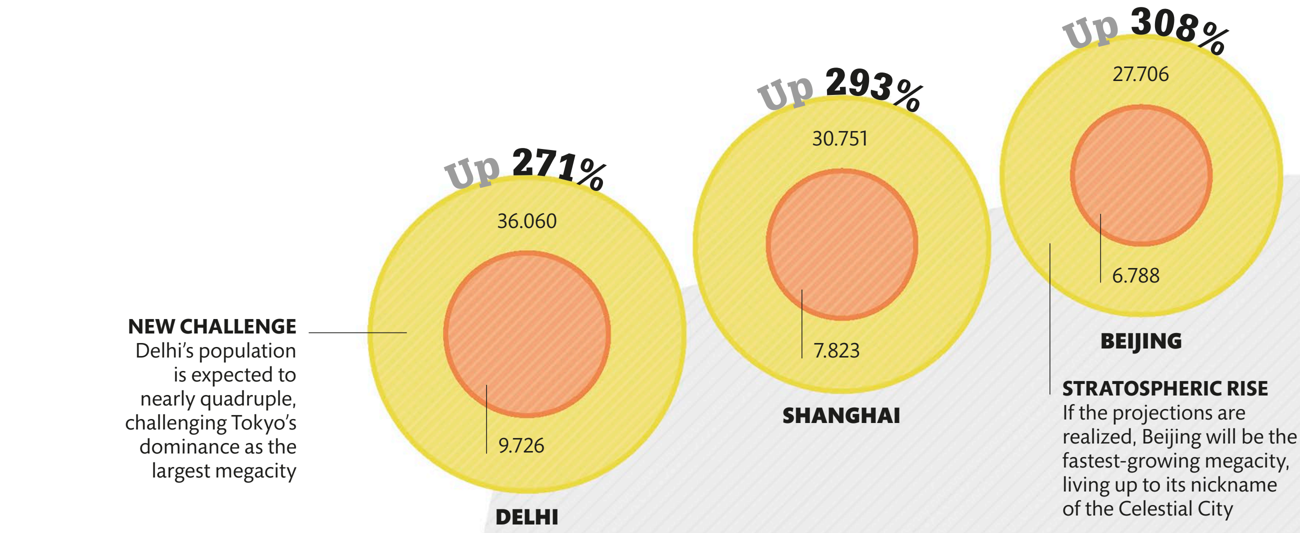
- **Global Power Shift** pp32–33
- **Rise of Consumerism** pp86–87
- **Unequal World** pp110–111

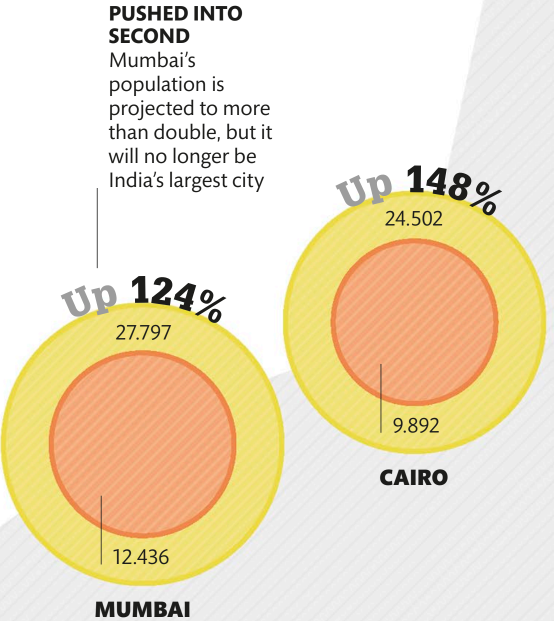

## Changes in the 10 largest cities

Asia has already seen spectacular growth, with 11 of the 31 cities that now exceed 10 million people located in China and India alone. However, not all of Asia is growing at such a rapid rate. Rising life expectancy and a relatively low birth rate will have a profound impact on Japan. Tokyo is currently the largest megacity and will continue to be in 2030, but Delhi is catching up.

**In 1990, there were 10 cities with more than 10 million inhabitants. Today, the number has tripled.**

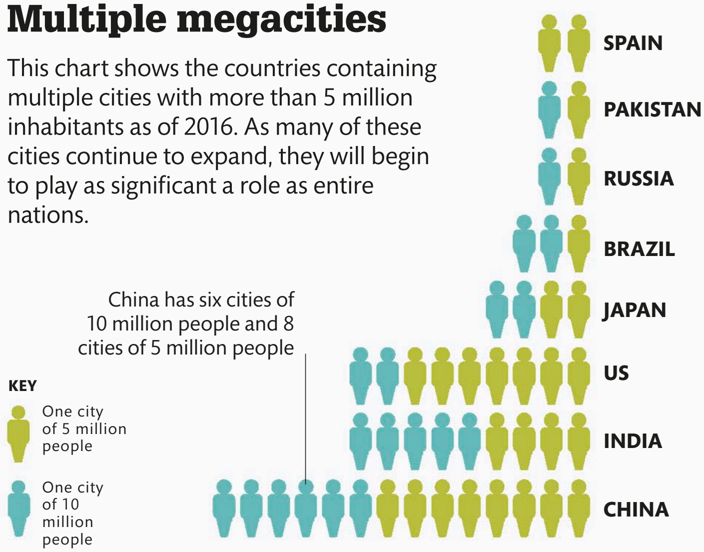





## Multiple megacities

This chart shows the countries containing multiple cities with more than 5 million inhabitants as of 2016. As many of these cities continue to expand, they will begin to play as significant a role as entire nations.




## DISTRIBUTION OF MEGACITIES

The current distribution of the 31 megacities in concentrated strongly in Asia. There are now 18 megacities in Asia, four in South America and three each in Africa, Europe and North America. Given that only 48 percent of people in Asia live in cities, and this is expected to rise to 64 percent by 2050, the number of megacities in this part of the world will continue to rise. Pressure on finite resources will be unprecedented.

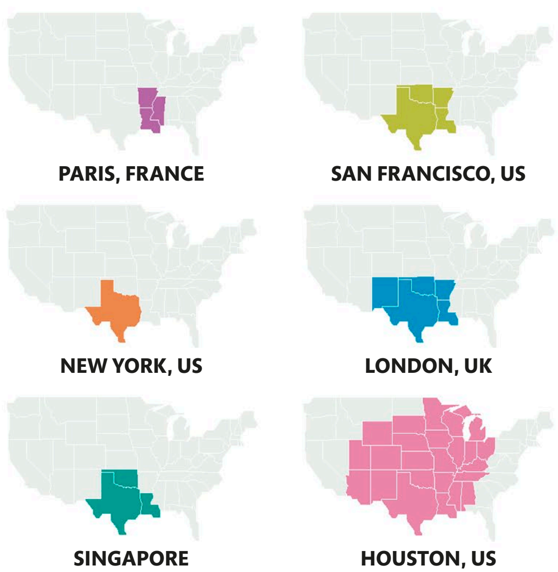
# Urban Pressures

**People living in cities tend to consume more energy, water, food, and resources than those in rural areas. Urban populations are responsible for about three-quarters of total consumption and half of all waste.**

Cities are economic engines. Fueled by natural resources, they generate most of the activity that leads to growth and wealth creation. This in turn leads to more people migrating from rural areas to the cities, which brings with it some disadvantages. The increase in the number of city dwellers requires more food, water, and energy. The use of private and public transportation also increases, and more pollution is produced. Often, former rural dwellers adopt higher-consumption lifestyles in the cities, further increasing the demand for natural resources. All these factors can lead to the destruction of natural habitats and damage the environment through increased consumption.

## URBAN DENSITY

Cities vary hugely in population density. An interesting way to compare urban density is to consider how large a city would need to be to accommodate all 7.3 billion people in the world, concentrated at the same rate. A city with the population density of New York would fit neatly into the state of Texas—an area of 250,400 sq miles (648,540 km$^2$), whereas a city with the low population density of Houston would occupy most of the landmass of the US at 1,769,085 sq miles (4,581,910 km$^2$). Paris has a population density four times that of London.

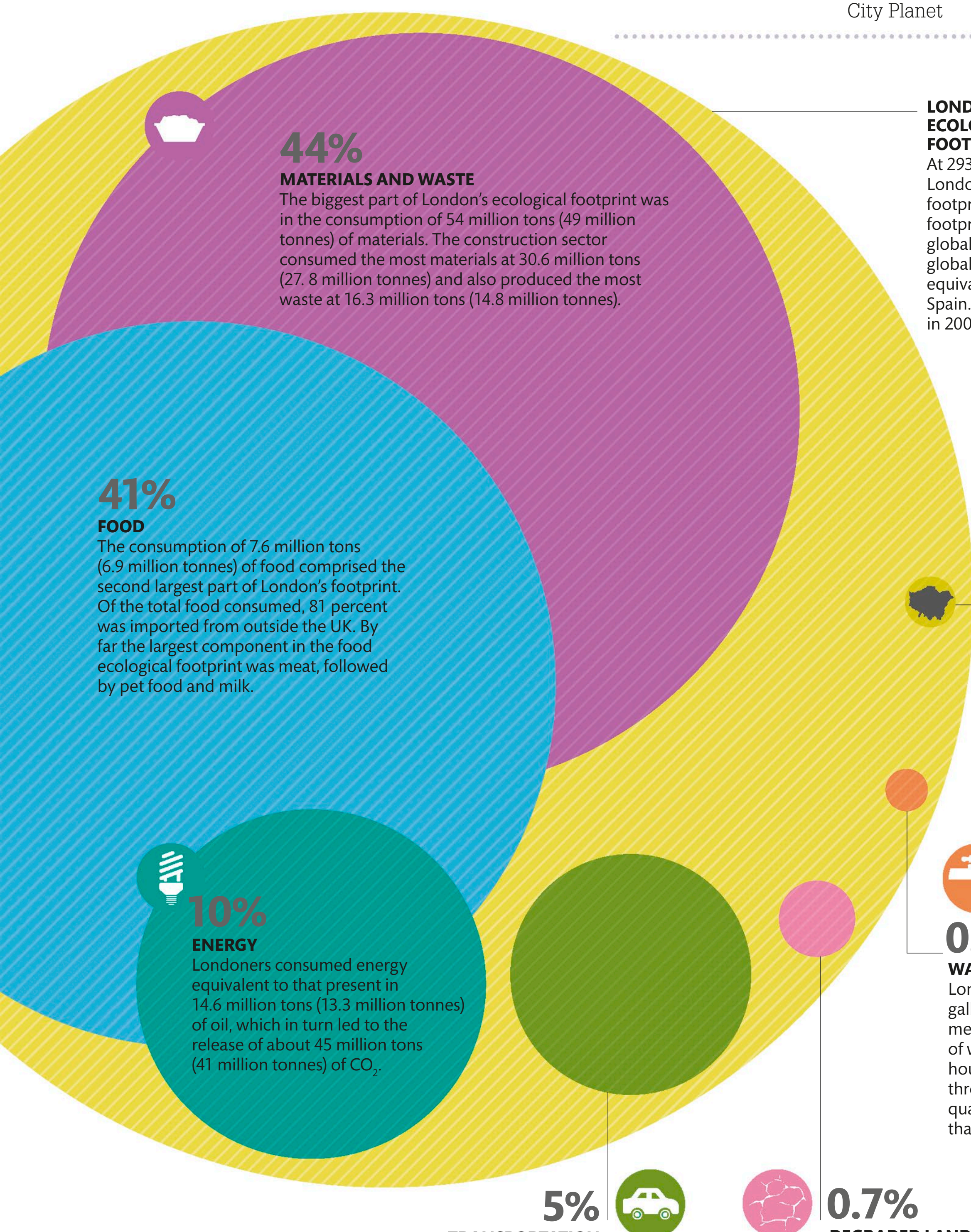



## Ecological footprints

An ecological footprint measures the impact of human activities on the natural environment. It is essentially an area measurement, represented in global acres (hectares), which places a value on how much biologically productive land and water is needed to both produce the resources we consume and to dispose of the waste. Every person, activity, company, and country has an ecological footprint. London's ecological footprint was analyzed as part of a report titled "City Limits." Published in 2002, it outlined the changes needed to turn London into a sustainable city.

**2%**

of the world's land surface is occupied by cities, which **consume 75% of the world's natural resources**



**LONDON'S ECOLOGICAL FOOTPRINT (2000)**
At 293 times the size of London's geographical footprint, its ecological footprint is 121 million global acres (49 million global hectares, gha)—equivalent to the area of Spain. London's population in 2000 was 7.4 million.

**44%**
**MATERIALS AND WASTE**
The biggest part of London's ecological footprint was in the consumption of 54 million tons (49 million tonnes) of materials. The construction sector consumed the most materials at 30.6 million tons (27. 8 million tonnes) and also produced the most waste at 16.3 million tons (14.8 million tonnes).

**41%**
**FOOD**
The consumption of 7.6 million tons (6.9 million tonnes) of food comprised the second largest part of London's footprint. Of the total food consumed, 81 percent was imported from outside the UK. By far the largest component in the food ecological footprint was meat, followed by pet food and milk.

**LONDON'S GEOGRAPHICAL FOOTPRINT**
The physical area covered by London measures 659 sq miles (1,706 km$^2$) or 1,796 acres (170,680 hectares).

**10%**
**ENERGY**
Londoners consumed energy equivalent to that present in 14.6 million tons (13.3 million tonnes) of oil, which in turn led to the release of about 45 million tons (41 million tonnes) of $CO_2$.

**0.3%**
**WATER**
London used 229 billion gallons (866,000 megaliters) in 2002, half of which was piped to houses. Water lost through leakage (about a quarter) was more than that used by businesses.

**5%**
**TRANSPORTATION**
Londoners traveled more than 40 billion passenger miles (64 billion km), of which 27 billion miles (44 billion km) were by car and light truck. Transportation caused 9.8 million tons (8.9 million tonnes) of $CO_2$ emissions.

**0.7%**
**DEGRADED LAND**
This is land that has had its bioproductivity degraded through contamination or erosion, including roads, runways, and railroad tracks.

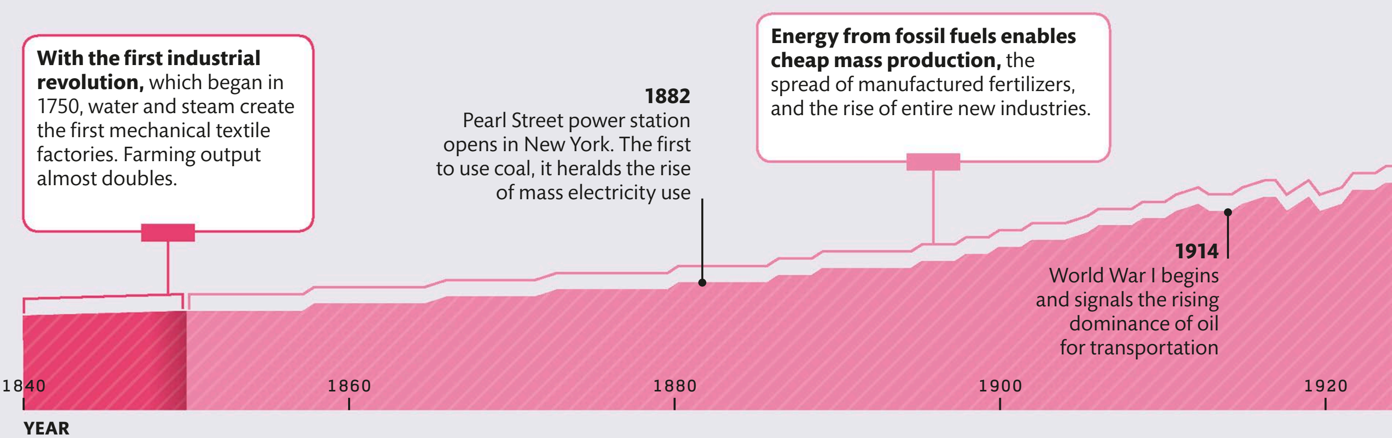
# Fuel for Growth

**Since our ancestors' first use of fire, the human race has continually sought access to ever-more-diverse energy sources. For centuries, economic development depended on the energy provided by animals, wood, wind, and water. Today, however, we rely on access to vast quantities of fossil energy from oil, coal, and gas to fuel electricity generation and power manufacturing, industrial farming, and long-distance transportation, as well as to drive the higher-consumption lifestyles that have developed as a result of each of these activities.**

## The energy revolution

The 20th century saw a massive surge in demand for energy, and this continues today, with the emergence of major economies such as China, India, Brazil, and South Africa. Meanwhile, other energy types have more recently begun to play important roles, including nuclear power, hydropower, and modern technologies that harness energy from the wind and the sun. Meeting any rising future demand presents a range of challenges, including those that relate to affordability, climate change, and air pollution.

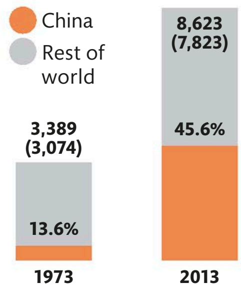
> "We can **no longer continue feeding our addiction to fossil fuels** as if there were no tomorrow. **For there will be no tomorrow.**"
>
> **ARCHBISHOP DESMOND TUTU, SOUTH AFRICAN HUMAN RIGHTS CAMPAIGNER**



## CHINA CRISIS: THE RISE IN COAL BURNING

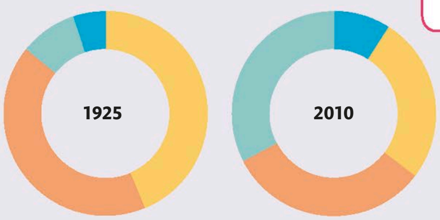
China's demand for energy has risen dramatically in recent decades. In addition to fueling rocketing domestic demand, this has been linked with economic growth in other counties via its vast export-oriented manufacturing sector. Because it is abundant and cheap, coal has been vital to China's export-oriented development and its burgeoning middle classes. Reliance on coal has, however, come at a price: for example, the resultant air pollution causes problems on a global scale as well as for the Chinese people in health terms.

**KEY**
**Regional share of coal production millions of tons (tonnes)**




**During the digital age,** digital technologies spread. They relied on the continuing rapid increase in access to electricity.

**KEY**




**Mass-produced electrical goods,** including more affordable TVs, washing machines, and refrigerators, boost energy use.

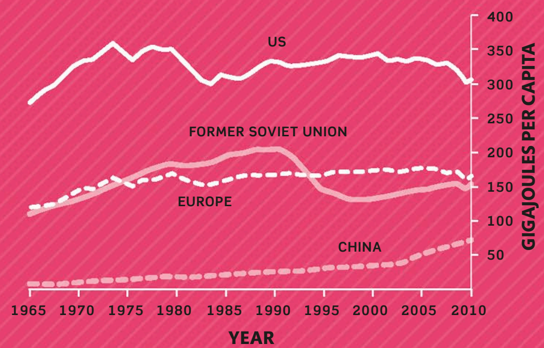
**1991**
The collapse of the Soviet Union causes a temporary slow down in the rate of growth in global energy use

### The changing energy mix

Global use of fuel types is constantly evolving, as can be seen by the shift from biomass (wood, plant material, manures) in the early 20th century to a major reliance on oil in the early 21st.

### Regional energy use per person

Mature European and North American economies have seen relatively stable demand, whereas the economy of the Soviet Union collapsed with the fall of communism. China's, meanwhile, has surged on the back of rapid economic development.




**1954**
The first civilian nuclear power station becomes operational in Obninsk, Russia

**1941**
A one-megawatt wind turbine in the US is the first in the world to supply electricity to a power grid

GLOBAL ENERGY USE IN EXAJOULES (EJ)

500
400
300
200
100

1940 1960 1980 2000

# Surge in Demand

**Economic growth has depended on access to vast quantities of cheap energy to generate electricity, produce heat, and provide transportation needs. Further development and urbanization mean demand will continue to rise.**

Based on current figures, most of this projected increase is expected to occur in the fast-growing economies of the global East and South, such as Asia and Africa. It is believed that fossil energy will continue to make the greatest contribution toward meeting the world's rising demand.

In the past, the human world was powered mainly by renewable energy in the form of wood, water, wind, and animal power. Since industrialization, we have increasingly relied on fossil fuels, and, to a limited extent, nuclear power. The increased use of natural gas to generate power (at the expense of coal) is helping curb emissions to levels that are below what they would have been otherwise. However, it is clear that if we are to prevent global warming by limiting the average planetary temperature increase to below 3.6°F (2°C) compared with the preindustrial period, then we will need to see a much lower reliance on fossil fuel sources and a much faster growth in renewable energy technologies.


**SEE ALSO...**

- **Carbon Crossroads** pp138–139
- **Renewable Revolution** pp52–53
- **Toxic Air** pp144–145


## Energy usage: present

The world's demand for energy continues to rise. By 2030, the amount of energy we need is expected to be about double the demand in 1990 and a third greater than that used in 2015. Today some countries are maintaining economic growth without causing rising emissions, but global demand for all energy types is increasing.

**KEY**

**RENEWABLES**
This category includes wind, solar, wave, tidal, and geothermal technologies. Some are still at small scale but growing fast.

**BIOENERGY**
Includes wood, sugarcane, and agricultural byproducts used as fuel sources to power transport and generate electricity and heat.

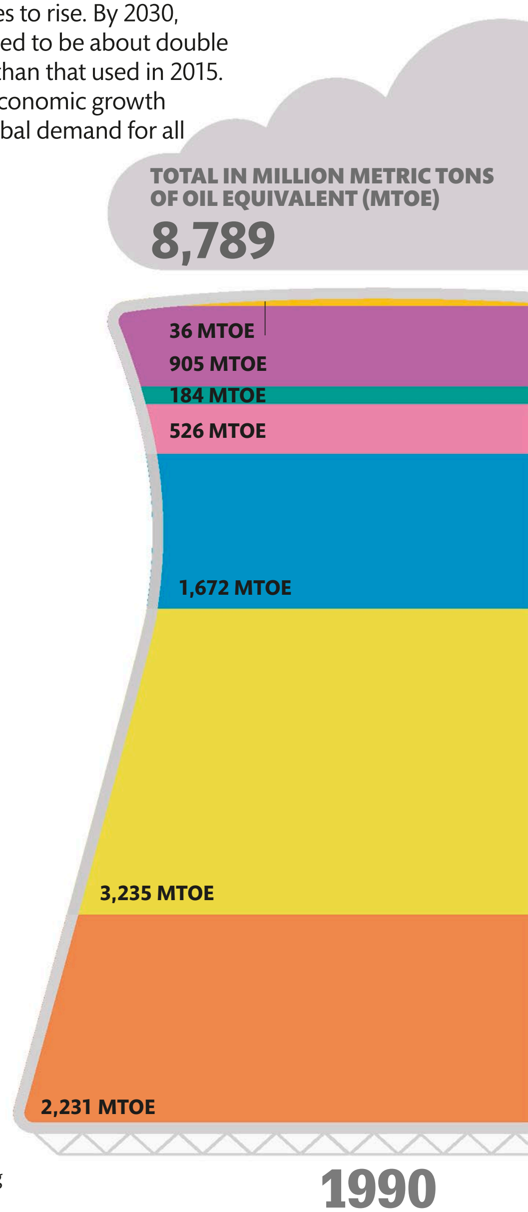
**HYDRO ENERGY**
Hydroelectric dams already generate substantial quantities of relatively low-carbon power. Expansion, however, is limited.

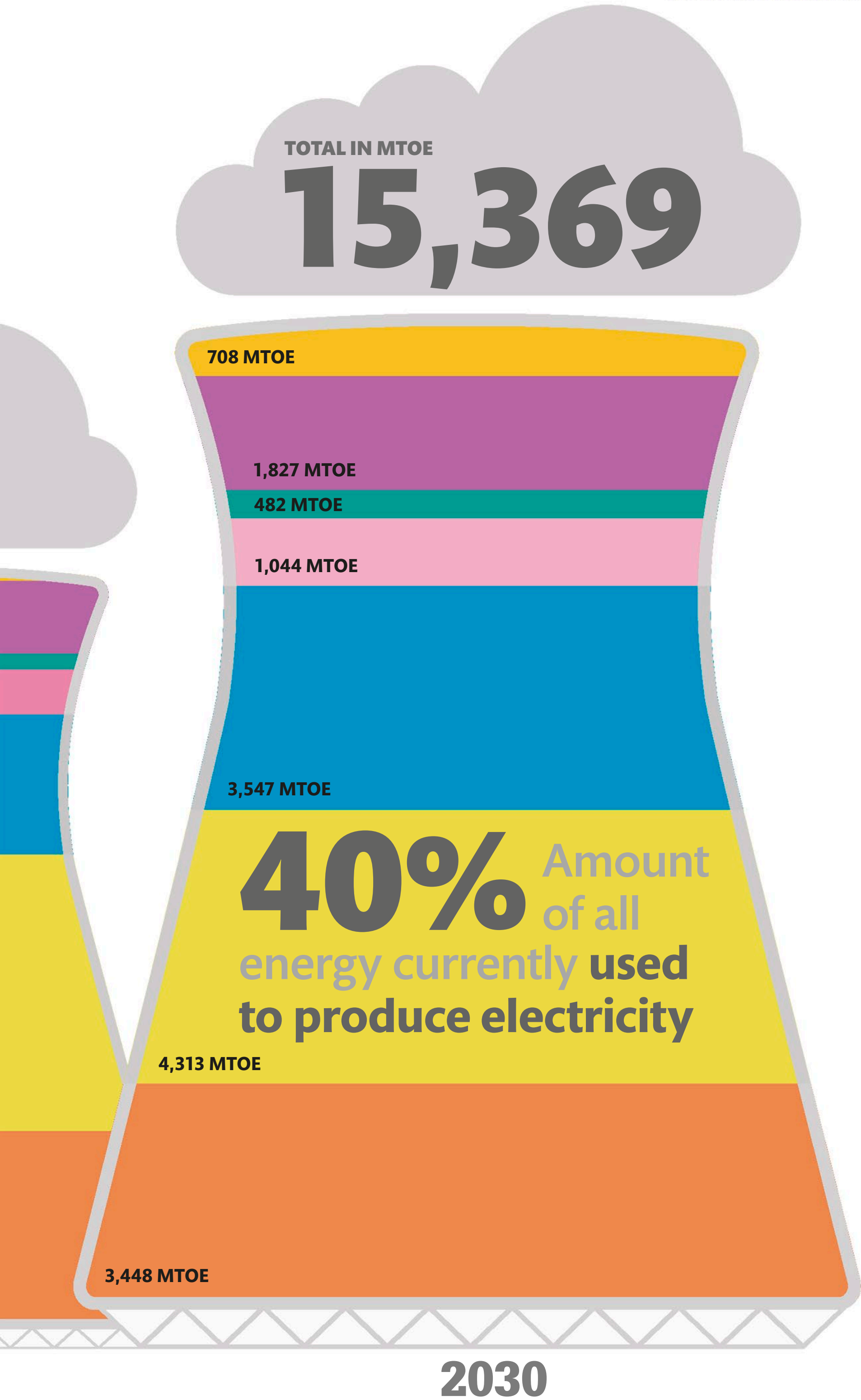
**NUCLEAR ENERGY**
Low-carbon at point of generation, this power source is expensive, with many technological and waste-management challenges.

**NATURAL GAS**
Although cleaner than coal, demand for gas is not compatible with strategies for limiting climate-changing emissions.

**OIL**
Used mainly to fuel road, sea, and air transportation. Demand can be reduced through more efficient technology and electric vehicles.

**COAL**
By far the "dirtiest" power source, coal has played a major role in the development of many fast-growing countries, such as China and India.






## The future of energy

By 2030, global energy consumption will be almost twice that used today; projections divide it into the segments shown (left). Yet the future energy mix can be changed to increase renewables while reducing reliance on fuels such as high-polluting coal. Renewables also face challenges, however. For example, hydroelectric power is at risk from droughts caused by climate change, while energy-storage technologies still need to be refined to cope with the intermittency of some renewables.

### What can we do?

- **Governments and international agencies** can use policies to create a faster transition to cleaner energy sources, while encouraging more efficient energy use among the industries that are the biggest consumers.
- **Governments** can shift public subsidies away from fossil fuel production toward cleaner, renewable energy alternatives.

### What can I do?

- **Buy electricity** from companies generating power via renewable sources.
- **Reduce your energy use** Turn down heating, use air conditioners less, unplug unused appliances, switch off unneeded lights. Walk or bicycle whenever possible.

# Power-Hungry World

**Developed countries run on reliable energy supplies. In developing countries with widespread poverty, a high proportion of the population are energy poor and lack access to regular electricity.**

Although access has spread widely in recent years, especially in Asia and Latin America, 1.4 billion people remain unconnected to grid-based power systems. Around 2.7 billion people, most of them in Africa and South Asia, depend on wood or dried animal dung for cooking, and millions use paraffin for lighting. In both cases, the resulting air pollution poses major health threats that kill huge numbers of people each year, especially women and children.


**SEE ALSO...**

- **Surge in Demand** pp46–47
- **Renewable Revolution** pp52–53
- **Energy Conundrum** pp60–61

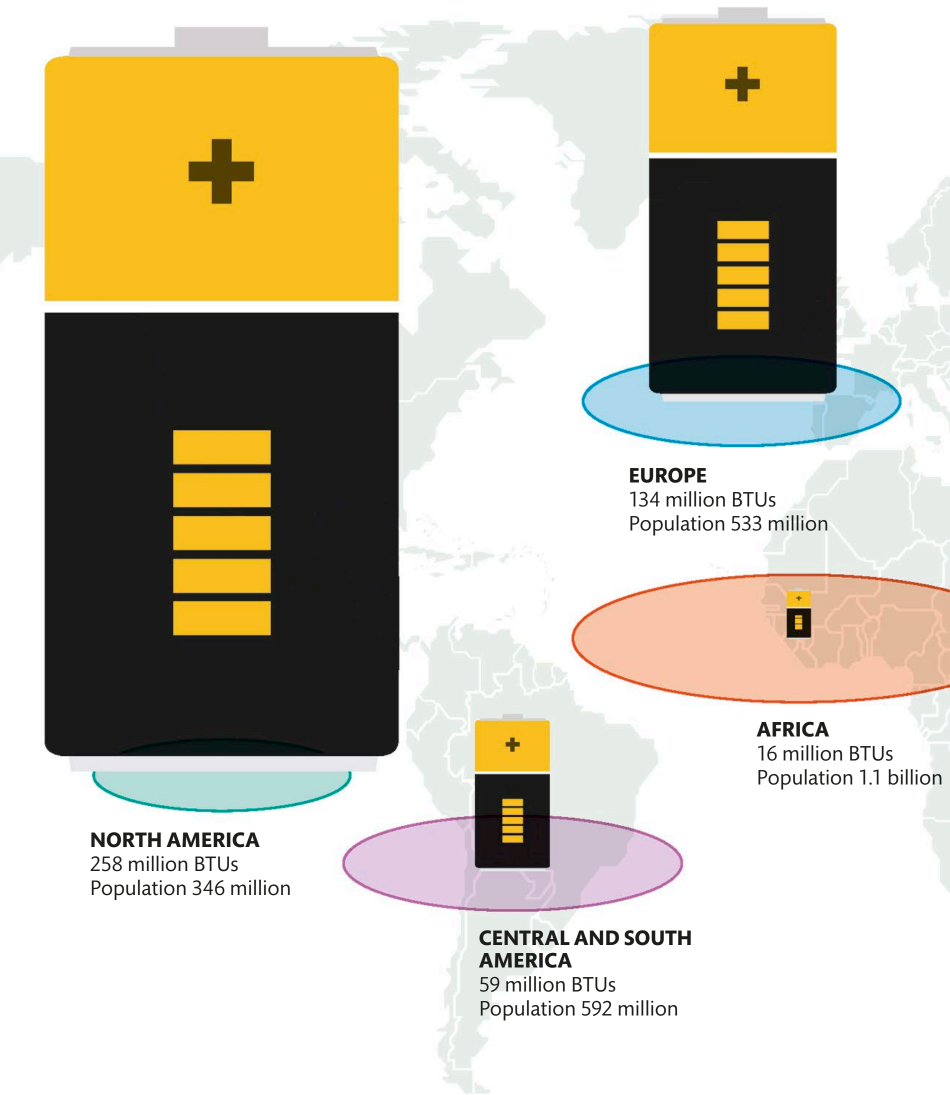

## The global divide

Huge disparities in world energy use are revealed by measuring how much energy is used per person. This shows the biggest users consuming hundreds of times more energy as those using the least. Population size and economic development rate affect energy use. Asia, for example, outstrips all other regions; as more of China's and India's 2.7 billion people achieve middle-class lifestyles, their energy use increases. Africa, meanwhile, uses relatively little energy—most of the continent is still without grid-supplied electricity and plunges into darkness at night. Clinics cannot refrigerate medicines, and schoolchildren don't have enough light to read. Clean, affordable power for all is vital for ending poverty.

**KEY**

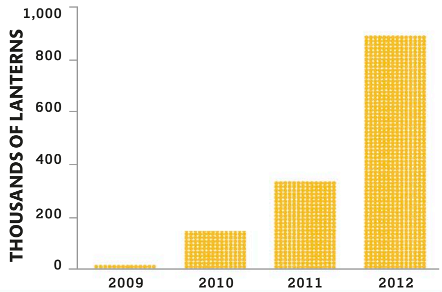
Energy use in British thermal units (BTUs) per person. A BTU is about equivalent to the heat generated by one lighted wooden match.

Total population by area



## KEEPING IT CLEAN USING SOLAR POWER

Some developing countries are bypassing traditional grid-based power systems altogether. For example, solar-powered lantern sales in Africa have soared, helped by low-cost support from microfinance projects, bringing emission-free lighting to millions.

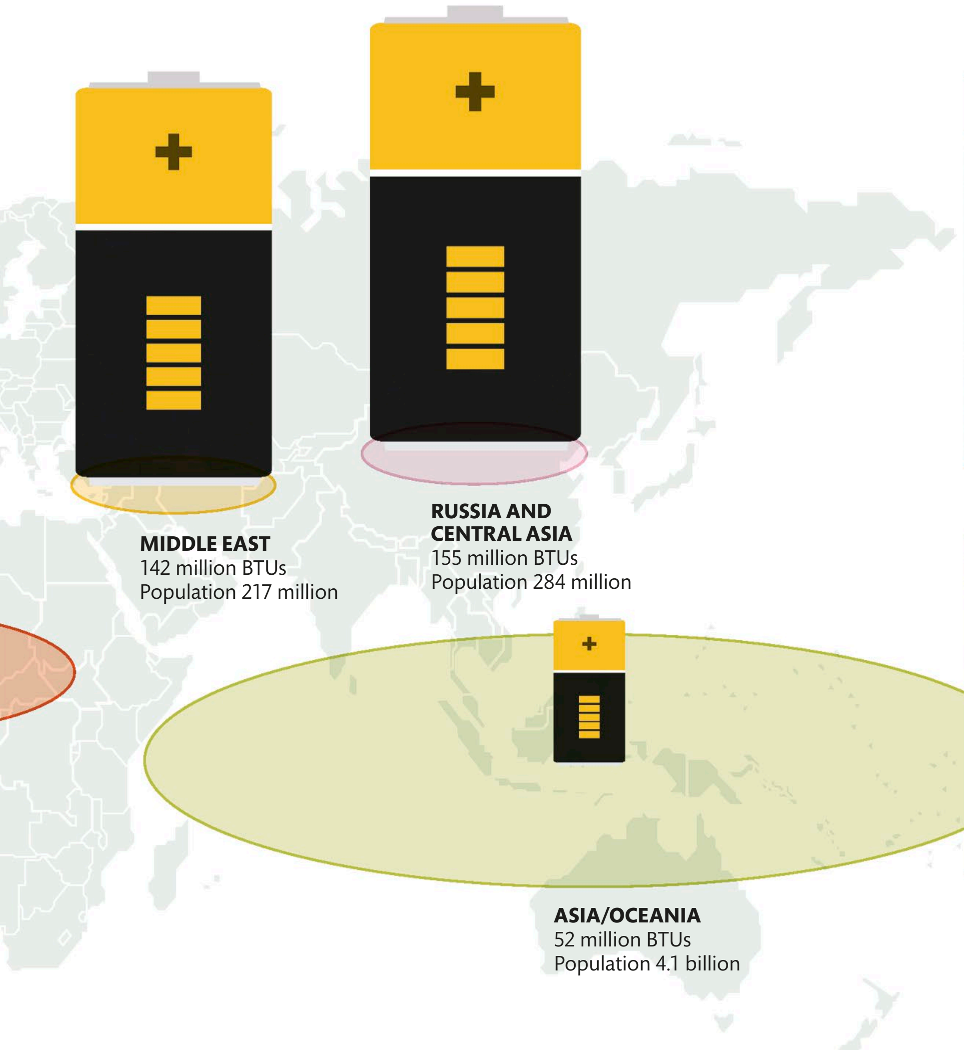



## What can we do?

- **Governments** can encourage companies to invest more in clean and renewable energy sources.
- **International development agencies** can adopt stronger policies to avoid fossil energy and instead help countries build clean energy systems.

## What can I do?

- **Urge your pension fund** to invest in companies that bring clean power to developing countries.
- **Join campaigns** that call on companies and governments to support the spread of clean energy to developing countries.




**Dark divide**
At night, the lights of wealthier countries shine in satellite imagery, while developing nations with limited access to electricity are dark.

# Carbon Footprint

**Many of the things we do generate a carbon footprint. This footprint describes the quantity of carbon dioxide ($CO_2$) emissions arising from particular products, activities, or services.**

Carbon footprints vary hugely. For example, that of an average American citizen is more than a hundred times that of a poor person living in sub-Saharan Africa. Some activities, such as a flight on an airplane, have a major short-term footprint, whereas other carbon-heavy decisions, such as buying a new car, will be spread over years and depend on how much the car is driven. Carbon footprints can be difficult to calculate very precisely, but still give a helpful indication of where the biggest impacts arise. This enables choices to be made by people, companies, and governments in limiting emissions.

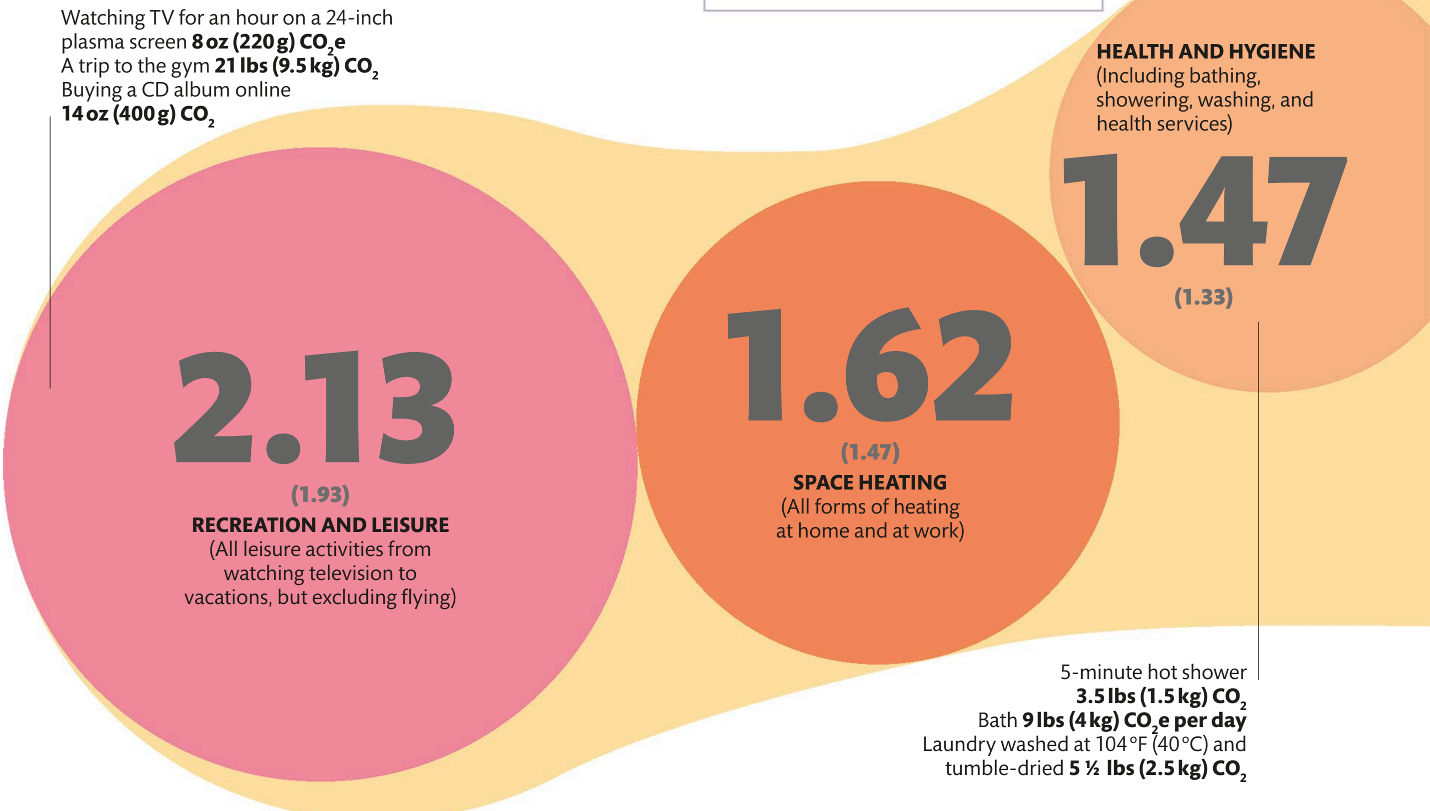
## Personal footprint

The average carbon footprint of a UK citizen reveals that consumption of food, transportation, heating, recreation, electricity, and products are among activities that generate a total of around 11 tons (10 tonnes) of emissions per person per year. Higher-consumption lifestyles are spreading across the world and, consequently, carbon footprints are rising fast.

**KEY**

Carbon dioxide (tons/tonnes)

**$CO_2$** quantity of carbon dioxide emitted as a result of the activity specified.
**$CO_2e$** carbon dioxide equivalent. Carbon dioxide plus other greenhouse gases emitted, converted to the common unit of carbon dioxide.



Sending an email **4g $CO_2$e**
Annual cell phone use at 1 hour per day **44 oz (1.25 kg) $CO_2$e**

**COMMUNICATION**
(Telephone and internet)
**1.8**
**(1.6)**

**FOOD AND CATERING**
(Agriculture, food transportation, cooking, restaurants)
**1.51**
**(1.37)**

Cappuccino
**8 oz (235 g) $CO_2$e**
2 ¼ lbs (1 kg) lamb
**86 lbs (39.2 kg) $CO_2$e**
2 ¼ lbs (1 kg) chicken
**15 lbs (6.9 kg) $CO_2$e**
2 ¼ lbs (1 kg) vegetables
**4 lbs (2 kg) $CO_2$e**
2 ¼ lbs (1 kg) fruit
**2 ½ lbs (1.1 kg) $CO_2$e**
2 ¼ lbs (1 kg) lentils **2 lbs (0.9 kg) $CO_2$e**

**COMMUTING**
(Traveling to and from work by car or public transportation)
**0.9**
**(0.8)**

Annual car use **5 tons (4.7 tonnes) $CO_2$e per year**
Bus trip **3 ¾ oz $CO_2$e per passenger mile / 66 g $CO_2$e per passenger km**
Commuter rail **6.1 oz (172 g) $CO_2$ per passenger mile**
Bicycling **1 oz per mile / 17 g $CO_2$e per km**

**CLOTHING**
(Production, road transportation, retail and washing/drying of clothes and shoes)
**10.8**
**(9.8)**

A T-shirt from manufacture to disposal **22 lbs (10 kg) $CO_2$**

**AVIATION**
**0.67**
**(0.74)**

Long flight **7 ¾ oz per mile / 138 g $CO_2$e per km**
Short flight **6 ¾ oz per mile / 120 g $CO_2$e per km**

**HOUSEHOLD**
(Including lighting, do-it-yourself, decoration, gardening)
**1.50**
**(1.36)**

Standard 100W light bulb **140 lbs (63 kg) $CO_2$ per year**
Lawn mower **160 lbs (73 kg) $CO_2$ per acre per year**
Building a new house (2-bedroom) **88 tons (80 tonnes) $CO_2$e**

**0.53**
**(0.48)**
**EDUCATION**
(Schools, and books and newspapers)
Daily newspaper, recycled, **14 oz (400 g) $CO_2$e**

**0.32**
**(0.29)**
**GOVERNMENT AND DEFENSE**

## What can I do?

- **Go online and use a carbon footprint calculator** to see where your emissions are coming from.
- **Identify where savings can be made**. Once you have calculated your carbon footprint, you can work out a plan to cut carbon while saving money.
- **Consider what you eat.** Food is a major part of a person's total carbon footprint in most western countries, especially where there is a substantial element of meat and dairy produce.

# Renewable Revolution

**Renewable energy sources are rapidly expanding, especially solar and wind power technologies. These and other clean energy sources will be vital for meeting rising demand while simultaneously combating climate change.**

The advantage of renewable energy is that it can be replenished indefinitely, without depleting finite resources such as fossil fuels. Renewables can be used to provide electricity and heat and to make fuel for transportation.

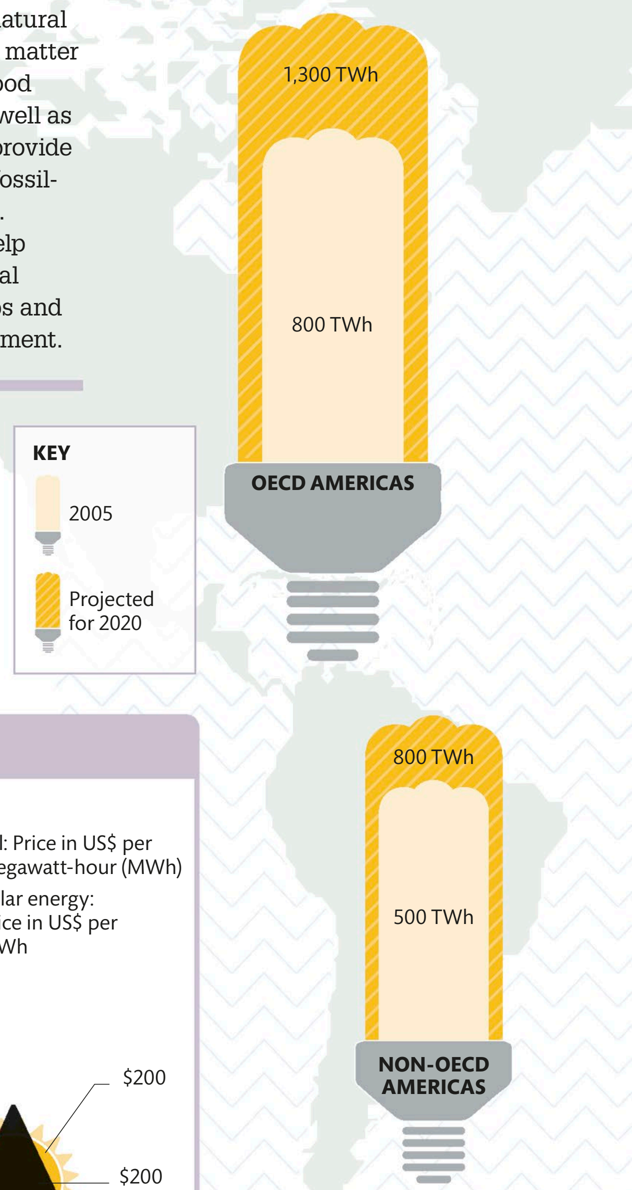
At present, electricity-generating wind and solar power technologies form the biggest, fastest-growing areas of the renewables sector.

Biogas (the same as fossil natural gas, but made from organic matter such as food waste) and wood can be used for heating as well as electricity. Liquid biofuels provide a renewable alternative to fossil-derived diesel and gasoline.

Renewable energy can help address many environmental issues, as well as create jobs and drive technological development.

## Growth of renewable energy

Renewable energy is the fastest-growing source of power worldwide. By 2016, it is expected to surpass the amount of energy generated from natural gas and be double that of nuclear power. Renewables are already the second most important global electricity source (after coal). By 2018, renewable energy generation is expected to comprise 25 percent of the world's gross power generation—an increase of 20 percent from 2011. By 2030, renewables will overtake coal.



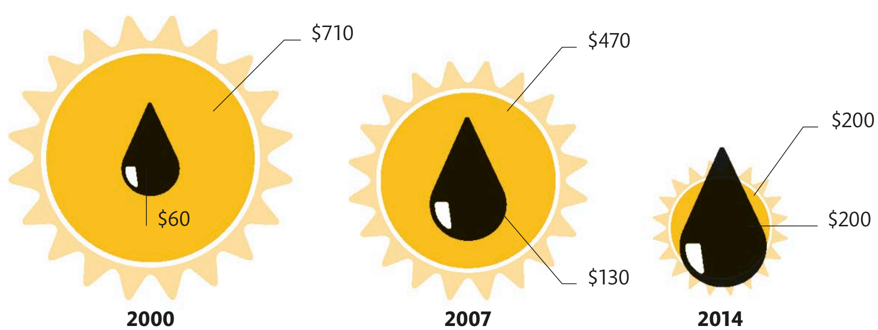

### FALLING COST OF SOLAR ENERGY

As the scale of renewable energy sources increases, market competition intensifies. As technology is refined, costs begin to fall. The cost of electricity sourced from solar photovoltaic power, for example, has dropped dramatically in recent years and is now level with that of oil.

**KEY**

Oil: Price in US$ per megawatt-hour (MWh)

Solar energy: Price in US$ per MWh

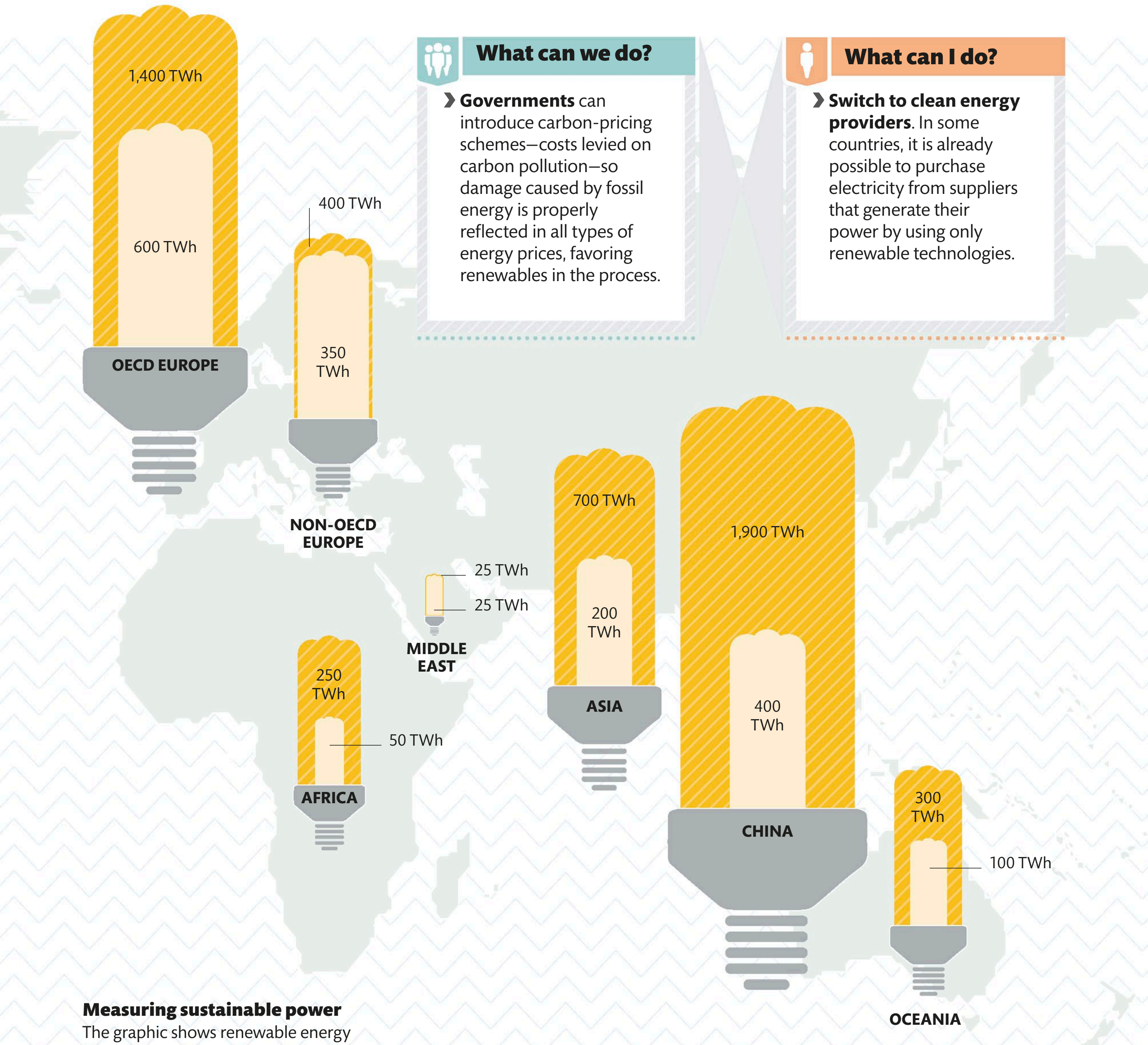


### What can we do?

**Governments** can introduce carbon-pricing schemes—costs levied on carbon pollution—so damage caused by fossil energy is properly reflected in all types of energy prices, favoring renewables in the process.

### What can I do?

**Switch to clean energy providers**. In some countries, it is already possible to purchase electricity from suppliers that generate their power by using only renewable technologies.




**Measuring sustainable power**

The graphic shows renewable energy use by nine regions, including OECD (Organisation for Economic Cooperation and Development) and non-OECD nations. The OECD is a coalition of the world's 34 most developed nations. (One terawatt-hour [TWh] is equal to 588,441 barrels of oil).

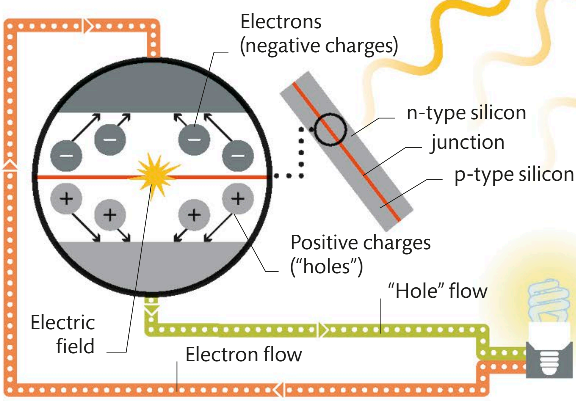
Renewables accounted for almost **22% of global electricity generation** in 2013—up 5% from 2012

# How Solar Energy Works

**The sun is the ultimate source of energy for nearly all life on Earth. With the right technology, our home star could also be the main power station providing the energy needed to run the human world.**

## Solar photovoltaic (PV) panels

These use semiconducting layers, usually silicon, to capture solar energy. Light hits a panel, creating an electric field across its layers that creates a current by separating positive and negative charges. The stronger the sunlight, the more electricity produced.

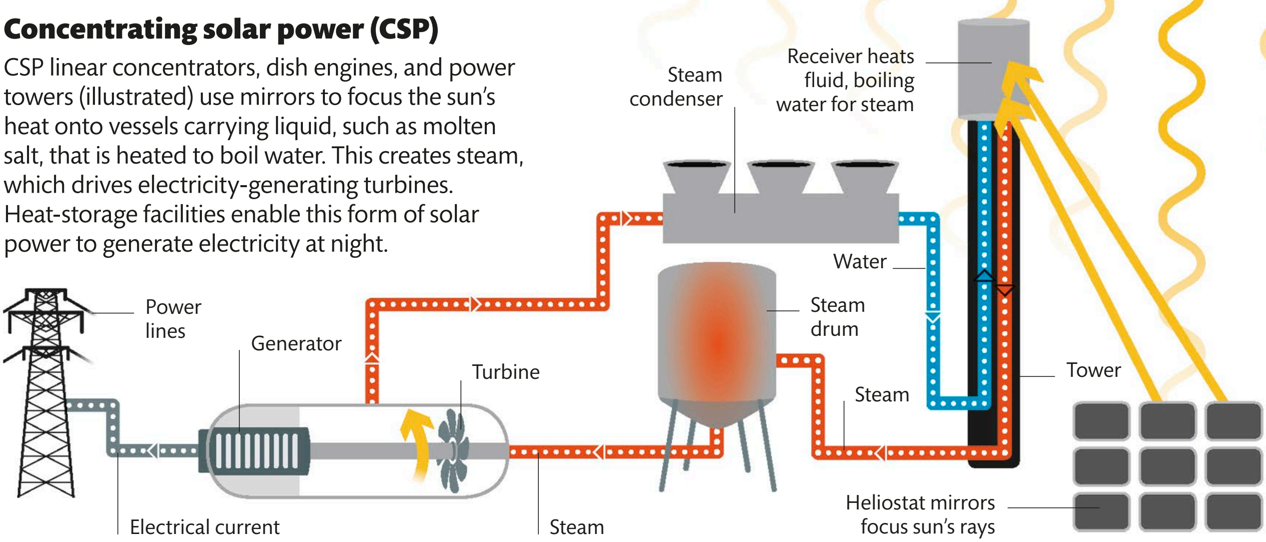



## Solar powerhouse

The sun emits a vast quantity of energy. The solar energy hitting Earth is sufficient to power around 4 trillion 100-watt light bulbs. The recent refinement of solar energy technologies and the rapid growth in their use lead many experts to believe that, by 2050, solar will be the world's principal energy source.

## Concentrating solar power (CSP)

CSP linear concentrators, dish engines, and power towers (illustrated) use mirrors to focus the sun's heat onto vessels carrying liquid, such as molten salt, that is heated to boil water. This creates steam, which drives electricity-generating turbines. Heat-storage facilities enable this form of solar power to generate electricity at night.

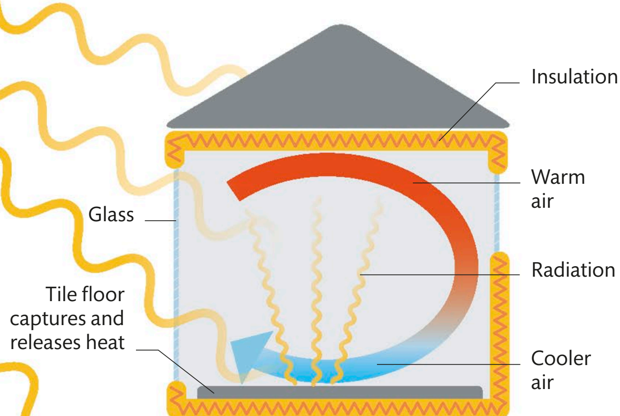


We have always relied on solar energy. For example, the horses that were once a main means of transporting people and goods were fed on grass and grains grown with sunlight. Today, however, new technologies are allowing us to make more use of solar energy, by converting heat or light from the sun into more usable forms of energy, such as electricity and hot water. Solar technologies have pros and cons, but in all cases they also offer massive potential. Increased use and refinement will lead to falling costs and potentially vast growth in the years ahead.

As the world struggles to cut climate-changing emissions, solar energy technologies are positioned to take over from fossil fuels.

## Passive solar energy

Windows positioned to receive maximum natural light can cut the electricity needed to power light bulbs. Solar heating of interior surfaces reduces the need for internal heating, especially if a building is carefully insulated.

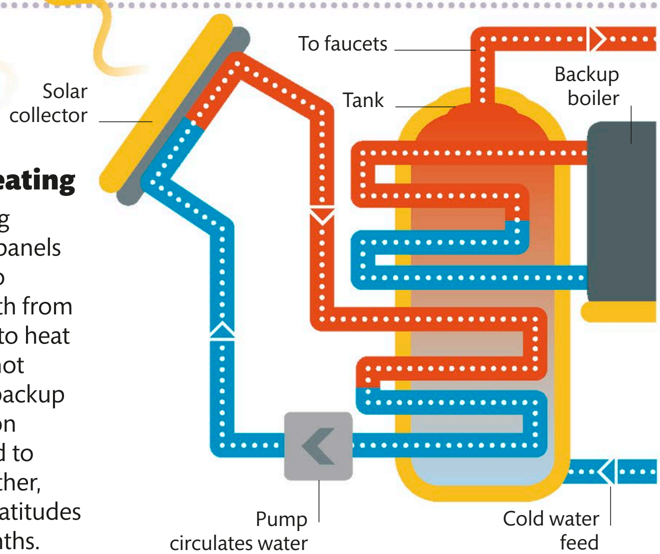



## GLOBAL HOTSPOTS

Solar energy technologies can work almost anywhere there is a good amount of daylight. They are most effective, however, in regions where there is consistently strong sunshine and little cloud. Many desert areas and other sunny parts of the world have the potential to produce huge quantities of electricity by using existing solar energy technologies, such as solar PV and concentrating solar power. These include the southwestern US, western South America, Africa, the Middle East, South Asia, and Australia.

## Solar water heating

Solar water heating systems use solar panels called collectors to accumulate warmth from the sun and use it to heat water stored in a hot water cylinder. A backup boiler or immersion heater can be used to heat the water further, especially at high latitudes during winter months.




**1 hour of sunlight hitting the Earth is roughly equal to the planet's annual energy consumption**

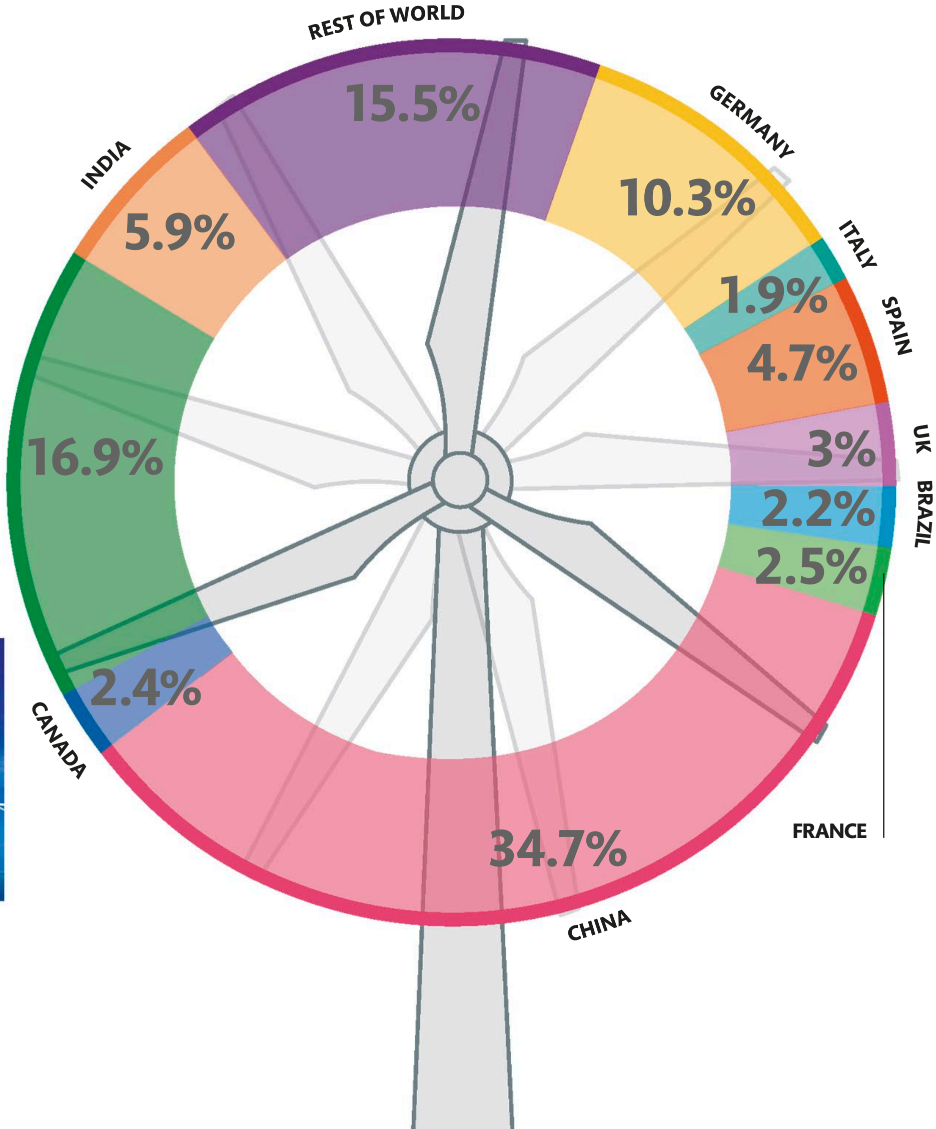
# Wind Power

**During recent decades, the use of wind-generated electricity has expanded rapidly in some parts of the world. Some countries, such as Denmark, now rely heavily on wind to supply much of their power.**

In ancient times, wind energy was used to propel boats along the Nile River, pump water, and grind grain. By about 1000 CE, it was used to drain large areas of the Rhine delta. Wind was first harnessed to generate electricity in Glasgow, Scotland, in 1887. In 1941, the world's first megawatt turbine was connected to the power grid in Vermont, followed by the first multi-turbine wind farm in New Hampshire in 1980, and the first offshore installation in Denmark in 1991. Since these pioneering wind farms were constructed, the technology has improved—and rapid growth has followed.

## Who's generating the most?

A number of countries have adopted policies to encourage the installation of wind-powered electricity generation. Many have done so in order to reduce greenhouse gas emissions. China currently has the world's biggest wind-power sector, followed by the US, although during recent years the latter has added far less new capacity than China. Germany comes third, with 10 percent of the world's wind power, and other major wind energy producers include India, Spain, the UK, Canada, France, Brazil, and Italy.




**Offshore wind power**
Stronger ocean winds provide more electricity than wind farms on land, but offshore setup costs are higher.

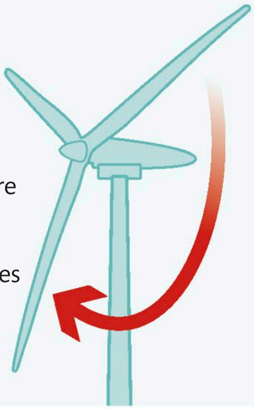
## How does wind power work?

Conventional generators use steam to drive turbines. With wind power, the process is powered by air instead of fuels such as coal or gas. The propeller-like blades are attached to a rotor that is connected to a main shaft, which in turn spins the generator. The whole assembly is mounted on a tower in order to take advantage of steadier and less turbulent winds.

1

**Blades rotate**

If the winds are sufficient, the passing air pressure causes the turbine blades to revolve.



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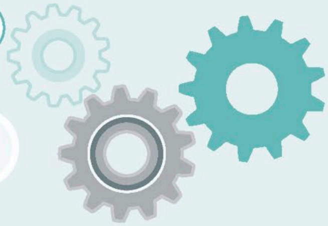


**Gears spin generator**

The blades turn a shaft connected to a gearbox, which increases the rotational energy produced.

3

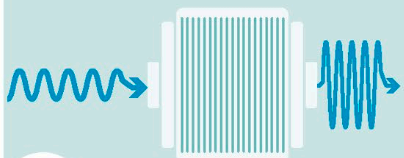
**Power out**

The rotational energy is converted into electricity by a generator.

4

**Transformation**

A transformer converts the electricity into the correct voltage for distribution.



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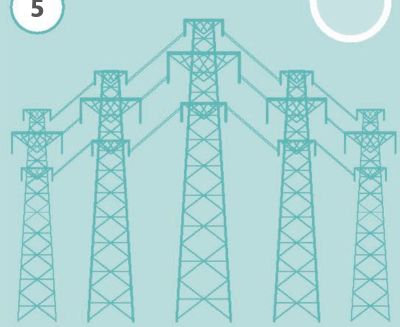


**Distribution**

Electricity is sent throughout the country via a national grid network of cables.

"The future is **green energy,** sustainability, **renewable energy"**

**ARNOLD SCHWARZENEGGER, FORMER GOVERNOR OF CALIFORNIA**

### WIND-GENERATED ENERGY: PROS AND CONS

***Pros***

- It's clean, green, and pollution-free. Wind turbines create no emissions.
- It's renewable. Winds originate from solar energy, so promise an endless supply.
- Prices have decreased by 80 percent since 1980 and will fall further. Operating costs are low.
- Potential for rapid growth.
- Technology improving to produce more power more quietly.

***Cons***

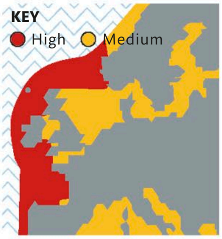
- Turbines typically operate at 30 percent capacity.
- Can cause hazards to birds and bats. Soil erosion can be a problem during installation.
- Still more expensive than coal or gas-generated power in some countries.
- Can cause visual changes to landscapes.
- Viable only in areas of land and sea with sufficient steady wind.

# Tidal and Wave Energy

**The seas hold vast quantities of energy that we are only beginning to convert into electricity through wave and tidal power systems. Like wind and solar technologies, they can produce pollution-free power.**

## Turning the tides

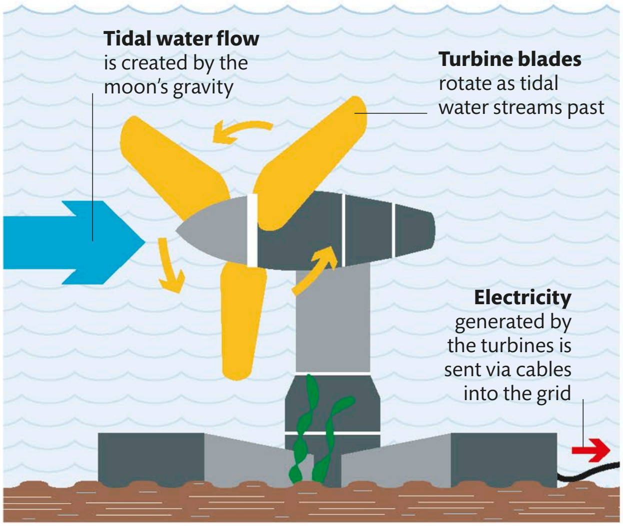
Tidal and wave energy technologies are becoming commercially viable power sources. The technology is advancing rapidly and has huge potential in coming decades. Wave farms and tidal energy systems harness the enormous power of the seas to generate power, and their global capacity could exceed that of about 120 nuclear reactors. Countries with the most potential for these reliable, renewable energy sources include France, the UK, Canada, Chile, China, Japan, Korea, Australia, and New Zealand.

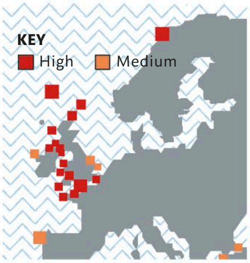



BEST SITES FOR WAVE POWER, EUROPE

## Making waves

Europe's best areas for wave farms are along the western Atlantic coast, where strong, persistent winds create lots of large waves.

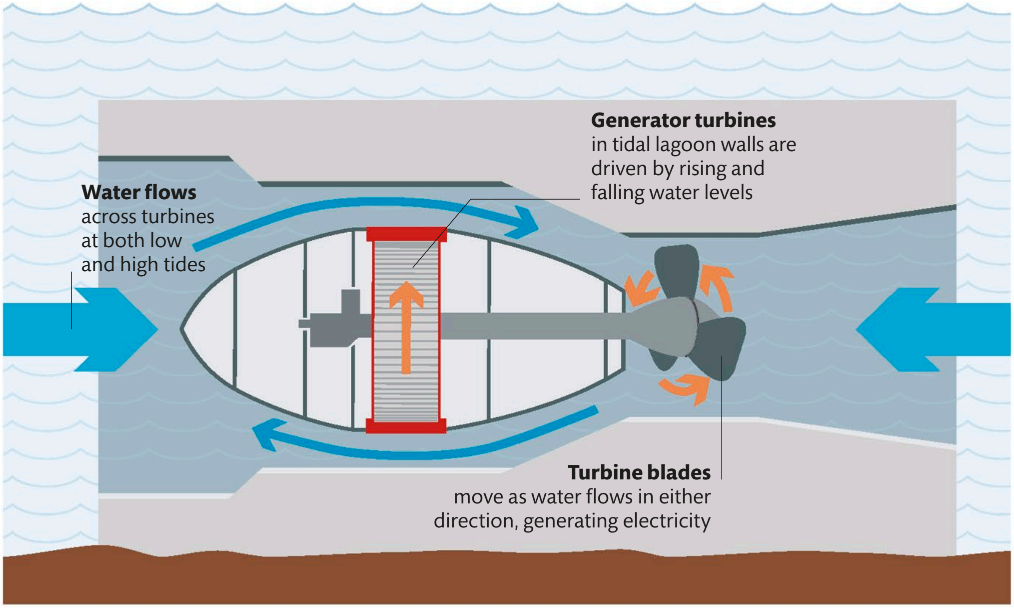



BEST SITES FOR TIDAL STREAM POWER, EUROPE

## Streaming tides

Around the UK in particular, headlands, inlets, and channels funnel and increase the speed of tidal stream currents—ideal for tidal energy.



Tidal and wave technologies harness the movement of tides and waves to drive electricity-generating turbines. In addition to cutting carbon dioxide emissions, these technologies could offer energy security and create jobs.

Electricity produced by wave and tidal power is currently priced higher than that generated by fossil fuels—partly because fossil fuels are burned (and valued) without taking the costs of the climate change they cause into account.

## SEE ALSO...


- **Surge in Demand** pp46–47
- **Renewable Revolution** pp52–53
- **Energy Conundrum** pp60–61


**80%** The potential **kinetic energy** from waves that can be **converted into electricity**

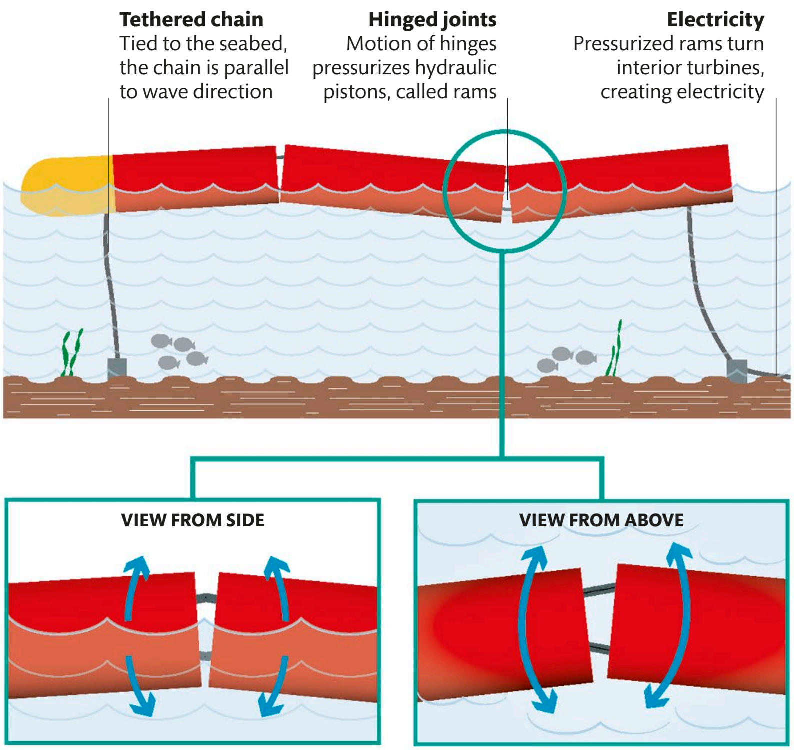
## CASE STUDY

### *Swansea Tidal Lagoon*

- Swansea Bay in South Wales is located on the Bristol Channel. Because this area of UK coastline has the second-greatest tidal range in the world, it provides an ideal location for a tidal lagoon.
- Sixteen underwater turbines are planned to be embedded in a breakwater wall extending 2 miles (3 km) out to sea.
- The tidal lagoon's proposed power station will generate clean, predictable power for more than 155,000 homes for at least 120 years.

## HARNESSING SURFACE WAVES

One of the most promising designs for capturing surface wave power is the wave attenuator. Waves are best along western coastlines due to stronger, more consistent winds, so hotspots for this technology include the Pacific US, the UK, France, Portugal, New Zealand, and southern Africa.




**Vertical bends**
The semisubmerged sections of a wave attenuator move vertically up and down with wave motion, flexing at their hinges.

**Oscillating motion**
In addition to being forced up and down, attenuator hinges allow sections to "yaw," capturing wave energy from rotational movement.

# Energy Conundrum

**Pros and cons accompany all of our energy choices. As rising demand leads to deepening tensions between competing priorities, it is vital that we see the full picture in order to make informed decisions.**

Many different types of existing and emerging technologies play vital roles in meeting our energy needs. Parallel technologies will shape future choices: for example, carbon capture and storage in the case of coal and natural gas, and energy storage in relation to some renewables.

Our approach to energy must address the issues of security, affordability, and environmental impact—three goals that often pull in different directions. For example, coal provides cheap, secure power but causes high carbon dioxide emissions and air pollution.

Energy policy is a highly political issue. Decision making often favors short-term cost and security objectives at the expense of environmental concerns. Factors like these make it all the more challenging to put the most rational—and globally beneficial—long-term choices in place.

## What are our options?

The simple comparison below is based on situations as they broadly prevail today. While circumstances for some technologies are highly variable—such as the potential for renewable energy sources in certain locations—some overall conclusions about each particular source of energy can be provided. Policy makers must decide which yield the best range of long-term results.

**Coal** | **Oil** | **Natural gas** | **Nuclear** | **Hydropower**


### Coal

The single largest source of electricity worldwide, with recent massive growth in demand from fast-growing countries, including China and India.

- Abundant supply fuels cheap electricity.
- High carbon emissions and local air pollution.

### Oil

The world's main transportation fuel.

- A major source of carbon dioxide and urban air pollution.
- Oil produced by hydraulic fracturing (fracking) and tar sands creates higher carbon emissions than conventional oil.

### Natural gas

Flexible, abundant, and used for electricity, heating, and cooking.

- Produces about half as much carbon dioxide as coal.
- Conventional gas and that produced by hydraulic fracturing (fracking) raise different issues.

### Nuclear

Produces low-carbon electricity but is expensive and complex.

- Major issues are linked with long-term radioactive waste management.
- Tensions persist over the link between nuclear power and nuclear weapons.

### Hydropower

Relatively low-carbon power source but limited by number of suitable rivers.

- Can lead to major ecosystem and social impacts.
- Vulnerable to prolonged droughts that are already affecting some regions.

### KEY TO SYMBOLS AND RATINGS

**Cost** Energy costs often dictate choice and are especially important for those on low incomes

**Tech ready?** Some technologies are well established, while others are just coming on stream

**Pollution and waste** Some technologies are much cleaner than others

**Energy security** Access to reliable energy is a vital prerequisite for economic development

**Land and ecosystems impact** Energy supply can conflict with other resource and environmental goals

**Overall rating** the extent of long-term contribution to meeting the three goals of energy security, affordability, and environmental protection.

1 Best 10 Worst

**Strong case**

**Advantages**

**Drawbacks**

**Major concerns**

## EFFICIENCY: THE INVISIBLE "FUEL"

The most neglected fuel source is efficiency. Cars that are more fuel-efficient, lights that use less power, insulation, and smart building technologies all save energy without affecting comfort or convenience. Efficiency can also save money, making this an obvious priority when it comes to finding the best ways of reaching the three energy goals.

In 2011, the amount of money saved by **energy efficiency** was **$743 billion***

* Compared to total fuel consumption in 11 countries: Australia, Denmark, Finland, France, Germany, Italy, Japan, the Netherlands, Sweden, the UK, and the US

### Liquid biofuel


Can replace fossil oil and bring carbon dioxide savings—for example, by using sugarcane to make ethanol.

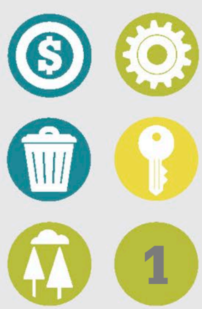
- Can divert food supply from plates to fuel tanks.
- Can drive deforestation, leading to $CO_2$ emissions and biodiversity loss.

### Biomass


Wood can be burned in power stations and replace gas and coal.

- Renewable, but can lead to high carbon emissions and soil damage.
- Can drive deforestation.

### Wind




Very clean power source that is growing fast.

- Intermittent wind means other power sources are needed to meet constant demand, but energy-storage technologies are developing.
- Changes the appearance of landscapes.

### Solar


Very clean power source that is growing fast.

- Depends on daylight, so very large-scale use will rely on emerging storage technologies, such as large-capacity batteries.
- Its use is rapidly expanding worldwide.

### Wave / Tidal


Very clean and potentially very significant power sources.

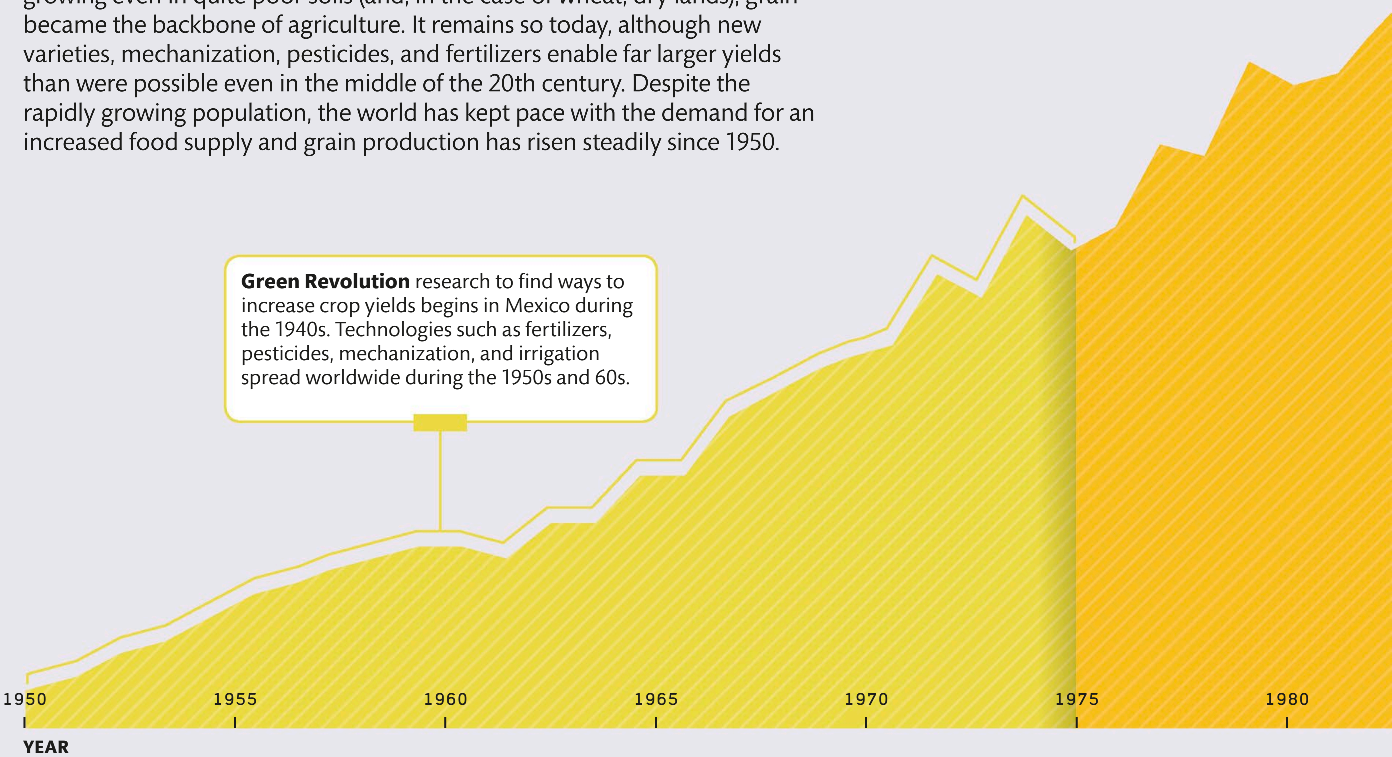
- Technologies are emerging, with first commercial power stations being installed.
- Relatively expensive. Needs government backing during start-up phase.

# Escalating Appetite

**The rise of agriculture has transformed the face of planet Earth and shaped the course of human history. Pre-farming, hunter-gatherer societies had a total population of a few million people, but today farming sustains more than seven billion people worldwide. The rise of high-productivity farming was a vital factor in the establishment of civilization and it enabled the continuing shift of people from rural areas to towns and cities. Sustaining the conditions that allow farming, including soil health and freshwater availability (pp78–79), are increasingly important challenges.**

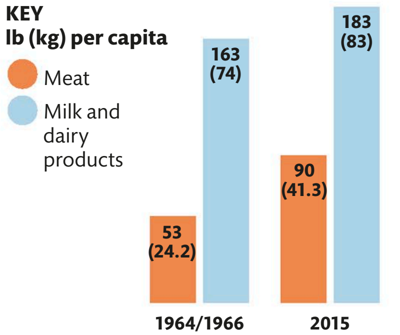
## Grain production

Early farmers domesticated wild grasses to produce grains, including rice, wheat, and corn. Rich in carbohydrate and protein, easy to store, and fast growing even in quite poor soils (and, in the case of wheat, dry lands), grain became the backbone of agriculture. It remains so today, although new varieties, mechanization, pesticides, and fertilizers enable far larger yields than were possible even in the middle of the 20th century. Despite the rapidly growing population, the world has kept pace with the demand for an increased food supply and grain production has risen steadily since 1950.



## THE RISE OF MEAT AND DAIRY

As people have become wealthier the consumption of meat and dairy products has risen dramatically. This has had negative effects both on the environment and on human health. Compared with vegetable-based diets, livestock-derived foods require more land and water to produce. Increased consumption of meat and dairy foods, both of which are high in protein and fat, raises the risk of heart disease, some cancers, and type 2 diabetes.




GLOBAL MEAT AND DAIRY CONSUMPTION

**1997**
First genetically modified corn is produced

1985 1990 1995 2000 2005 2010

601 (600) · 1,100 (1,000) · 1,650 (1,500) · 2,200 (2,000)

ANNUAL GRAIN PRODUCTION (MILLION TONS/TONNES)

**"Civilization as it is known today could not have evolved, nor can it survive, without an adequate food supply."**

**NORMAN BORLAUG, AMERICAN SCIENTIST AND "FATHER" OF THE GREEN REVOLUTION**

**Global grain production**
In 2016, nearly half of the world's grain was produced by just three countries: China, the US, and India. Corn, wheat, and rice account for most of the world's grain harvest.

# Farmed Planet

**About one third of the world's land is now used for farming. Only about one quarter of that third is used to produce crops, however; the rest used to rear animals.**

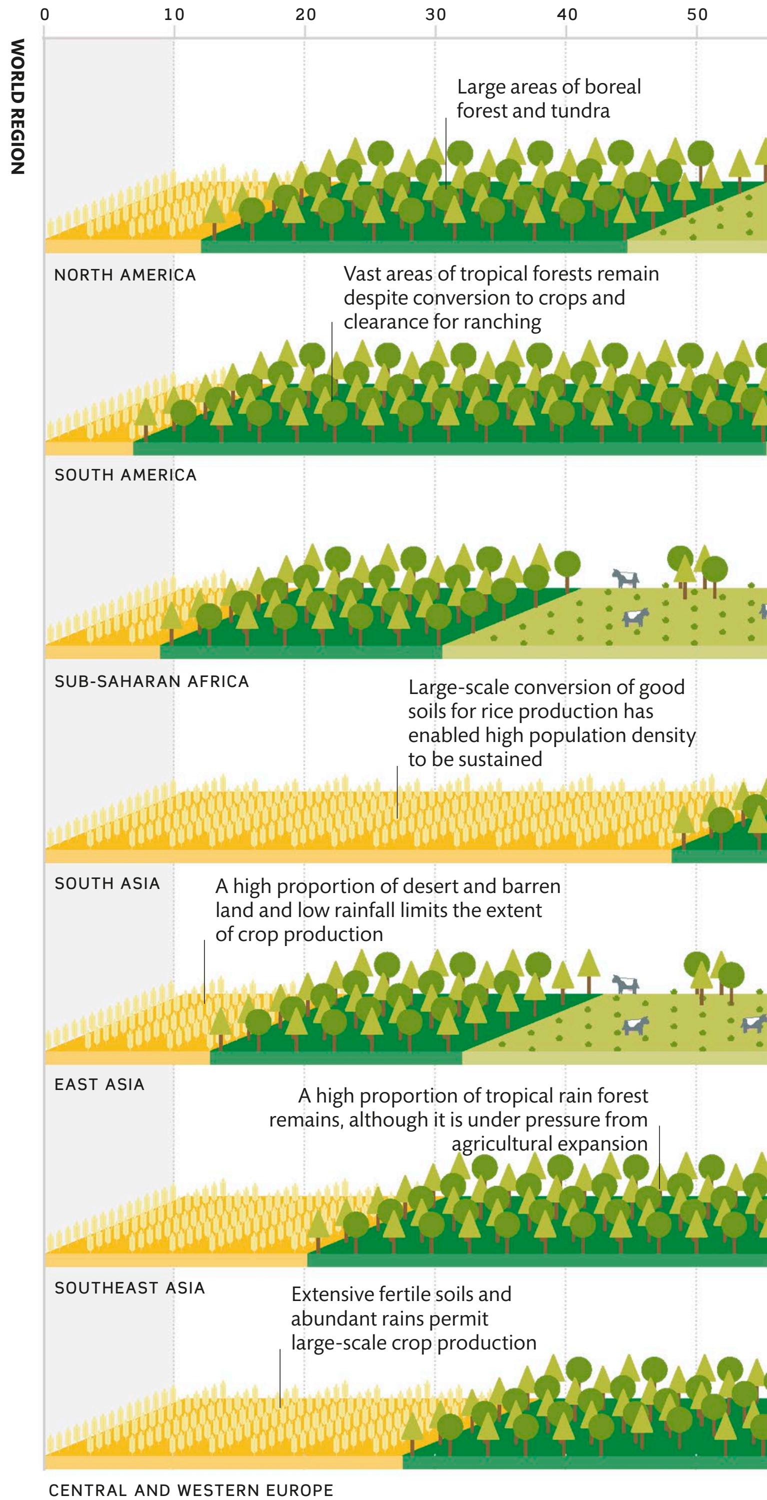
Most of the world's land is desert, ice-covered, or supports forests and grasslands, much of which is unsuitable for farming. Where conditions permit, there has been a steady expansion of agriculture, although the total land area with suitable soils and sufficient water for crop production is, in a global context, limited. Rising demand for food is leading to the continuing expansion of farming into the remaining unconverted areas, where there is suitable soil and sufficient water. The consequences of this include deforestation, declining wildlife, increased greenhouse gas emissions, declining water quality, and widespread soil damage (see pp74–75).

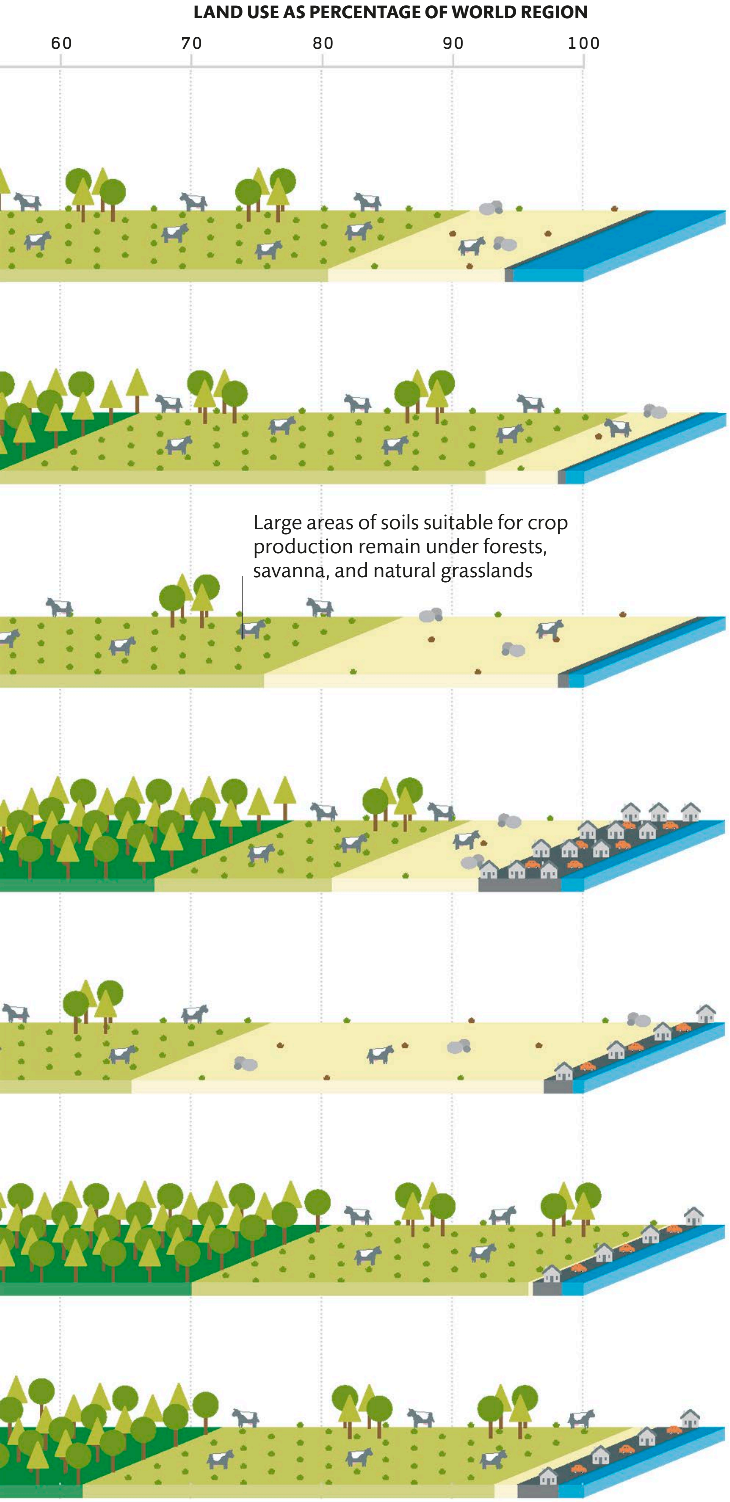
## Crops versus meat

About three quarters of the world's land that is producing food is devoted to rearing livestock to supply meat and dairy products. The remaining land is used to produce grains, fruits, and vegetables. Consumption of livestock products has increased in line with the rise in the number of middle-class consumers. This trend is set to continue, as the major emerging economies shift their dietary preferences. Only a fraction of farmland is cultivated for grain and vegetable production, and a high proportion of the crops produced are fed to livestock. Grasslands, sparsely wooded country, and barren lands are also partly grazed by domesticated animals.

**KEY**

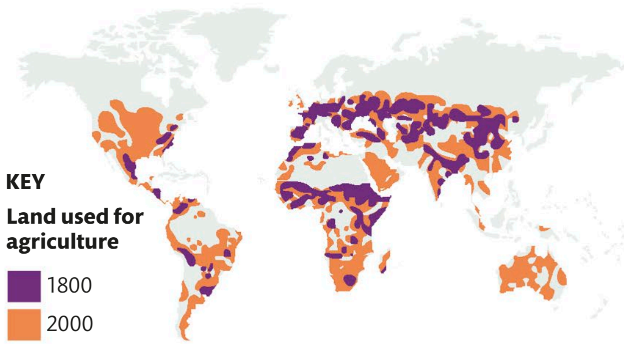
- Cultivated land
- Forested land
- Grassland and woodland ecosystems
- Sparsely vegetated and barren land
- Settlement and infrastructure
- Inland water bodies






## Change over time

The rise of agriculture during the last two centuries has been dramatic. In 1800, most of the farmed land was in Europe and parts of Asia. Today, it has expanded across those continents and transformed the face of North and South America, and much of Africa and Australia, where natural vegetation has been cleared to make way for crops and livestock.



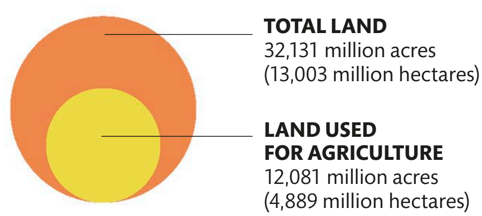

## GRAIN USES

Each year, the world produces around 3.1 billion tons (2.8 billion tonnes) of grains. Rice and wheat are primarily consumed by people, but most corn is fed to livestock. Feeding crops to animals, which are then consumed by people, uses more land, water, and fossil fuels than people eating crops directly.

**People 45 per cent** – under half of all grain production is eaten directly by people.

**Cattle feed per cent** –grains such as corn are used to feed pigs, cattle, and chickens.

**Other uses 20 per cent** – some grains have nonfood uses, and are used for biofuels and industrial materials.




TOTAL AGRICULTURAL LAND

# Fertilizer Boom

**The dramatic increase in food production achieved during recent decades has rested in large part on a corresponding increase in the use of fertilizers. However, this success has brought major challenges.**

The plants that sustain all people and animals need soil nutrients—including nitrogen, phosphorus, and potassium—to grow. These are depleted by agriculture and need to be replaced. For millennia, farmers used nutrients recycled from wastes, such as manure. Industrial farming is sustained by the input of fertilizer from other sources, which has had a major environmental impact.

## Improving yield

The invention of the Haber-Bosch process in the first half of the 20th century enabled nitrogen fertilizer to be made using natural gas and nitrogen from the atmosphere. Large-scale fertilizer application allowed farmers to produce more food from the same land, thereby keeping pace with increasing demand. Between 1950 and 1990, world food production almost tripled, while farmland increased only by 10 percent.

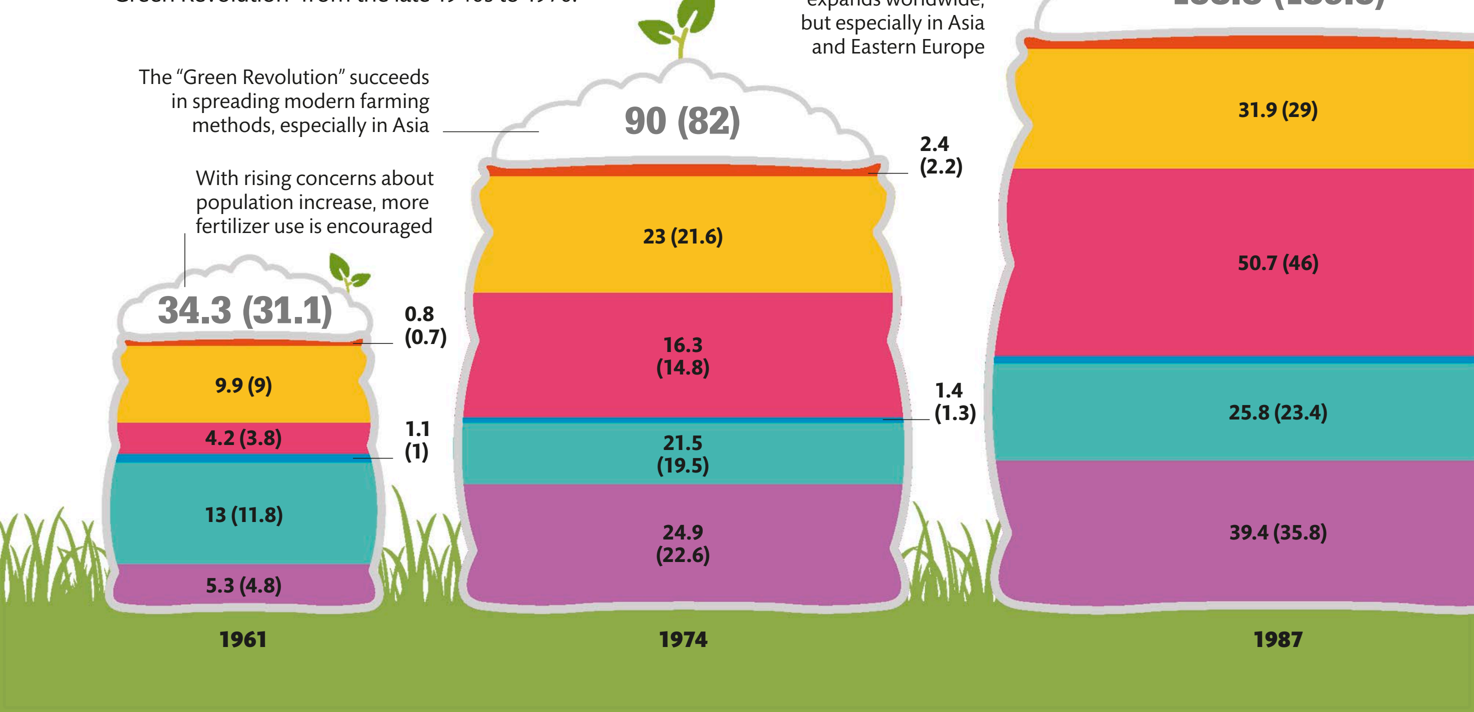

## Rise of fertilizer use

In the aftermath of World War II, chemical factories began to produce nitrogen fertilizer. New sources of rock phosphate were identified, and the availability of phosphorus increased. With encouragement in some countries from government subsidies, the use of fertilizer grew rapidly, especially during the "Green Revolution" from the late 1940s to 1970.

**KEY**

**Fertilizer consumption (million tons/tonnes)**

- Africa
- Americas
- Asia
- Oceania
- Europe (without Eastern Europe)
- Eastern Europe



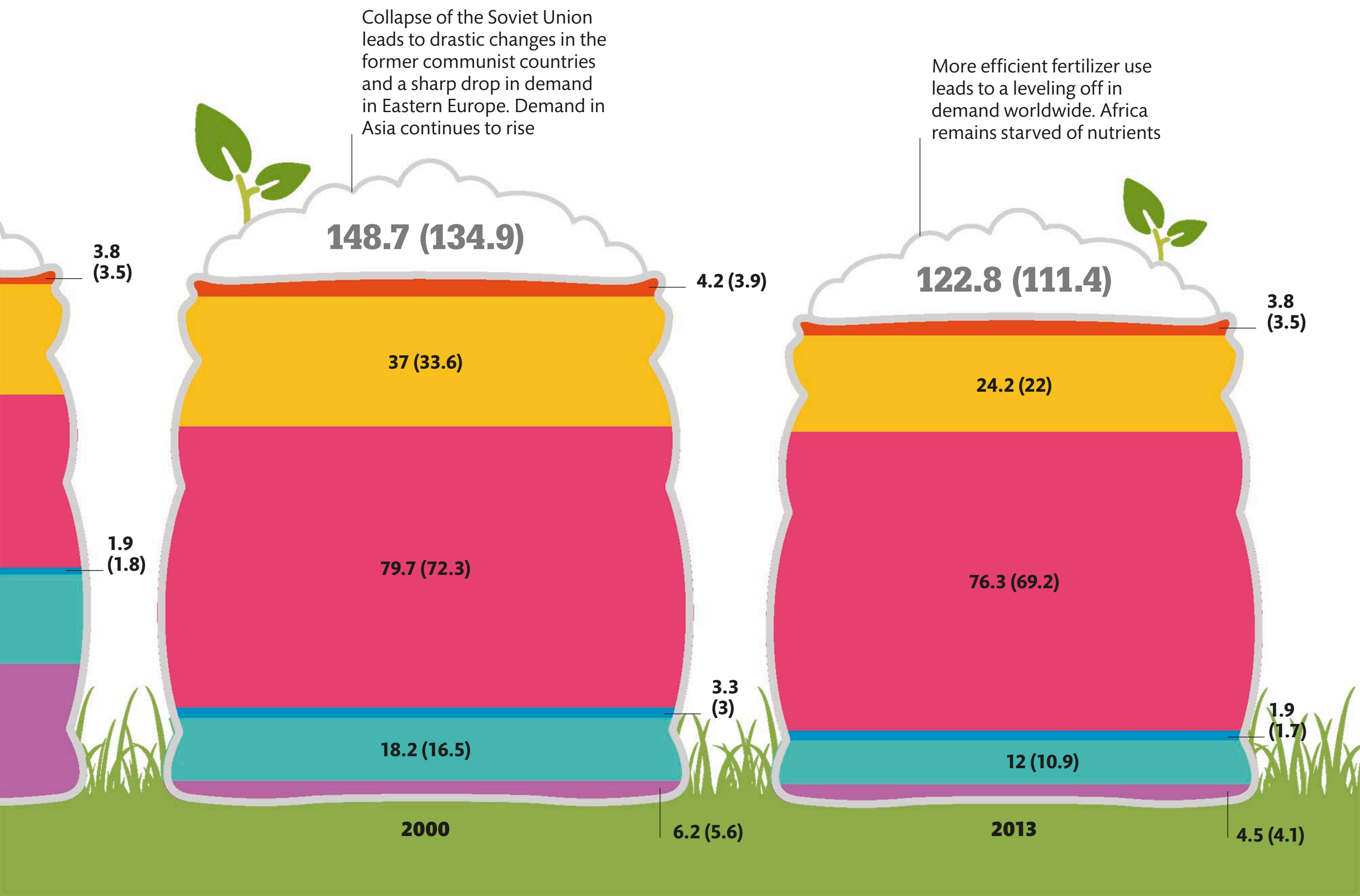
## EFFECTS OF NITRATE FERTILIZERS

The main reason for the increased concentration of nitrous oxide in the atmosphere is the application of nitrogen fertilizers. These have a number of harmful effects on the environment and human health.

- Nitrous oxide is the third most important greenhouse gas causing climate change.
- Nitrogen fertilizers are partly responsible for the depletion of the ozone layer.
- Nitrogen (and phosphate) can cause ecological changes, especially in aquatic and marine environments, harming fish and other wildlife (see pp162–163).
- Fertilizer enrichment causes changes to ecosystems on land, thereby enabling more aggressive plants to displace more fragile ones.
- Nitrates building up in the environment can get into drinking water and present threats to human health. These include risk of "blue baby syndrome," various cancers, and thyroid conditions.

**100%**

**increase in fixed nitrogen** on planet Earth over the last century due to **human activities**



# Pest-Control Challenge

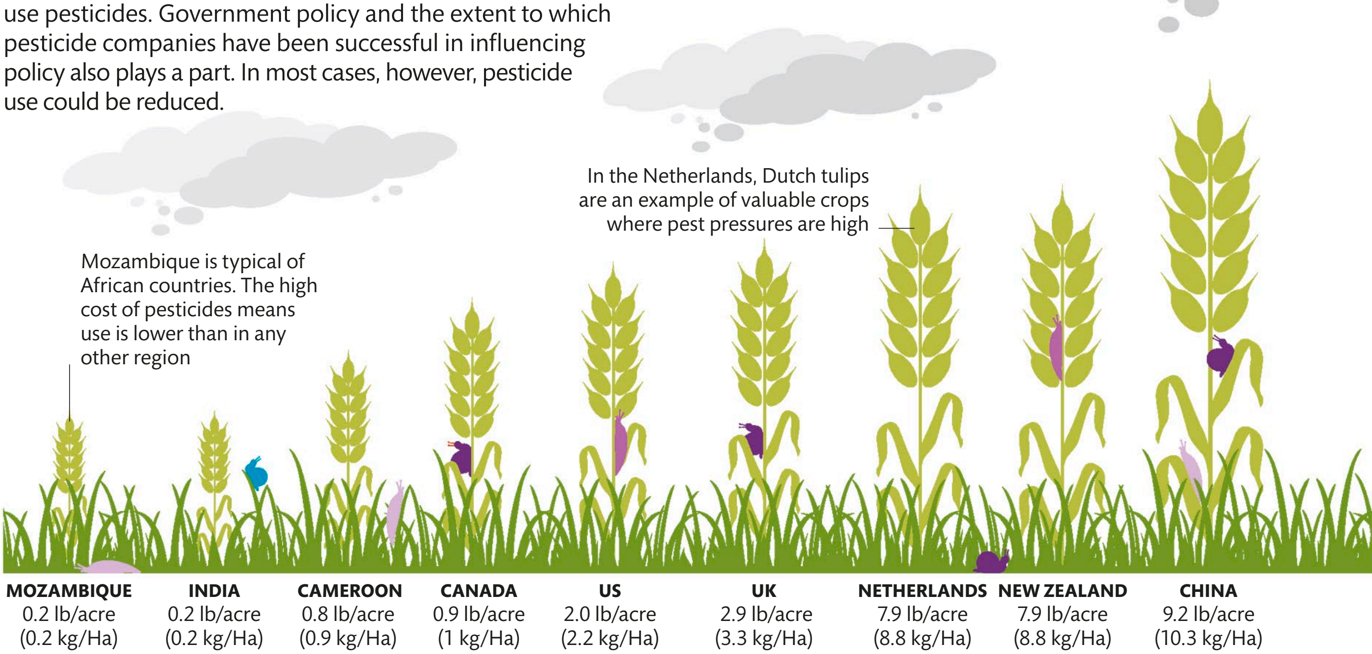
**Weeds, fungi, microbes, and insects assault food crops, reducing yields and spoiling food. We have fought back with pesticides but in the process have caused damage to wildlife.**

For millennia, farmers grew crops without chemical pesticides. In the decades after World War II, toxic compounds came into widespread and ever-increasing use, emerging as a key factor in the rapid expansion in food production. But the damage caused to wildlife has been considerable. The effects are wide ranging and include the loss of food plants for insects and a decline in the food supply for insect-eating birds. The populations of beneficial animals are affected, too, including pollinators. Some pesticides accumulate in food chains, causing populations of top predators to decline (see pp92–93). At the same time, pests have developed resistance to pesticides.

## How much pesticide is used

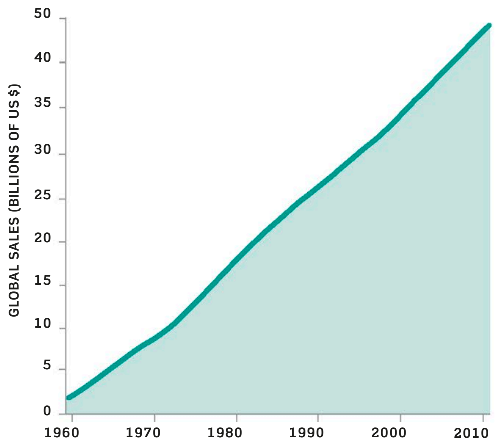
Pesticide use is rising almost everywhere, but countries vary widely in the quantity that they use. This is determined by the type of crops being grown, how valuable they are, and whether pest pressures are high. It also depends on the potency of the chemicals being applied, agricultural practices, and the stage of development the country has reached, with very poor countries unable to afford to use pesticides. Government policy and the extent to which pesticide companies have been successful in influencing policy also plays a part. In most cases, however, pesticide use could be reduced.

The amount of pesticides used internationally has risen **50-fold since 1950**

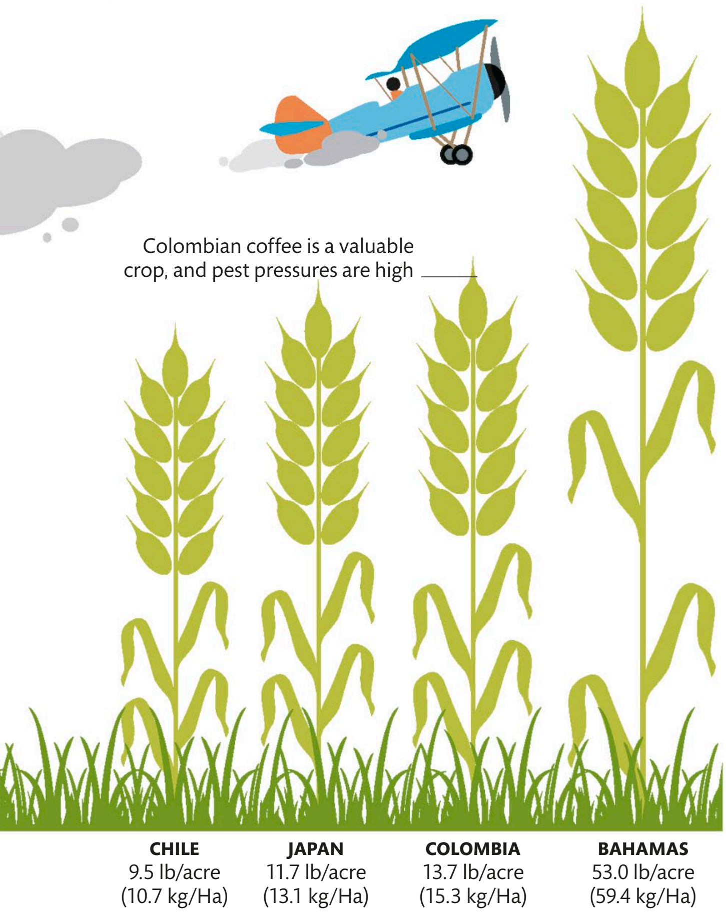


## GLOBAL RISE IN PESTICIDE SALES

Global pesticide sales have been rising rapidly since the 1940s. Since 2000, sales have continued to increase, particularly in Asia, Latin America, and Eastern Europe. However, they have stagnated in the Middle East and Africa. Pesticide companies boost their sales by charging lower prices for older products or in poorer markets.

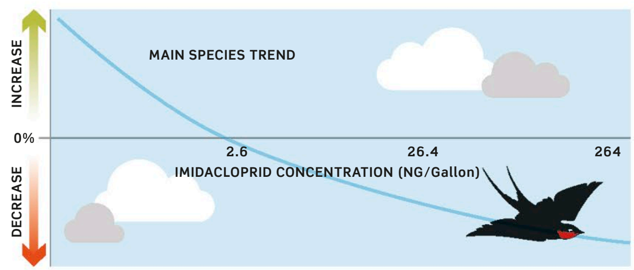



**Pesticide application**
Pesticides play an important role in growing rice in South and Southeast Asia. Spraying by hand is a common practice.




## Threat to wildlife

Neonicotinoid pesticides are potent toxins that affect the nervous system of insects. Their use has affected many bird populations because insects comprise an important part of their diet. A study found that in areas with imidacloprid (a neonicotinoid pesticide) concentrations higher than 5.13 ng/gallon (19.43 ng/liter), bird populations were in decline.




### What can we do?

- **Governments, farmers, and chemical companies** can promote integrated pest management. This involves adopting strategies to enable food production with fewer chemicals, through growing a more diverse range of crops, and the use of crop rotations. Encouraging the recovery of bat and bird populations can improve natural pest management.

# How Food is Wasted

**The extent of food waste means that more than one quarter of the world's farmland is discarded. As population and economic growth lead to rising demand, reducing food waste is an ever more important priority.**

Worldwide, we waste about 1.4 billion tons, or one third, of the food we produce every year. This in turn wastes water equivalent to the annual flow of Russia's massive Volga River. Food waste adds more than 3.3 billion tons of greenhouse gases to the atmosphere, not least because rotting food can create methane emissions that add to climate change. It wastes millions of tons of fertilizer and costs food producers US$750 billion annually. It also represents a missed opportunity to make sure everyone has access to food.

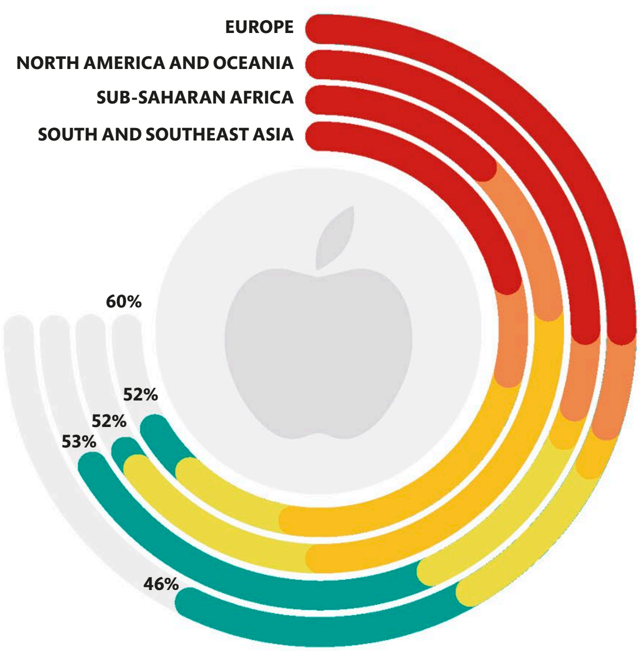
The later a food item is spoiled in the trip from field to plate, the bigger the environmental impact because more resources will have been used up in getting it there.

## Where is it lost?

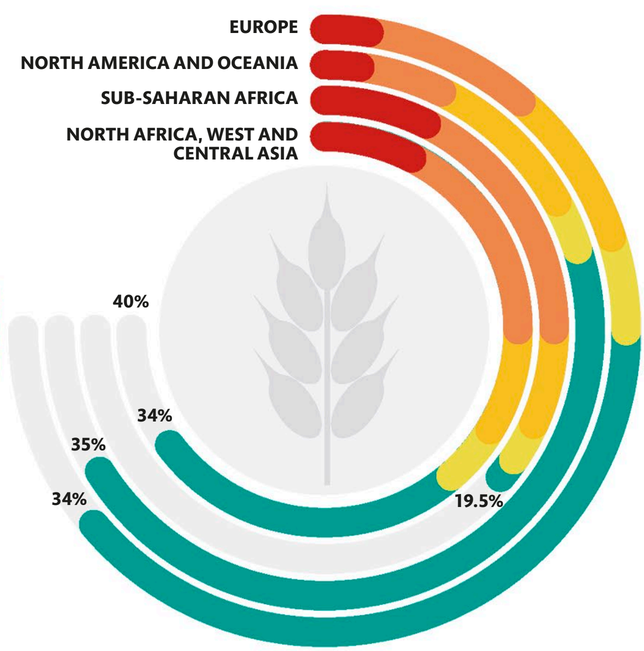
Food waste occurs at every stage of the supply chain, from initial production right down to household consumption. In developing countries, 40 percent of food losses occur at early stages of the process, and can be attributed to constraints in harvesting techniques and storage and cooling facilities. In developed countries, over 40 percent of waste occurs at the retail stage, due to quality standards that overemphasize appearance, or during the consumption stage when food is thrown away.

**KEY**
**Cause and stage of food loss (% of total production)**

- Agriculture
- Post-harvest or slaughter
- Processing
- Distribution
- Consumption



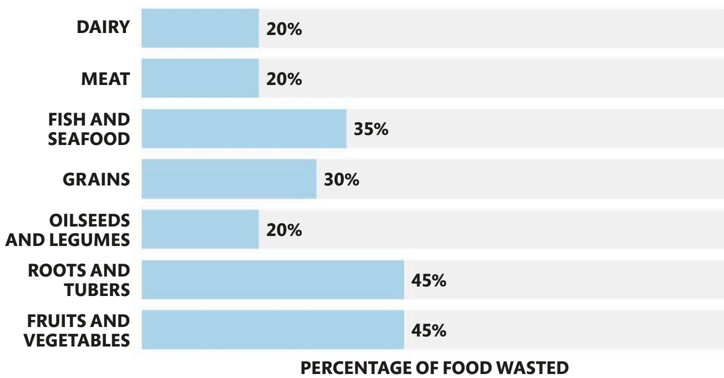

FRUIT AND VEGETABLES FOOD LOSS




GRAINS FOOD LOSS

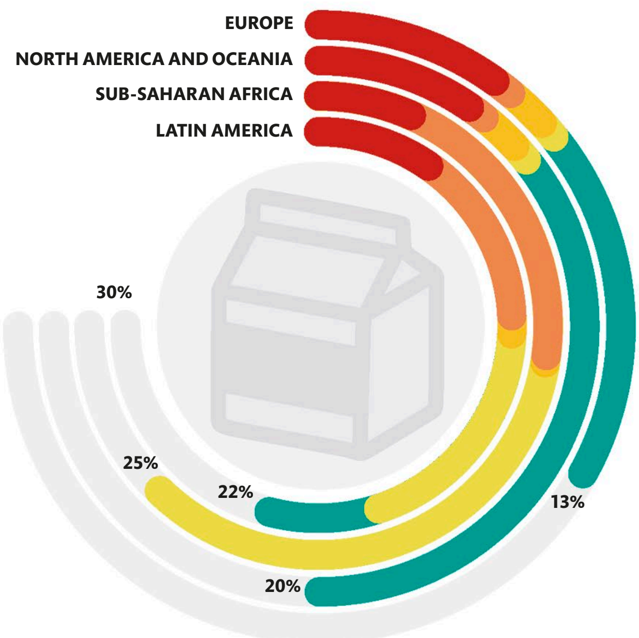
## WHAT ARE WE WASTING?

All the major food groups are subject to substantial waste globally, but it is among the more fragile and perishable fruits, vegetables, roots, and tubers that the biggest proportion is lost. Meat waste is comparatively low, but the impact is bigger because calories from livestock farming come with a larger environmental footprint.

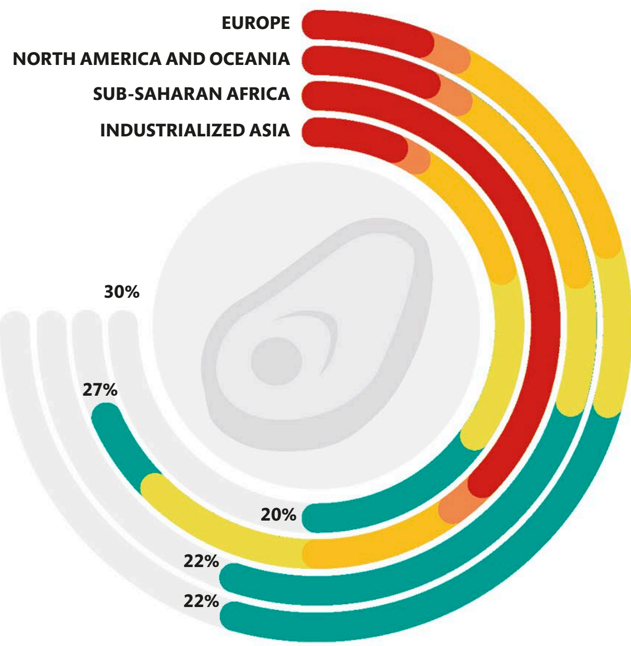



## What can we do?

- **Reduce waste.** Avoid wasting food between farm and table.
- **Feed people in need.** Good food that would otherwise be wasted can sometimes be diverted to people in need.
- **Feed livestock.** Food unfit for human consumption can be fed to animals, such as pigs and chickens.
- **Compost and make renewable energy.** Badly spoiled food can be used to generate power via anaerobic digestion, while at the same time recovering nutrients that can be used as fertilizer.



DAIRY FOOD LOSS



MEAT FOOD LOSS

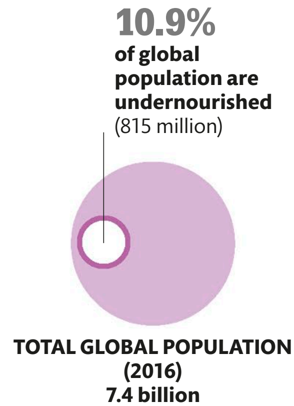
# Feeding the World

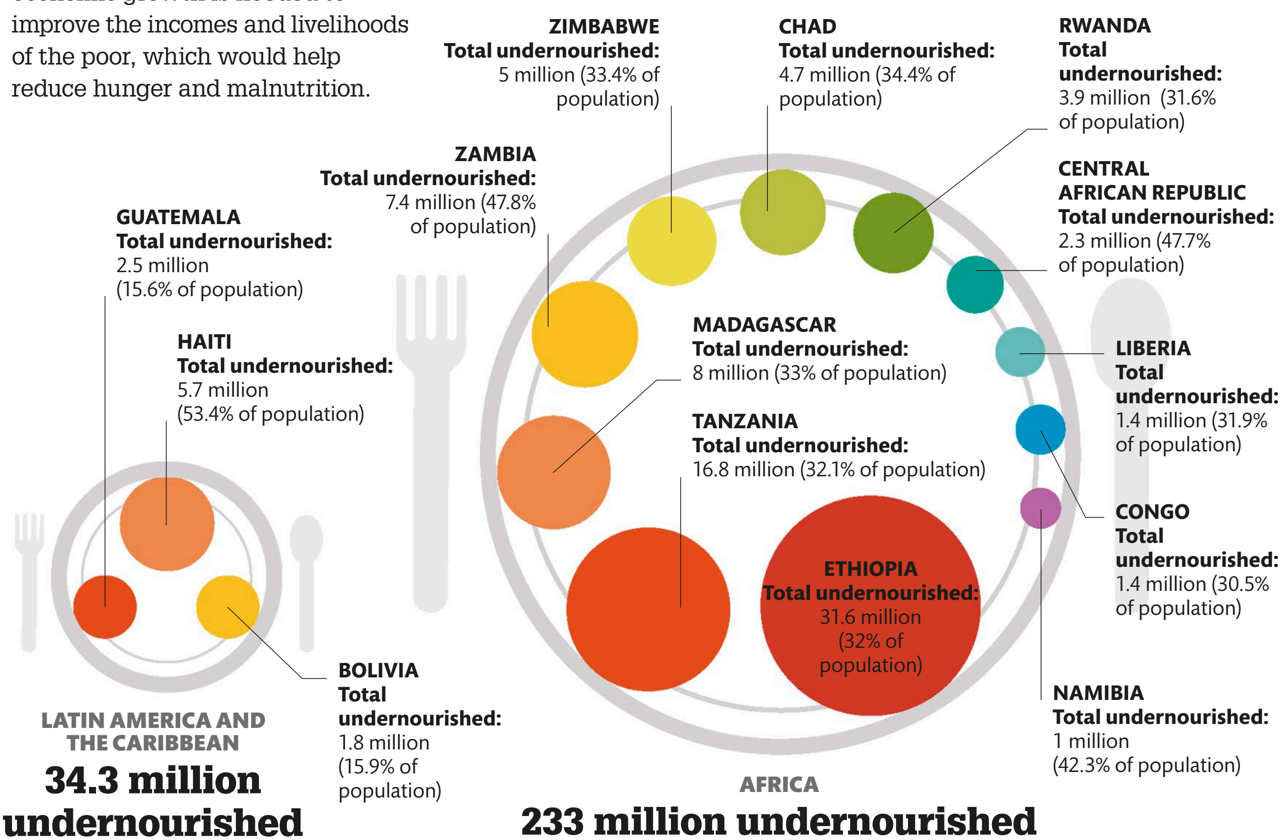
**Across the world, hundreds of millions of people are hungry while hundreds of millions more are obese. This demonstrates how absolute levels of food production are not enough to ensure good nutrition.**

In many rich and more developed countries, growing numbers of people are becoming overweight or obese, while in many developing countries a large proportion of people are undernourished. These outcomes are linked with various factors, including political and climatic conditions, and the proportion of their income people must spend on food. Despite an increase in food production during recent decades, poverty and hunger remain closely related. Inclusive economic growth is needed to improve the incomes and livelihoods of the poor, which would help reduce hunger and malnutrition.

## Where are the hungry?

More than 800 million people worldwide are chronically undernourished. These are the poorest of the poor, who have limited financial assets and often live in rural areas. In Southern Asia and sub-Saharan Africa, progress in reducing hunger has been slow, and undernourishment is still prevalent in both regions. In sub-Saharan Africa, nearly one quarter of the population has insufficient food. India is home to the highest number of undernourished people in the world, although they represent a smaller percentage of the country's population.



## THE COST OF FOOD

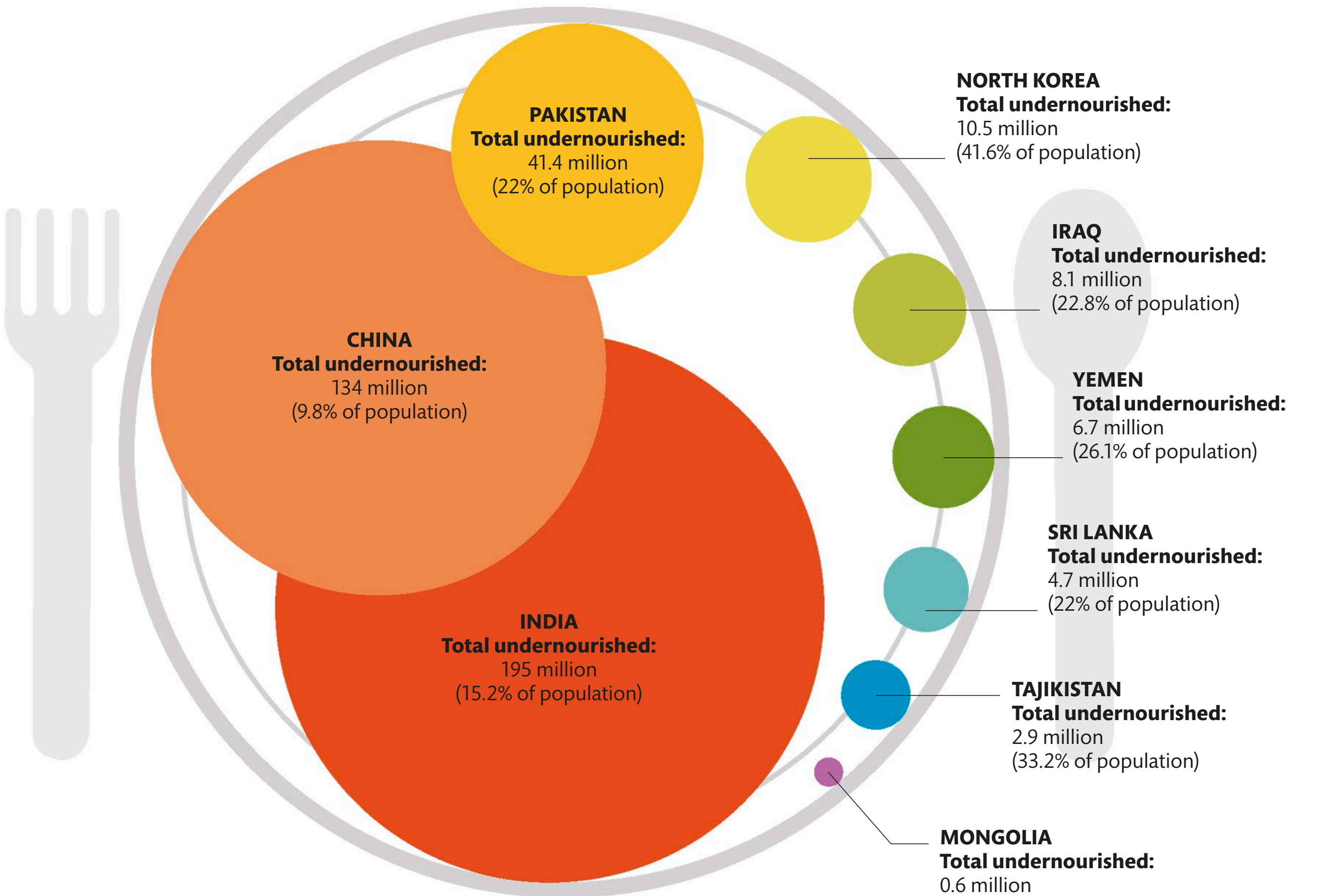
The price of food, in both absolute terms and relative to income, is an important determinant of hunger and obesity. In the USA, the average citizen spends a relatively small proportion of a large income on food. In India, the average person spends a far larger proportion of a tiny average income on food.

**US$32,051**
AVERAGE HOUSEHOLD EXPENDITURE

**US$620**
AVERAGE HOUSEHOLD EXPENDITURE


> "The **war against hunger** is truly **mankind's war of liberation.**"

**JOHN F KENNEDY, 35TH US PRESIDENT**




ASIA
**512 million undernourished**

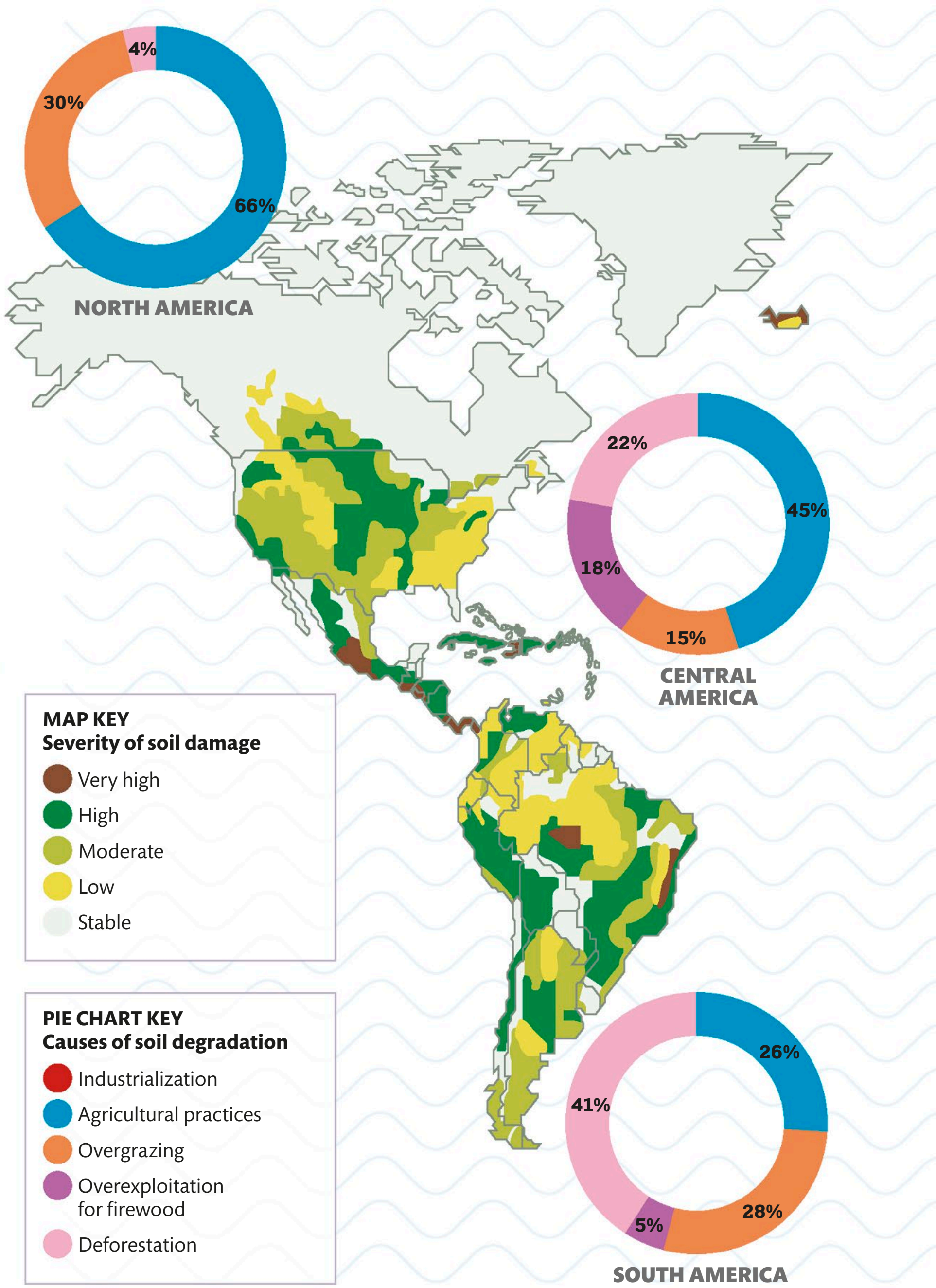
# Threats to Food Security

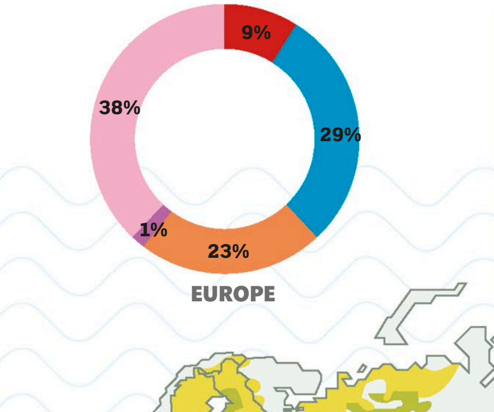
**Nearly all food production depends on soil and freshwater. In both cases, environmental changes are leading to threats to food security. The challenge is global but becoming acute in many developing countries.**

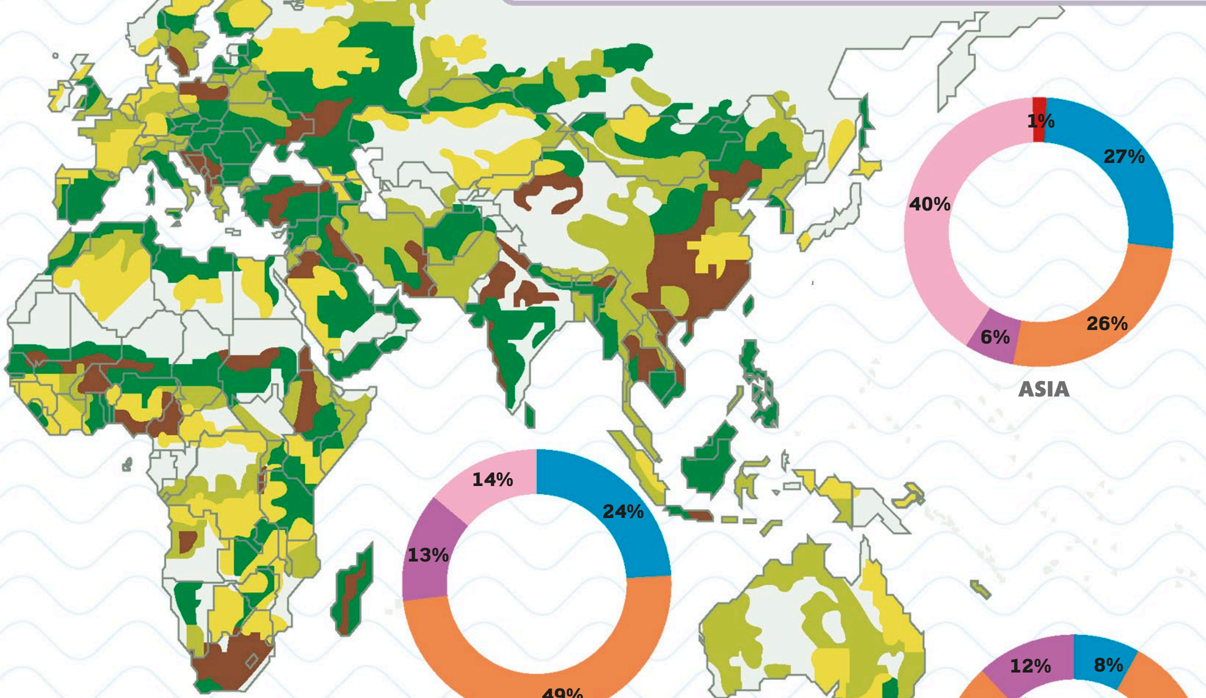
Every year 12–17 million acres (5–7 million hectares) of farmland are degraded with 27.5 billion tons (25 billion tonnes) of topsoil eroded by wind and water. Since settled agriculture began, the US has lost about one-third of its topsoil. Farming practices cause damage that can reduce the level of organic matter (decomposing plants and soil organisms). Soils with more organic matter hold more water, rendering growing plants more resilient to drought. In developing countries, soil damage and drought are prevalent. It is expected that later this century large portions of the world will experience extreme and, in some cases, unprecedented dryness.

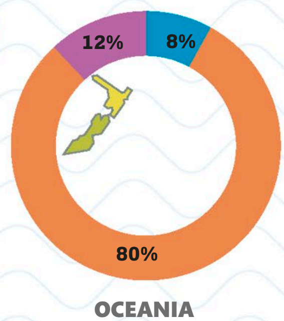
## Soil degradation

Soil damage is a widespread and worsening global problem. Human-induced soil degradation has already made many areas unsuitable for farming, especially in semiarid parts of the world. Plowing and excessive pressure from grazing animals can leave soils bare and vulnerable to removal by wind and rain. This is the cause of nearly all soil damage in North America. In South America, Europe, and Asia, deforestation is responsible for widespread soil damage. Relatively small areas of land have been damaged by industrial pollution.



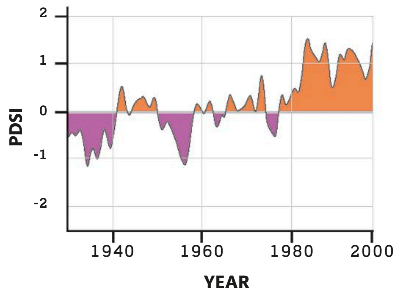


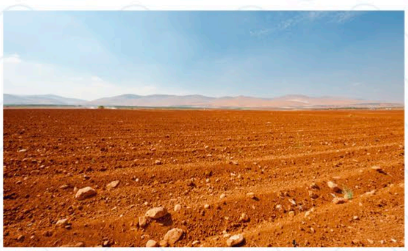




## WORSENING DROUGHT

The Palmer Drought Severity Index (PDSI) combines precipitation and temperature data to reveal changing levels of dryness over time. Since the 1970s, the propensity for drought has increased worldwide, in terms of both the severity and frequency of droughts.



**Soil degradation in Israel**
Moderate to severe soil degradation globally affects an area of land larger than that of the US and Mexico combined.

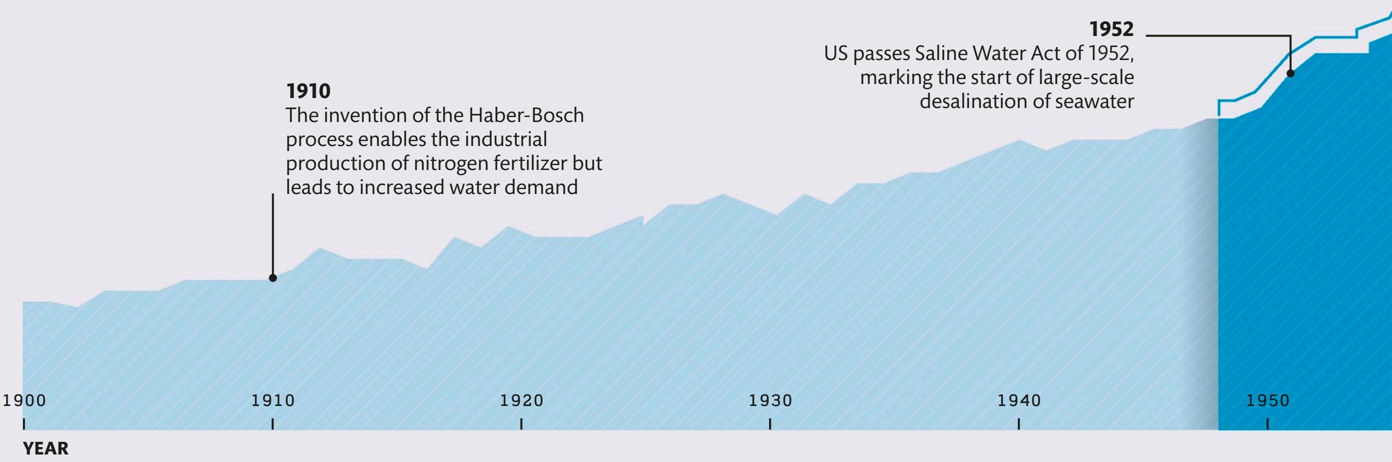
# Thirsty World

**Our need for freshwater has risen dramatically over the last century. In addition to being required for drinking, washing, and agriculture, freshwater also helps power economic development. In the natural world, all land plants and animals rely on freshwater. Some ecosystems, such as tropical forests and wetlands, are dependent on regular replenishment of water. In recent years, several parts of the world have suffered from the effects of severe drought. The result has affected harvests and food prices and increased the number of hungry people by millions.**

## Pressure on water supplies

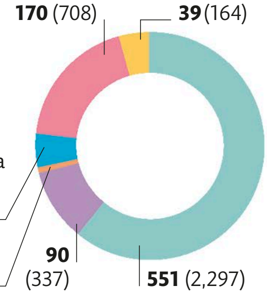
Water covers 70 percent of our planet, but less than three percent of this is freshwater, and most of that is unavailable for our use (see pp78–79). Since 1900, population and economic growth have led to around a fivefold increase in water consumption. In some parts of the world, access to sufficient water is a serious constraint to development. Matters are made worse by the inefficient use of water in farming, industry, and homes and through damage to ecosystems that help replenish secure water supplies. Pressure on water resources can be expected to become even more challenging as the effects of climate change disrupt the water cycle, including the effect of more severe droughts, and areas already prone to water stress.

> "A nation that **fails to plan** intelligently for the **development and protection of its precious waters** will be **condemned to wither...**"
>
> **LYNDON B. JOHNSON, 36TH PRESIDENT OF THE UNITED STATES**



## WHERE WATER IS USED

More than half of the world's freshwater withdrawals occur in Asia, where most major irrigated lands are found. On average, however, water use per person is higher in richer countries, with people in the US using about five times more than people in Bangladesh. In rich, dry countries, water stress is acute.



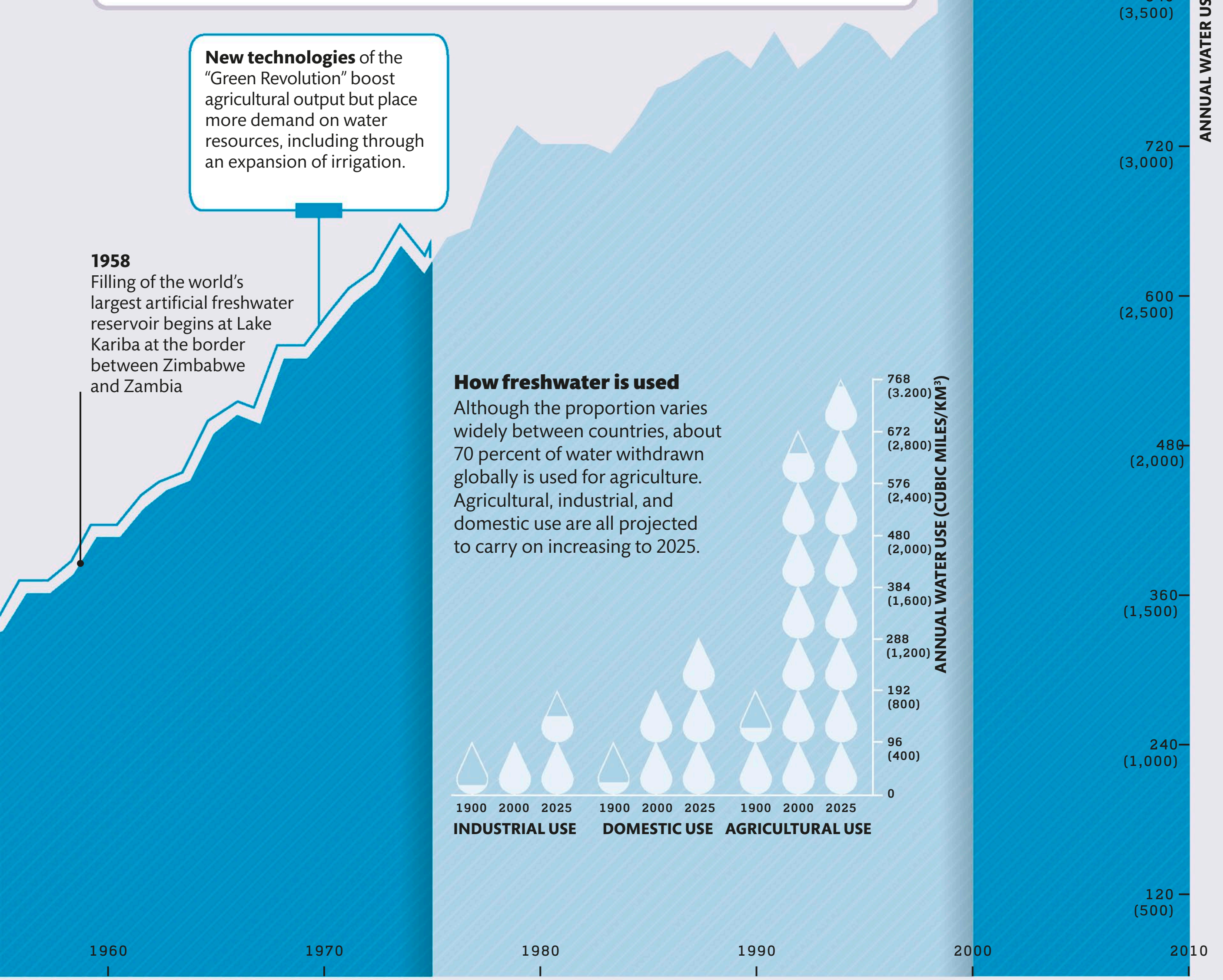

**A series of record-breaking droughts** and heat waves lead to reduced crop production across the world.

**New technologies** of the "Green Revolution" boost agricultural output but place more demand on water resources, including through an expansion of irrigation.

**1958**
Filling of the world's largest artificial freshwater reservoir begins at Lake Kariba at the border between Zimbabwe and Zambia

### How freshwater is used

Although the proportion varies widely between countries, about 70 percent of water withdrawn globally is used for agriculture. Agricultural, industrial, and domestic use are all projected to carry on increasing to 2025.



# Freshwater Scarcity

**About 97.5 percent of the world's water is in the oceans and salty. The rest is freshwater, but most of this is locked up in ice, with only about 0.3 percent accessible for human use.**

Freshwater is a surprisingly scarce resource. It is also unevenly spread, and in areas with low rainfall or high evaporation, scarcity can be a major problem. Water scarcity already affects 1.2 billion people, across every continent. Another 1.6 billion people are affected by the challenges of extracting and transporting water. These numbers are rising, not least because water demand has been rising at more than twice the rate of population growth, causing the spread of longterm water scarcity to other parts of the world. Although too much of it is presently wasted, polluted, or used in unsustainable ways, there is still enough water on Earth to meet our needs. Making more rational use of water will be vital in the decades ahead.


**SEE ALSO...**

› **The population explosion** pp16–17

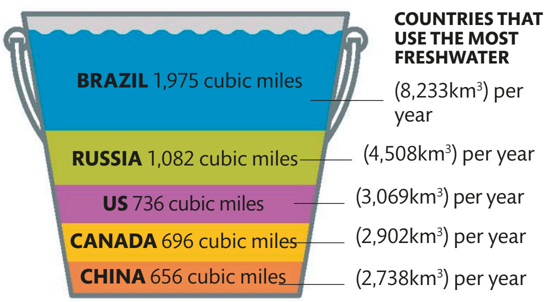
› **Escalating appetite** pp62–63

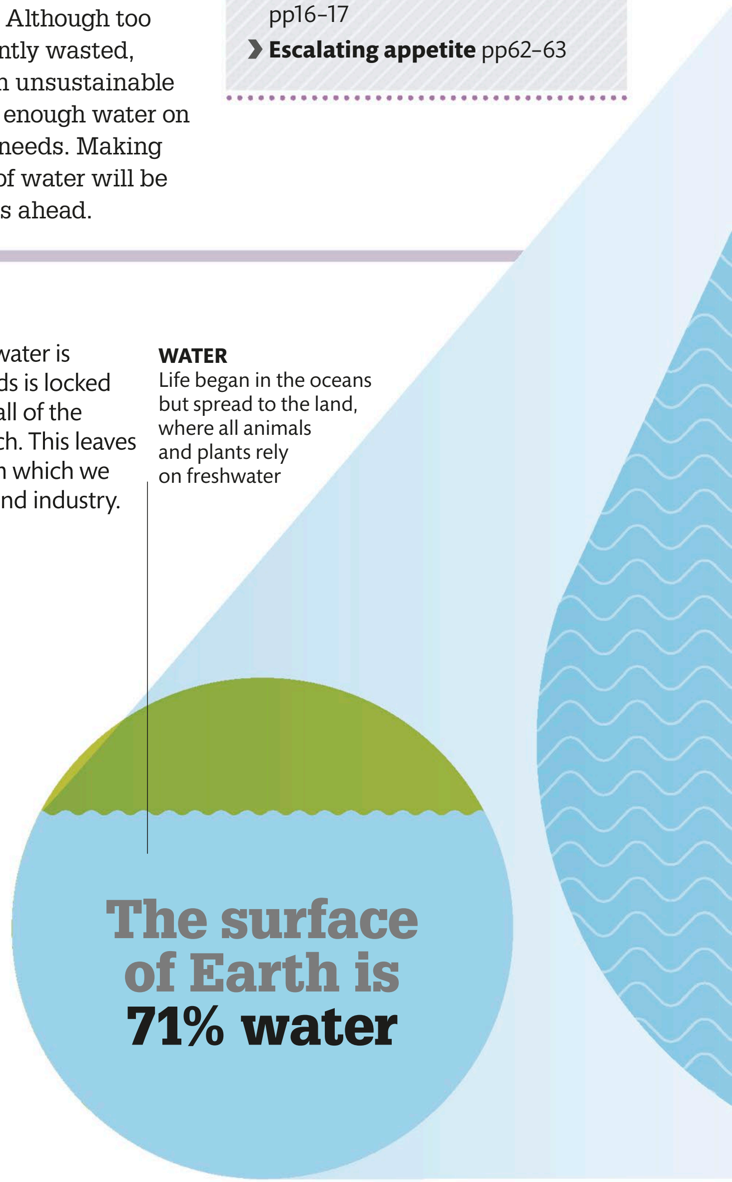

## Earth's water resources

Almost all of Earth's 336 million cubic miles (1.4 billion km³) of water is saltwater. Of the small portion that is fresh, more than two thirds is locked up in ice caps, especially on Antarctica and Greenland. Nearly all of the remaining third is in the ground, and much of that is out of reach. This leaves only a tiny proportion as freshwater in the lakes and rivers from which we meet demand for drinking water as well as supplying farming and industry.

### WATER-RICH NATIONS

Countries' economies rely on freshwater. Brazil's most populous region, São Paulo, suffered a severe drought in the years 2014–17. With two-thirds of the country's power grid dependent on water reservoirs providing hydroelectric power, rationing is inevitable. Meanwhile, the continuing expansion of China's huge industrial output demands more and more freshwater.



**LIQUID WATER**
At just 0.3 percent, a tiny proportion of the world's freshwater is in liquid form and readily accessible at the surface from rivers, lakes, and swamps

"When the well is dry, we learn the worth of water."

BENJAMIN FRANKLIN

**ICE AND GLACIERS**
The vast majority of freshwater is stored in glaciers, ice caps, and permanent snow cover in the mountains and polar regions of Earth

**Total water on Earth 336 million cubic miles (1.4 billion km$^3$)**

**68.9% in glaciers and ice**

**GROUNDWATER**
Of the freshwater on Earth, 30.8 percent is groundwater. In some parts of the world, such as the USA and Arabia, fossil groundwater is being depleted to irrigate crops.

**30.8% as groundwater**

**2.5% Freshwater**

**97.5% Saltwater**

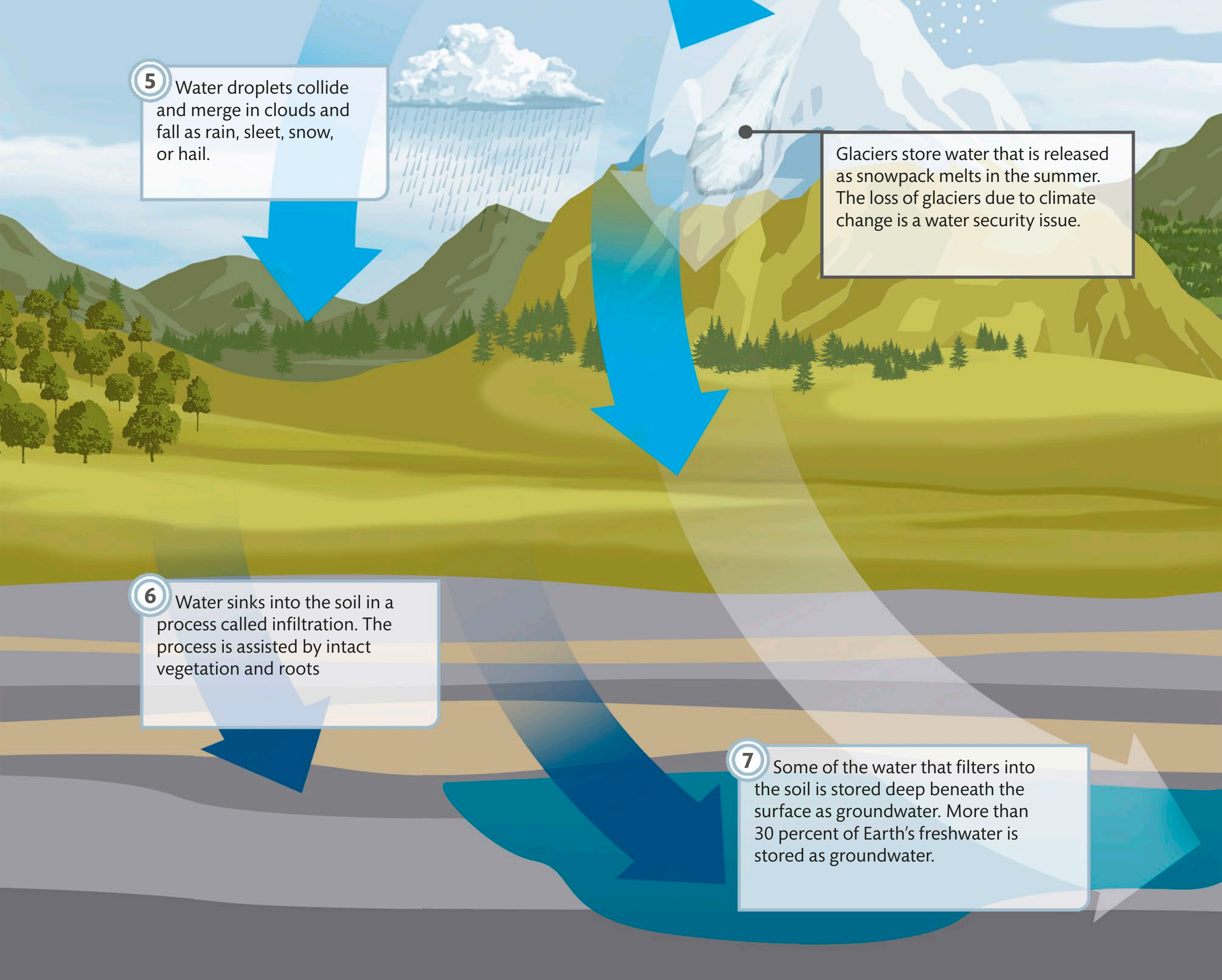
## Freshwater sources

Ecosystems that store water include healthy soils, forests, and wetlands such as marshes and blanket bogs. Acidic peatlands in cool, wet climates also hold a lot of water. These environments are changing due to three main forces: global warming, which can change rainfall patterns and melt glaciers and ice caps; excessive water extraction to meet rising demand; and pollution, which contaminates an already limited water resource.

WETLANDS OF NORTHERN AUSTRALIA

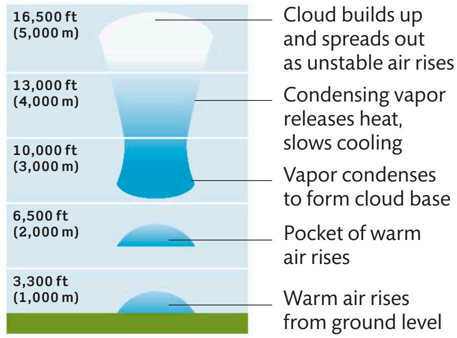
# The Water Cycle

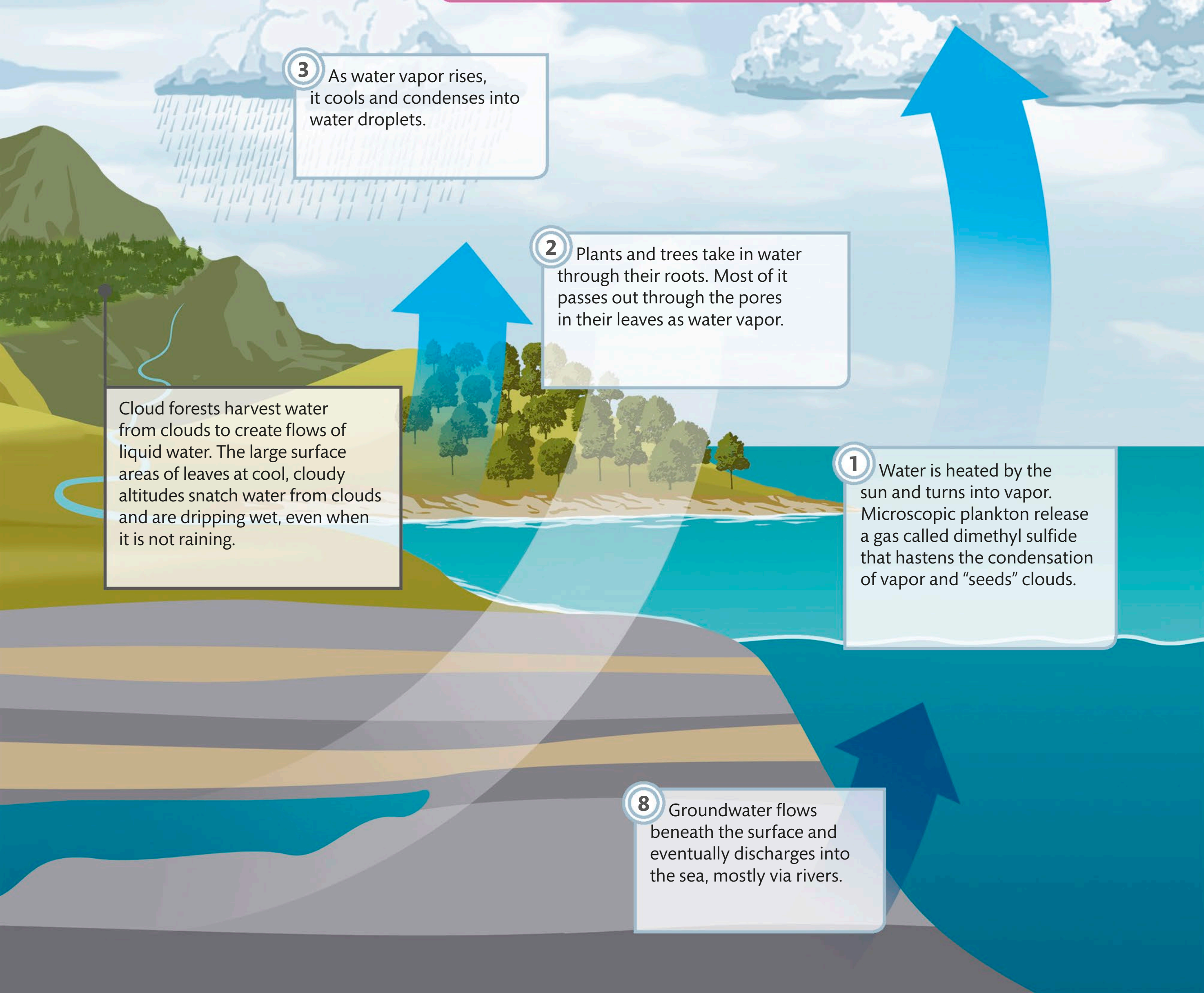
The freshwater that is vital for life on land, economic development, and farming is endlessly recycled. The process begins with water evaporating from seas, lakes, and forests to form clouds (see panel, opposite). When rain falls, the water is stored in forests, soil, and rocks to be released into rivers and lakes. Some is stored as snow, which melts in spring and summer, enabling rivers to flow during otherwise dry periods. Different human impacts, including deforestation, climate change, and soil damage, are interfering with how the water cycle works, with resulting water shortages in some parts of the world including North Africa and the Middle East.



## HOW CLOUDS ARE FORMED

Clouds form as warm air is forced upward. As water condenses in rising air, it releases heat. This warms the air mass and causes it to rise farther. The air cools and the relative humidity increases. Rising air is saturated, and water vapor collects around airborne particles to form a cloud.

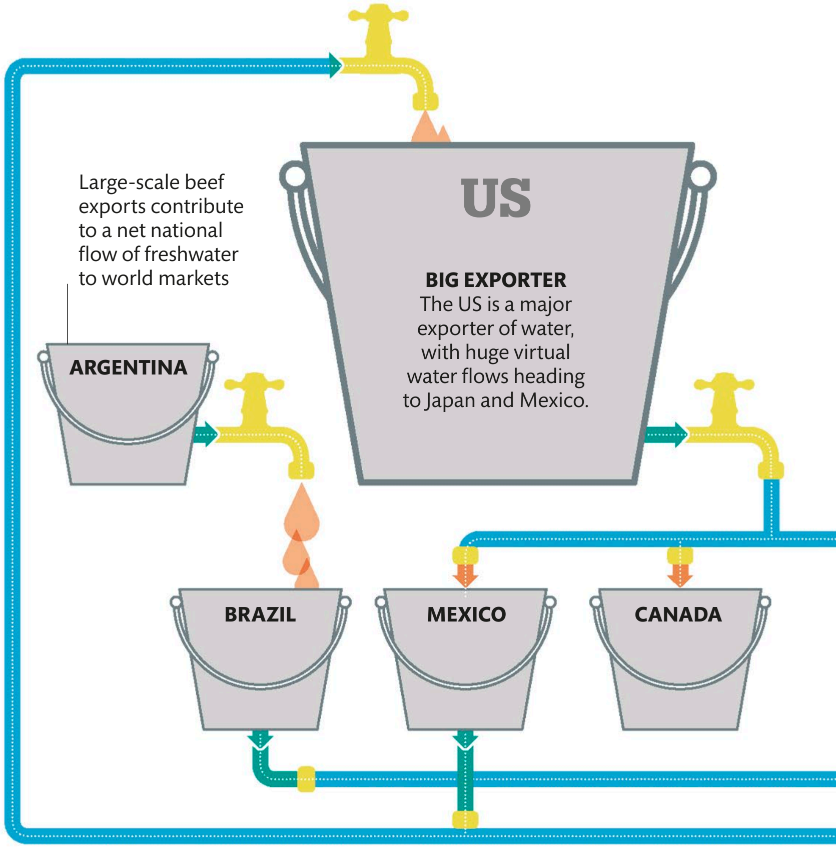


# Water Footprint

**It is not the everyday water that we use at home that forms most of our water consumption. The vast majority we use is "hidden" water needed to grow food, produce goods, and generate energy.**

Water resources are more vital to world trade than oil and financial capital. Similar to a carbon footprint (see pp50–51), a "water footprint" shows the extent and location of water used by individuals, businesses, and countries. This allows us to calculate the amount of "virtual" water. This is the water used to make traded goods and helps reveal which countries rely on freshwater imports to meet their needs—for example, those with limited water resources of their own.

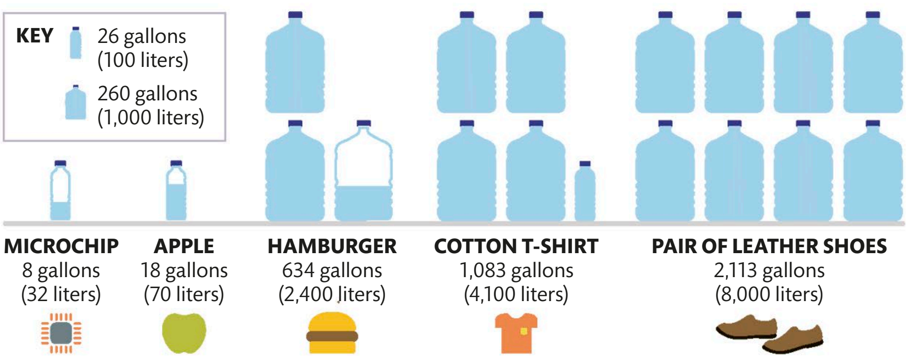



## Trading virtual water

All countries import and export food, so they all trade virtual water. The volume of water needed to trade agricultural and industrial products in 1996–2005 averaged 82 trillion cubic feet (2.3 trillion cubic meters) per year, or about five times the volume of Lake Erie, North America. Among the biggest net exporters of virtual water are the US, China, Canada, Brazil, and Australia. Among the biggest net importers are Europe, Japan, Mexico, South Korea, and the Middle East.

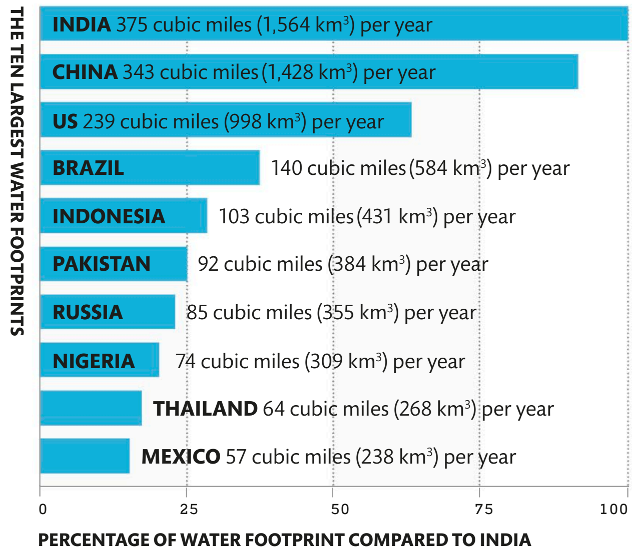
## HOW MUCH WATER?

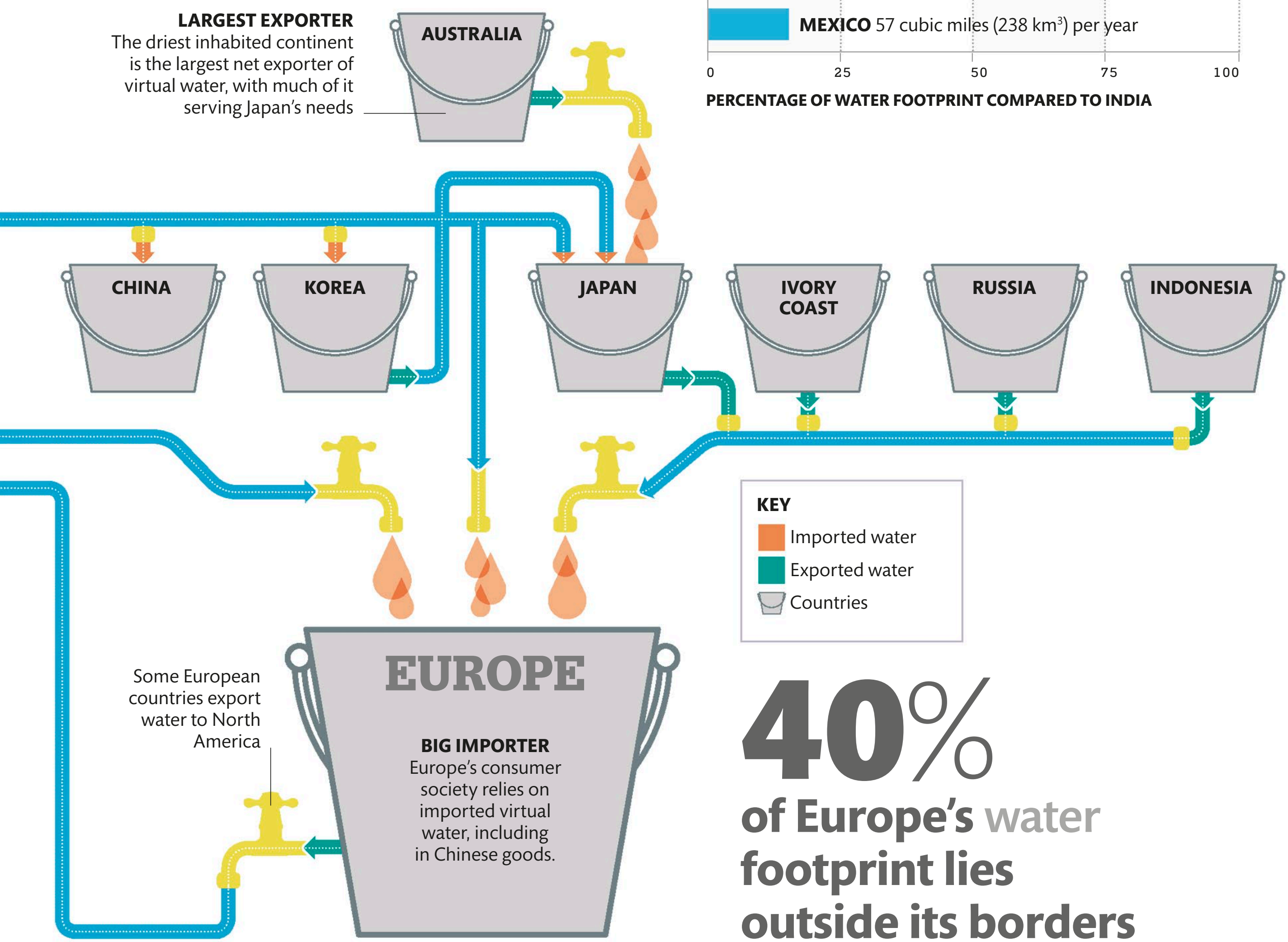
Each person in the UK uses an average of 38 gallons (145 liters) of water each day for cooking, cleaning, and washing. When including virtual water, however, this figure rises to a colossal 898 gallons (3,400 liters) per day. Cotton and leather goods have a significant water footprint. The longer these products can be made to last, the lower their overall impact will be.



## Largest water footprints

The top water-consuming countries include those with both high and low per capita incomes, revealing that freshwater is vital at all stages of economic development. Countries with low rainfall face bigger challenges than wetter ones. Some countries, such as Brazil, rely on rainwater to meet their needs for food production, whereas India uses a lot more river water to irrigate crops for its huge agricultural sector. Roughly two-thirds of China's water footprint is used for agriculture, with one-quarter supplying its massive manufacturing sector.




**40%**

**of Europe's water footprint lies outside its borders**

# Consuming Passions

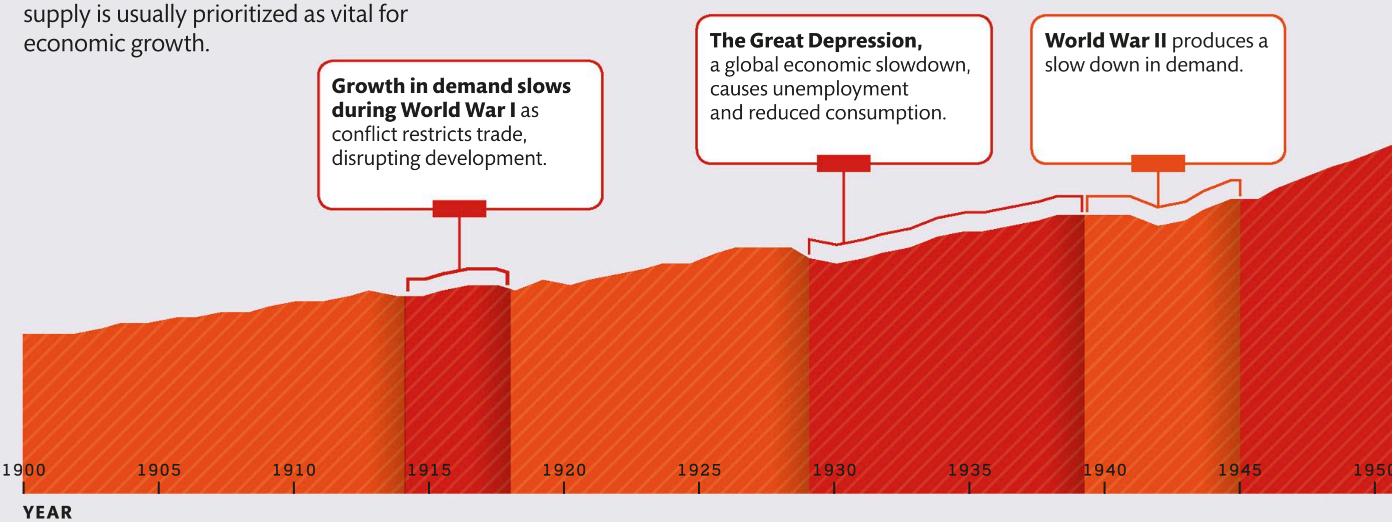
**The last century saw a dramatic increase in demand for all kinds of natural resources. Today, the total combined consumption of construction materials, ores and minerals, fossil fuels, and biomass is about 10 times bigger than in 1900. While rising demand fuels economic growth, it places increasing pressure on natural systems, leading to a wide range of environmental problems. Unless we adopt different consumption and production patterns, projected population growth and economic development will lead to a further rise in demand—and this will intensify environmental pressures.**

## Rocketing resources

Every item we use and dispose of originates from natural resources. Some, such as wood used to make paper, are renewable; others, such as minerals, are not. Turning raw materials into products uses energy and water and creates wastes of different kinds, including carbon dioxide. The world's rocketing demand for resources is rarely seen in the context of the atmospheric and ecosystem damage it causes. Even if such impacts are understood, resource supply is usually prioritized as vital for economic growth.

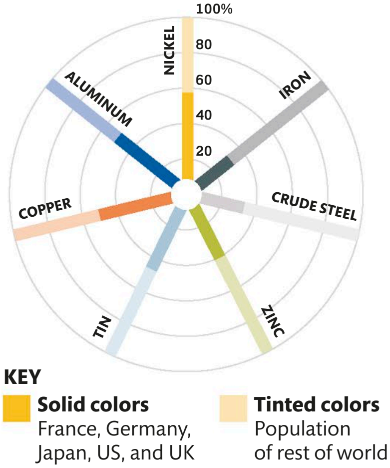
"There are **constant assaults** on the natural environment, the result of **unbridled consumerism,** and this will have **serious consequences** for the world economy."

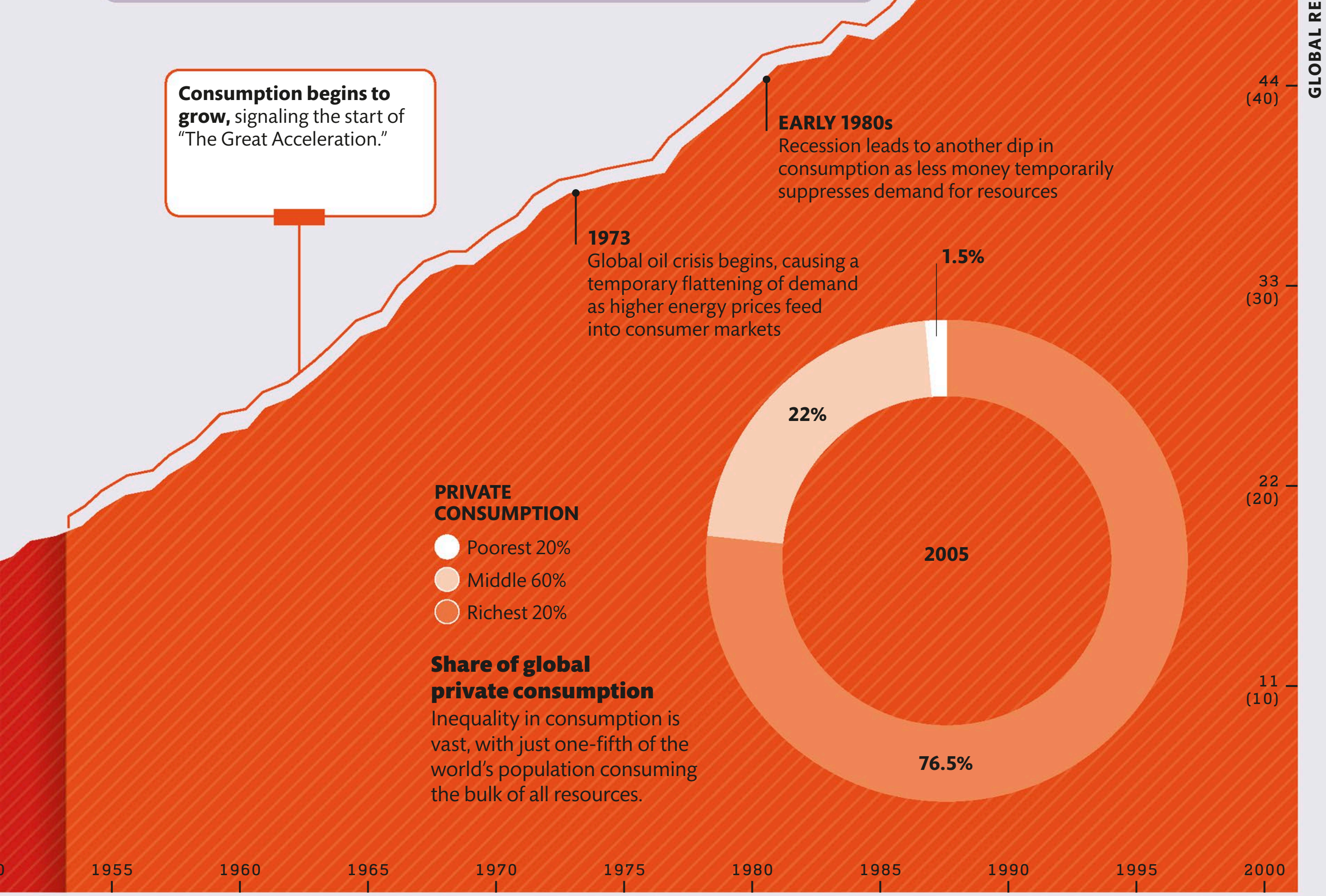
**POPE FRANCIS**



## THE BIG USERS

When it comes to the consumption of natural resources, we are not all equal. Higher-income countries, such as France, Germany, Japan, the US, and the UK, use more natural resources due to their high-consumption patterns than countries with a lower average income per person. As efforts to stimulate economic growth in poorer countries achieve some level of success, however, consumption patterns there will begin to follow those of wealthier nations.




**Share of global private consumption**

Inequality in consumption is vast, with just one-fifth of the world's population consuming the bulk of all resources.

# The rise of Consumerism

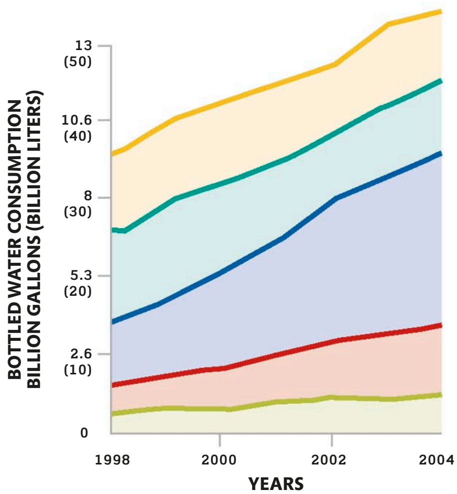
**Rising living standards have led to an explosion in demand for all kinds of consumer goods, ranging from disposable packaging to complex durable products such as cars. All require natural resources—and all eventually become waste.**

The spread of middle-class lifestyles has produced a rocketing demand for resources. Bottled water and cars are just two examples that reflect wider trends. Whereas both were once absent from our lives, today they are pervasive, especially in richer countries and those with fast-growing economies.

Rising demand for these and other products puts pressure on limited natural resources such as oil and minerals. Increasing amounts of water and energy are needed for their manufacture, while increased product consumption is adding to global waste. Cleaner, more efficient production methods and the more effective elimination of waste, which can in turn be used to make new products, can diminish the impact of more affluent lifestyles.

## Bottling water: the true costs

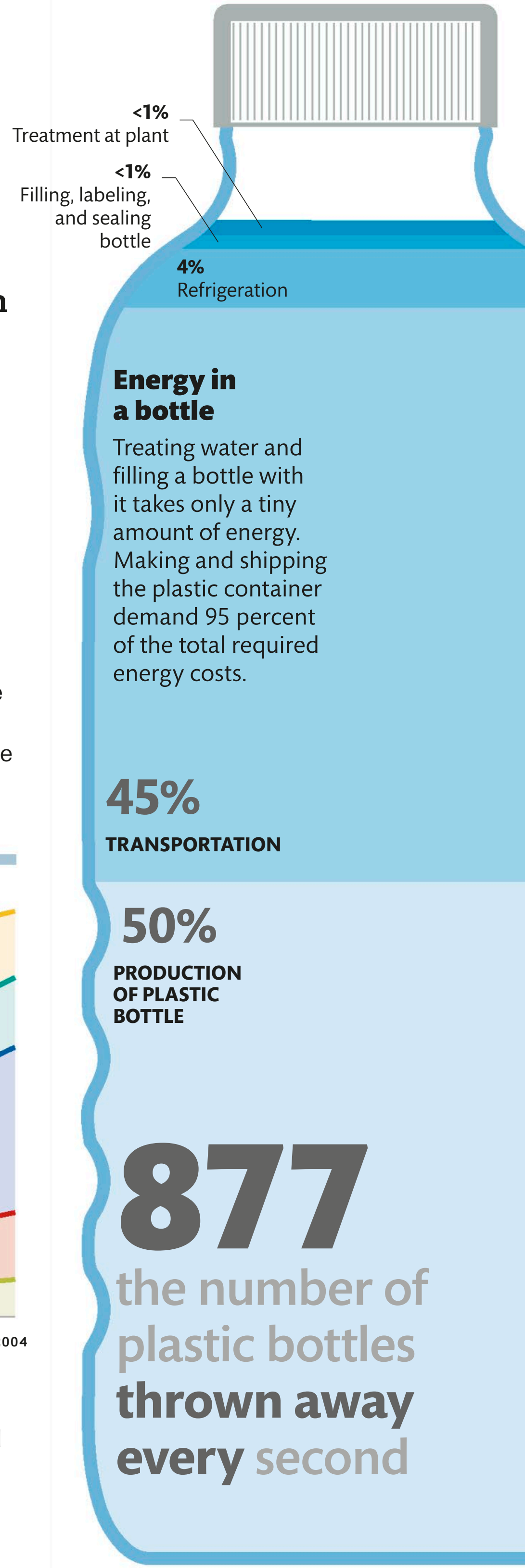
Bottled water is usually sold in plastic or glass bottles. Extracting the water itself can sometimes deplete resources and lead to local environmental impacts, but it is in the energy used for transporting the product and the manufacture of its packaging that the biggest global effects are seen. Waste generated by plastic bottles is another serious problem.




**KEY**
- Europe
- North America
- Asia
- South America
- Africa, Middle East, Oceania

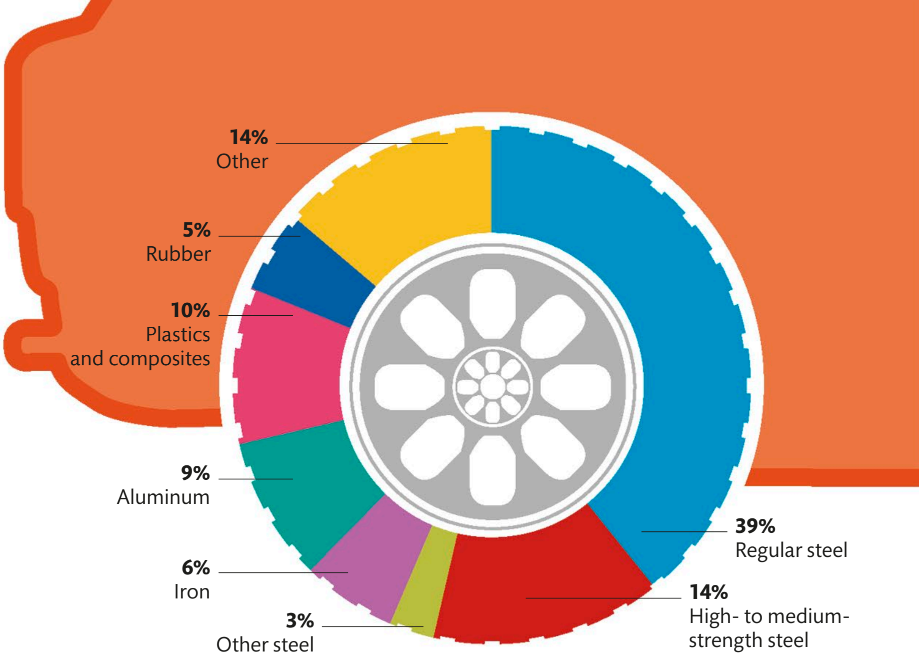
### Increasing consumption

Sales of bottled water have increased dramatically since the 1990s and by 2010 had reached a staggering 61 billion gallons (230 billion liters) worldwide.



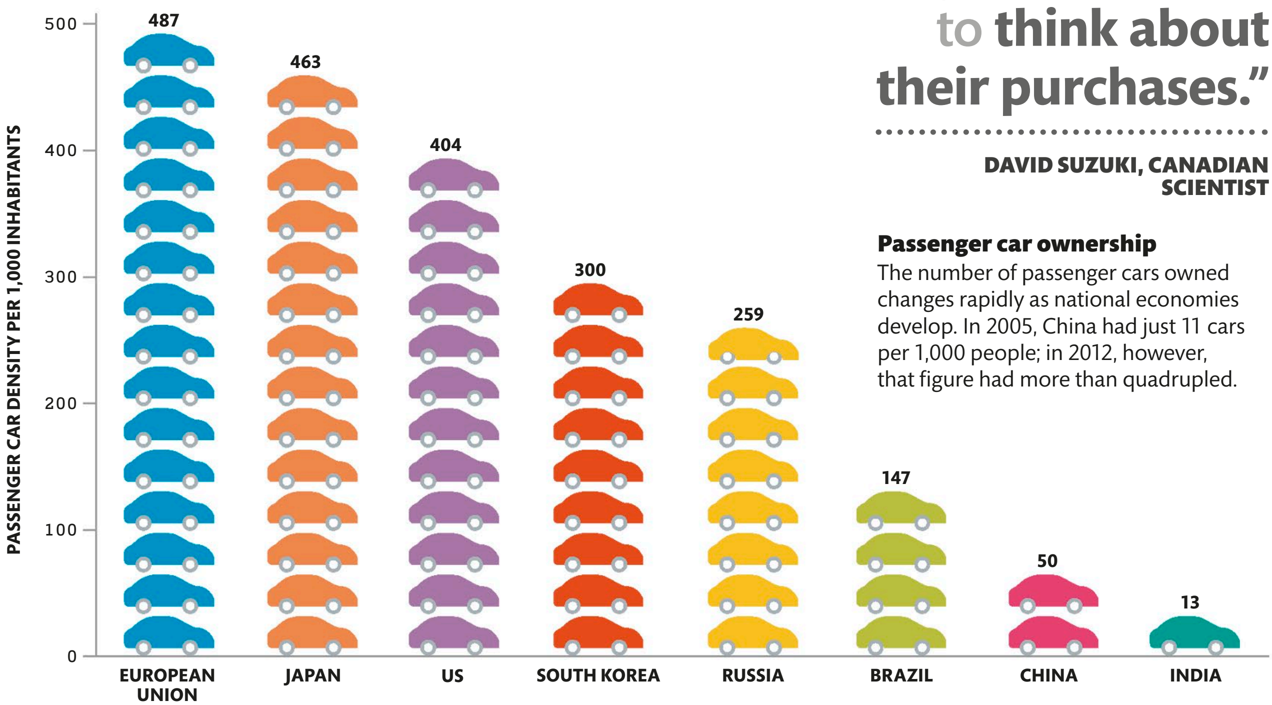
## Materials in a car

The process of car manufacturing requires everything from metal ore extraction to applying paint and fitting complex electronics. Making cars also uses huge quantities of energy and water. Manufacturers seek ways to reduce the overall impact of vehicles, not only when driven but also in production and by recovering materials when cars are scrapped. To that end, some companies are building lighter-weight and more fuel-efficient cars made from recycled aluminum.




## Vehicle ownership

Personal car ownership is strongly correlated with rising household income. Only in the US, the world's most mature car market, has the number of cars per 1,000 people recently stabilized; there were about 400 vehicles per every 1,000 people in the country in 2012.




"If we want a **sustainable society,** we need to get **consumers** to **think about their purchases.**"

**DAVID SUZUKI, CANADIAN SCIENTIST**

### Passenger car ownership

The number of passenger cars owned changes rapidly as national economies develop. In 2005, China had just 11 cars per 1,000 people; in 2012, however, that figure had more than quadrupled.

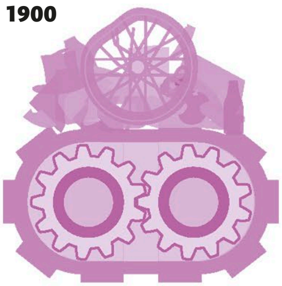
# Wasteful World

**All the waste we generate originates from natural resources, which are often extracted in environmentally damaging ways. Waste disposal also causes problems, such as pollution and climate change.**

World population increase and economic growth have led to an explosion in demand for resources. As the overall level of consumption has risen, there has been a dramatic increase in the amount of waste generated. That waste includes food, wood, metals, construction materials, and plastics, as well as complex high-technology products such as cars and computers. The production of all of these items results in greenhouse gas emissions, and even more are added during the process of disposing of them: for example, rotting food waste in landfill sites releases methane, a very powerful climate-changing gas.

There are three basic approaches to waste management: burying it in the ground, burning it (sometimes with energy recovery technology), or recycling. From an environmental viewpoint, however, the best option is to avoid producing waste in the first place.

**1900**



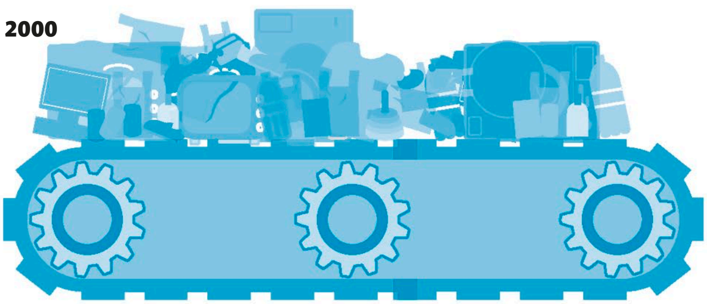
**0.55** million tons/day

**(0.5 MILLION TONNES/DAY)**

## Mounting waste

In 1900, the world produced about half a million tons of solid waste per day. By 2000, that quantity was six times higher, and by 2100, based on projected population, social, and economic trends, it is expected to quadruple again to about 12 million tons. Adopting more ecologically sound consumption patterns and increasing recycling could, however, lead to a much lower daily peak of approximately 10.5 million tons by the middle of the 21st century.

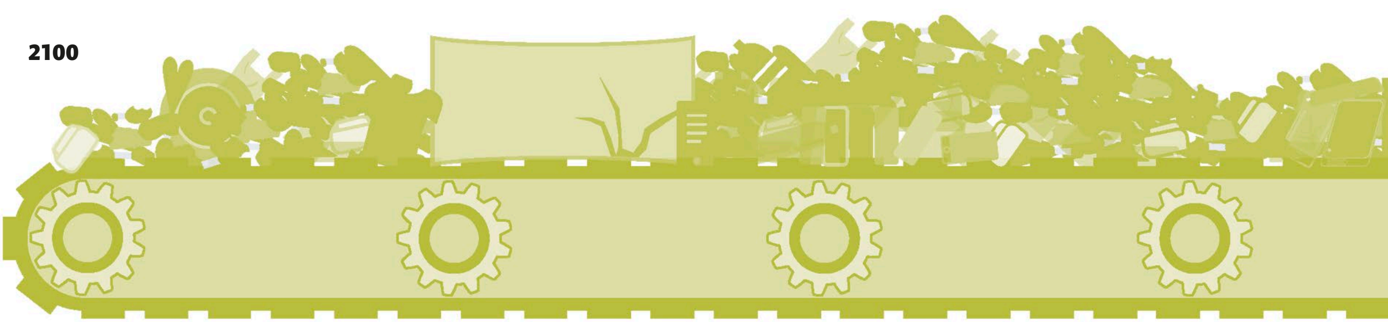
**2000**



**3.3** million tons/day

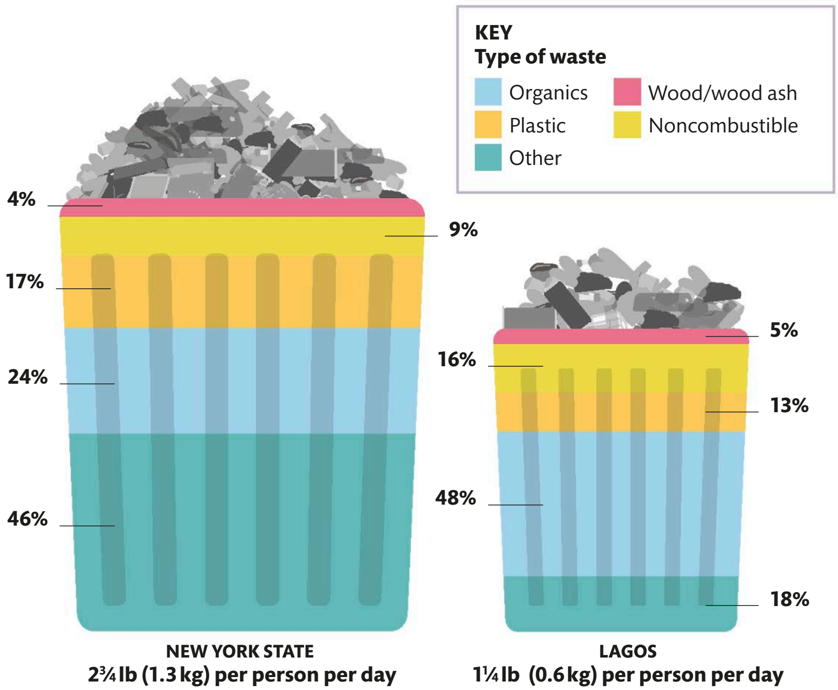
**(3 MILLION TONNES/DAY)**

**2100**



## What's in the bin?

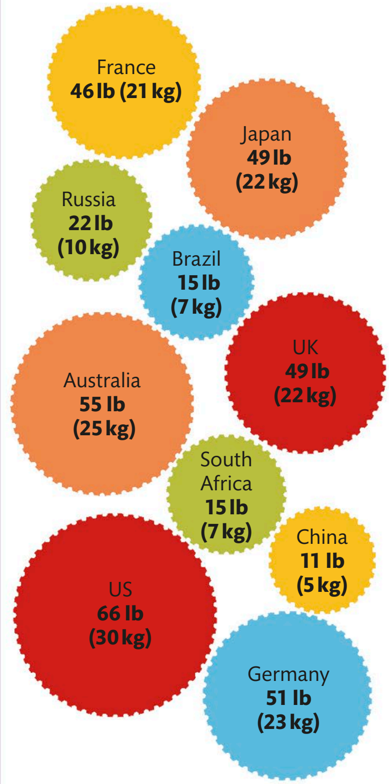
There are huge differences in waste produced in the affluent west and that generated by developing nations. For example, a far higher proportion of organic waste is put into trash cans in Lagos, Nigeria, compared with New York State. New Yorkers waste far more plastic, and overall, the American consumers are producing about three times as much waste per person per day as people who generally live on lower incomes in Lagos.



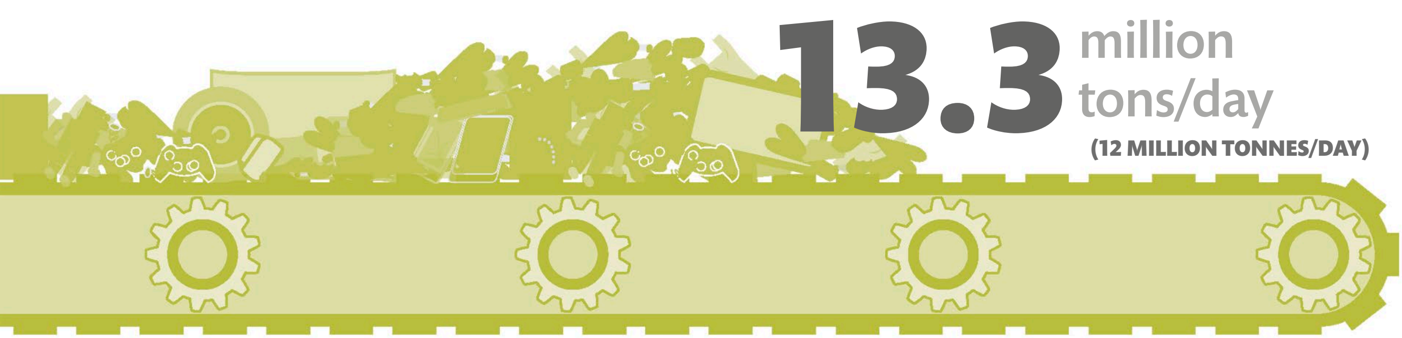

**700** The number of years it can take **a plastic bottle** to break down

## TECHNO TRASH

About 55 million tons (50 million tonnes) of electronic waste is generated each year. Computers, cell phones, and televisions are among the products that comprise this growing mountain.




**TOP 10 ELECTRONIC WASTE PRODUCERS PER PERSON**



**13.3** million tons/day
**(12 MILLION TONNES/DAY)**

# Where Does It All Go?

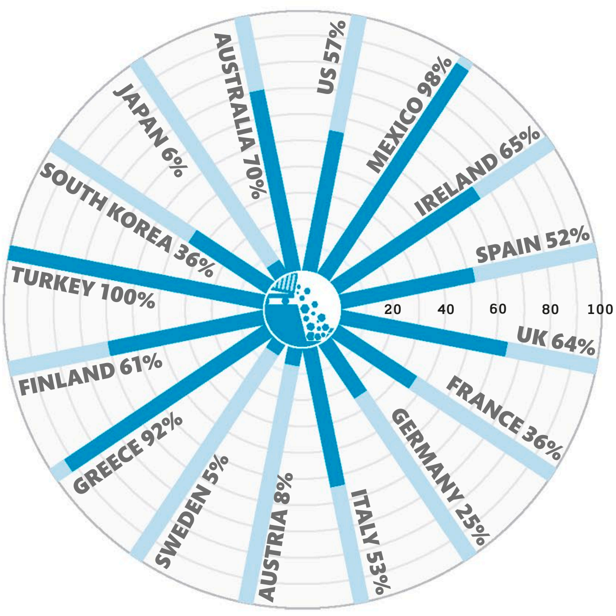
**As our consumption levels rise and we generate increasing quantities of trash, the management of solid waste has become an unprecedented—and increasingly important—challenge.**

Currently, four main options exist when it comes to the disposal of solid waste material: burying waste in landfill; burning it in different kinds of incinerators, some of which are also capable of generating heat and/or power; recycling; and, for organic matter, composting or anaerobic digestion to produce biogas for energy, while also recovering nutrients that would otherwise be lost.

The first two disposal methods are the least environmentally sustainable. The huge diversity of man-made materials, including many types of plastic, that cannot be easily separated and therefore recycled exacerbate the problem. Unfortunately, however, these two options are still viewed as the cheapest and easiest solutions for the growing waste mountains being generated by many societies today.

## Where waste ends up

The figures presented here are based on data collected on member countries of the Organization for Economic Cooperation and Development. Each wheel shows the percentage of a particular waste-disposal method used by each country in 2003–2005. Since then, some of the nations involved have made progress by reducing landfill use and increasing recycling rates.




**Landfill**
Burying waste in the ground can cause groundwater pollution when toxic substances are released. Rotting organic waste also emits methane, one of the primary greenhouse gases.


**Incineration**
Burning any kind of waste can cause air pollution. In addition, burning plastics and other man-made substances also produces residual toxic ash that is frequently buried in landfill.

## What can we do?

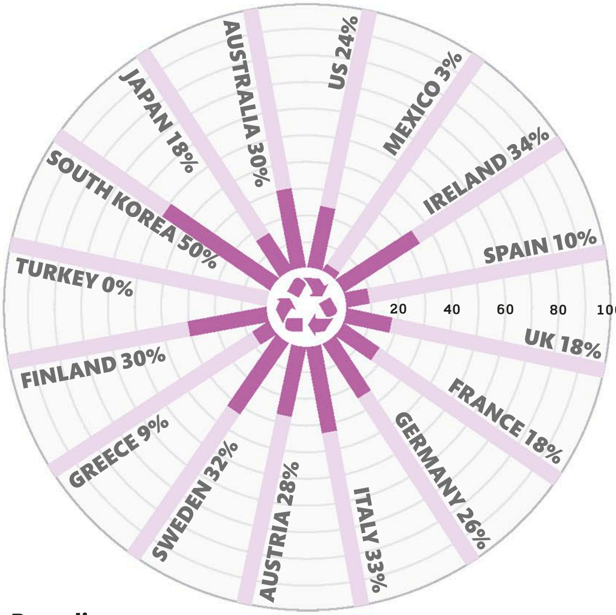
- **Governments** can set targets to shift more waste to composting and recycling.
- **Governments can** provide incentives to waste operators for change, for example, by taxing landfill waste.
- **Companies can** make packaging and electronic goods more recyclable.

## What can I do?

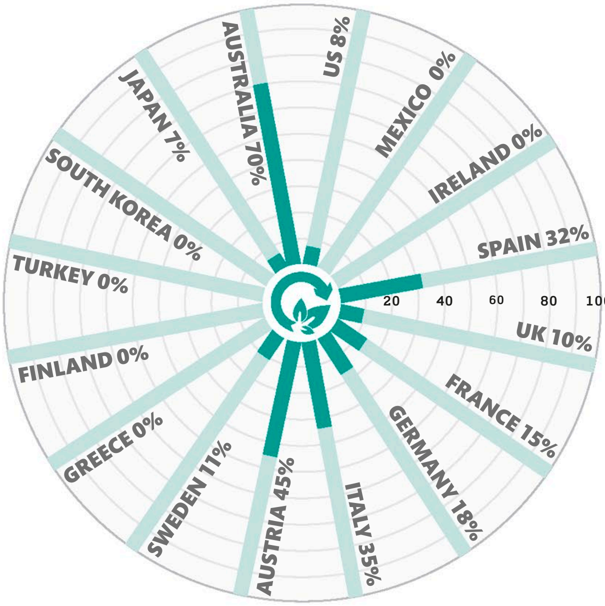
- **Know your waste**. Learn what can be recycled and put it in the correct bin, whether in your home or at a collection facility.
- **Buy with care**. Avoid unnecessary packaging and single-use or disposable items.
- **Avoid plastic bags.** Buy durable shopping bags to use when you go shopping.

**Poisoning the Earth**
As waste breaks down in landfill, water filters through it, forming a toxic liquid called leachate that can seep into soil and groundwater.

**90%** The **energy saving** when making an aluminum can from **recycled waste** compared with **ore**




**Recycling**
Glass, metals, paper, cardboard, and some types of plastic can be recycled into new products. This process takes much less energy than manufacturing the same items from raw materials—and it also saves resources.




**Composting**
Organic matter such as food waste, agricultural waste, and plant material can be used to make biogas, generating heat and electricity while at the same time saving nutrients that can be returned to the soil as fertilizer.

# Chemical Cocktail

**The number of man-made chemical substances being released into the environment is increasing dramatically. We don't yet know the impact they may have, including any "cocktail effects" if two or more combine.**

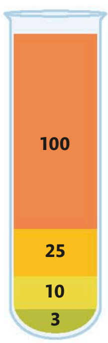
Persistent organic pollutants (POPs) are mostly man-made compounds that do not readily degrade or break down in the environment. Because of this, they last a long time and accumulate in food chains, causing serious biological effects, especially among larger organisms. POPs include many chemicals that were developed as beneficial substances, such as the insecticide DDT and the PCBs once used in electrical equipment. Others, such as dioxins, are created via combustion, such as by burning waste in incinerators.

## THE RISE IN NEW CHEMICALS

Since the 1940s, millions more synthetic compounds have been invented, registered, manufactured, and released into the environment. Many have not been properly assessed for their biological impacts, either on their own or in combination with other substances.

**KEY**
**Cumulative number of new chemical substances (millions)**

- 2015
- 2005
- 1990
- 1975




## What is biomagnification?

As POPs move through food webs, they become more concentrated as one species feeds on another. For example, after the (now banned) insecticide DDT entered lakes and other water sources, it built up in the bodies of top predators such as fish-eating ospreys, causing them to lay thin-shelled eggs that broke when adult birds incubated them.

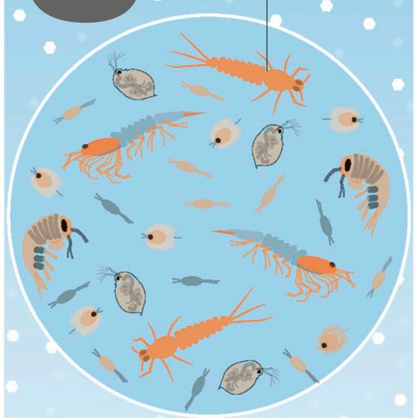
**DDT ENTERS** water body; contamination begins

**0.000003** parts per million (ppm)

**DDT runs off fields in rainwater**
Once applied, DDT enters bodies of water, such as rivers, lakes, and reservoirs, at about 0.000003 parts per million (ppm).

**ZOOPLANKTON** feed on DDT-contaminated food

**0.04** ppm



**Small creatures consume DDT**
Zooplankton, tiny creatures that live in water, consume microscopic food items contaminated with DDT, and their bodies accumulate the chemical to around 0.04 ppm because the substance does not break down once eaten.

## What can we do?

- **Governments can work together** to control the effects of chemicals, such as via the Stockholm Convention on Persistent Organic Pollutants.
- **Governments can** introduce more rigorous testing regimes to reveal the potential biological effects of new and existing chemicals.

## What can I do?

- **Reduce your exposure** to potentially harmful substances. Start by looking up what is listed on the labels of consumer goods.
- **Join campaigns** that support regulating chemicals entering the environment and advocate more effective screening of new substances.


### Small fish feed on the plankton

As small fish eat small creatures contaminated with DDT, they further concentrate the DDT to around 0.5 ppm. The DDT is lodged in the fish's bodies but does not break down; it continues to accumulate in larger amounts.

### Predatory fish

Larger fish, such as trout, that eat smaller fish have higher concentrations of DDT in their bodies, at around 2 ppm. These fish become food for top predators, such as bears, fish-eating birds, and ultimately humans.

### DDT reaches top of the food chain

At around 25 ppm—about 10 million times more concentrated than when the chemical first entered the water—this amount threatens the survival of many species; for example, bald eagle populations were wiped out in much of North America when DDT was used.

"As **human beings, we are more urbanized than ever before,** and we are out of touch with the natural world. Yet we are **100% dependent on its resources."**

**SIR DAVID ATTENBOROUGH, BRITISH BROADCASTER AND NATURALIST**

**The Global Age**

**Better Lives for Many**

**Our Changing Atmosphere**

**Changing the Land**

**Sea Changes**

**The Great Decline**

# 2 CONSEQUENCES OF CHANGE

Some aspects of rapid change are positive, but others are causing negative consequences for people and the natural world, including the impacts of climate change, pollution, and land degradation.

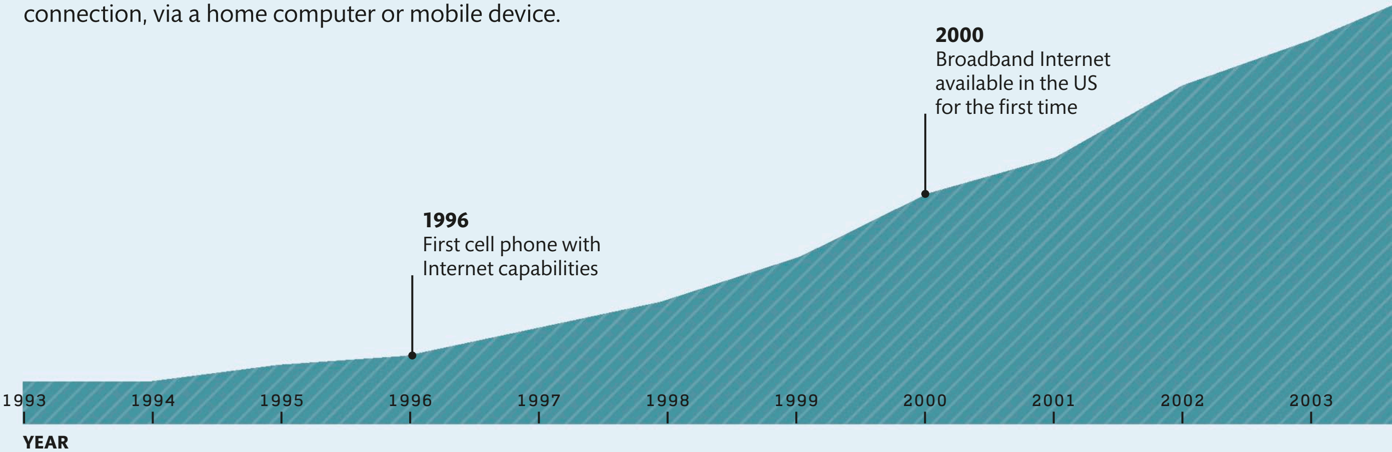
# The Global Age

**Our world is more interconnected than ever before. People can share information, ideas, and images between computer devices all over the world. Airplanes fly millions of travelers to cities huge distances apart every day. Once the domain of a small elite, access to cheap travel, high-speed Internet, and mobile communications is now growing fastest in developing countries. Interconnection speeds up economic growth, and it shapes all forms of businesses.**

## Rise of the Internet

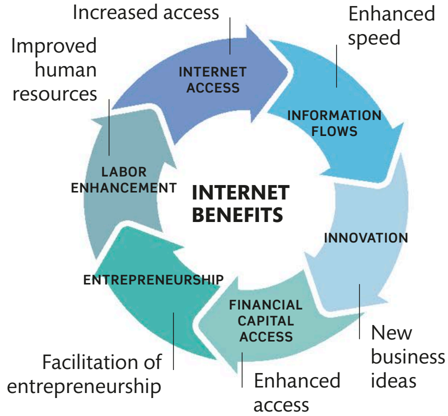
In 1989, English inventor Tim Berners-Lee devised the World Wide Web, which kick-started an information revolution. Events can be watched anywhere in real time, while email offers cheap communications for anyone with an Internet connection. Home Internet connections became available in the 1990s, and each year many millions more people joined the global digital community. By 2005, there were 1 billion Internet users. This doubled in just five years and by 2015 tripled to about 3 billion. This graph charts the incredible rate of expansion, with more than 40 percent of the global population having access to an Internet connection, via a home computer or mobile device.

> "We must **make globalization an engine** that **lifts people out of hardship and misery,** not a force that holds them down."
>
> **KOFI ANNAN, FORMER UNITED NATIONS SECRETARY-GENERAL**



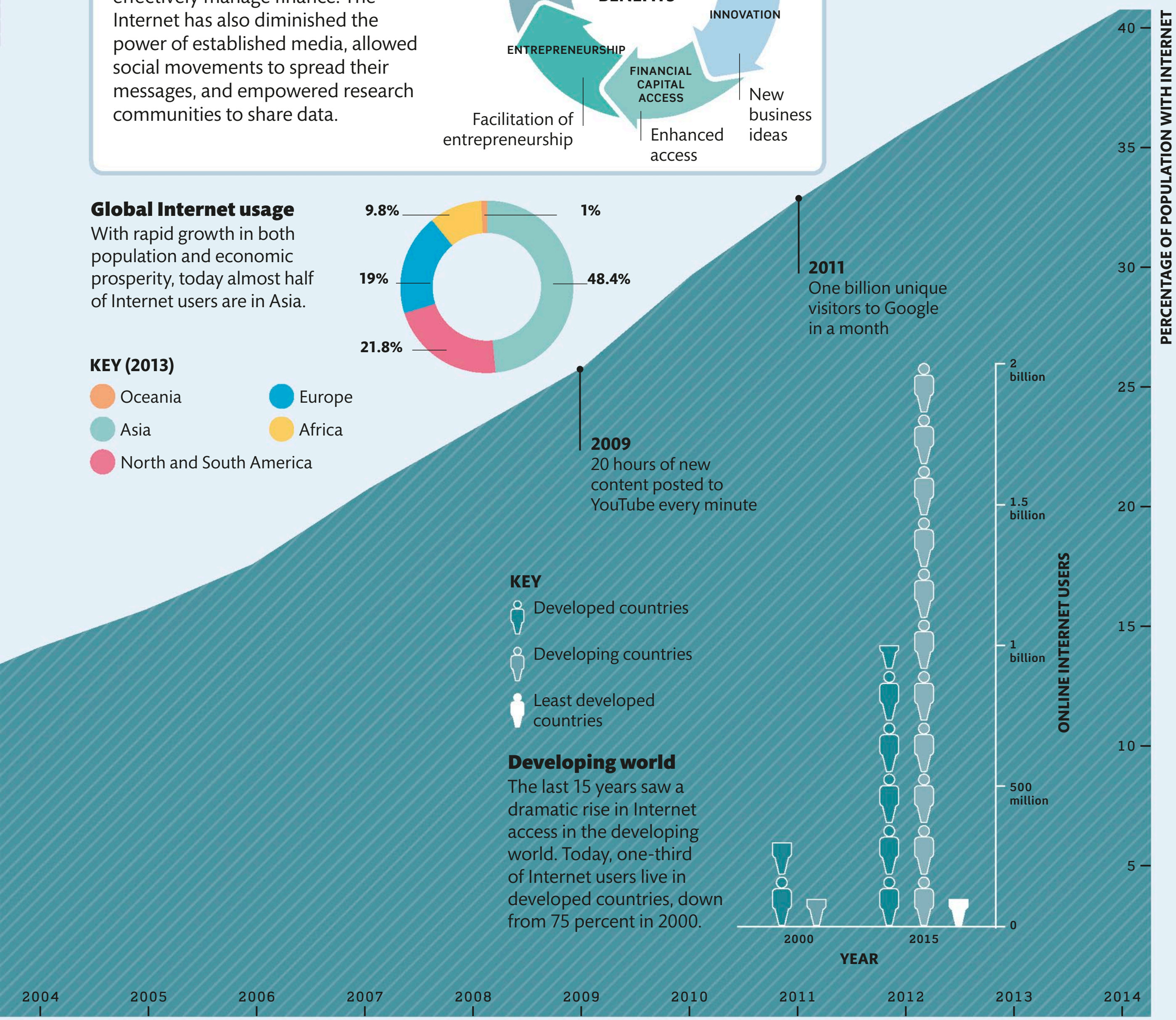
## ENHANCING ECONOMIES

Internet access has had a positive impact on economies across the world. The ability to deliver company information quickly, widely, and cheaply means businesses can share corporate news, provide flexible working, lead in innovation, and effectively manage finance. The Internet has also diminished the power of established media, allowed social movements to spread their messages, and empowered research communities to share data.




### Global Internet usage

With rapid growth in both population and economic prosperity, today almost half of Internet users are in Asia.




**KEY (2013)**

- Oceania
- Europe
- Asia
- Africa
- North and South America

**KEY**

- Developed countries
- Developing countries
- Least developed countries

### Developing world

The last 15 years saw a dramatic rise in Internet access in the developing world. Today, one-third of Internet users live in developed countries, down from 75 percent in 2000.

# Mobile Technology

**Today, cell phones are ubiquitous all over the world—from the biggest cities to remote villages—as more and more people connect to the virtual grid to make calls, send texts, and use the internet.**

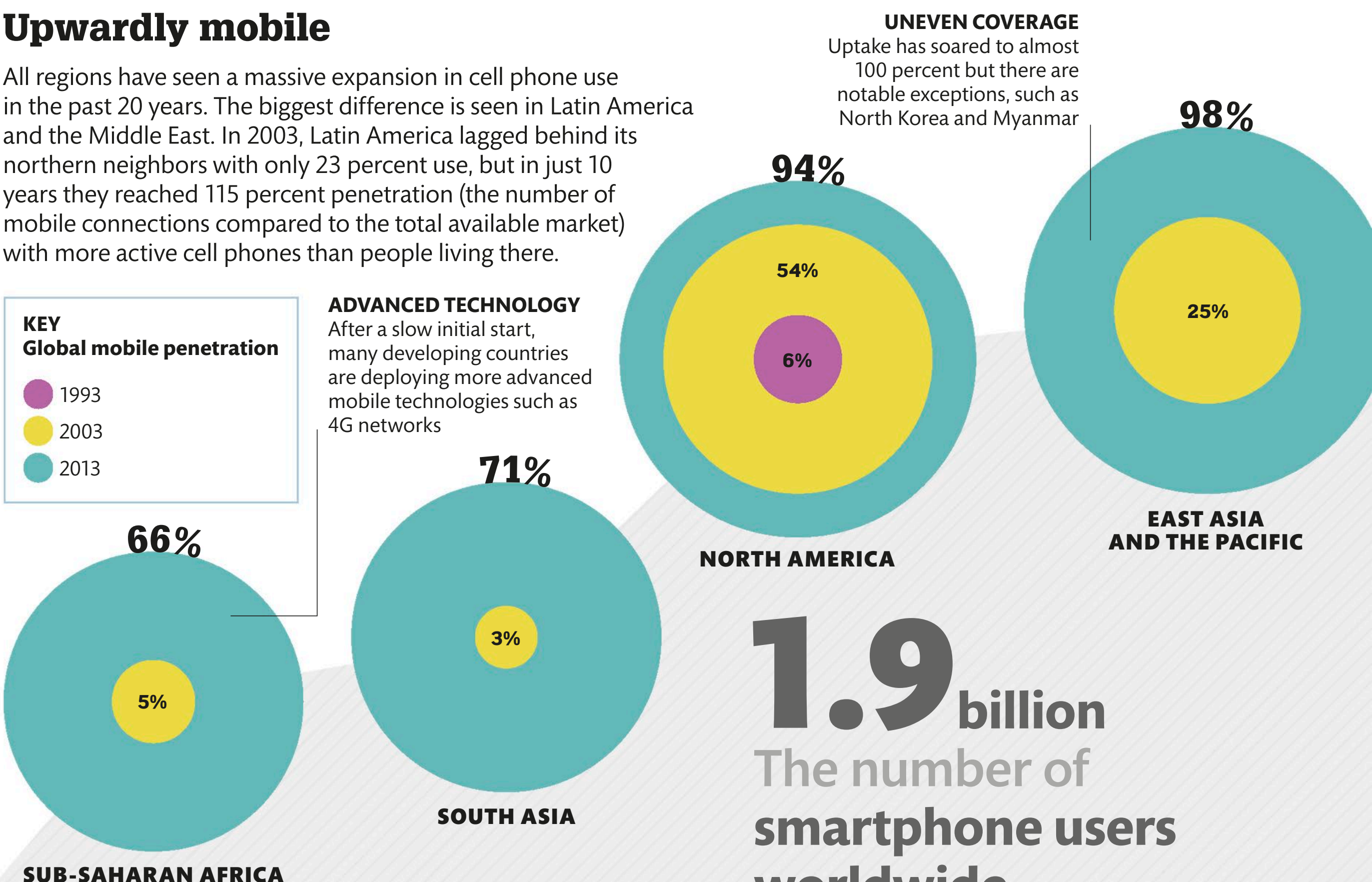
Cell phones have changed from being a bulky luxury to an everyday item. The first cell phone was developed in 1973, but it didn't become commercially available for another 10 years, when it was sold for US$4,000— equivalent to US $10,000 in 2018 prices. Many thought it a pricey gimmick.

At the turn of the century, cell phone use was concentrated in Europe and North America, but usage has skyrocketed throughout the world as the technology has become cheaper. The instant communication and information of mobile technology is transforming the way people live their lives. Cell phones are no longer just a means of voice communication but also give users access to banking, healthcare, and global news.

**Remote connectivity**
Nomadic peoples such as this Maasai warrior on the Kenyan plains now have ready access to mobile communication.

## Upwardly mobile

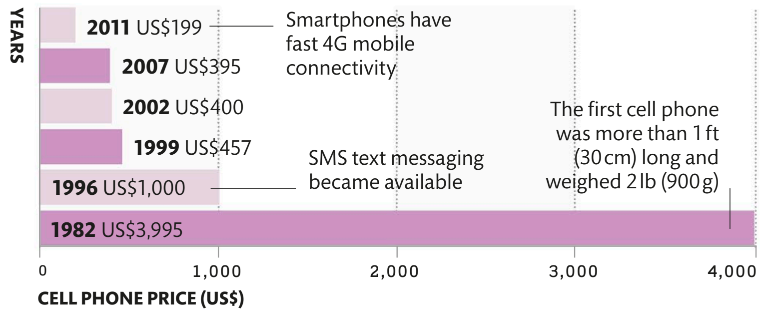
All regions have seen a massive expansion in cell phone use in the past 20 years. The biggest difference is seen in Latin America and the Middle East. In 2003, Latin America lagged behind its northern neighbors with only 23 percent use, but in just 10 years they reached 115 percent penetration (the number of mobile connections compared to the total available market) with more active cell phones than people living there.

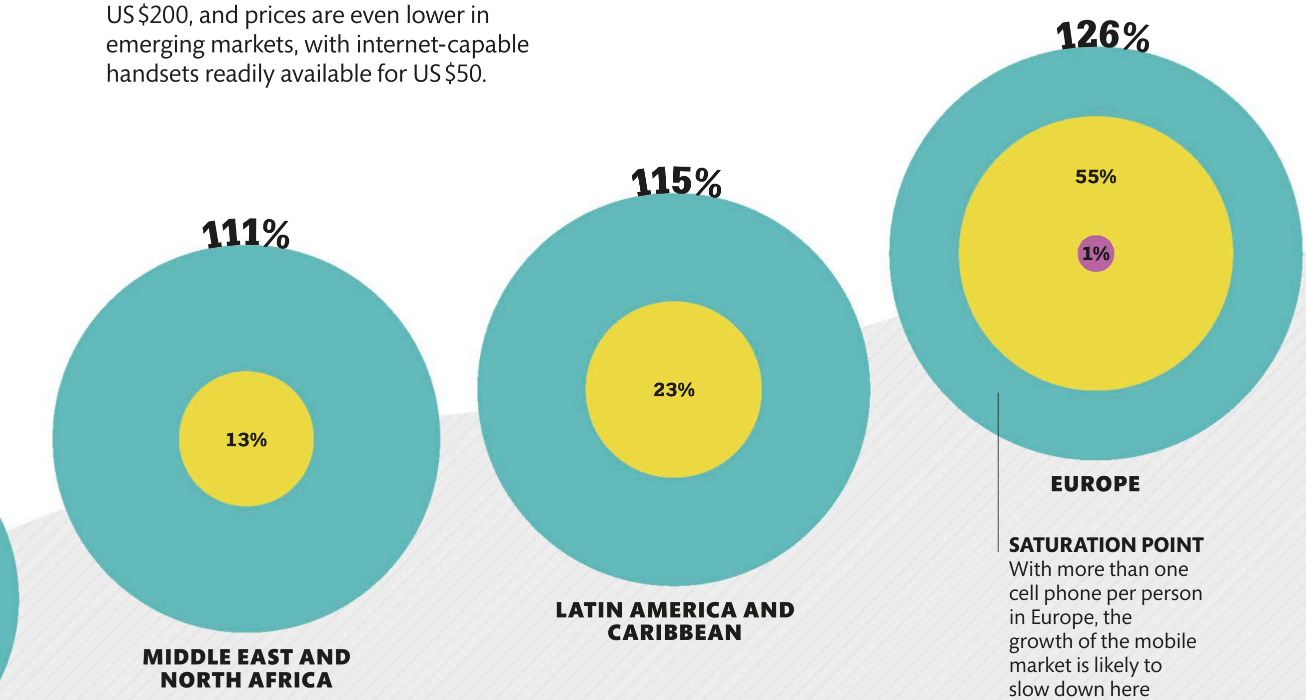



**1.9 billion**
**The number of smartphone users worldwide**

## Affordable technology

The first available cell phones were out of reach for all but the very wealthy, but as demand has soared, prices have fallen. As prices fell, features increased, leading to the current success of the smartphone. Ongoing improvements in signal coverage, battery life, and handset size have helped drive their popularity since. In Europe, the average basic smartphone costs about US $200, and prices are even lower in emerging markets, with internet-capable handsets readily available for US $50.

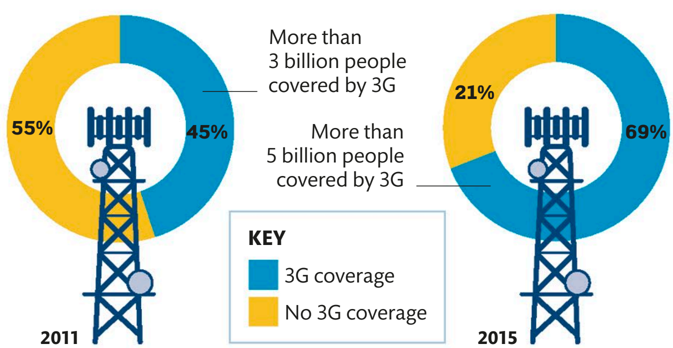



**SATURATION POINT**
With more than one cell phone per person in Europe, the growth of the mobile market is likely to slow down here

## EXPANDING MOBILE INTERNET ACCESS

Mobile internet is hugely popular across the globe, and in 2015 almost 70 percent of the world's population lived within 3G coverage—up from 45 percent in 2011. This is particularly significant in less-developed countries that lack the infrastructure needed for fixed connections. With smartphones available for as little as US $50, cell phone internet subscriptions in the least developed countries increased 10-fold in the years 2012–17.



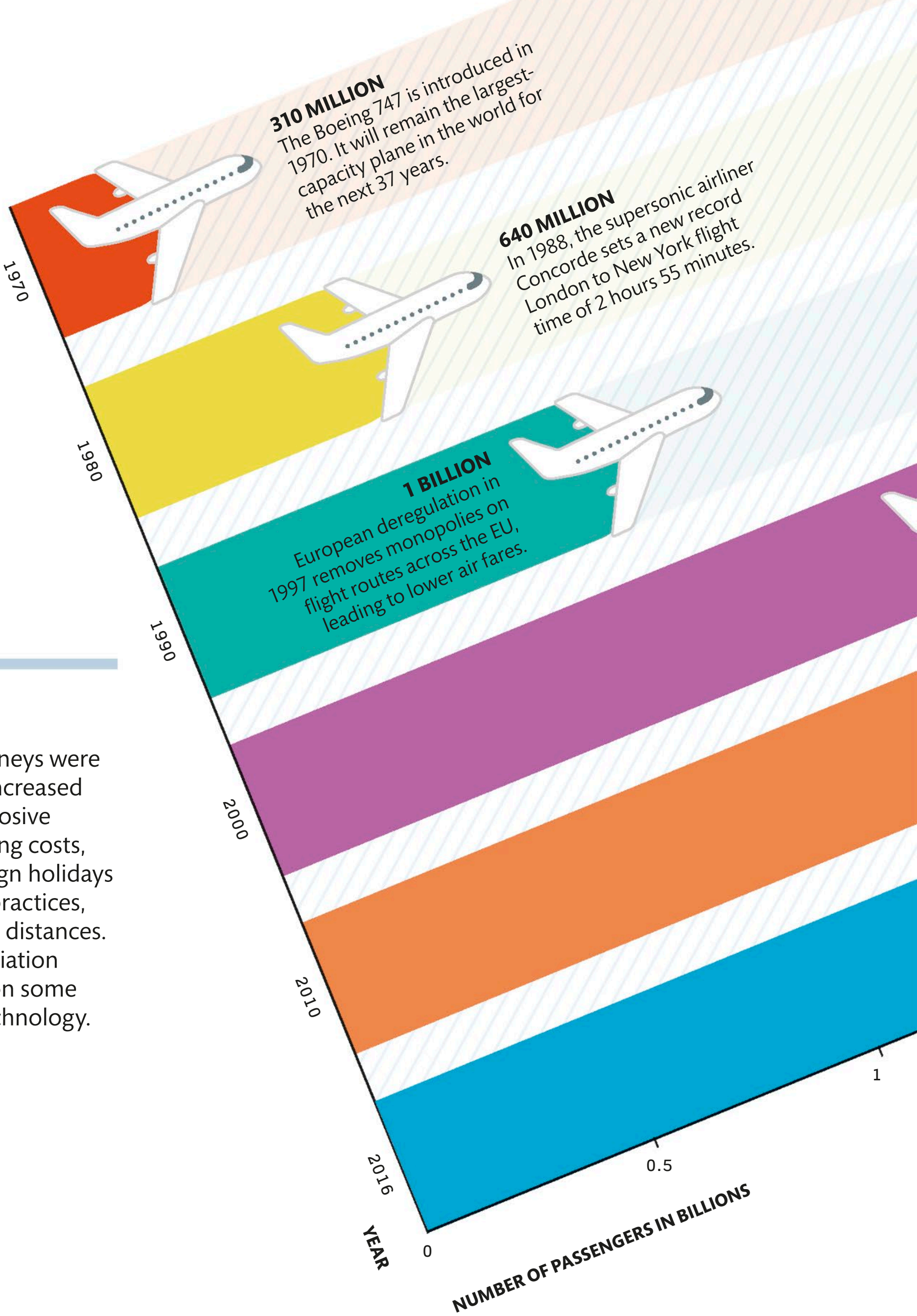
# Taking to the Skies

**The spectacular rise of air travel connects the world as never before. Modern aircraft permit cheap, long-distance transportation, enabling millions of people to travel and driving economic growth.**

The first passenger aircraft took to the skies in the 1920s, with the first commercial jet airliners being introduced in the 1950s. Since then, passenger numbers have grown almost yearly as more routes have opened and become more affordable, and aircraft technology has continued to improve. Today, modern aircraft can carry several hundred people. In 2014, there were more than 30 million commercial flights, with the result that about half a million people were in the air at any one time. A network of major airports now connects the globe. The world's busiest airport is Hartsfield-Jackson airport in Atlanta, Georgia, which handled more than 104 million passengers in 2016.

## Growth of air travel

In 1970, some 300 million passenger journeys were made by plane. By 2016, this figure had increased more than tenfold to 3.7 billion. This explosive growth was largely a result of rapidly falling costs, which enabled more people to take foreign holidays and also permitted changes to business practices, with more face-to-face contact over long distances. The key drivers of reduced costs in the aviation sector were the removal of monopolies on some routes and more reliable and efficient technology.



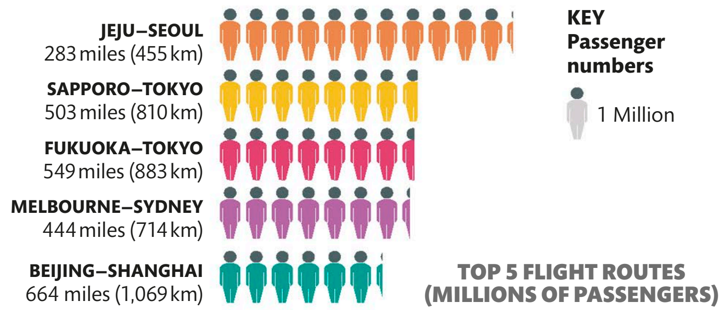


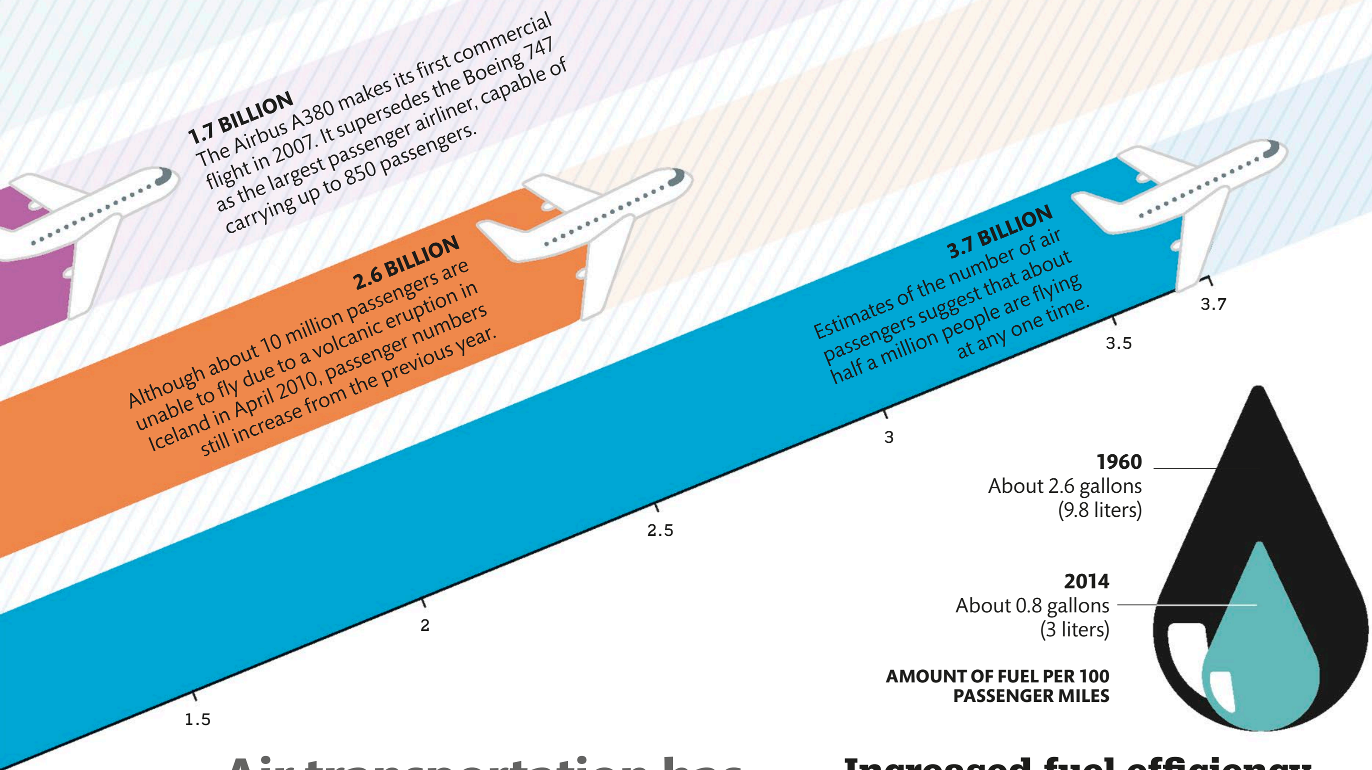
**SEE ALSO...**

› **Carbon footprint,** pp50–51

## TOP FLIGHT ROUTES

The most popular flight routes in 2016 were all domestic, and four out of the top five were within the borders of South Korea, Japan, and China. This is because the rapid growth of a relatively affluent middle class in Asia has led to increased demand for flights, including short-haul pleasure trips. The most popular route was between the South Korean capital, Seoul, and Jeju, a holiday island in the south of the country.



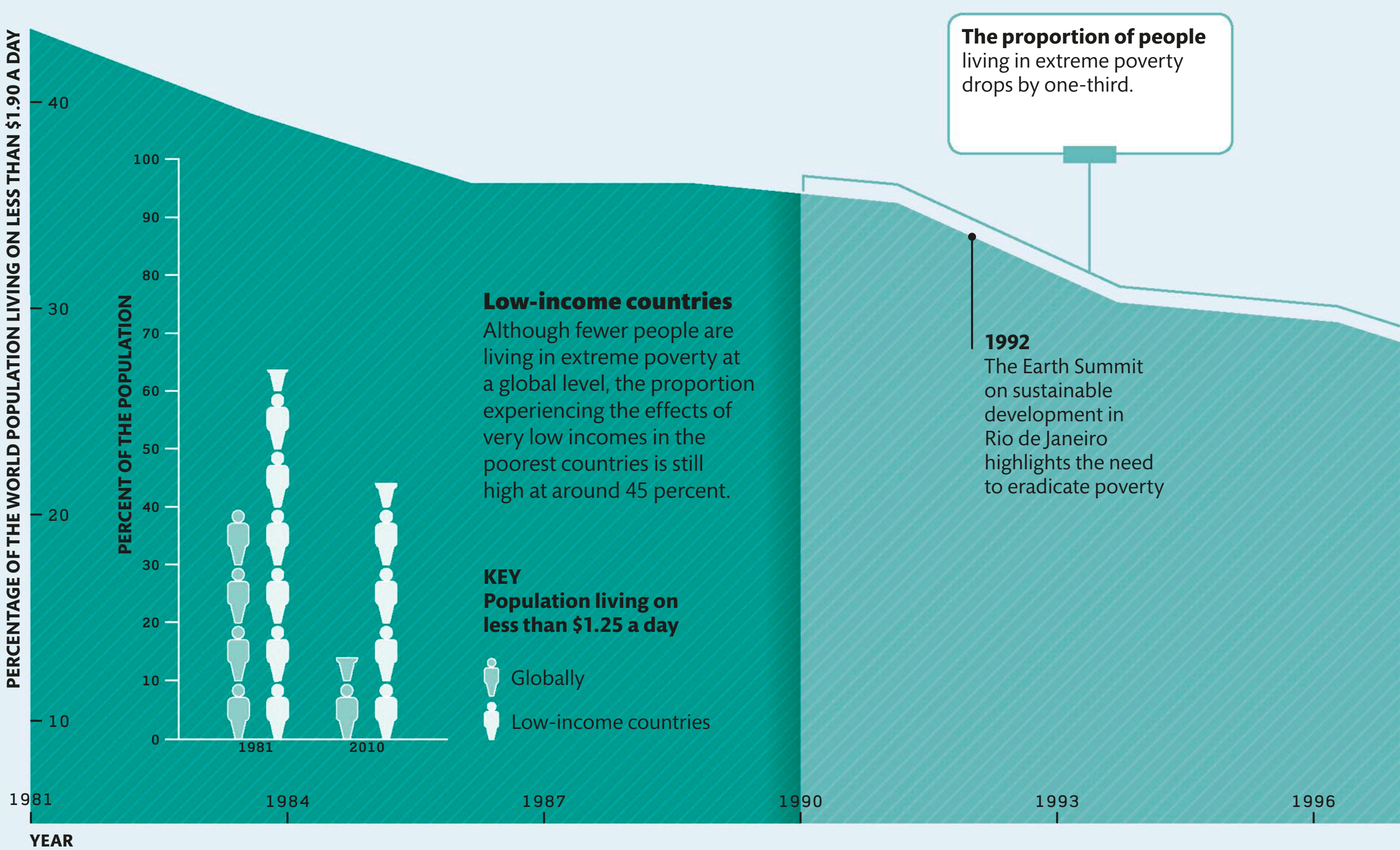

**Air transportation has reduced its fuel use and $CO_2$ emissions per passenger mile by well over 70% compared to the 1960s**

## Increased fuel efficiency

Rising fuel costs and pressure over environmental concerns, especially about air pollution, noise, and climate-changing emissions, have stimulated manufacturers to develop more efficient aircraft. As a result, the fuel needed to fly one passenger 100 miles (161 km) has decreased by more than two-thirds since the 1960s, with a similar reduction in climate-changing emissions.

# Better Lives for Many

There has been significant progress in reducing extreme poverty over recent decades, partly due to economic growth. Access to education, connection to electricity, and the provision of health care, clean water, and sanitation all reduce poverty. By helping people escape poverty and improving the economy, these factors create a beneficial cycle for the whole society. However, while there is global improvement, some parts of the world remain affected by war, conflict, and inequality, which means there is still plenty of work to be done in ensuring better lives for all.



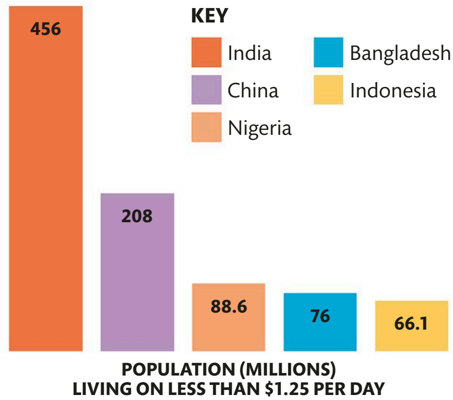
## Declining poverty

During the last three decades, the number of people living in extreme poverty has declined significantly. Extreme poverty is defined as living on less than $1.25 a day—the level at which basic survival conditions can be met. This figure is called the poverty line, and it was raised to $1.90 a day in 2015.

This reduction in extreme poverty happened despite large population growth during the same period. It occurred because of the steady expansion of countries' economies, leading to increases in average per-capita incomes in both developed and developing nations. The steepest decline began in 1997, when explosive economic growth took off in Asia—particularly in China. This rapid reduction in extreme poverty masked the effect of the two regions where poverty increased—in Eastern Europe and Central Asia after the fall of communism.

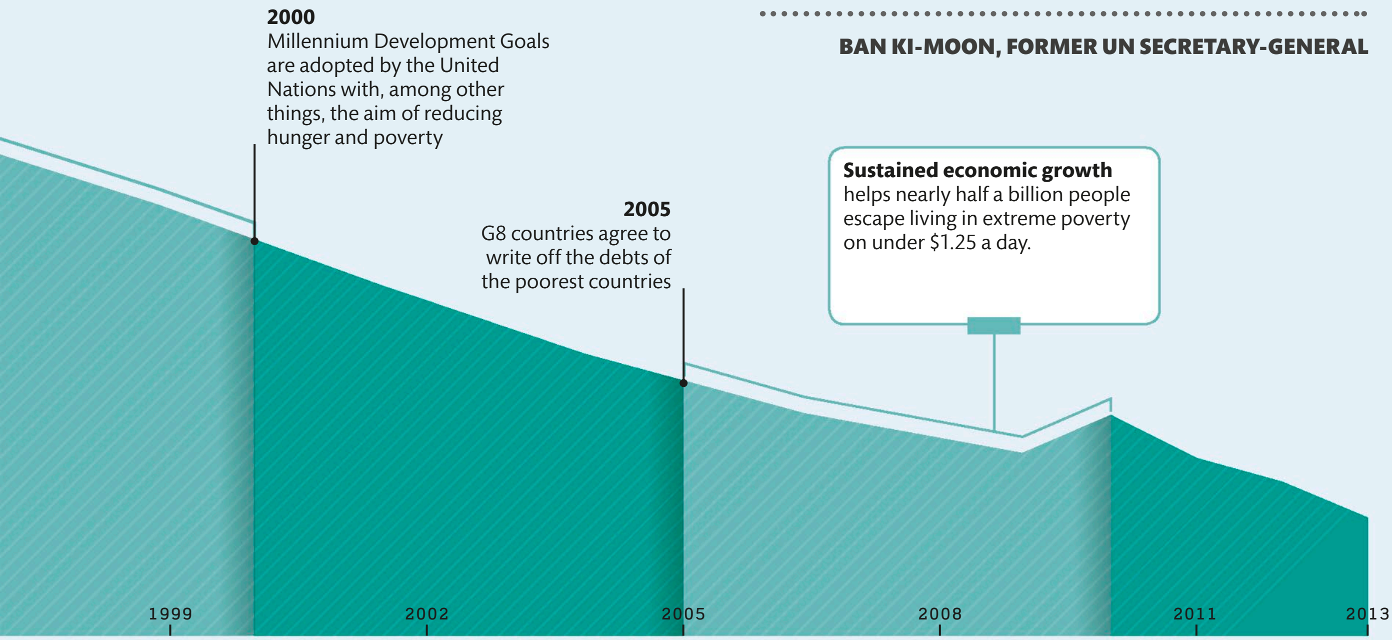
### WHERE ARE THE WORLD'S POOREST PEOPLE?

A 2015 ranking that compared countries based on income and the cost of living found the 10 poorest nations in the world were all in Africa. The greatest absolute numbers of people in extreme poverty, however, are mainly located in Asia, because this is where the most populated countries are. Millions of people live in vast slums, and large rural populations survive from subsistence farming, all living on tiny incomes.




**"Saving our planet, lifting people out of poverty, advancing economic growth... these are one and the same fight."**

BAN KI-MOON, FORMER UN SECRETARY-GENERAL

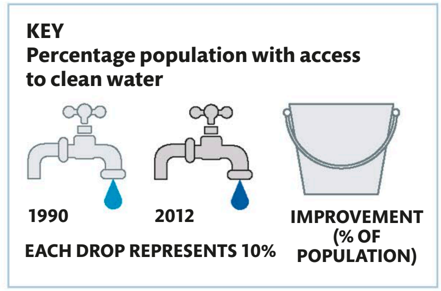


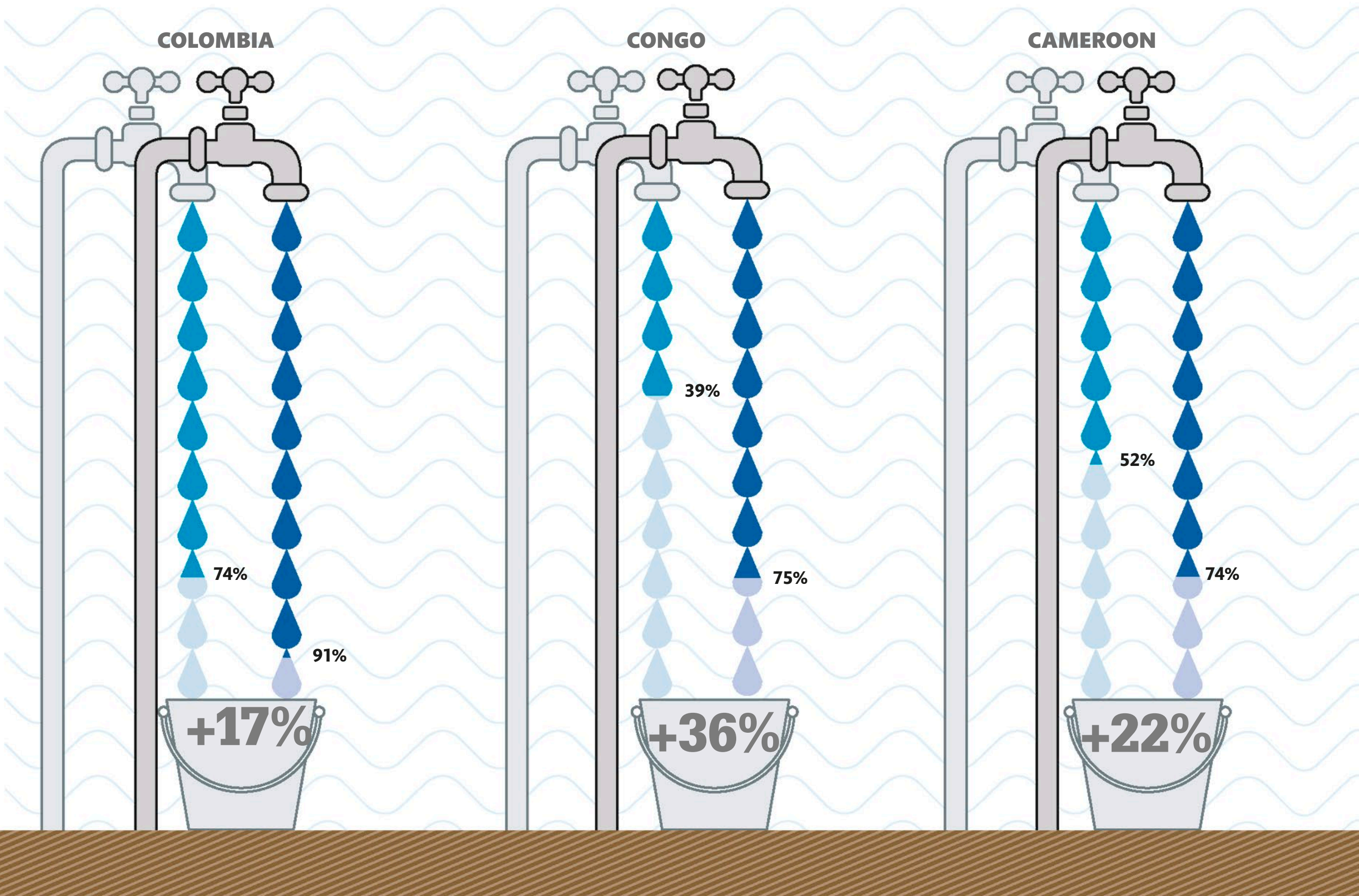
# Clean Water and Sanitation

**Clean water and sewage treatment facilities are key factors in influencing outcomes for public health, development, and poverty. Impressive progress has been made in extending these basic necessities to billions more people.**

## Improved access to clean water

According to World Health Organization data collected over 22 years, the countries below have made the greatest progress in the world and respective regions by supplying a greater proportion of their citizens with access to safe and clean drinking water. Disparities remain, however, between rural and urban areas, and more people living in the countryside are still unable to make use of reliable water supplies than those residing in towns and cities. Despite recent positive progress, millions still die each year from diseases spread in dirty water. Asia and Africa remain the areas where people are at greatest risk of water-borne diseases.

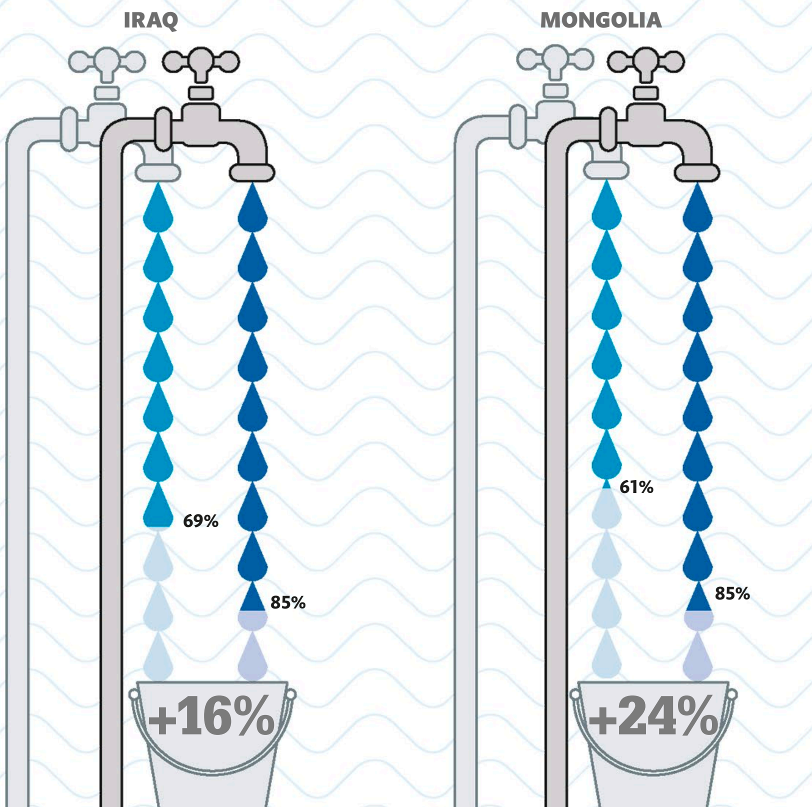


Cleaning up water is often the quickest and most cost-effective way to improve public health, saving both lives and money. Following a global improvement program, around 91 percent of the world population now has access to safe drinking water access—up by 2.6 billion people compared with 1990. A parallel effort in sanitation means that, today, 68 percent of the global population has improved sewage treatment and disposal services—up by 2.1 billion compared with 1990. In 2015, however, 2.4 billion people lacked access to basic sanitation facilities. Nearly 1 billion people are still forced to defecate outside, causing the spread of diseases such as cholera, diarrhea, and hepatitis A.

**1 in 9** people in the world **lack access** to safe water

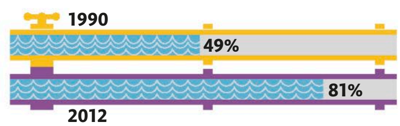
**Safe to drink**
In India, 70 percent of people had clean water supplies in 2012, leaving 30 percent still using untreated sources.



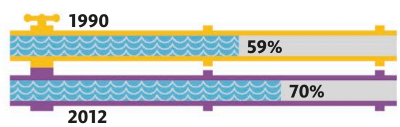

## ACCESS TO SANITATION

The stark differences in the improved sewage treatment of the selected countries below reveal their contrasting national circumstances, including the level of development, the rate of economic growth, and the prevalence of corruption.

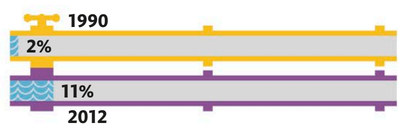
**KEY Percentage of population with access to sanitation**
1990
2012




**BRAZIL**
**Improvement** 32%
**Population still without access** 19%




**RUSSIA**
**Improvement** 11%
**Population still without access** 30%




**TOGO**
**Improvement** 9%
**Population still without access** 89%

# Reading and Writing

**Improving literacy skills is essential when trying to reduce poverty. While positive progress has been made in increasing the proportion of people who can read and write, major challenges remain, especially in Africa.**

In 2011, there were still 774 million adults in the world who lacked basic literacy skills. Three-quarters of them were living in South Asia, the Middle East, and sub-Saharan Africa, and two-thirds were women.

The past 30 years have seen substantial efforts from governments, charities, and individuals to improve literacy in the poorest and most deprived parts of the world. The ability to read and write greatly improves people's prospects to enter employment, generate income, and contribute to development.

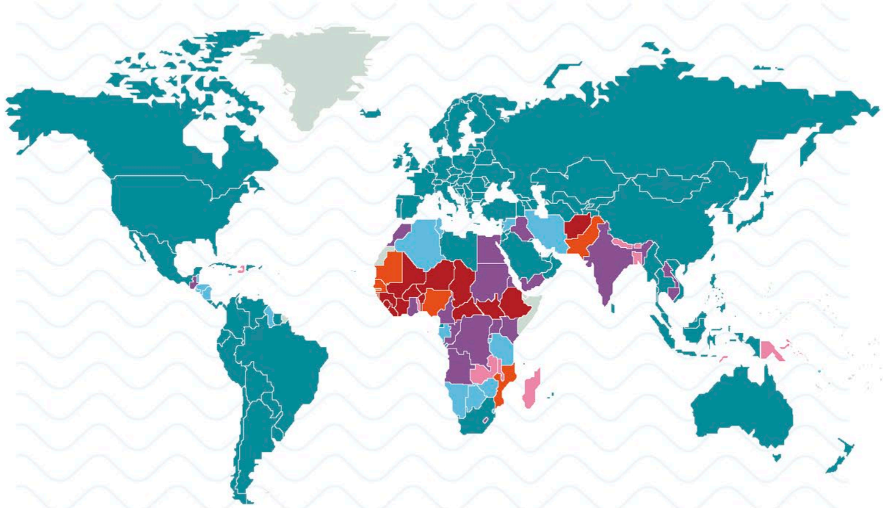
The challenge in achieving universal literacy begins with the acquisition of basic skills during childhood and access to primary education. This was one focal point for the Millennium Development Goals—a set of eight goals set out in a UN initiative in 2000—and today 91 percent of children receive primary schooling.

## How the world reads

North America, Europe, and Central Asia have all achieved near-universal literacy. The situation in South America has improved during recent decades to reach an average literacy rate of 92 percent, although the Caribbean still lags behind with just 69 percent of adults able to read and write. The lowest literacy rates are in sub-Saharan Africa, the Middle East, and South Asia.

**KEY**

- 90–100%
- 80–89%
- 70–79%
- 60–69%
- 50–59%
- Under 50%
- No data



## Women's literacy rates

In four of the worst-performing countries, the female literacy rate is less than half that of the male population. In Niger, only one in nine women have basic literacy skills, while literacy in the male population is three times higher. This disparity makes other challenges far harder to address: for example, it poses a fundamental barrier to both reducing poverty and slowing population growth (see p22).

**Reading benefits**
These women and girls are some of the lucky few who are taught to read and write in Somalia. Here, only 25 percent of women can read and write compared with almost 50 percent of men.

**Mali**
In 15 years, Mali has more than doubled its overall adult literacy rate, but this still means that less than half of the population can read and write.

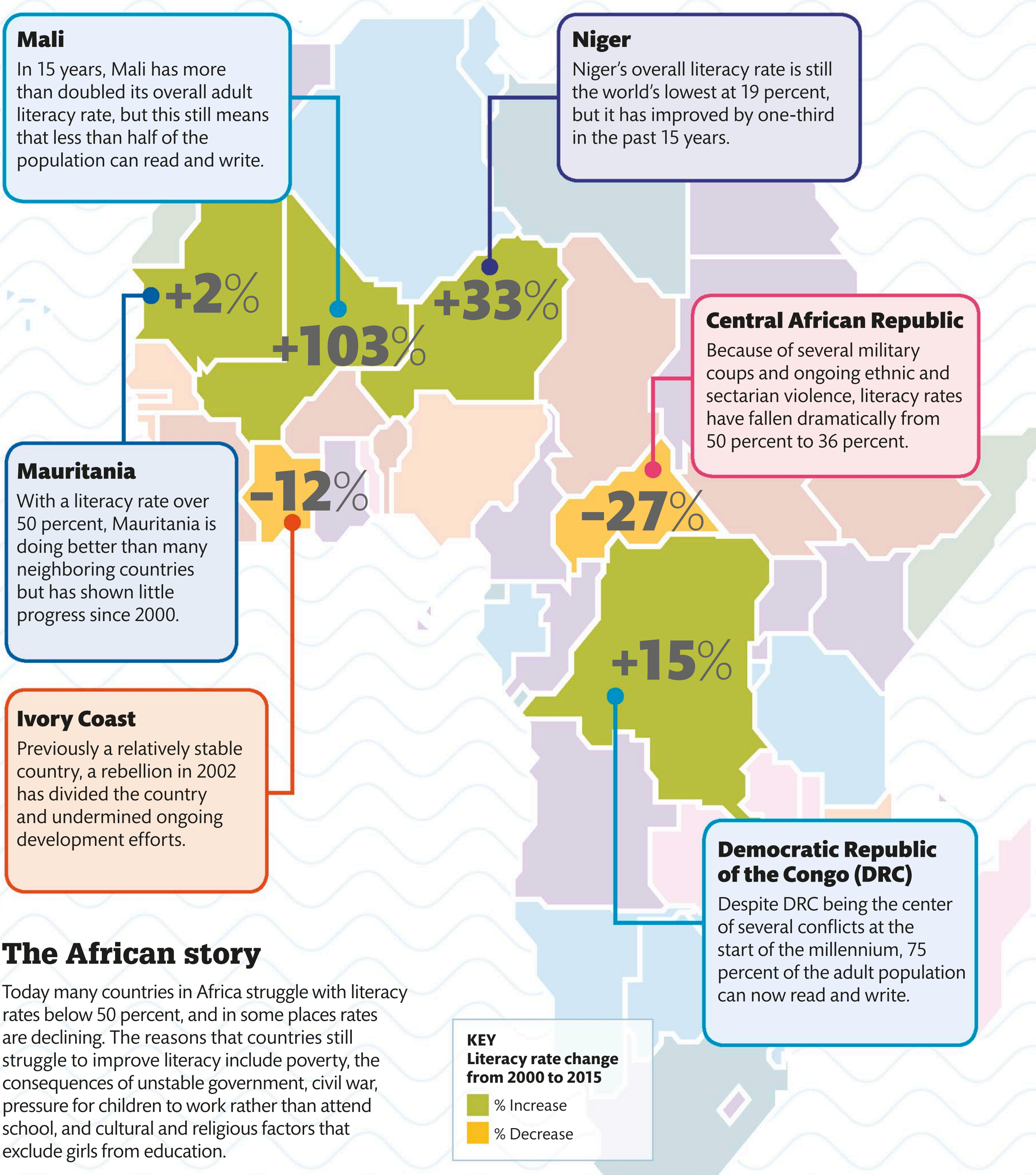
**Niger**
Niger's overall literacy rate is still the world's lowest at 19 percent, but it has improved by one-third in the past 15 years.

**Mauritania**
With a literacy rate over 50 percent, Mauritania is doing better than many neighboring countries but has shown little progress since 2000.

**Central African Republic**
Because of several military coups and ongoing ethnic and sectarian violence, literacy rates have fallen dramatically from 50 percent to 36 percent.

**Ivory Coast**
Previously a relatively stable country, a rebellion in 2002 has divided the country and undermined ongoing development efforts.

**Democratic Republic of the Congo (DRC)**
Despite DRC being the center of several conflicts at the start of the millennium, 75 percent of the adult population can now read and write.




## The African story

Today many countries in Africa struggle with literacy rates below 50 percent, and in some places rates are declining. The reasons that countries still struggle to improve literacy include poverty, the consequences of unstable government, civil war, pressure for children to work rather than attend school, and cultural and religious factors that exclude girls from education.

# Healthier World

**In the 21st century, the incidences of deadly communicable diseases have fallen dramatically, so people lead, on average, longer lives. The major causes of death are now cardiovascular diseases and cancers.**

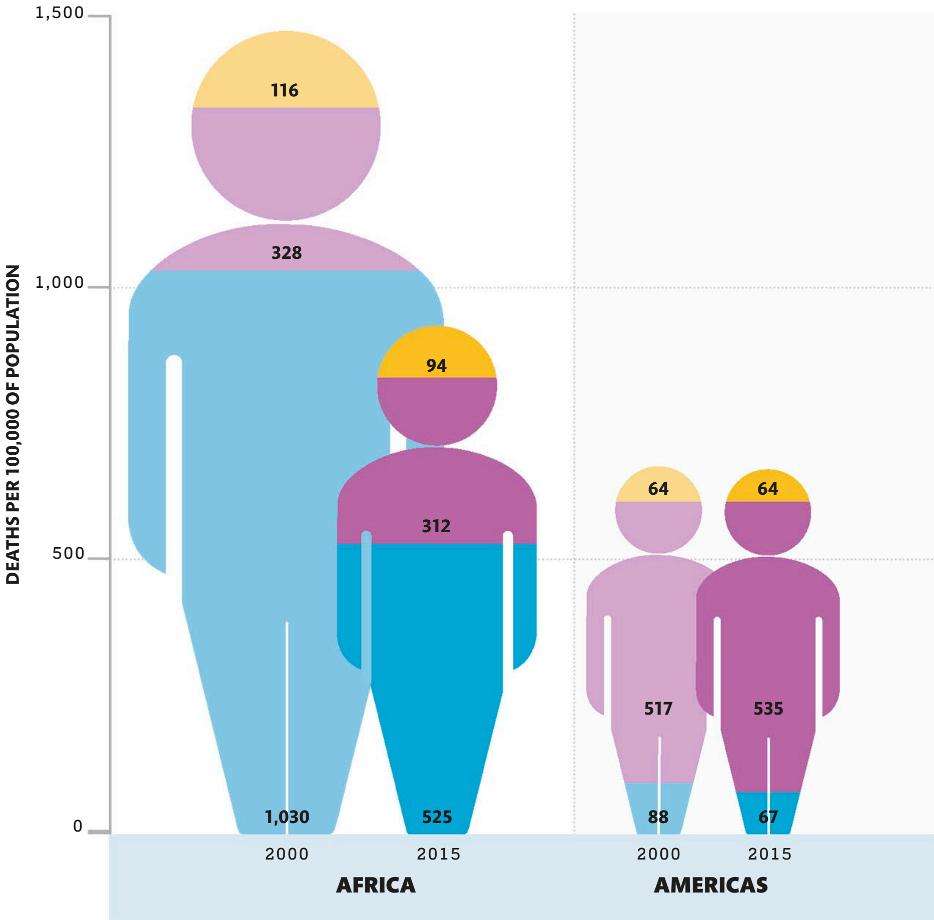
Between 2000 and 2015, the mortality rate in Africa dropped by more than one third, largely due to a reduction in deaths from communicable diseases (those spread from one person to another), including HIV/AIDS. During that same period, deaths caused by malaria in Africa were cut by nearly one half. This was due to simple measures being introduced, such as the increased availability of insecticide-treated mosquito nets and greater access to life-saving medications.

Since 1990, there has been a 44 percent reduction in maternal deaths around the world, although 830 women still die each day due to complications in pregnancy and childbirth. The success in preventing and treating communicable diseases and reducing premature mortality through better public health services has led the causes of sickness and death to shift more toward age- and lifestyle-linked problems, especially cardiovascular and cancer-related conditions.

## Major causes of death

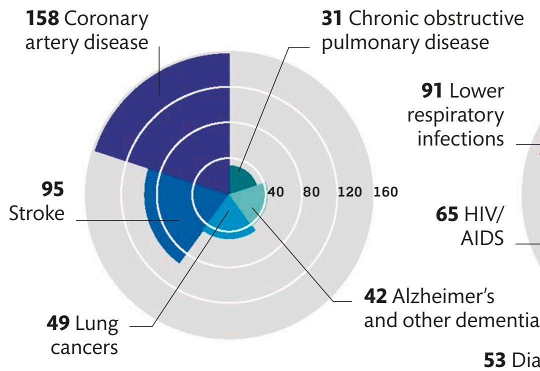
The reduction in the death rate across almost all regions means that fewer people are dying each year and, on average, they are living longer. Injuries are responsible for a large number of deaths in Africa, with a proportion far greater than anywhere else in the world. Deaths by noncommunicable diseases have stayed relatively consistent across the world.

**HIV clinic**
A nurse comforts a boy diagnosed as HIV positive at a clinic in Kampala, Uganda. Medical investments have reduced mortality from communicable diseases.

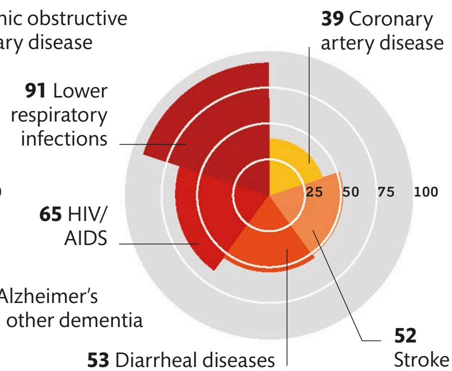


## DISEASE AND INCOME

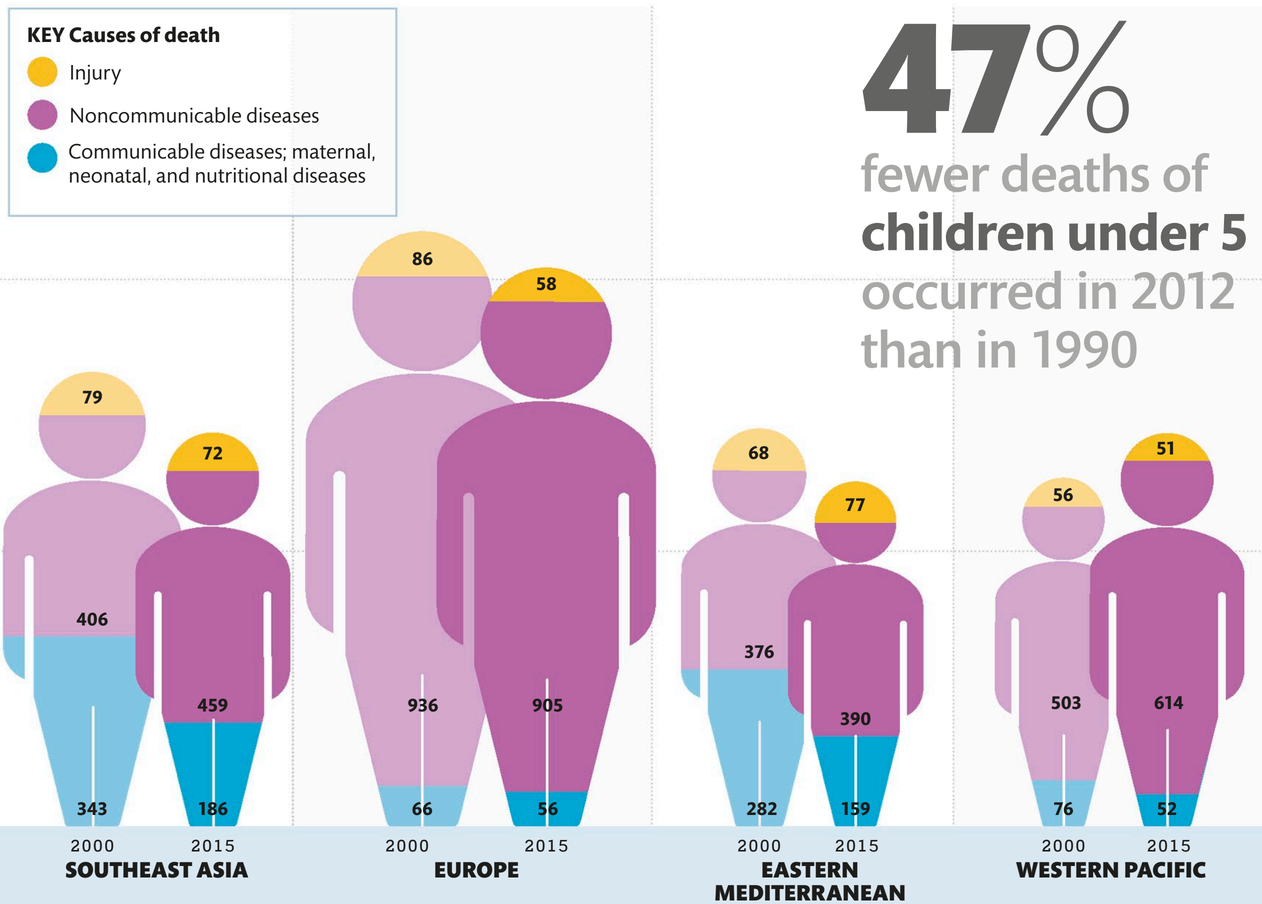
Despite recent improvements in the prevention and treatment of many infectious diseases, the leading causes of death in the world's poorest countries are lower respiratory infections, including pneumonia, bronchitis, and tuberculosis. In the richest countries, one of the fastest-growing causes of death is Alzheimer's disease and dementia, reflecting the increased longevity in the developed world. This puts greater long-term pressure on health services already under strain.




TOP FIVE CAUSES OF DEATH IN HIGH-INCOME COUNTRIES (DEATHS PER 100,000 POPULATION)




TOP FIVE CAUSES OF DEATH IN LOW-INCOME COUNTRIES (DEATHS PER 100,000 POPULATION)




**47%** fewer deaths of **children under 5** occurred in 2012 than in 1990

# Unequal World

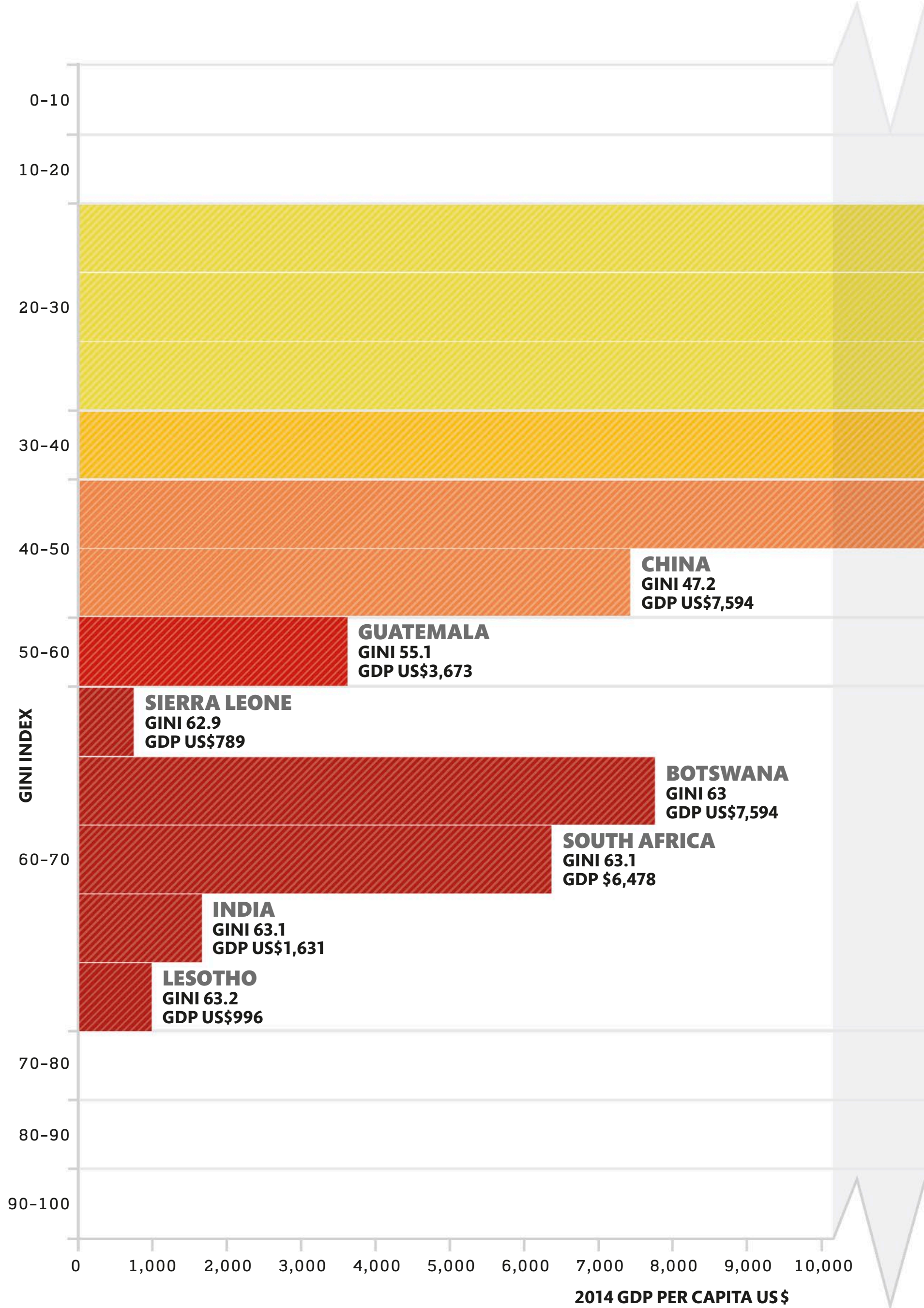
**Many people in the world are enjoying better lives, but inequality has grown dramatically. Disparities in wealth and income are seen both internationally and within individual countries.**

Wealth inequality between countries can be demonstrated by looking at a country's gross domestic product (GDP) per person—a measure that gives a rough idea of income and standard of living. Rich countries such as Sweden are vastly better off than less developed nations such as Lesotho or Botswana.

Inequality also exists at a domestic level, which is quantified using the Gini coefficient, a statistical tool that measures differences in income. Recent economic growth in developed countries has mainly benefited those at the top of society, widening the gap between rich and poor—a situation that is bad for everyone. Research shows that the more unequal a society, the more social problems it faces. Issues such as violent crime, mental illness, drug abuse, and teenage pregnancy are reduced in societies that are more equal.

## Global inequality

Using both Gini ranks and GDP per capita shows that the most equal societies are also the richest. The world's most equal country, Sweden, had the sixth largest GDP per capita, while Lesotho, the least equal, had just US$996 GDP per head.



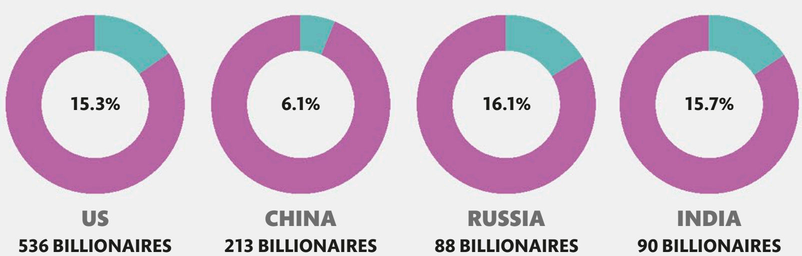
# 1% of the world's population has **more money than the other 99%** in 2016


## What wealth is worth

Billionaires control around 10 percent of the world's assets, yet many call poor nations home. A third of India's people live in poverty, but India ranks in the top five nations with the most billionaires.

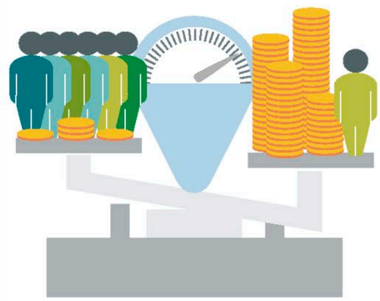
**KEY**

- National Gross Domestic Product (GDP)
- Billionaires' net worth as % of national GDP

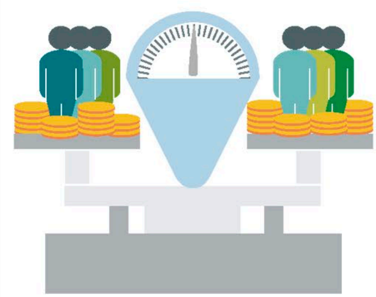



## WHAT'S THE GINI COEFFICIENT?

Developed in 1912 by Italian statistician and sociologist Corrado Gini (1884–1965), the Gini coefficient is a measure of national equality, calculated by measuring how evenly income is distributed across a country. A country with perfect income equality will have a Gini coefficient of 0, while 100 indicates complete income inequality.



**What a high Gini score means**
Perfect inequality means one person has all the wealth while all others have nothing. In unequal nations, a few are very rich and a large number have very little.



**What a low Gini score means**
Perfect wealth equality would see all people having exactly the same amount of money, so countries with low Gini scores have more equal wealth distribution.

# Corruption

**In many countries, efforts to combat poverty and halt environmental degradation have been seriously hampered by the effects of corruption. Corrupt practices often hit the poorest hardest.**

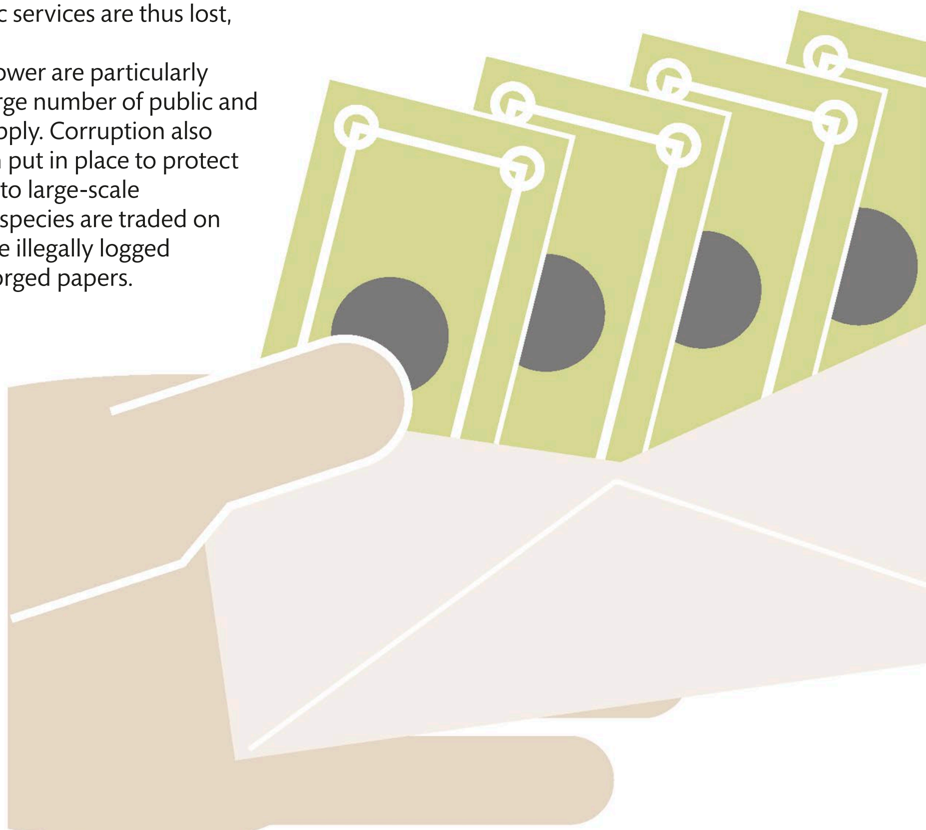
Corrupt practices divert financial resources away from poor people and undermine controls intended to protect environmental assets such as forests and rare wildlife. Such practices embrace a wide range of activities, including bribery, embezzlement of public funds, obstruction of justice, and concealment and laundering of the proceeds of corruption.

All of this can have disastrous impacts on economic development because income inequalities increase, social policies are undermined, and economic growth stalls. In many countries affected by corruption, the exploitation of natural resources that should lead to development benefits for all instead enriches small elites. These conditions can contribute to civil war, as was the case in Sierra Leone in 1991.

## Where corruption corrodes progress

According to the World Bank, each year corrupt practices lead to the siphoning off of about $1 trillion. Funds desperately needed for education, health care, and other public services are thus lost, trapping people in poverty.

All sectors are affected, but water and power are particularly vulnerable to corruption because of the large number of public and business organizations involved in their supply. Corruption also leads to the flouting of laws that have been put in place to protect natural resources and ecosystems, leading to large-scale environmental damage. Protected wildlife species are traded on the back of bribes to customs officials while illegally logged timber enters international markets with forged papers.



### Givers

Bribery can help commercial interests gain access to natural resources, such as protected forests or fish stocks, and is vital in getting illegally harvested goods to market. Businesses offer bribes in order to win public contracts. Bribes are paid to customs officials to turn a blind eye to the export or import of contraband, such as in the trafficking of ivory between Tanzania and China.

### Water supplies

Bribes are paid for licenses to dispose of waste in open water. Large agribusinesses pay officials for access to irrigation.

- Corruption adds 30 to 45 percent to the connection costs of a clean water supply.

### Essential services

Drugs intended for poor people are diverted for sale via private pharmacies. In addition, stolen funds hamper efforts to combat major health challenges, such as malaria and HIV/AIDS.

- The World Bank estimates that up to 80 percent of nonsalary health funds never reach some nations' local facilities.

### What can we do?

- **Governments can bar companies** involved in corruption from bidding for public contracts.
- **Public bodies can instill** a zero-tolerance culture for corrupt practices.
- **Governments can prioritize** implementing UN anti-corruption policies.

### Illegal animal trade

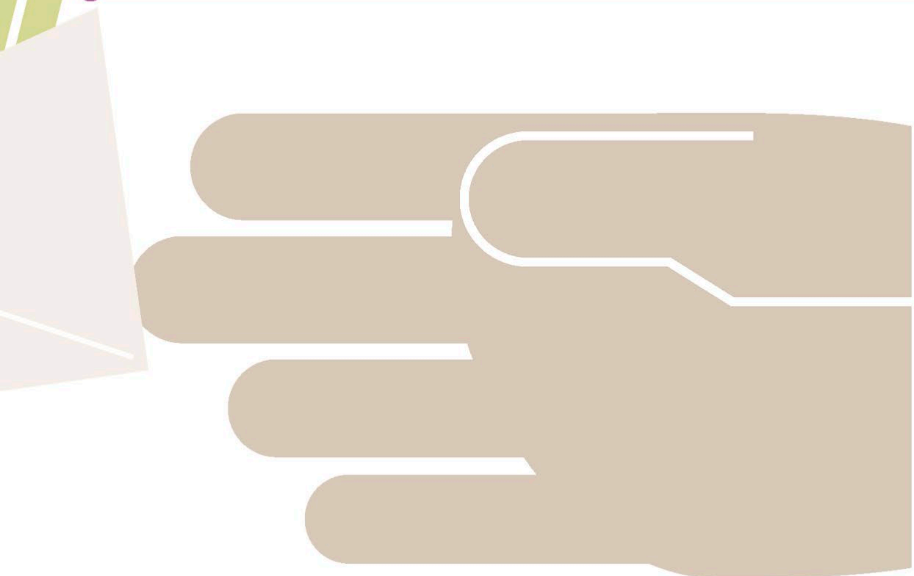
An unprecedented rise in illegal wildlife trading threatens decades of conservation work, making this the fourth most lucrative transnational crime, after drugs, arms, and human trafficking, worth between \$10 and \$20 billion a year.

- At least 20,000 elephants are illegally killed for their tusks in Africa each year.

### Forestry and illegal logging

Illegal logging now accounts for up to 30 percent of the international timber trade. Cutting and shipping logs on the black market is a complex process and can occur only with the aid of corruption.

- The World Bank estimates that each year up to \$23 billion worth of wood is illegally cut, losing \$10 billion in revenue.



### Takers

In all parts of the world, officials and politicians at all levels have been shown to be susceptible to taking bribes. In much of sub-Saharan Africa, for example, the low salaries paid to public servants mean bribery is an open and accepted part of business. Such embedded corruption makes it extremely hard for many companies to conduct business legally.

# The Rise of Terrorism

**Violence created by terrorists seeks to advance political or religious goals through fear, often using dramatic shock tactics. Terrorist acts increasingly influence headlines, civil liberties, and social agendas.**

The *Global Terrorism Index* (*GTI*), produced by the Institute for Economics and Peace, defines terrorism as "illegal force and violence by a nonstate actor to attain a political, economic, religious, or social goal through fear, coercion, or intimidation." This definition excludes civil war, and thus most of the 300,000 deaths that have occurred in Syria alone because of violence since 2011.

The *GTI* shows a strong correlation between terrorism and political instability, intergroup tensions (including between` religious factions), and the lack of legitimate states. While poverty, health, and illiteracy indicators are not directly linked with terrorist activity, terrorism is a block to sustainable development, diverting resources from poverty reduction and discouraging investment.

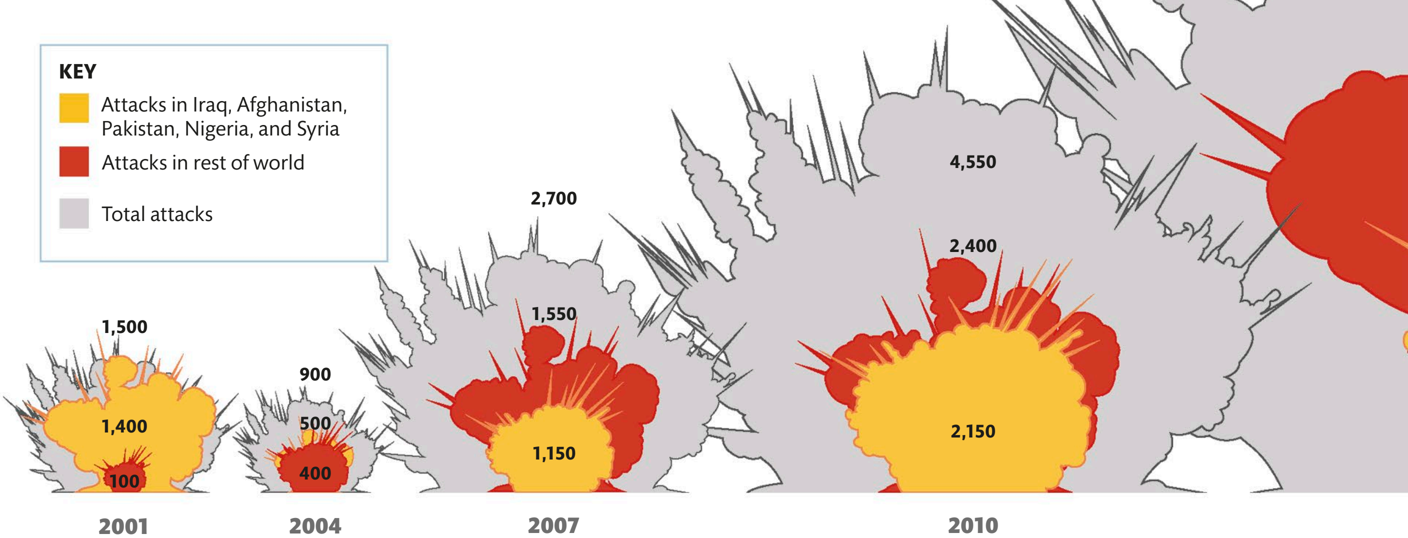
Unstable countries are often unable to elect accountable, democratic governments, and this prevents environmental and social progress.


**SEE ALSO...**

- **Corruption** pp112–113
- **Displaced People** pp116–117
- **Extreme World** pp130–131

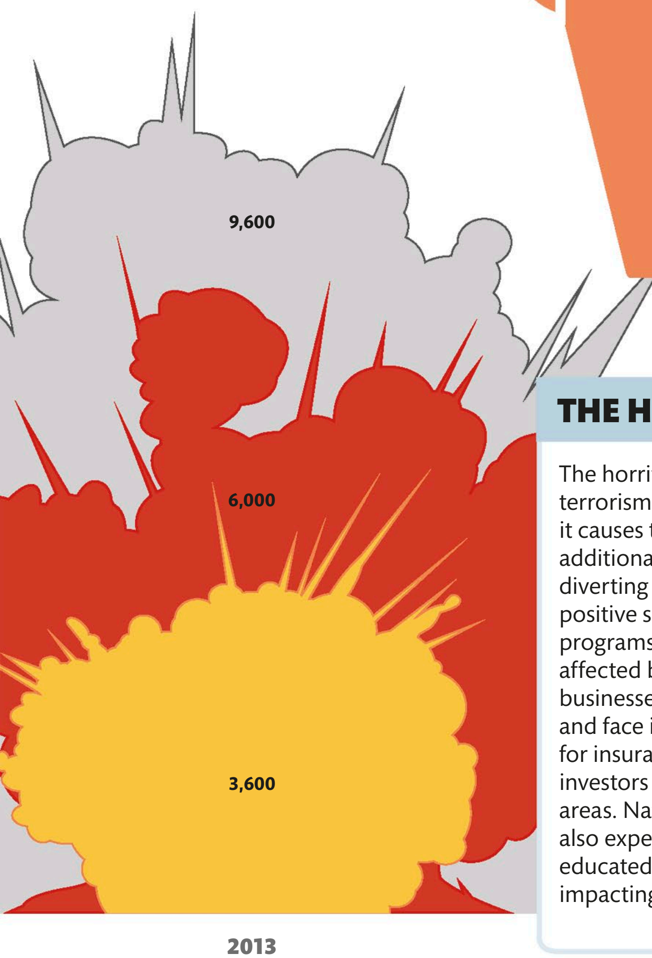

## Terror by numbers

In 2013, almost 10,000 terrorist incidents resulted in approximately 18,000 deaths. Excluding the five most affected countries, the almost 4,000 attacks in the rest of the world killed 3,236 people. The main driver of terrorism in the Middle East, Africa, and South Asia is religious ideology. Elsewhere, terrorism is more associated with political, nationalistic, and separatist movements.



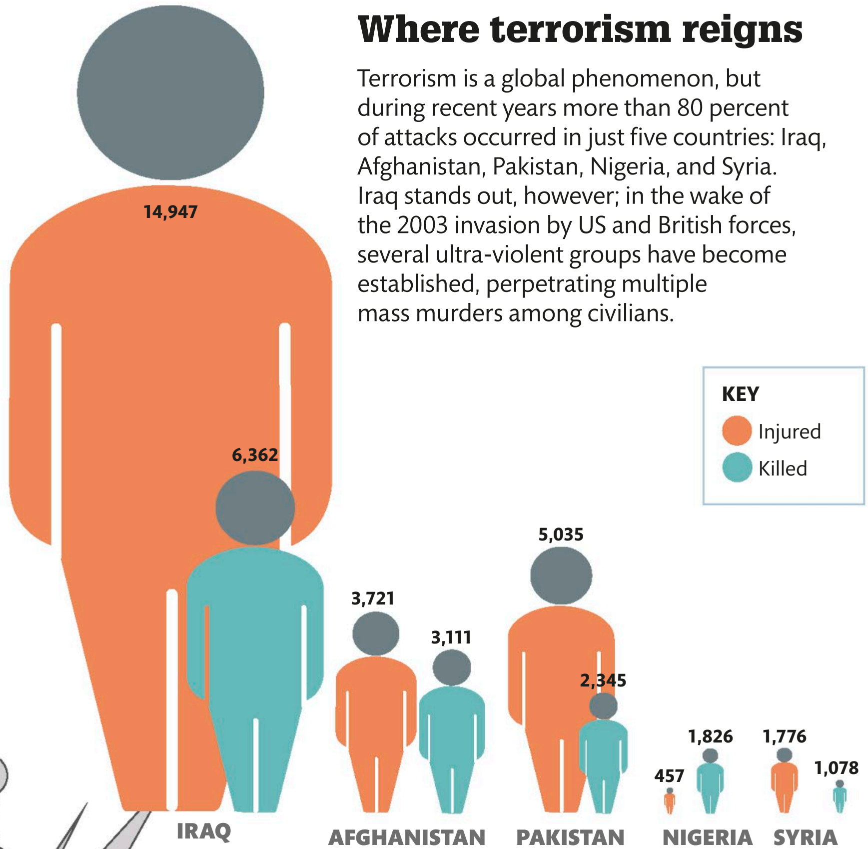
# 13%

The decrease in the number of deaths **caused by terrorism** from 2015 to 2016




## Where terrorism reigns

Terrorism is a global phenomenon, but during recent years more than 80 percent of attacks occurred in just five countries: Iraq, Afghanistan, Pakistan, Nigeria, and Syria. Iraq stands out, however; in the wake of the 2003 invasion by US and British forces, several ultra-violent groups have become established, perpetrating multiple mass murders among civilians.




## THE HIDDEN COSTS OF TERRORISM

The horrific human toll exacted by terrorism is just part of the damage it causes to societies. There is the additional cost of increased security, diverting financial resources from positive social and environmental programs. Economic growth is affected by terrorist activities because businesses experience uncertainty and face increased costs, such as that for insurance, while at the same time investors move funds to more stable areas. Nations affected by terrorism also experience the emigration of educated and talented people, further impacting their development.


**The high price of fear**
Terrorist attacks in Paris in November 2015 caused global outrage, leading to an escalation of bombing by Western and Russian aircrafts in Syria and Iraq.

# Displaced People

**The number of refugees, asylum seekers, and people displaced inside their own countries has rocketed. Forced out by war, persecution, and environmental change, the total is roughly equal to the UK's population.**

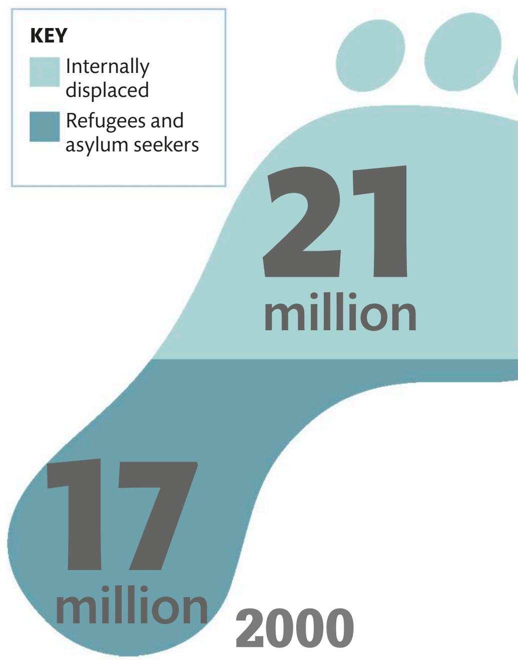
Following several years of substantial increases, the United Nations High Commission for Refugees estimated that, in 2016, the global total number of displaced people reached a staggering 65 million—an increase of over 50 percent in five years. This amounts to forced movement on an unprecedented scale creating a "nation of the displaced." Its population includes refugees, asylum seekers, and internally displaced people still living within their national borders. The causes include armed conflict, human rights violations, political violence, and the effects of drought.

The main destinations for people escaping across borders are Turkey, Pakistan, Lebanon, Iran, Uganda, and Ethiopia. These host countries hold more than 40 percent of people seeking safety outside their country of origin, and increased demands on their already inadequate services cause serious stresses.

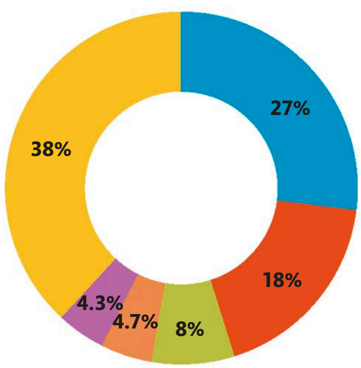
## A growing problem

By 2000, rapid globalization and the end of the Cold War had created new pressures that forced people to move, including those sparked by organized crime networks. In 2007, countries with the most internally displaced people included Eritrea, Colombia, Iraq, and the Democratic Republic of Congo—all fueled by internal conflict. More recent increases are largely explained by the conflict in Syria and ongoing terrorist activities in Iraq.

**Somali refugee camp**
People displaced from their homes have to find shelter in camps, often creating a huge strain on local resources.




KEY
- Syria
- Afghanistan
- Somalia
- Sudan
- South Sudan
- Rest of the world




**Where they come from**
Of the millions of refugees crossing international borders in 2014, over half came from just three countries: Syria, Afghanistan, and Somalia.

# 10.3

million people were newly displaced in 2016 due to **conflict or persecution**

**25** million

**40** million

**2016**

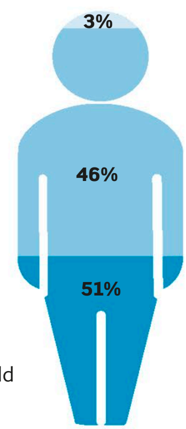
**17** million

**26** million

**2007**

## HOW OLD IS A REFUGEE?

In 2014, just over half of all refugees were under 18 years old, up from 41 percent in 2009. In that year, 34,300 asylum applications were lodged by unaccompanied or separated children, mostly from Afghanistan, Eritrea, Syria, and Somalia—the highest figure since such data was first collected in 2006.




**KEY**

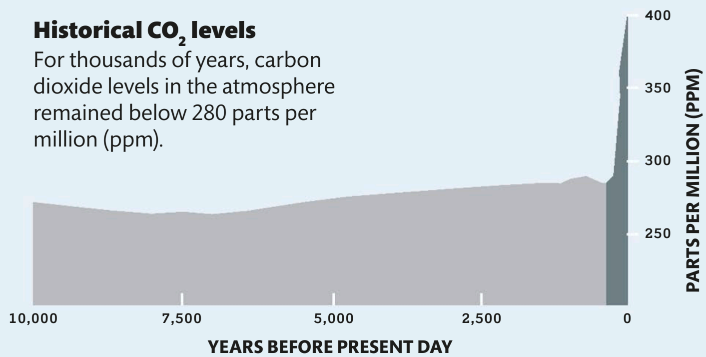
- Over 60
- 18-59 years old
- under age 18

# Our Changing Atmosphere

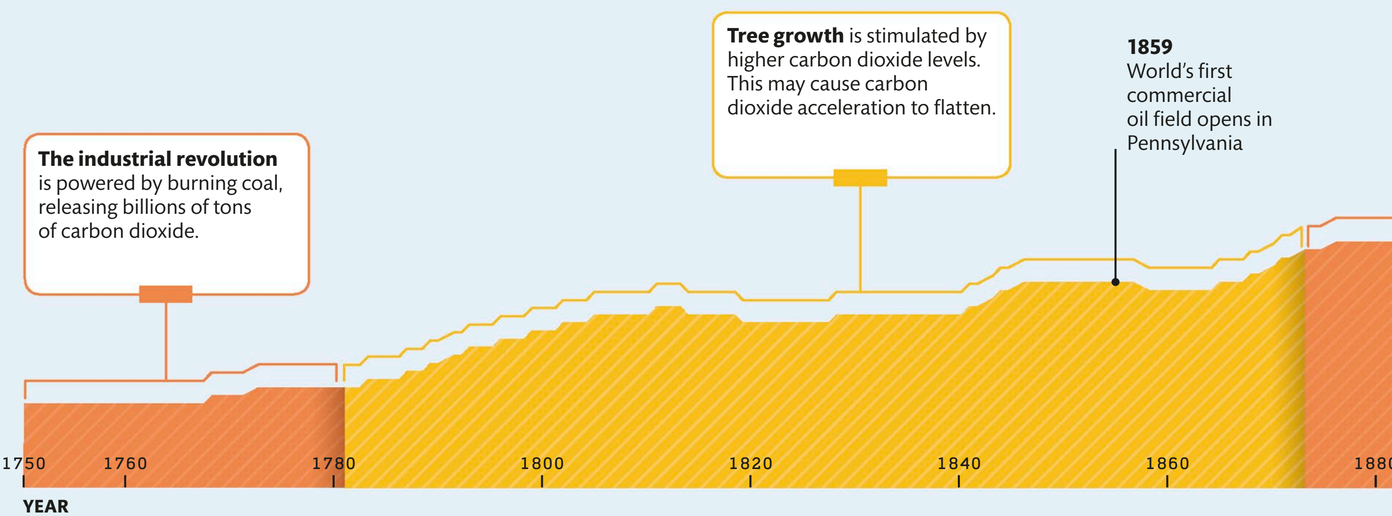
**Without the atmosphere, there could be no life on Earth. The shallow layer of gases that envelops our planet allows us to breathe and creates the climatic conditions we experience. Over the course of Earth's long history, the climate has changed many times. Natural factors caused this, but the main reason for recent climate change is the buildup of heat-trapping greenhouse gases produced by human activities (see pp 120–121). Because of this, the atmosphere is trapping more of the sun's energy, causing average temperatures to rise, in turn altering the climate.**

## Carbon acceleration

The greenhouse gas most responsible for the recent warming of the atmosphere is carbon dioxide ($CO_2$). This trace gas occurs naturally and keeps Earth warm, maintaining favorable conditions for living things. The concentration of $CO_2$ fluctuates but has recently risen at an accelerating rate and is at the highest level it has been for at least 800,000 years. The main cause for this is the burning of fossil fuels, with some contribution from deforestation and emissions from soils.

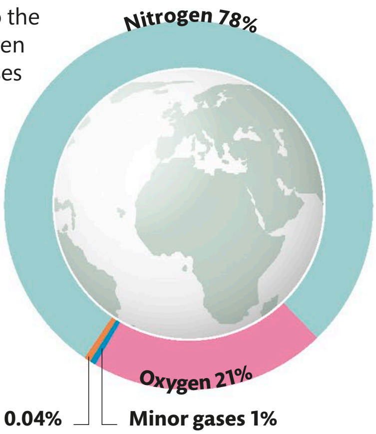



**Historical $CO_2$ levels**
For thousands of years, carbon dioxide levels in the atmosphere remained below 280 parts per million (ppm).



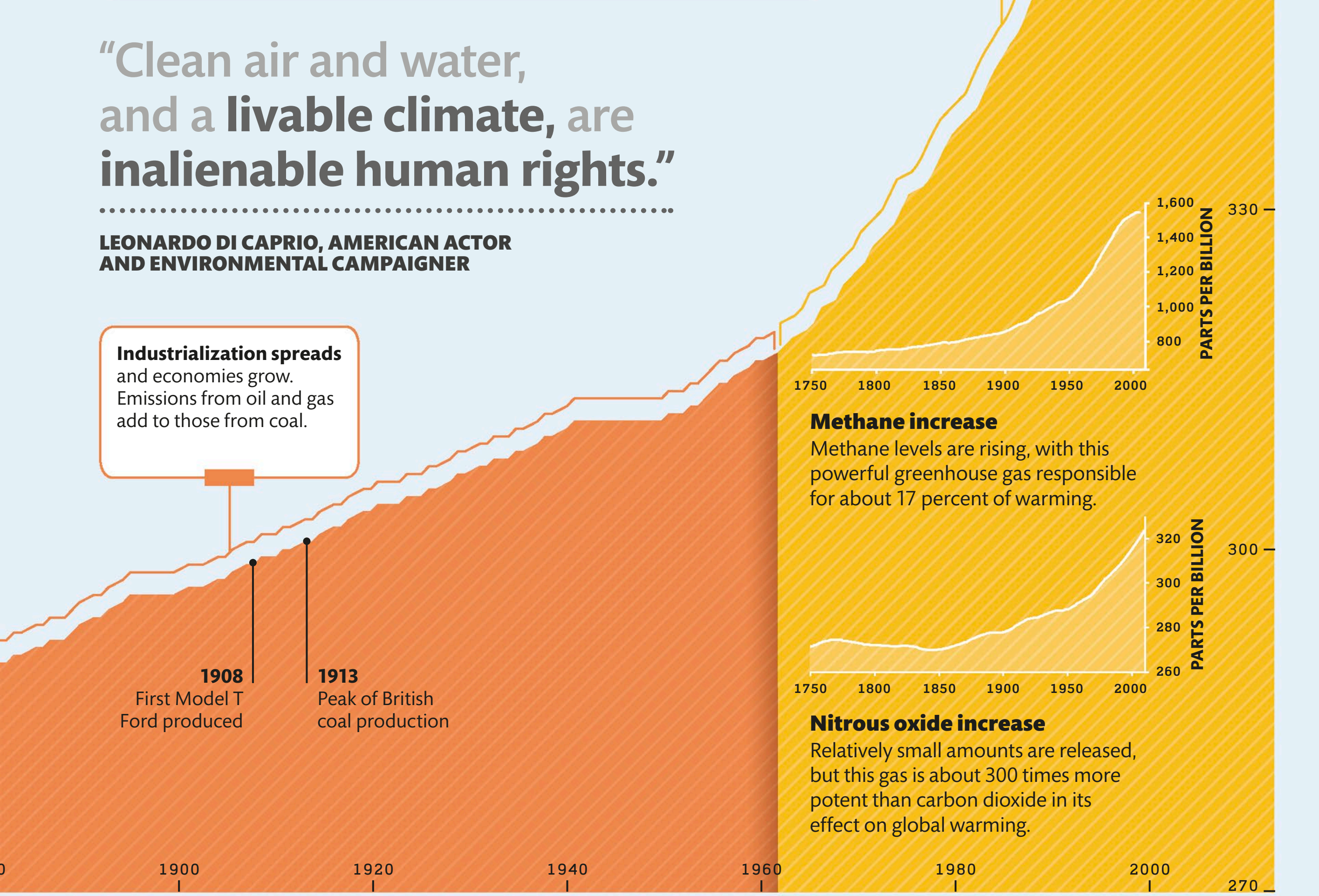
## WHAT IS THE ATMOSPHERE?

The thin shell of gases that clings to the Earth is mostly comprised of nitrogen and oxygen. A handful of minor gases make up just 1 percent. These include greenhouse gases, which trap outgoing heat from Earth's surface, keeping the surface and lower atmosphere warmer than it would be otherwise. The atmosphere contains the air that we breathe, protects us from the sun's radiation, and plays a vital role in the water cycle and in climate patterns.



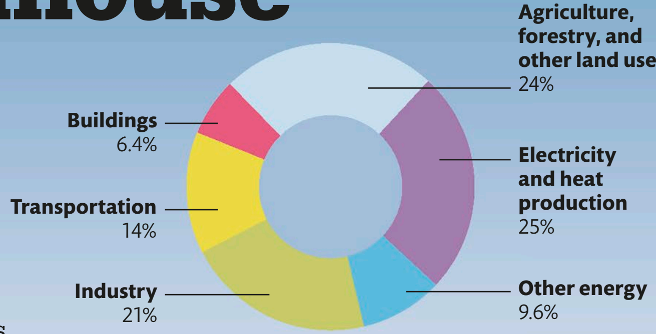

"Clean air and water, and a **livable climate,** are **inalienable human rights.**"

**LEONARDO DI CAPRIO, AMERICAN ACTOR AND ENVIRONMENTAL CAMPAIGNER**

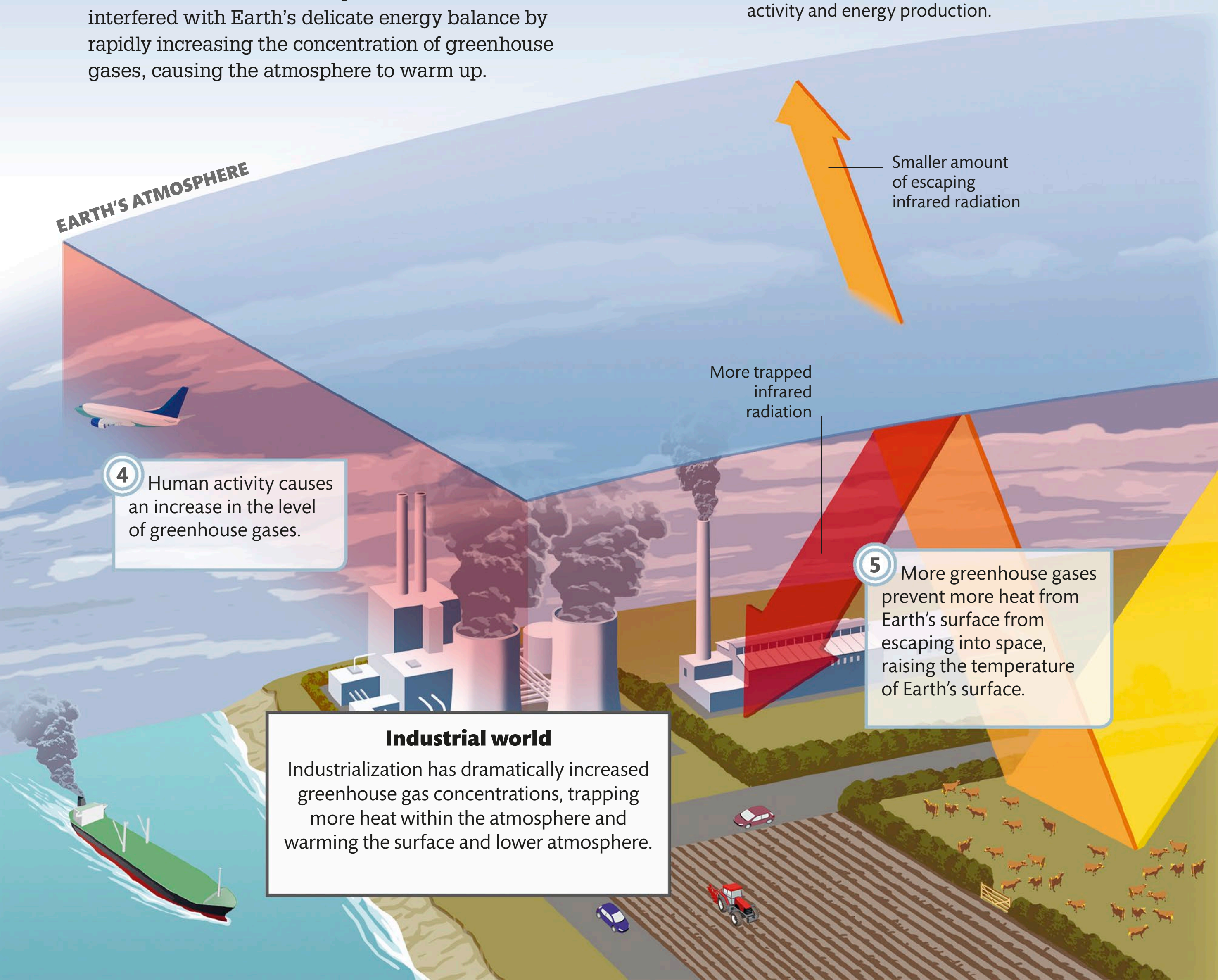


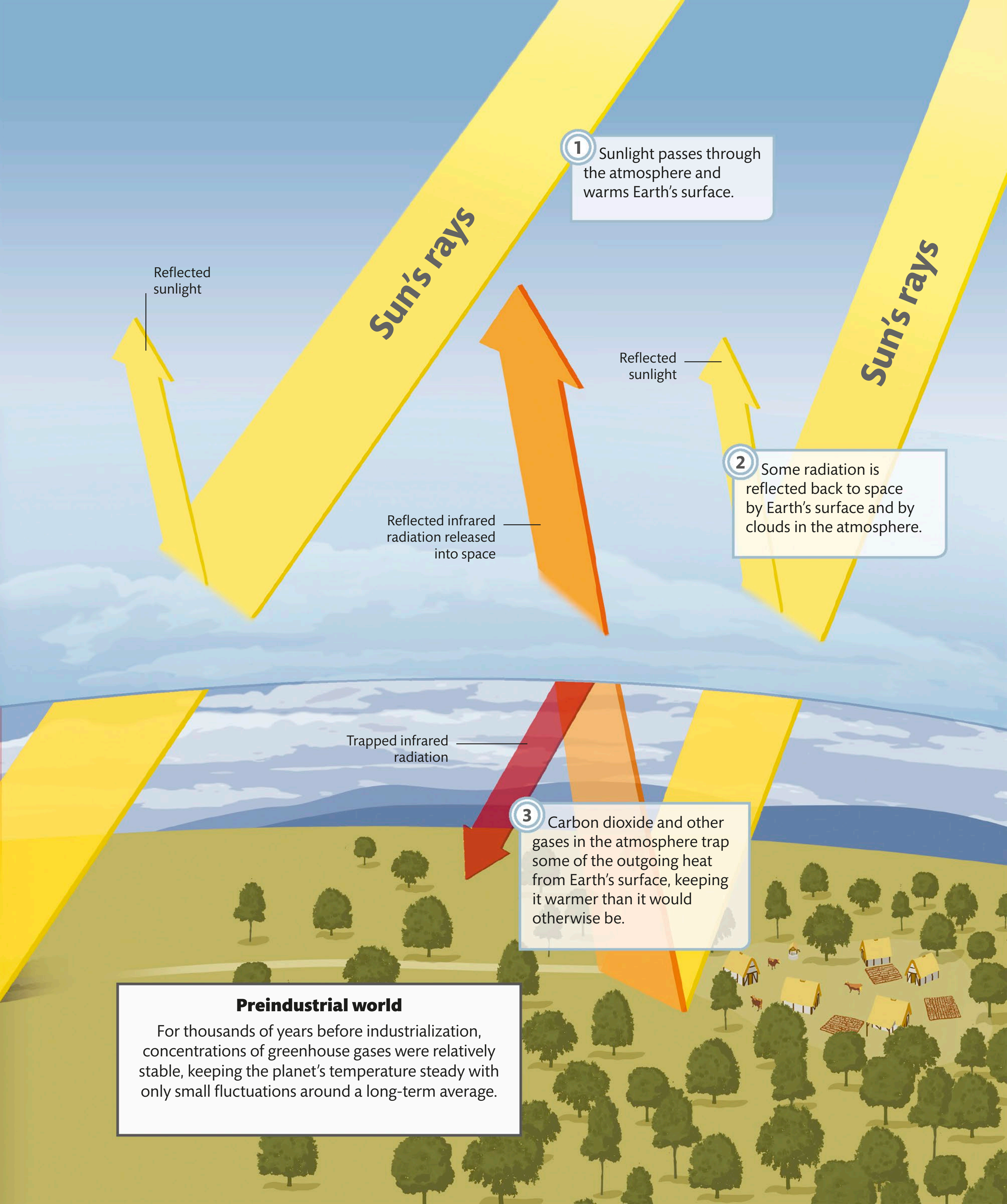
# The Greenhouse Effect

Light energy from the sun is absorbed by Earth's surface, warming it up. The resulting heat is emitted from land and sea in the form of infrared radiation, most of which escapes back into space. However, heat-trapping gases in the atmosphere keep Earth much warmer than it would be otherwise. These gases create a "greenhouse effect," forming a layer that traps heat going out from Earth's surface and retains some of it within the lower atmosphere. Human activities interfered with Earth's delicate energy balance by rapidly increasing the concentration of greenhouse gases, causing the atmosphere to warm up.




**Sources of greenhouse gases**
Human activities produce greenhouse gases in many ways but particularly by industrial activity and energy production.






**Preindustrial world**

For thousands of years before industrialization, concentrations of greenhouse gases were relatively stable, keeping the planet's temperature steady with only small fluctuations around a long-term average.

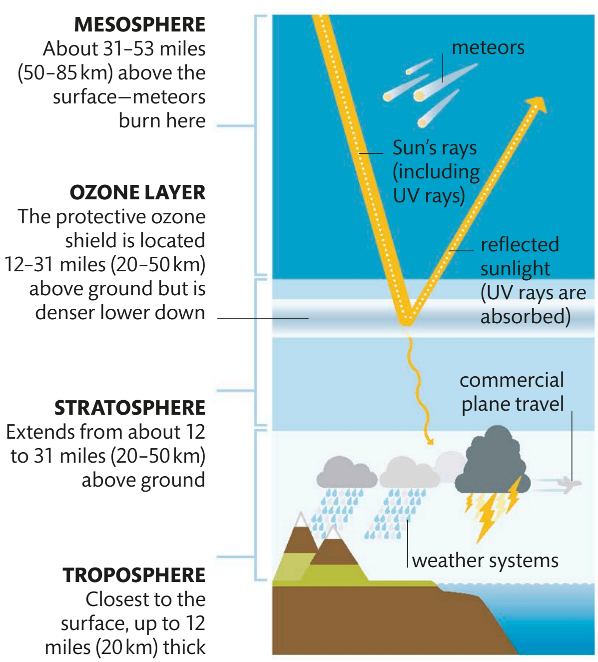
# Hole in the Sky

**High in Earth's upper atmosphere, miles above the planet's surface, is a diffuse layer of ozone gas. Its presence protects life on Earth and is vital for the functioning of the planet itself.**

Ozone formation relies on the oxygen in our atmosphere. As ultraviolet (UV) light from the sun hits oxygen molecules in the stratosphere, ozone is formed, and this in turn absorbs UV radiation that would otherwise damage the DNA (genetic material) of plants and animals. Oxygen was scarce until about 2.3 billion years ago, when an event called the Great Oxygenation occurred, the result of an increase in photosynthesis by microscopic organisms called cyanobacteria.

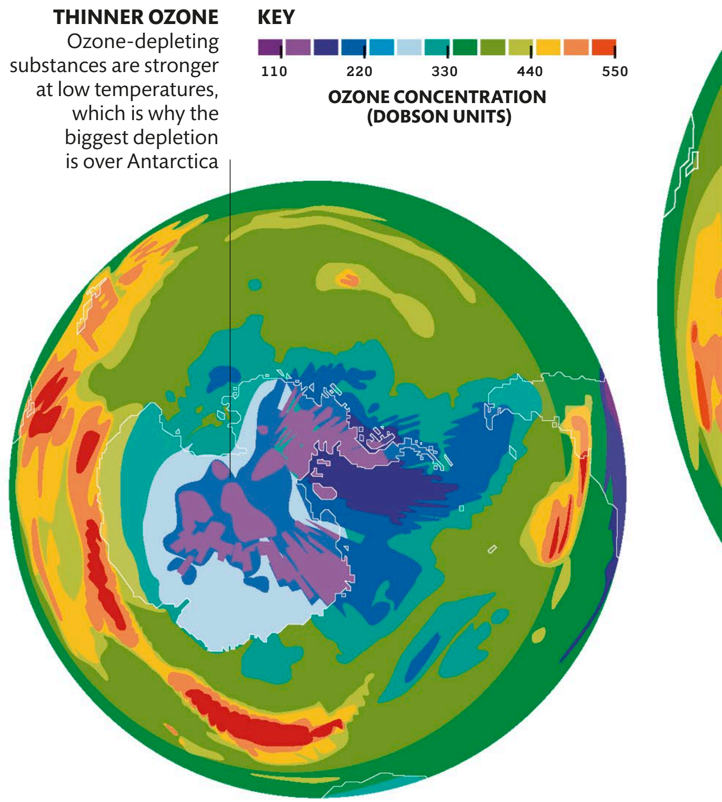
## The ozone layer

Stratospheric ozone is most dense about 12–19 miles (20–30 km) above Earth's surface, where the atmosphere is about a thousand times thinner than at ground level. Compounds released by human activities have depleted the ozone layer, raising concerns about greater levels of UV radiation reaching the surface. In addition to damaging key groups of organisms such as marine plankton, increased UV exposure increases the risk of skin cancer in humans.




## Antarctic ozone

Ozone concentration is measured in Dobson units (DUs). Prior to 1979, ozone had never been recorded below 220 DUs, but from then on it became apparent that during spring over Antarctica, Earth's natural sunscreen was getting thinner. This area of depleted ozone became known as the ozone hole. In 1994, concentrations fell to just 73 DU.

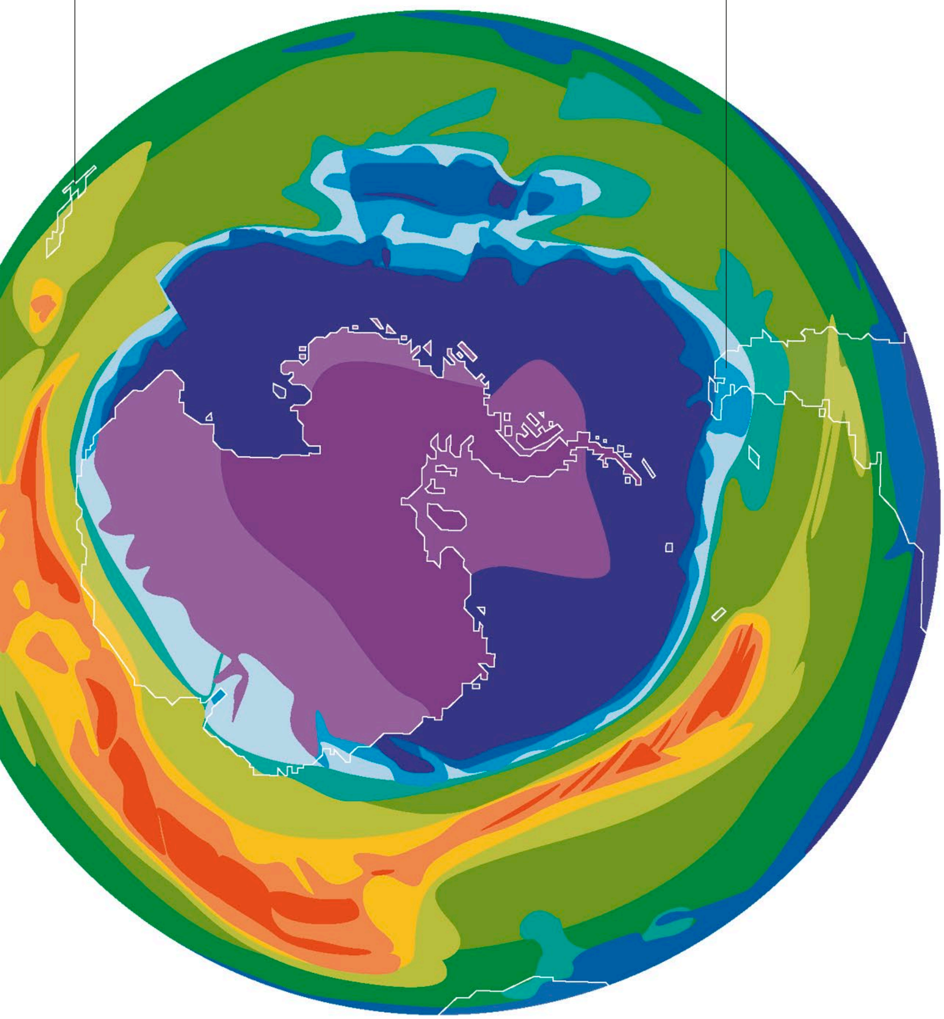



**1979**
Ground-based measurements of ozone began in 1956, at Halley Bay, Antarctica. Satellite monitoring started in the early 1970s, and the first worldwide measurements began in 1978 with the Nimbus-7 satellite. The findings of this monitoring helped galvanize global political action.

**NEW ZEALAND**
From time to time, the ozone hole breaks apart, and fingerlike areas of depleted ozone extend over inhabited areas, including New Zealand

**SOUTH AMERICA**
During September 2015, the ozone hole spread over Punta Arenas, Chile, exposing inhabitants to very intense UV radiation

# 40%
## depletion in ozone
## above the Arctic in 2011



**2013**
In 2013, the ozone hole was still massive and deep, despite the phasing out of most ozone-depleting substances. Models suggest that Antarctic ozone will largely recover by the mid-21st century, although this might be delayed by climate change.

## OZONE ENEMIES

When it became clear that certain chemicals were depleting the ozone layer, an international agreement—the Montreal Protocol—was negotiated in 1987. This successfully reduced the manufacture and release of ozone-depleting substances. Even so, ozone concentrations need time to recover. Meanwhile, monitoring ensures that warnings can be issued to areas at risk. Despite industry concerns about costs, alternatives to ozone-depleting substances were developed and are now widely used.

### *CFCs*
Chlorinated fluorocarbons (CFCs) were used in aerosols, sterilization equipment, and refrigerators and freezers. Hydrofluorocarbons (HFCs) were used as substitutes.

### *Halons*
These powerful greenhouse gases were used in fire extinguishers and technology systems employed by the aviation and defense industries. Production of halons ceased in 1994 under the US Clean Air Act.

### *Methyl bromide*
Methyl bromide was used to control a huge range of agricultural pests. Many chemical and nonchemical alternatives now exist.

# A Warmer World

**Rising temperatures, higher sea levels, and polar ice melt are just some of the many changes resulting from mankind's impacts on the atmosphere. These and other effects caused by increased concentrations of greenhouse gases are leading to a range of economic, social, and environmental consequences.**

The world is getting hotter. From 1850 to the present day, surface temperatures have risen 1.5°F (0.8°C) on average across the globe. The primary cause is undoubtedly the higher levels of heat-trapping gases, such as carbon dioxide, $CO_2$ (see pp120–121). This rise in temperature is already leading to melting ice sheets and glaciers, which contributes to sea level rise. These changes are set to continue, but they may not be linear in relation to temperature increase. The planet's total amount of ice melt may accelerate as critical "tipping points" are reached—as is possible for the Greenland ice sheet and some Antarctic ice sheets.

**10 million people each year are affected by coastal flooding**

**SEE ALSO...**

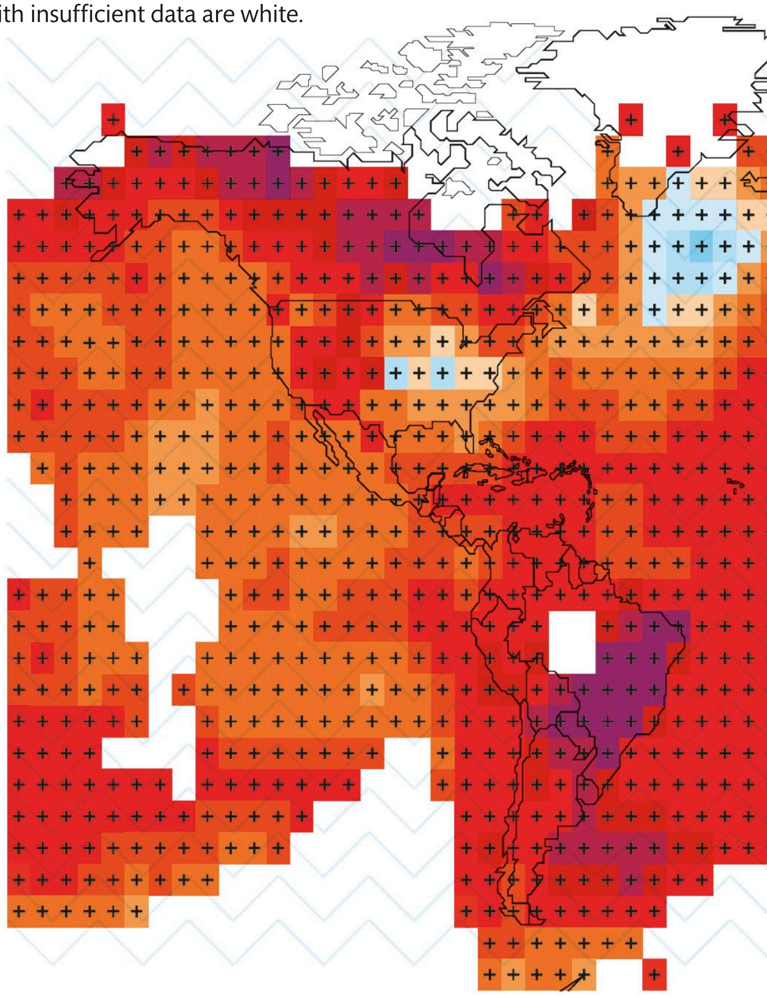

- **Seasons Out of Sync** pp126–127
- **Extreme World** pp130–131
- **Feedback Loops** pp134–135


## Temperature rise

Throughout the Northern Hemisphere, 1983 to 2012 was probably the warmest 30-year period in the last 1,400 years. This map shows estimated global surface temperature changes from 1901 to 2012. Temperature decreases appear as shades of blue, while increases appear as shades of orange and purple. Areas with insufficient data are white.

**KEY**
**Temperature change**

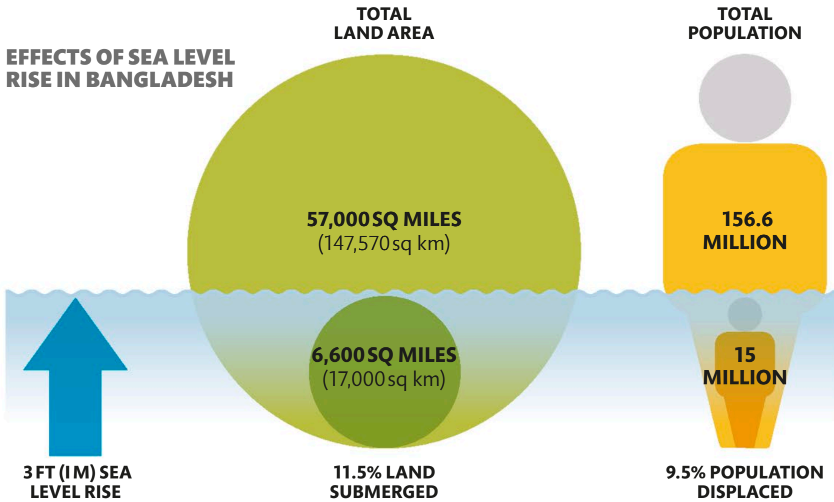
- -1.1°F (-0.6°C)
- -0.7°F (-0.4°C)
- -0.4°F (-0.2°C)
- 0°F (0°C)
- 0.4°F (0.2°C)
- 0.7°F (0.3°C)
- 1.1°F (0.6°C)
- 1.5°F (0.8°C)
- 1.8°F (1.0°C)
- 2.3°F (1.25°C)
- 2.7°F (1.5°C)
- 3.2°F (1.75°C)
- 4.5°F (2.5°C)

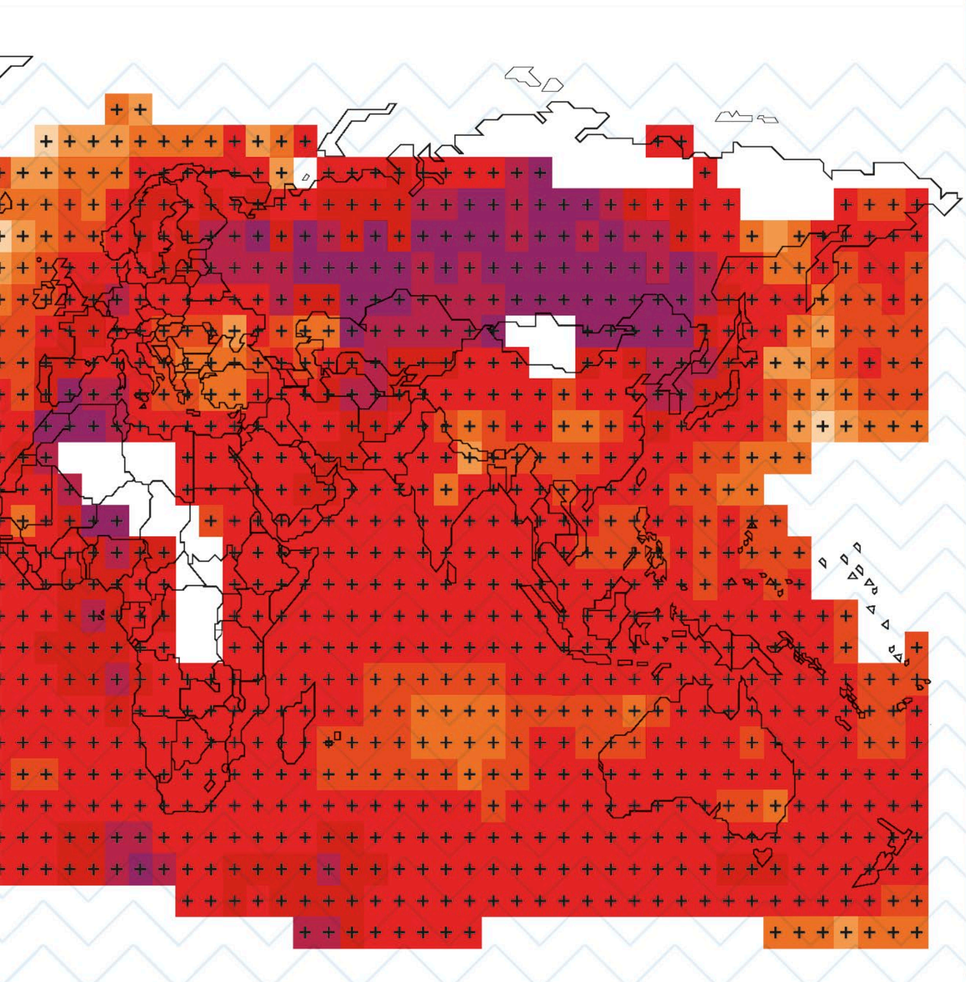


**Flooding**
Rising water levels already affect life in Bangladesh. The problem is likely to get worse.

## Rising waters

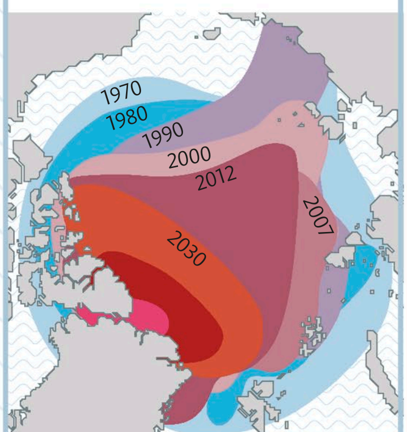
Sea levels are rising because of land-based ice melt and because ocean water expands as it gets warmer. The rate of sea level rise since the mid-19th century has been larger than the average rate during the previous two millennia. From 1880 to 2013, global mean sea level rose by about 9 in (23 cm). It will rise further as the ocean continues to warm and the melting of glaciers and polar ice sheets increases. The consequences of sea level rise are particularly severe in low-lying countries such as Bangladesh.



## ICE MELT

The world has seen a massive loss of ice over the last two decades, from both ice sheets and glaciers. The average rate of ice loss from the Greenland ice sheet increased substantially from 2002 to 2011, and recent major ice loss has also been reported from Antarctica. The diagram below shows the seasonal shrinking of Arctic ice cover since 1970. By 2030, Arctic sea ice cover will be a fraction of 1970 levels. By 2100, there is likely to be little or no summer sea ice remaining here.




SEASONAL ARCTIC ICE MELT 1970–2030

# Seasons Out of Sync

**Across the world, climate change is leading to shifts in seasonal patterns. Sometimes subtle and taking place over decades, the implications can nonetheless be profound, for people and nature.**

Many parts of the world have marked seasons that are important for farming, water supply, and energy demand, and for sustaining the complex relationships between different wildlife species. Although many seasonal changes have been fairly predictable, longer-term shifts in climate are causing some patterns and relationships to fall out of balance—for example, because of the earlier arrival of spring warmth and earlier flowering of plants.

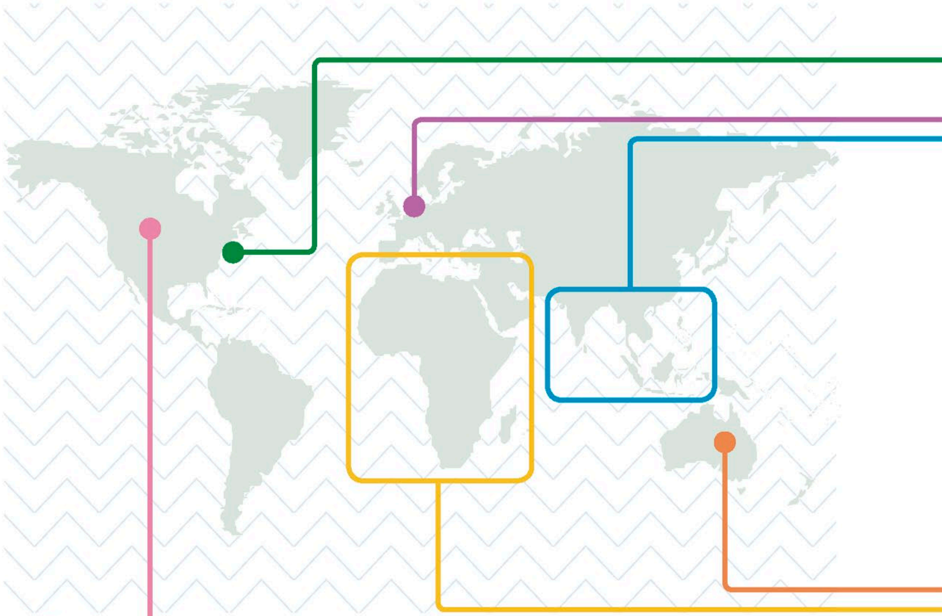
Records reaching back decades, and in some cases centuries, allow scientists to document long-term trends. These records include data on the first and last leaves on ginkgo trees in Japan, the dates of first butterfly appearances in the UK, bird migration in Australia, and of course temperature records that reveal increasingly short winters and the earlier arrival of spring. More important than these individual changes, however, is the impact that they may have on the many different and complex relationships between elements of the natural world.


**SEE ALSO...**

- **Farmed Planet** pp64–65
- **Extreme World** pp130–31
- **How Climate Patterns Work** pp128–129

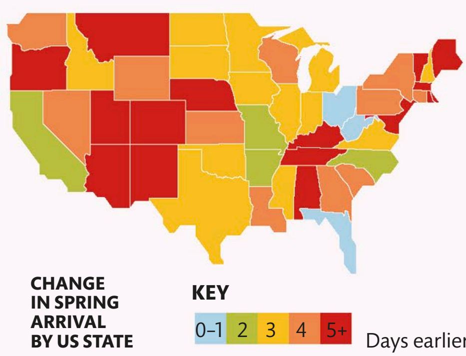

## Global impact

The natural world and the human civilizations that depend on it are heavily influenced by seasonal cycles. These cycles have been relatively stable and predictable for thousands of years. That is now subject to ongoing change, however, as the timing and intensity of temperature change and rainfall respond to global warming, affecting people and wildlife in a variety of ways.



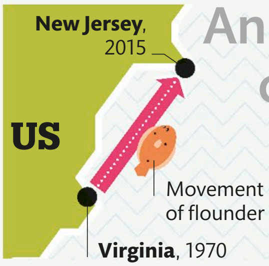
### Earlier spring

Spring is arriving earlier across most of the US. This map estimates the first day that leaves emerge in each state, comparing the average for 1991–2010 with the 1961–1980 average. Such changes could have potential effects on plant and animal life cycles, which are tied to the seasons.



## Warming waters

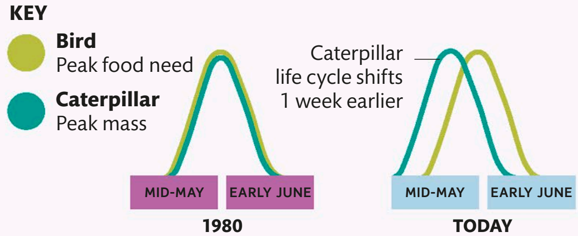
From 1982 to 2006, the North Atlantic Ocean warmed by about 0.4°F (0.23°C) per decade. Surveys running from the 1960s reveal that the commercially important summer flounder population has moved north, causing problems for fishing fleets.




Annual flounder catch is worth **more than $30 million**

## Hungry birds

A Dutch study has shown how the breeding cycle of Great Tits has fallen out of sync with the peak abundance of caterpillars that the adult birds feed their chicks. Insects have adapted to earlier springs by breeding earlier, but the birds have not. This could lead to lower chick survival rates.

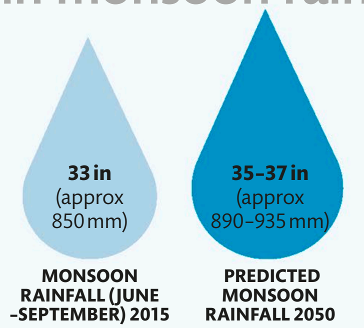



First leaves and blooms came **one day earlier per decade** in the Northern Hemisphere from 1955 to 2002

## Indian monsoon

The Indian monsoon is a stable, reasonably predictable annual weather pattern, but it is believed that rainfall each year will become more variable as the climate warms. Both flooding and drought (between the rains) are predicted to increase. Even a 10 percent change can have huge impacts on farming, food prices, and the economy.

**5–10% increase** in monsoon rain




## Farming

More than 70 percent of African farmers rely on rain (rather than irrigation) to produce food. Changes in the timing and intensity of seasonal rains are leading to reduced yields and lower incomes.

## Rainfall

Australia is the driest inhabited continent, and changes in average rainfall have a major impact on farming. Scientists believe the Australian climate has already changed with recent droughts revealing the cost of less rain. More intense heavy downpours have also affected some areas.

### Warming up

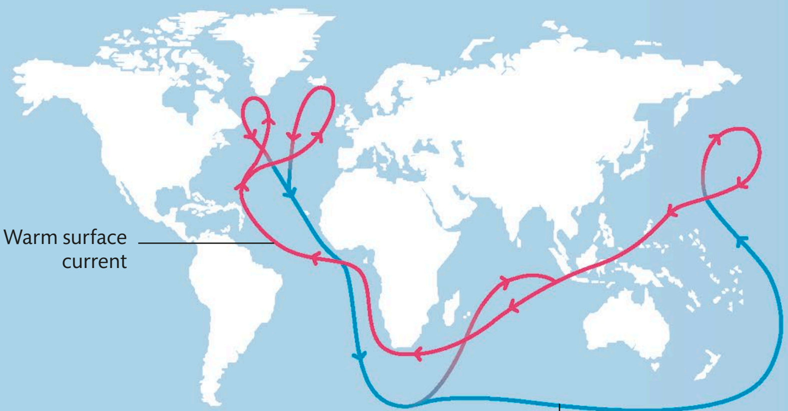
Seven of Australia's 10 warmest years on record occurred in the 13 years since 2002, with a record mean temperature for 2005–2014. High temperatures worsen the effects of low rainfall.

### Bushfires

The drying climate of southeastern Australia has increased the risk of bushfires. From 1973 to 2007, there was an overall increase in high-fire-danger weather.

# How Climate Patterns Work

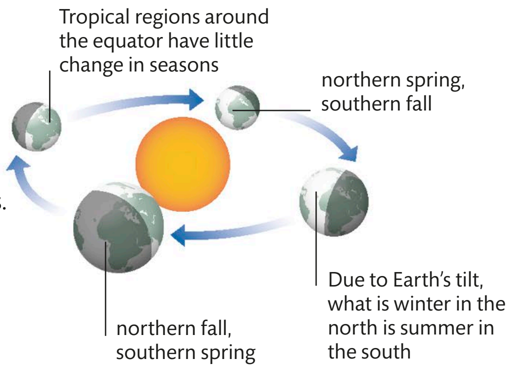
Climate is determined by the interaction of a finely balanced set of factors. Solar energy warms the oceans and the atmosphere, while differences in atmospheric pressure and temperature drive air and sea currents. Climate is influenced by latitude as well as factors such as distance from the ocean and height above sea level. Climatic conditions are measured in averages over decades. Weather is shorter term, changing from day to day. Solar heating causes the air in Earth's atmosphere to cycle around the globe in three sets of giant loops, called atmospheric cells—Hadley, Ferrel, and Polar cells. These produce north–south airflows, which are modified by Earth's spin, producing winds that blow diagonally.

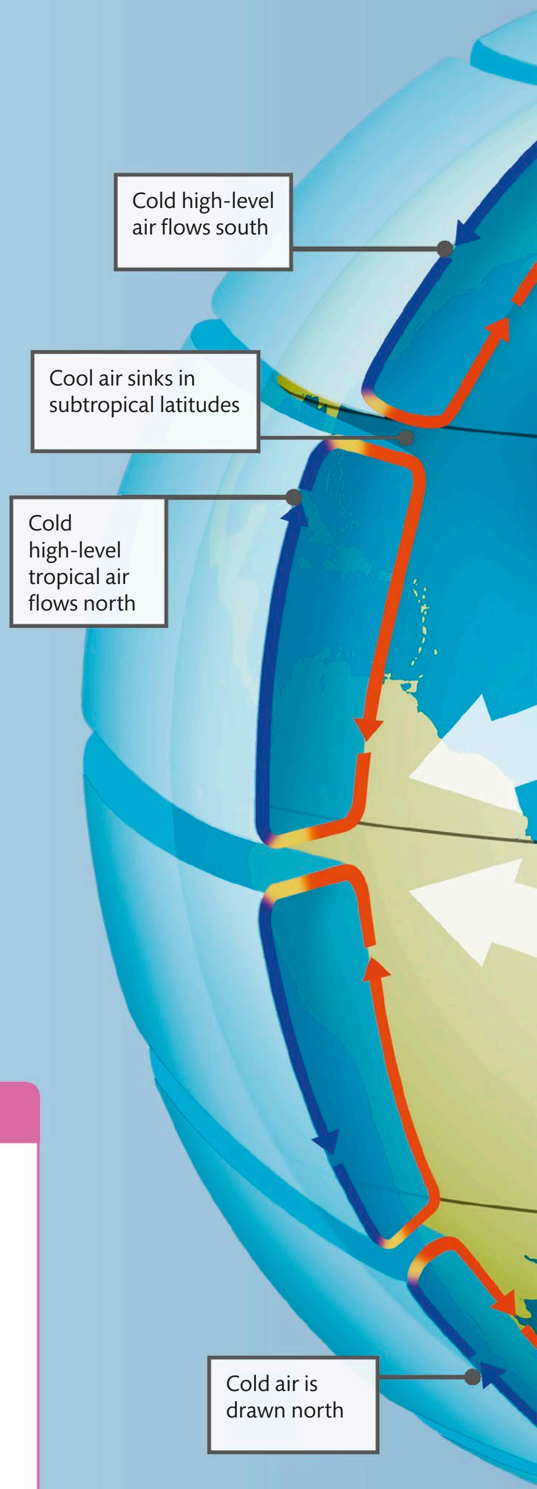


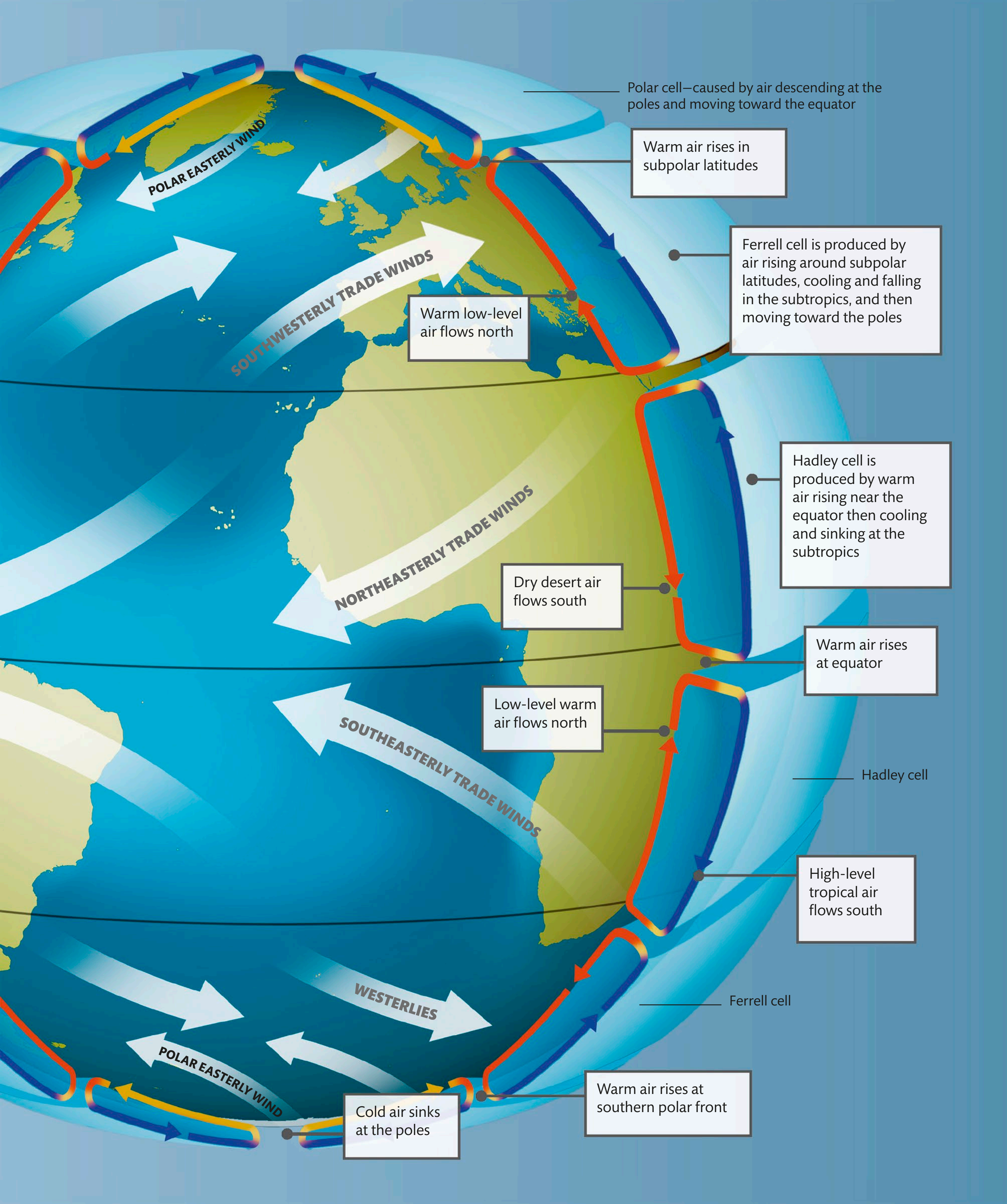

**Ocean currents**
Oceans absorb energy from the sun and move it around in surface currents. Ocean currents carry warm tropical water into cooler regions, affecting the climate there.

## SEASONS

Earth rotates around the Sun on a tilted axis in an orbit that takes one year. Because different areas of the Earth face toward or away from the sun, the length of day and the temperature changes. This leads to long days and short nights in summer and the reverse in winter. Seasons are most pronounced near each pole.





Polar cell—caused by air descending at the poles and moving toward the equator
Warm air rises in subpolar latitudes
POLAR EASTERLY WIND
Ferrell cell is produced by air rising around subpolar latitudes, cooling and falling in the subtropics, and then moving toward the poles
SOUTHWESTERLY TRADE WINDS
Warm low-level air flows north
Hadley cell is produced by warm air rising near the equator then cooling and sinking at the subtropics
NORTHEASTERLY TRADE WINDS
Dry desert air flows south
Warm air rises at equator
Low-level warm air flows north
SOUTHEASTERLY TRADE WINDS
Hadley cell
High-level tropical air flows south
WESTERLIES
Ferrell cell
POLAR EASTERLY WIND
Warm air rises at southern polar front
Cold air sinks at the poles

# Extreme World

**Weather records are being broken around the world. As the climate warms, extreme weather is becoming more frequent and leading to a series of devastating knock-on consequences.**

The buildup of more heat in the atmosphere is leading to changed patterns of evaporation and atmospheric circulation. This causes unusual and extreme weather. Weather is highly variable in the short term, but climate trends are based on averages that span decades. The trend toward more extreme weather events is in line with the predicted impacts of progressive warming. A continued increase in warming will lead to more extreme conditions, in turn generating a wide range of economic, social, and environmental consequences. These are being intensified by other environmental changes, including deforestation.

## Weather warning

The impact of more extreme weather events will undermine food production, place increased pressure on emergency services, elevate demand for humanitarian assistance, create security tensions, and exacerbate conflict. A vital aspect of future economic planning will be to prepare for extreme events so that their impact is reduced and a quick recovery can occur. This might be through storing more rainwater, conserving and restoring forests, adopting new standards for infrastructure, improving soil quality, and developing more diverse agriculture.

**Hurricanes**
The intensity, frequency, and duration of North Atlantic hurricanes, such as Hurricane Dean (pictured hitting the coast of Mexico in 2007), have all increased since the early 1980s.

## Droughts

Australia, California, parts of East Africa, and southern Brazil have all recently suffered the effects of severe drought. This has resulted in limited availability of water for industry, farming, households, wildlife, and energy generation.

## Floods

Devastating floods have recently affected parts of West Africa, Thailand, western Europe, and South America. This has led to loss of life, damage to property, and major interruptions to business activity. Damage to soil caused by farming has made flood events more severe.

## Storms

As oceans heat up, storms powered by warm air rising from them are on average becoming more violent. The most severe tropical cyclones ever recorded have occurred during the last decade. As the world warms, severe storms are expected to become more frequent.

### Food shortage

Floods, droughts, and storms can reduce food production. This causes shortages, rising prices, and hunger among the poorest people. Recently, drought and heat waves have hit yields in the US and Australia.

### Lack of drinking water

Severe droughts have recently led to restrictions on public water consumption, including in parts of Australia, Brazil, and the US. Flooding and storm damage can lead to contaminated drinking water supplies.

### Homelessness

Huge floods, such as those in Pakistan, destroy thousands of homes. Over recent years, cyclones have devastated islands and coastal areas, leaving tens of thousands of people homeless.

### Damaged infrastructure

Roads, ports, railroads, and power-distribution systems are all affected by severe weather. This damage has increased the level of weather-related insurance claims.

### Mass migration

Many of the migrants arriving in Europe over recent years have come from parts of Africa that are suffering from the effects of desertification, in turn made worse by reduced or more erratic rainfall. In the future, others will be forced to move by rising sea levels. Many also flee from conflict, which may in turn be connected to the impacts of severe weather events.

### Conflict

The impacts of severe weather can be linked to conflict. The Syrian Civil War began at a time of severe drought. This aggravated political tensions when about 1.5 million rural people were forced to move to urban areas. The exceptionally dry period was consistent with climate change projections for the eastern Mediterranean that suggest progressively less rainfall there.

### Human casualties

Some storm events cause massive loss of life directly, such as that brought about by Hurricane Mitch in 1998. About 18,000 people lost their lives as a result of this exceptional storm, which also wrecked infrastructure across large swathes of Central America. The impacts of extreme events—such as hunger, exposure, and conflict—also lead to human casualties.

# The Two-Degree Limit

**In 2009, governments agreed the need to keep the global temperature rise to below 3.6°F (2°C) compared with preindustrial times. In 2015, it was agreed to aim for the more challenging limit of 2.7°F (1.5°C)**

The two-degree limit was adopted to meet the central aim of the 1992 UN Framework Convention on Climate Change to avoid "dangerous" human interference with the climate system. Although there is no single scientific verdict as to what constitutes "dangerous," 3.6°F (2°C) is a widely accepted limit to guide policy. The reasons include the expected impacts on water security (see pp78–79), food production (see pp74–75), ocean acidification (see pp160–161), and the extent to which going above this level might trigger fundamental shifts in the climate. By adopting a two-degree limit as the overall aim, it is possible to construct a "carbon budget" to help achieve it. If we are to contain warming to the safer limit of 2.7°F (1.5°C), then the carbon budget will be far smaller.


**SEE ALSO...**

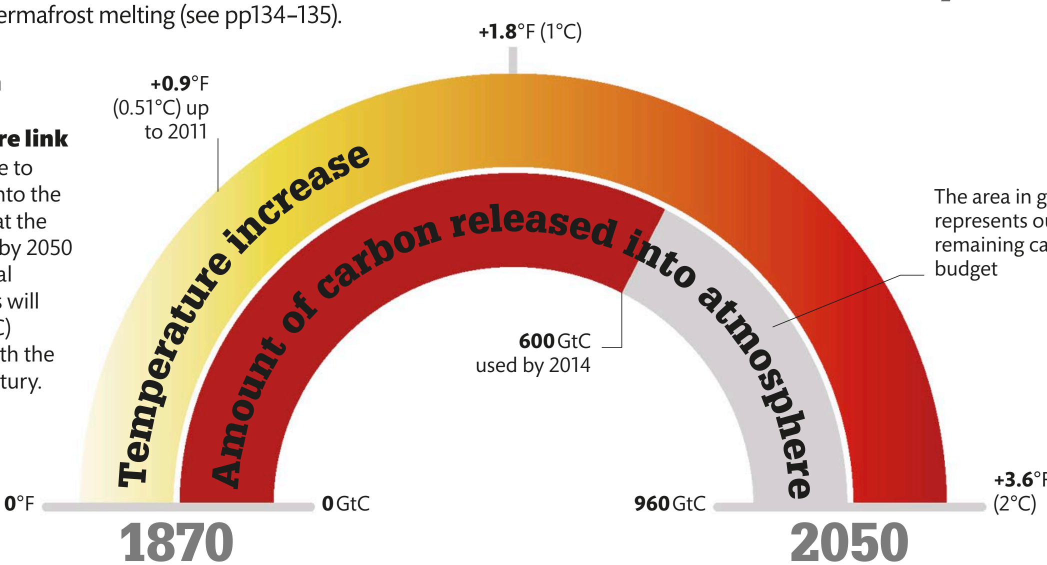
- **A Warmer World** pp124-125
- **How Much Can We Burn?** pp136-137
- **The Carbon Crossroads** pp140-141
- **Targets for the Future** pp142-143

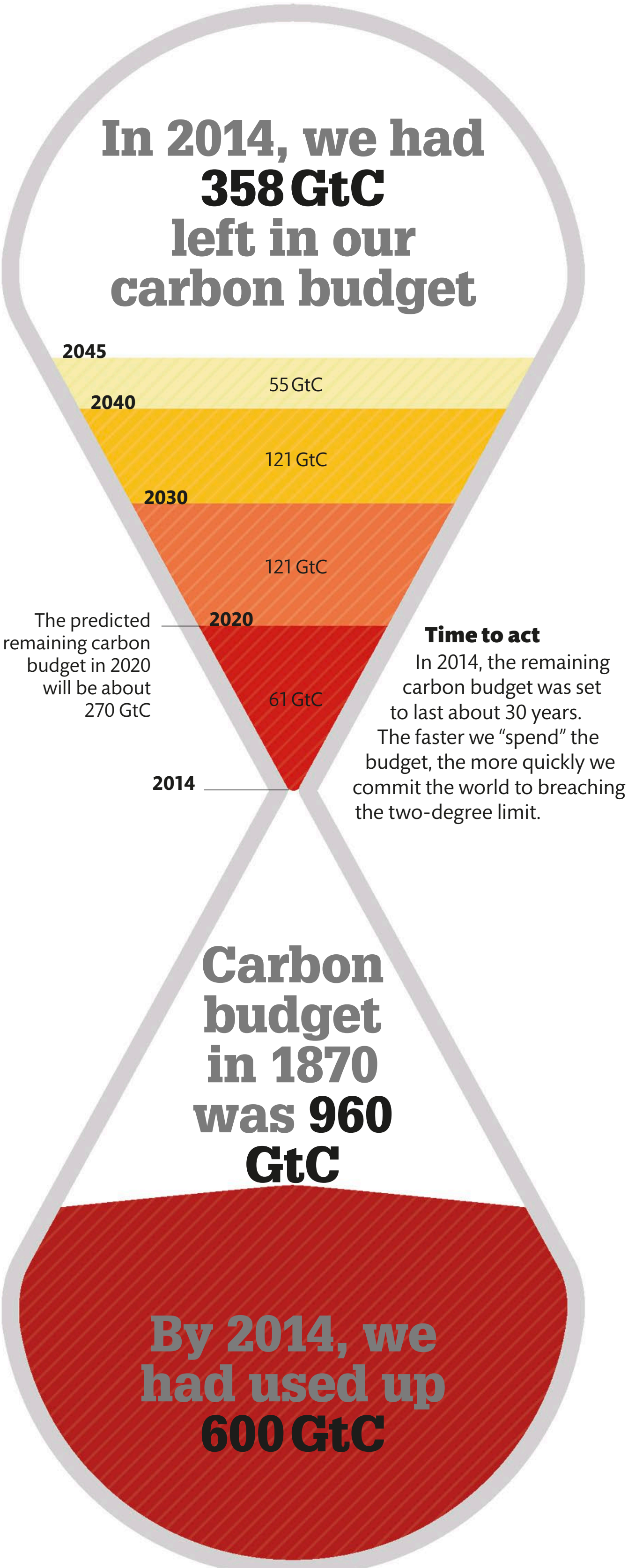

## Our carbon budget

The carbon budget sets a limit on human emissions of carbon dioxide ($CO_2$). If we are to have a two-thirds chance of limiting warming to below 3.6°F (2°C), then a total of 960 gigatons of carbon (GtC) can be released (starting from 1870). If other greenhouse gases (such as methane and nitrous oxide) are added, the budget shrinks to 870 GtC. The diagrams show an optimistic scenario based only on carbon and without the possible contribution of feedbacks, such as caused by permafrost melting (see pp134–135).

The UK was the first country to set a **legally binding carbon budget**, committing to an **80 percent reduction from 1990 levels by 2050**

**The carbon dioxide/ temperature link**
If we continue to release $CO_2$ into the atmosphere at the present rate, by 2050 average global temperatures will rise 3.6°F (2°C) compared with the mid-19th century.






## FINDING THE RIGHT PATH

A range of different strategies is needed to follow an emissions pathway consistent with a maximum 3.6°F (2°C) temperature increase. Many of these strategies relate to energy choices but also to deforestation, land use, and economic policies. Some encouraging progress is already being made, but more action is urgently required.

**Electricity efficiency** Emissions can be reduced through efficient uses of power: for example, by fitting modern electrical motors in factories or LED light bulbs in homes.

**Renewable electricity** Switching from fossil fuels to renewable alternatives will be a major focus in getting onto an emissions pathway for two degrees.

**Carbon capture** Capturing waste $CO_2$ and storing it (see pp136–137) can reduce emissions from power stations, although limited progress is being made with this technology.

**Vehicle efficiency** More efficient conventional engines, hybrid-electric technology, and electric vehicles will reduce emissions and make air cleaner to breathe.

**Low-carbon fuels** Blending biofuels with gasoline and diesel to power vehicles, and using sustainably sourced biomass in industry, would reduce dependence on fossil fuels.

**Smart growth** Building communities with housing and sustainable transportation close to offices, schools, and stores would protect the environment and support local economies.

**Carbon taxes** Requiring polluting industries to pay a price for their carbon emissions would send a clear economic signal and encourage investment toward cleaner energy sources.

**Forest and soil carbon** Halting deforestation and restoring forests could make a significant contribution to meeting the two-degree target, as well as helping conserve wildlife and water.

**Switching subsidies** Removing fossil fuel subsidies could lead to around a 13 percent cut in emissions. These valuable subsidies could then support renewable alternatives.

# Feedback Loops

**While reducing fossil fuel emissions and limiting land-use change is under some human control, so-called feedbacks play an increasingly important part in climate change as our world gets warmer.**

Climate feedbacks are effects of climate change that either speed up (positive feedback) or slow down (negative feedback) warming. For example, certain cloud types that might become more abundant at higher temperatures could create a cooling effect and slow down the speed of climate change. The warmer the world becomes, the greater the risk that major positive feedbacks will hasten climate change regardless of any actions taken to cut emissions.

**The Amazon drought of 2010 caused the release of about 2.2 billion tons of carbon**

## Feedback loops and their impact

There are some potentially serious positive feedbacks that could add to global warming. This is one reason why, in 2009, governments adopted the goal of limiting warming to less than 3.6°F (2°C) above average global temperature. If temperatures rise more than this threshold, feedbacks could accelerate climate change. These feedbacks include the loss of ice cover, dieback of rain forests, release of methane from seabeds, and melting permafrost.


### Arctic melt

Most of the sun's energy that hits icy surfaces is reflected back into space. As ice melts in the Arctic and elsewhere, the darker surfaces of ocean and tundra are exposed. These absorb much more of the sun's energy, speeding up global warming, and, in turn, melting more ice.

### Seabed methane release

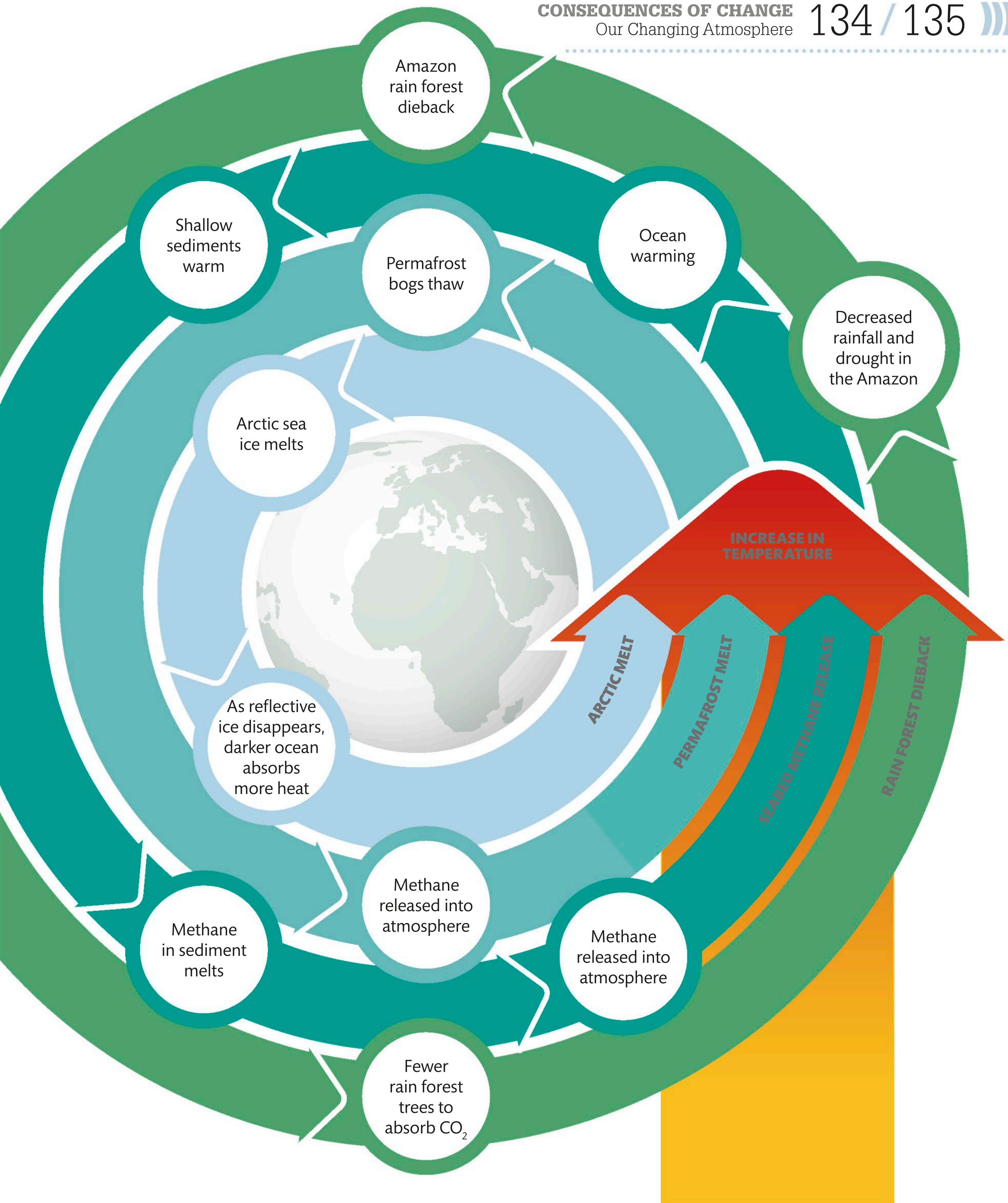
Huge quantities of methane are stored in seabeds. This methane is stable at lower temperatures, but global warming could cause the gas to be released into the atmosphere. This powerful greenhouse gas would speed up warming and cause further methane release from the seabed and permafrost.

### Permafrost melt

At high latitudes, close to polar regions, there are vast areas of peat soils frozen as permafrost. They contain trapped carbon dioxide and methane. As the climate warms and causes the permafrost to melt, these greenhouse gases are released. As more of these gases are released, there is further melting and emissions.

### Rain forest dieback

Decreased rainfall and heat stress could cause large areas of rain forest to dry out and turn into savanna, or grasslands. These ecosystems hold less carbon than dense forests, thereby increasing levels in the atmosphere. Changes to forests will also affect wildlife.


Amazon rain forest dieback
Shallow sediments warm
Ocean warming
Permafrost bogs thaw
Decreased rainfall and drought in the Amazon
Arctic sea ice melts
INCREASE IN TEMPERATURE
ARCTIC MELT
PERMAFROST MELT
SEABED METHANE RELEASE
RAIN FOREST DIEBACK
As reflective ice disappears, darker ocean absorbs more heat
Methane released into atmosphere
Methane in sediment melts
Methane released into atmosphere
Fewer rain forest trees to absorb $CO_2$

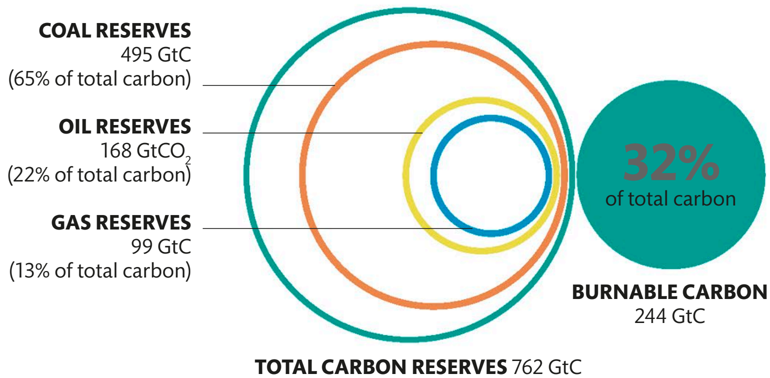
# How Much Can We Burn?

**It is now possible to calculate the amount of greenhouse gases that can be emitted before temperature thresholds are exceeded. With this in mind, we must decide how best to use the fossil fuel reserves we have.**

Carbon budgets describe the amount of greenhouse gases, especially carbon dioxide ($CO_2$), that countries agree can be released into the atmosphere. These budgets are being compared with known fossil fuel reserves to determine the amount of coal, oil, and gas that can be burned before the world commits to a dangerous temperature increase. A hazardous level of warming was agreed in 2009 to be 3.6°F (2°C) above the global average temperature in preindustrial times (see pp132–133). It is estimated that to have an 80 percent chance of keeping the overall temperature increase to below 3.6°F (2°C), less than one-third of reserves can be burned.

## Staying on budget

There is a much larger amount of fossil fuels in the ground than we can safely burn. Potential emissions of $CO_2$ from total known reserves are calculated to be 762 GtC (gigatonnes of carbon). This figure excludes any new deposits that are yet to be discovered. Effective action on climate change would thus lead to coal, oil, and gas companies' assets being left in the ground or "stranded."




## CARBON CAPTURE TECHNOLOGY

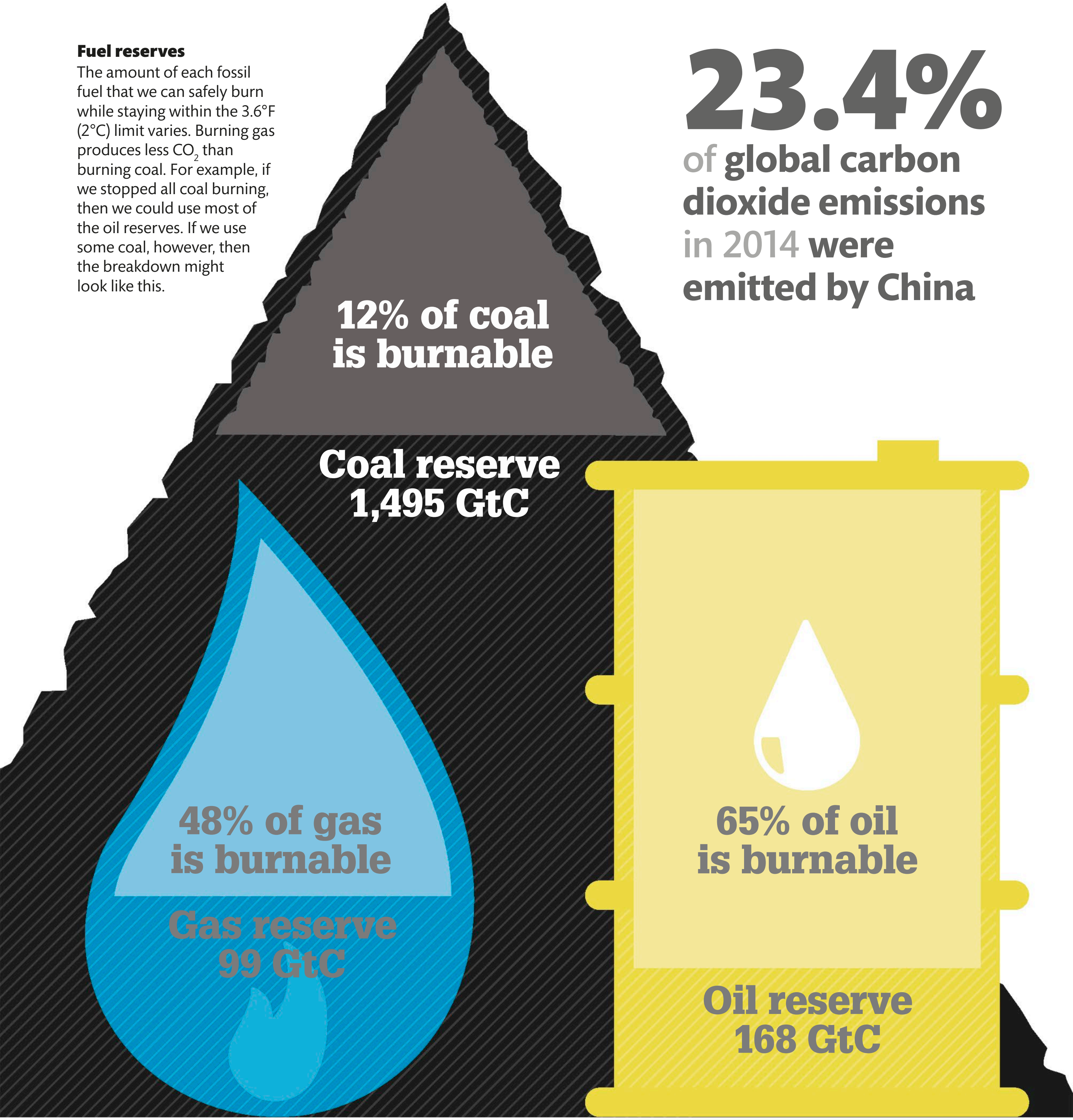
Experimental carbon capture technology may allow fossil fuels to be used without exceeding the 3.6°F (2°C) carbon budget. This process traps carbon emissions at the source and compresses the gas to liquid form. It is then piped into geological structures for storage.

**Unmineable coal seams**
Carbon dioxide can be injected into deep, inaccessible, or otherwise uneconomic coal deposits for storage. During this process, methane, a greenhouse gas, is released. The methane can then be recovered and used as an energy source.

**Depleted oil deposits**
Oil and gas fields that are nearing the end of their productive lives can be used for carbon storage. Injecting carbon dioxide can increase pressure in depleted oil fields to retrieve more oil in a process known as enhanced oil recovery.

**Deep saline geology**
Deep geological formations made up of sandstones and limestones that hold salty water are sometimes impermeable because they are capped by another type of formation. This means that they are able to hold injected carbon dioxide.

**Fuel reserves**
The amount of each fossil fuel that we can safely burn while staying within the 3.6°F (2°C) limit varies. Burning gas produces less $CO_2$ than burning coal. For example, if we stopped all coal burning, then we could use most of the oil reserves. If we use some coal, however, then the breakdown might look like this.




**23.4%** of global carbon dioxide emissions in 2014 were emitted by China

# The Carbon Crossroads

**The world is at a crossroads. To limit global warming to below 3.6°F (2°C) above the preindustrial average temperature, action is required now.**

Future concentrations of carbon dioxide ($CO_2$) and other greenhouse gases in the atmosphere will be determined by a range of factors, including energy sources, population changes, and individual consumption. Without urgent action, it will be nearly impossible to limit global warming later this century to below 3.6°F (2°C).


## SEE ALSO...

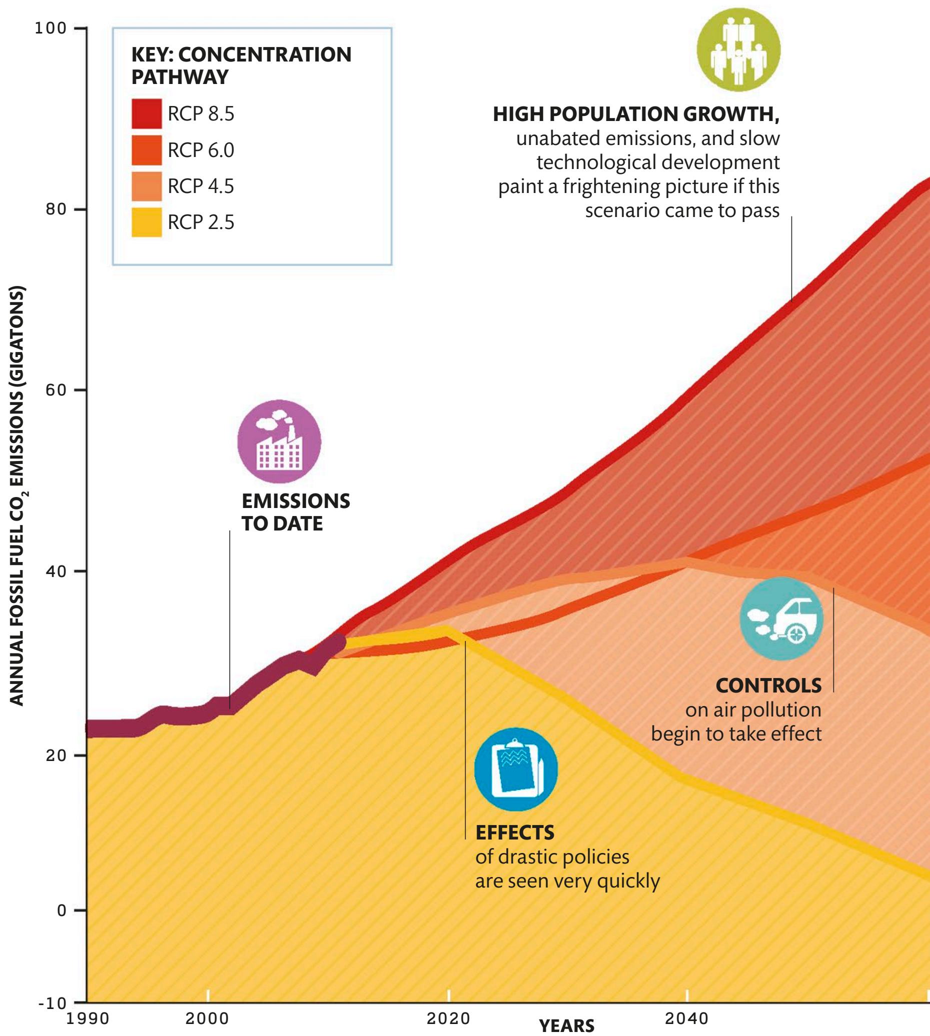
- **A Warmer World** pp124–125
- **The Two-Degree Limit** pp132–133
- **How Much Can We Burn?** pp136–137
- **Targets for the Future** pp142–143
- **What's the Global Plan?** pp186–187


## Past, present, and future

The Intergovernmental Panel on Climate Change's (IPCC) Fifth Assessment Report, which was finalized in 2014, is a comprehensive assessment of climate change. Among its key findings were that human activities, especially the release of $CO_2$, are causing a sustained, unequivocal rise in global temperatures. Even if all emissions are stopped immediately, temperatures will continue to rise as a result of greenhouse gases already in the atmosphere. Mitigating this rise will need significant and lasting reductions of greenhouse gas emissions from this point onward.

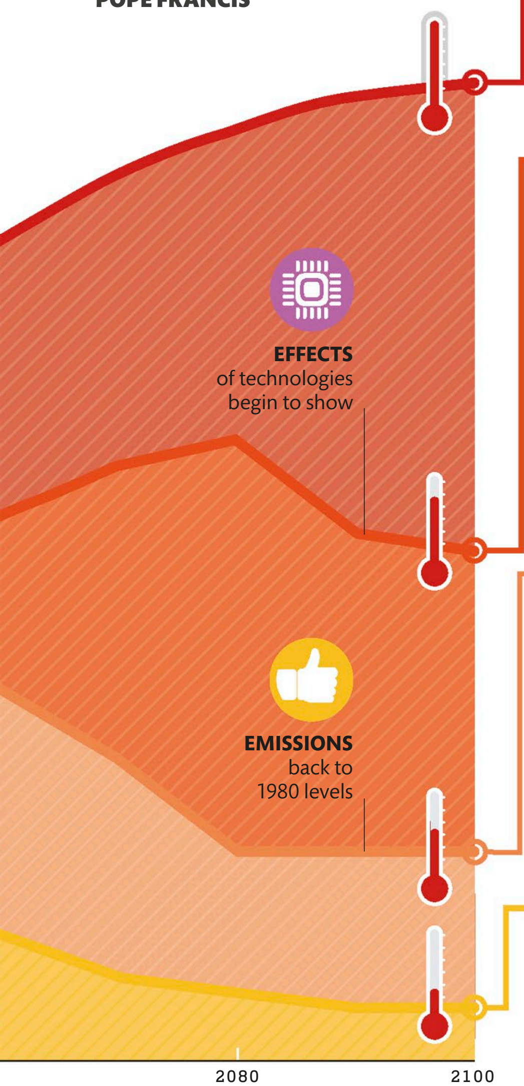
### WHAT IS AN RCP?

As part of their findings, the IPCC explored four contrasting scenarios of future climate change. These scenarios, known as Representative Concentration Pathways (RCPs), project greenhouse gas concentrations and their impact on global temperatures over the 21st century. Each pathway is consistent with different scenarios based on various socioeconomic trends and policy choices.



"We received this world...as **a loan from future generations**, to whom **we will have to return it!**"

**POPE FRANCIS**




### Highest concentration pathway

RCP 8.5 is consistent with high population growth, lower incomes in developing countries, slow technology development, and rising emissions from burning fossil fuels. Emissions eventually level out, but the average global temperature increases by around 9°F (5°C).

**Ecosystem failure** Many ecosystems, such as large areas of tropical rainforest, will collapse, releasing more $CO_2$.

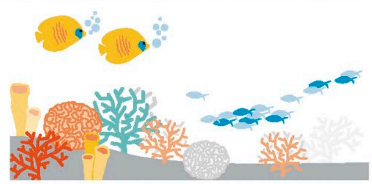
### High concentration pathway

RCP 6 is consistent with technological advances that begin to have a large-scale impact during the 2080s. This causes concentrations of $CO_2$ and other greenhouse gases to stabilize at around the year 2100. Under this scenario, the average global temperature increase is about 5.4°F (3°C).

**Food shortages** Changing rainfall and temperature reduce food production, especially in the tropics.

### Medium concentration pathway

RCP 4.5 is consistent with moderate action on climate change and air pollution. Forest conservation and regrowth brings significant positive effects from the 2040s to 2060s. During the 2080s, emissions are about the same as during the 1980s. The increase in temperature is 3.6–5.4°F (2–3°C).



**Reef loss** About two-thirds of the world's coral reefs suffer major long-term degradation.

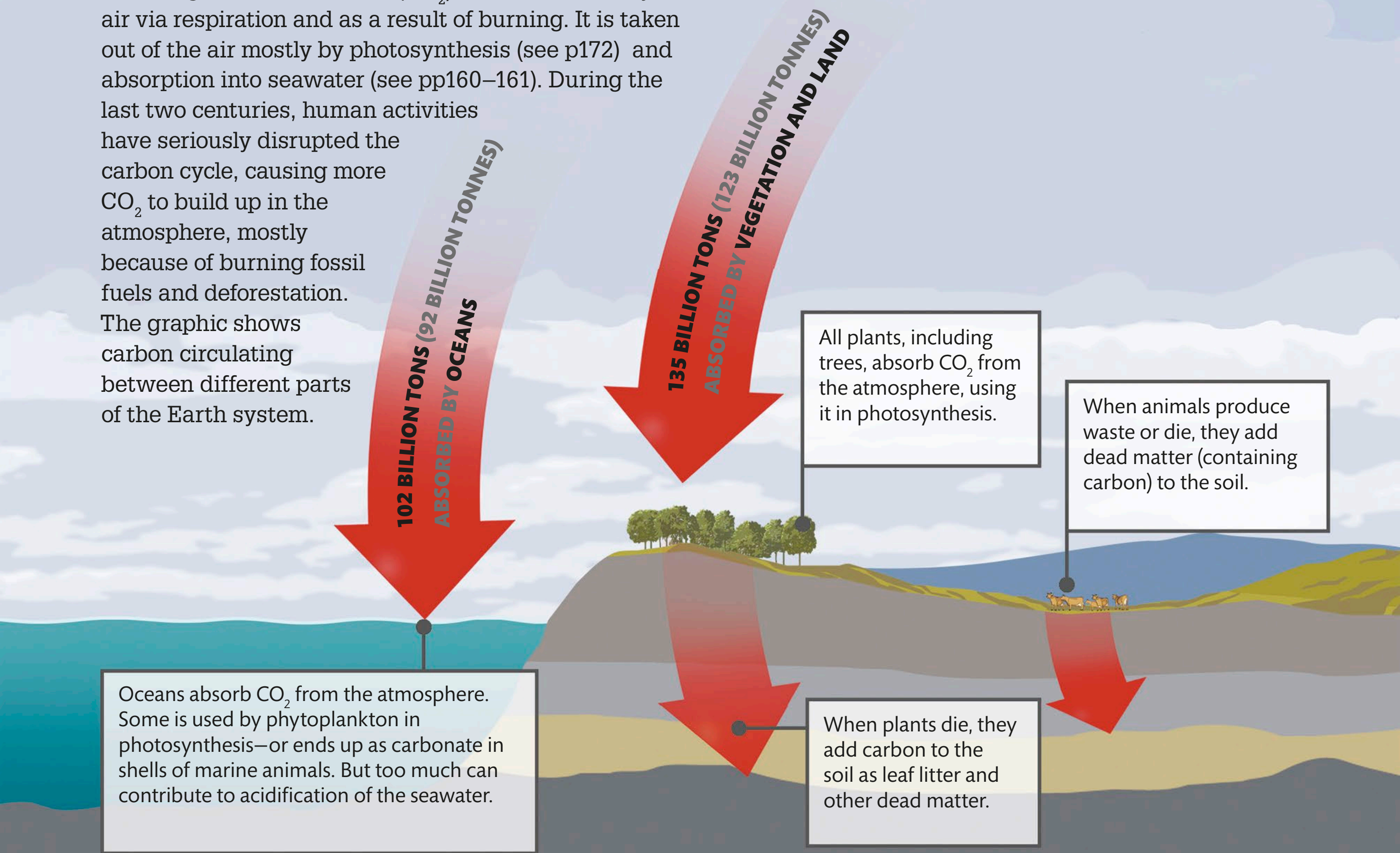
### Low concentration pathway

RCP 2.5 is consistent with an early peak and then a decline in emissions, arising from a radical and almost immediate policy change to encourage renewable energy, energy efficiency, and forest conservation on a large scale. In this scenario, the overall average temperature stays below the critical 3.6°F (2°C) mark.

**Declining milk production** Lower-quality pasture and higher heat stress on cows affects major dairy exporters such as Australia.

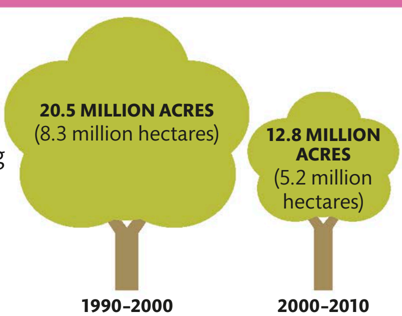
# The Carbon Cycle

Carbon is essential for life and is present in all living things. It flows in cycles through Earth's systems, passing between rocks, plants and animal life, the atmosphere, and the oceans, including as carbon dioxide ($CO_2$). This finds its way into the air via respiration and as a result of burning. It is taken out of the air mostly by photosynthesis (see p172) and absorption into seawater (see pp160–161). During the last two centuries, human activities have seriously disrupted the carbon cycle, causing more $CO_2$ to build up in the atmosphere, mostly because of burning fossil fuels and deforestation. The graphic shows carbon circulating between different parts of the Earth system.

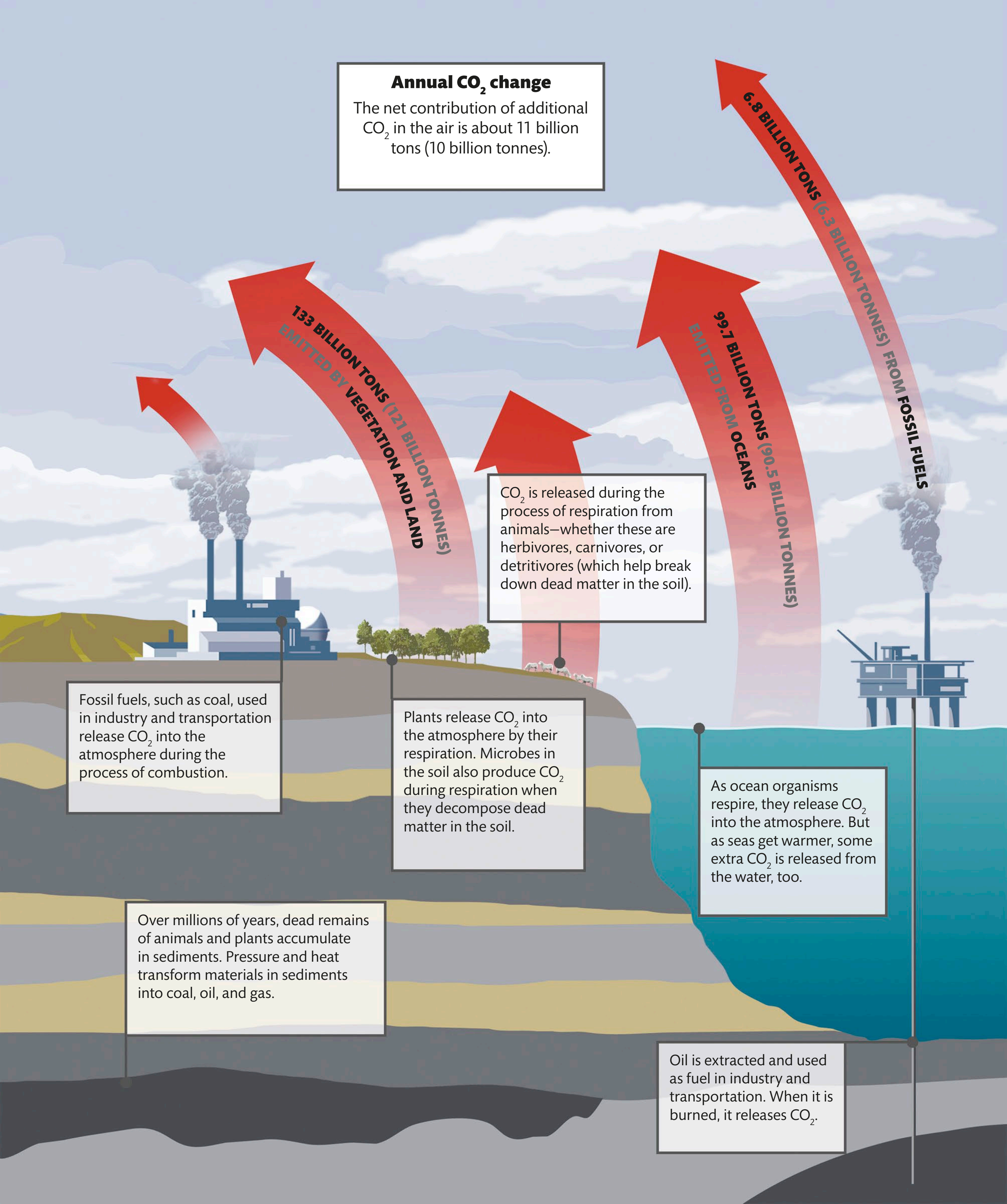



## THE COST OF DEFORESTATION

Deforestation accounts for about one-fifth of greenhouse gas emissions caused by human activities—exceeding emissions from global transportation. Halting deforestation and restoring forests that have been cleared could provide about one-third of the action needed to combat climate change.




AREA OF FOREST LOST PER YEAR


Annual $CO_2$ change
The net contribution of additional $CO_2$ in the air is about 11 billion tons (10 billion tonnes).
6.8 BILLION TONS (6.3 BILLION TONNES) FROM FOSSIL FUELS
133 BILLION TONS (121 BILLION TONNES) EMITTED BY VEGETATION AND LAND
99.7 BILLION TONS (90.5 BILLION TONNES) EMITTED FROM OCEANS
$CO_2$ is released during the process of respiration from animals—whether these are herbivores, carnivores, or detritivores (which help break down dead matter in the soil).
Fossil fuels, such as coal, used in industry and transportation release $CO_2$ into the atmosphere during the process of combustion.
Plants release $CO_2$ into the atmosphere by their respiration. Microbes in the soil also produce $CO_2$ during respiration when they decompose dead matter in the soil.
As ocean organisms respire, they release $CO_2$ into the atmosphere. But as seas get warmer, some extra $CO_2$ is released from the water, too.
Over millions of years, dead remains of animals and plants accumulate in sediments. Pressure and heat transform materials in sediments into coal, oil, and gas.
Oil is extracted and used as fuel in industry and transportation. When it is burned, it releases $CO_2$.

# Targets for the Future

**In the 2015 UN Climate Change Conference in Paris, countries confirmed their commitment to limit global warming to less than 3.6°F (2°C) and also agreed to aim for the more challenging limit of 2.7°F (1.5°C).**

The UN Framework Convention on Climate Change was adopted at the Earth Summit in Rio de Janeiro, Brazil, in 1992. Negotiations under this legally binding treaty led to a new agreement being forged in Paris in 2015. Under this new agreement, countries adopted to voluntary national action plans to reduce greenhouse gas emissions. Although this marked a major step forward, the total cuts are insufficient to meet a 3.6°F (2°C) warming limit. However, a five-yearly review process will require countries to reexamine their ongoing efforts and to consider whether deeper cuts are necessary.


**SEE ALSO...**

- **The Two-Degree Limit** pp132–133
- **Carbon Crossroads** pp138–139
- **What's Working?** pp190–191


### Timeline of change

Since 1992, there have been many significant summits at which countries have debated how best to deal with the challenge of climate change. However, success has been elusive.

## Main polluters

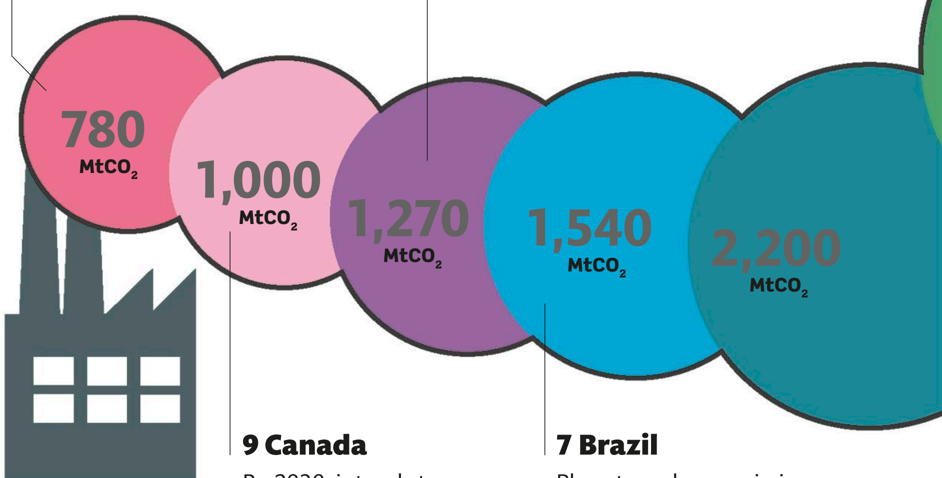
The top 10 biggest emitters of carbon dioxide in 2011 accounted for about two-thirds of global emissions. All these countries (and 175 others) committed to reducing emissions as part of the 2015 Paris climate agreement. In the diagram, the figures are millions of tons of $CO_2$ ($MtCO_2$) emitted in 2011. Proposed cuts are for 2020–2030.

**10 Mexico**

Plans to cut emissions by 22 percent by 2030 and will go further if conditions are met, such as a global agreement addressing international carbon price

**8 Japan**

Despite economic difficulties and nuclear power problems, Japan still aims to cut emissions by 26 percent compared with 2013




**9 Canada**

By 2030, intends to reduce emissions by 30 percent compared with 2005

**7 Brazil**

Plans to reduce emissions by 37 percent by 2025 to be met through renewable energy expansion and saving forests

**1979**
First World Climate Conference in Geneva, Switzerland

**1988**
Inter-governmental Panel on Climate Change (IPCC) founded

**1992**
UN Framework Convention on Climate Change (UNFCCC) agreed at Earth Summit

**1997**
Kyoto Protocol, extending the UNFCCC, is signed

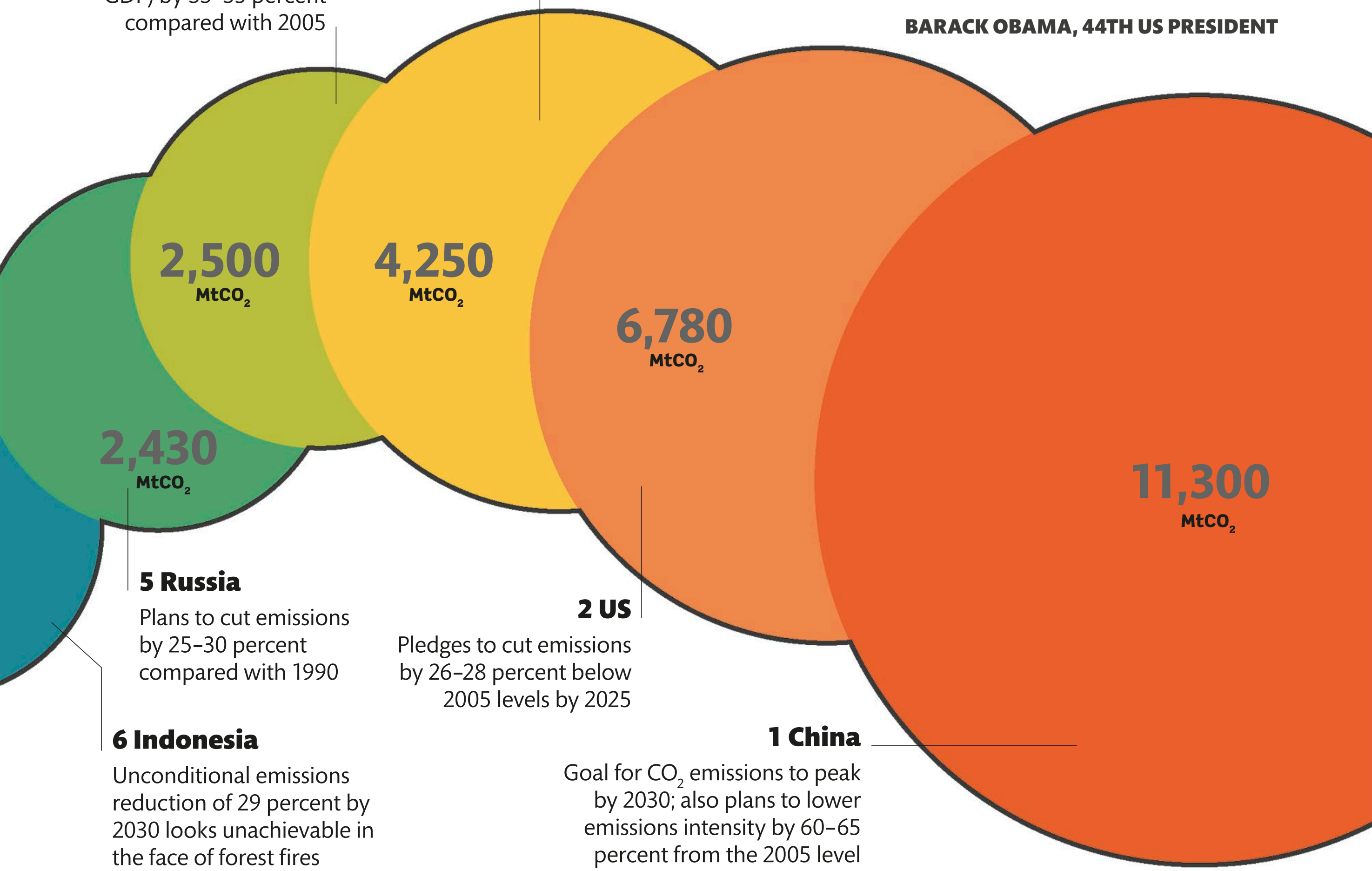
**2007**
China announces its first National Climate Change program in response to overtaking the US as the world's largest polluter

**3 European Union**
Binding target of at least 40 percent emissions reduction by 2030 compared to 1990 levels

**4 India**
Plans to reduce emissions intensity (the ratio of emissions to GDP) by 33–35 percent compared with 2005

**"If we unite our highest aspirations, if we make our best efforts to protect this planet for future generations, we can solve this problem"**

**BARACK OBAMA, 44TH US PRESIDENT**




**5 Russia**
Plans to cut emissions by 25–30 percent compared with 1990

**2 US**
Pledges to cut emissions by 26–28 percent below 2005 levels by 2025

**6 Indonesia**
Unconditional emissions reduction of 29 percent by 2030 looks unachievable in the face of forest fires

**1 China**
Goal for $CO_2$ emissions to peak by 2030; also plans to lower emissions intensity by 60–65 percent from the 2005 level

**2009** Copenhagen Summit results in a weak, nonbinding agreement

**2011** Durban climate change talks agree to open negotiations for a new legally binding climate change treaty to be agreed in Paris in 2015

**2014** IPCC Fifth Assessment Report concludes that "human influence on the climate system is clear" and that "human emissions of greenhouse gases are the highest in history"

**2015** Paris climate talks agree a global legally binding commitment to limit the temperature rise to 3.6°F (2°C) and, if possible, 2.7°F (1.5°C)

# Toxic Air

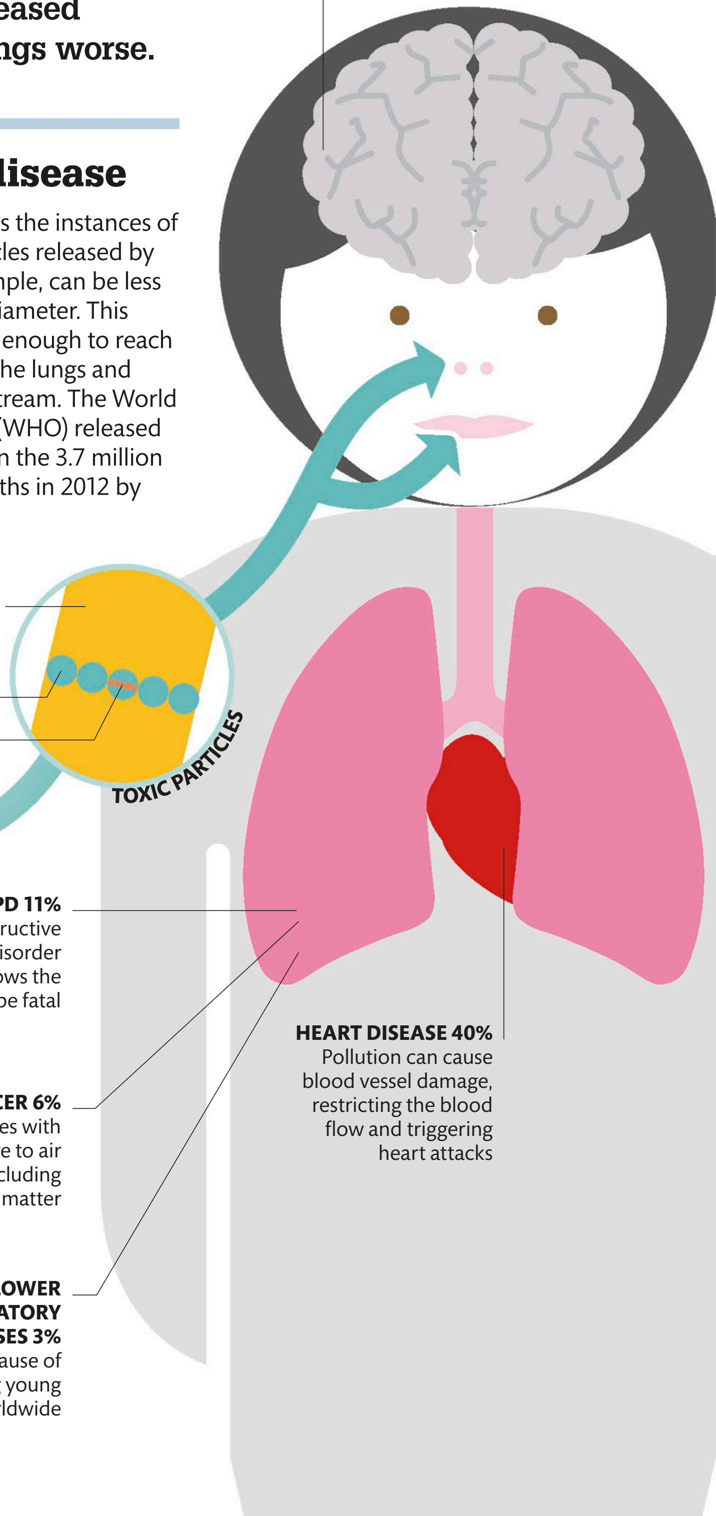
**Air pollution is a major cause of premature death. The rise of huge cities, combined with increased demand for energy and cars, is making things worse.**

A wide range of pollutants get into the air and cause damage to human health. Vehicle exhausts, emissions caused by power stations, and forest fires are the principal sources. Common health-threatening pollutants include microscopic particles, oxides of nitrogen, carbon monoxide, and ozone, which is toxic when it is in the air we breathe. Cars and trucks are especially problematic. Nitrogen oxides and particles released from diesel engines, and photochemical smog arising from sunlight acting on gasoline exhausts, kill millions.

## Deaths by disease

Air pollution increases the instances of major diseases. Particles released by combustion, for example, can be less than 2.5 microns in diameter. This means they are small enough to reach the deepest parts of the lungs and cross into the bloodstream. The World Health Organization (WHO) released figures breaking down the 3.7 million pollution-related deaths in 2012 by types of disease.

**STROKES 40%**
Pollutants can cause damage to blood vessels in the brain, causing oxygen starvation in brain tissues and death




**COPD 11%**
Chronic obstructive pulmonary disorder (COPD) narrows the airways and can be fatal

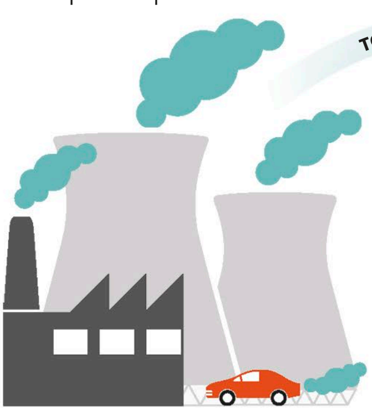
**LUNG CANCER 6%**
The risk rises with increasing exposure to air pollution, including particulate matter

**ACUTE LOWER RESPIRATORY DISEASES 3%**
The biggest cause of deaths among young children worldwide

**HEART DISEASE 40%**
Pollution can cause blood vessel damage, restricting the blood flow and triggering heart attacks

### DAMAGING PARTICLES

Polluting particles are divided into two groups: PM2.5 and PM10, based on their diameter. The WHO sets the maximum safe limit over 24 hours as 25 of the PM2.5 particles per 35 cubic feet of air.



### Sources of pollution

The main sources of air pollution include power stations, factories, and vehicles. These pollutants are all recognized, but not enough has been done to reduce emissions, and millions of people die as a result.

## Most toxic parts of the world

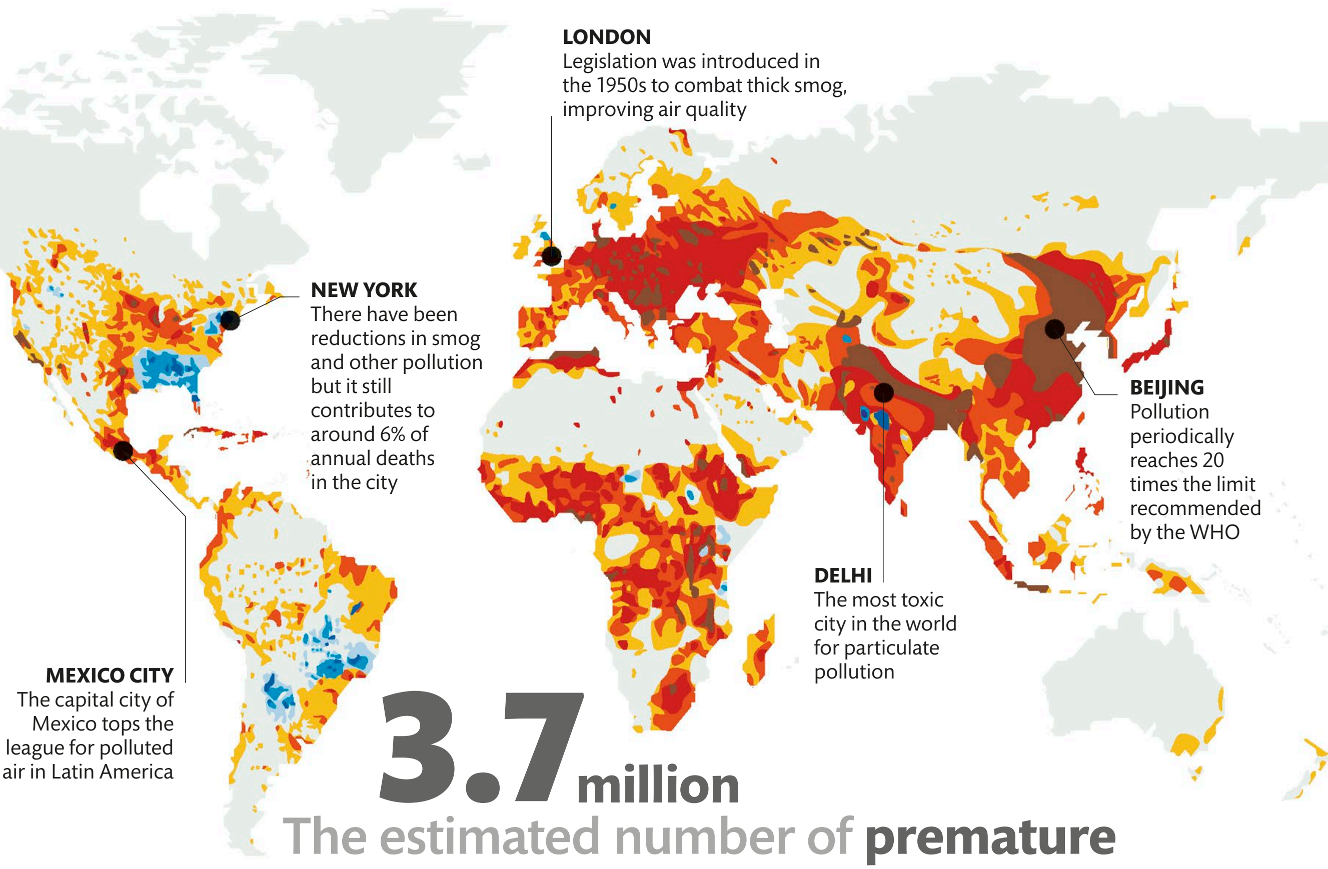
About 88 percent of deaths caused by air pollution occur in low- and middle-income countries, which between them are home to 82 percent of the world's population. As of 2012, the Western Pacific and Southeast Asian regions were the worst offenders, with 1.67 million and 936,000 deaths, respectively. Some experts believe that the increasing number of fossil fuel–powered megacities —cities with more than 10 million inhabitants (see pp40–41)—will double the number of air-pollution deaths by 2050 compared with 2012. Air quality has actually improved in some parts of the world—the blue regions on the map below signify reductions in air-pollution deaths since the 1850s.

**KEY**
**Premature mortality due to air pollution (deaths per year per 400 square miles)**

| | | |
|---|---|---|
| –1,000 | –0.1 | 100 |
| –100 | 0.1 | 1,000 |
| –10 | 1 | |
| –1 | 10 | |

### What can we do?

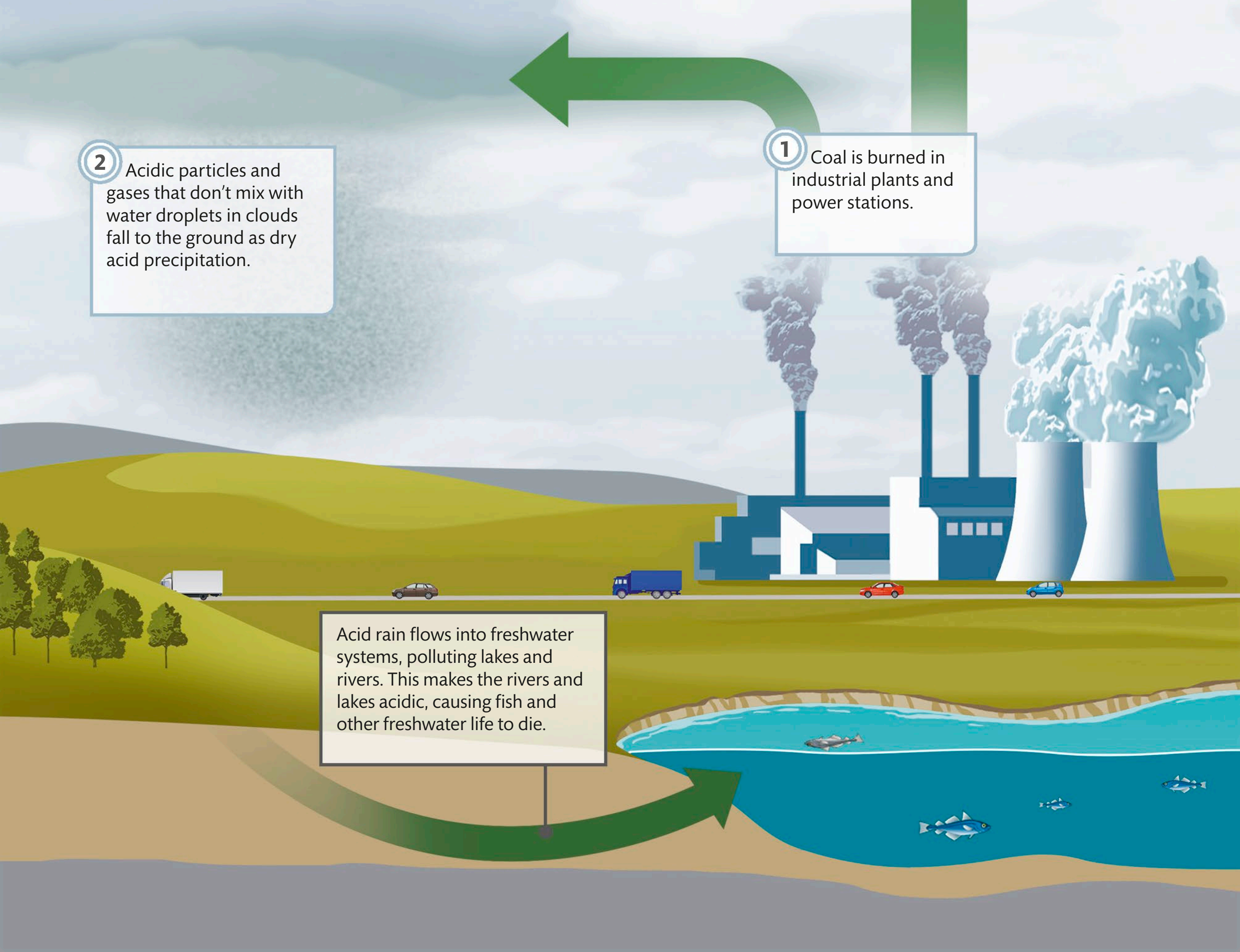
- **Go electric** Choosing an electric vehicle over a gasoline- or diesel-powered car will do your bit to improve air quality and improve public health.
- **Plant trees** Increasing the number of trees in polluted urban areas can help clean up the air. Leaves catch particles and other pollutants that are washed to the ground when it rains.

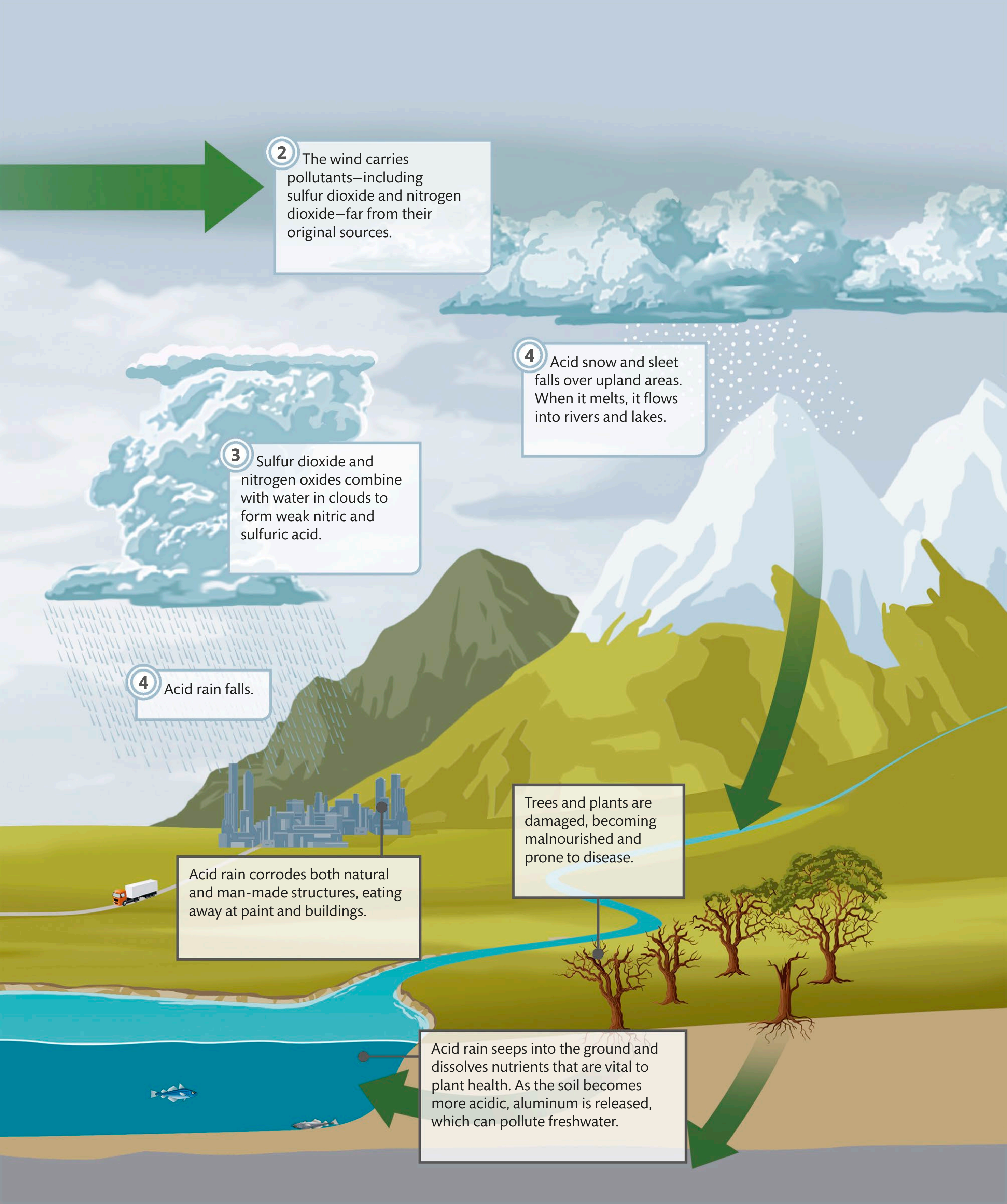



**3.7 million**
The estimated number of **premature deaths caused by air pollution in 2012.** The majority were in developing countries.

# Acid Rain

Acid rain is caused by emissions of sulfur dioxide and nitrogen oxide, which react with water in the atmosphere to produce acids that cause harm to plants, aquatic animals, and buildings. It can also pose serious respiratory problems for humans. The main source of acid rain (and acid snow and sleet) is the large-scale combustion of coal in power stations and industrial plants, such as steel and cement works. Acid rain can travel for hundreds or even thousands of miles. Action taken in some parts of the world, especially in North America and Europe, has reduced the pollutants causing acid rain. It remains a major problem in other countries, however, including China and Russia.




2 The wind carries pollutants—including sulfur dioxide and nitrogen dioxide—far from their original sources.
3 Sulfur dioxide and nitrogen oxides combine with water in clouds to form weak nitric and sulfuric acid.
4 Acid snow and sleet falls over upland areas. When it melts, it flows into rivers and lakes.
4 Acid rain falls.
Acid rain corrodes both natural and man-made structures, eating away at paint and buildings.
Trees and plants are damaged, becoming malnourished and prone to disease.
Acid rain seeps into the ground and dissolves nutrients that are vital to plant health. As the soil becomes more acidic, aluminum is released, which can pollute freshwater.

# Changing the Land

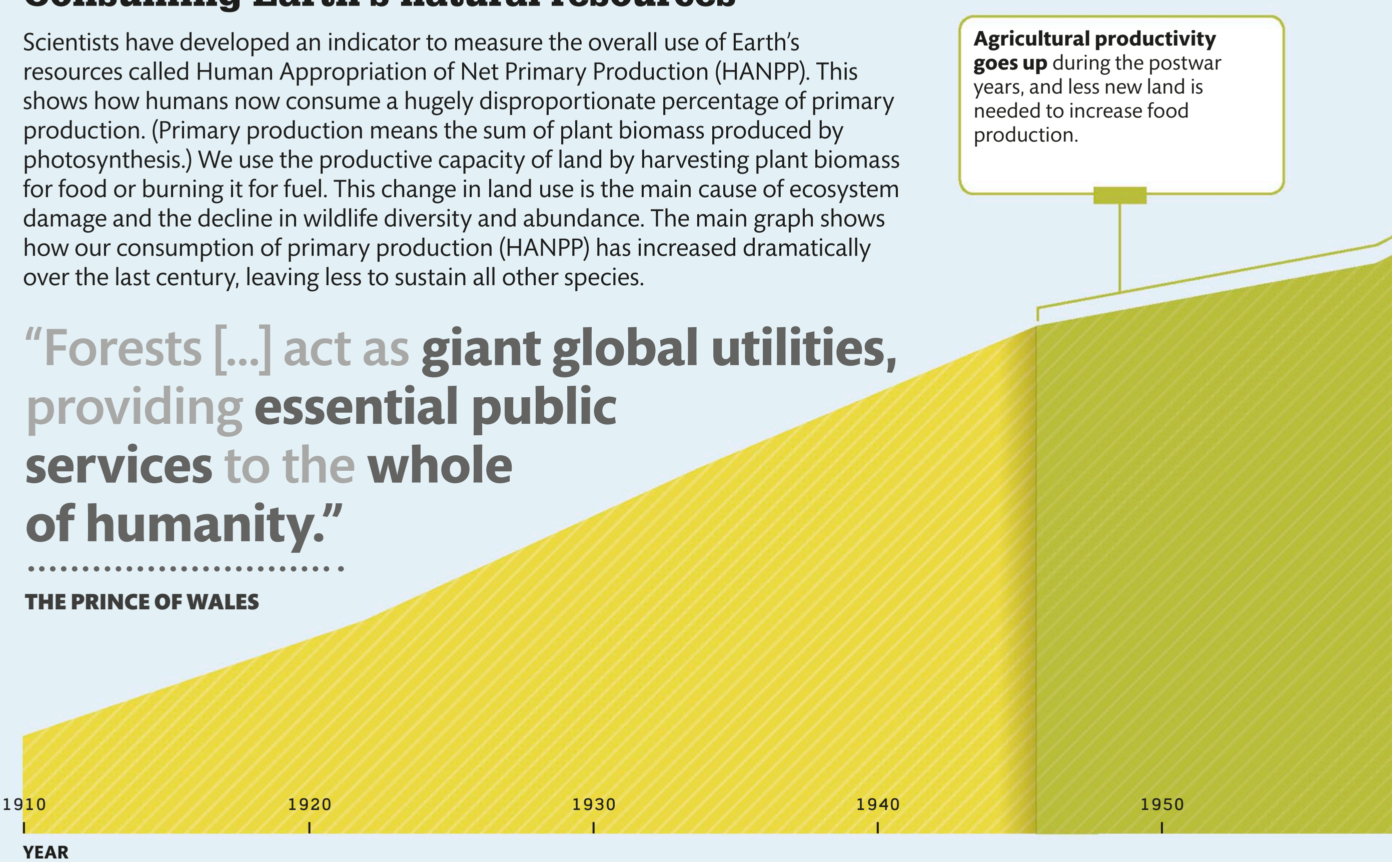
**During the 20th century, the expansion of croplands and of pastures to feed animals, and the development of forestry to sustain a rising demand for lumber and paper, has put increasing pressure on the planet. At the same time, we have destroyed various ecosystems by chopping down forests and by using land for our own needs at the expense of wildlife. One of the results of this is the desertification of once productive land. Land has become a scarce resource in some countries, and many regions have started to invest in lands far away to produce food and biofuels.**

## Consuming Earth's natural resources

Scientists have developed an indicator to measure the overall use of Earth's resources called Human Appropriation of Net Primary Production (HANPP). This shows how humans now consume a hugely disproportionate percentage of primary production. (Primary production means the sum of plant biomass produced by photosynthesis.) We use the productive capacity of land by harvesting plant biomass for food or burning it for fuel. This change in land use is the main cause of ecosystem damage and the decline in wildlife diversity and abundance. The main graph shows how our consumption of primary production (HANPP) has increased dramatically over the last century, leaving less to sustain all other species.

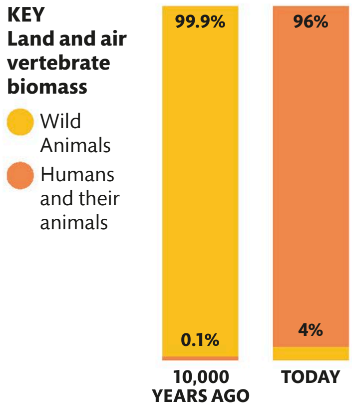
"Forests [...] act as **giant global utilities, providing essential public services to the whole of humanity.**"

**THE PRINCE OF WALES**



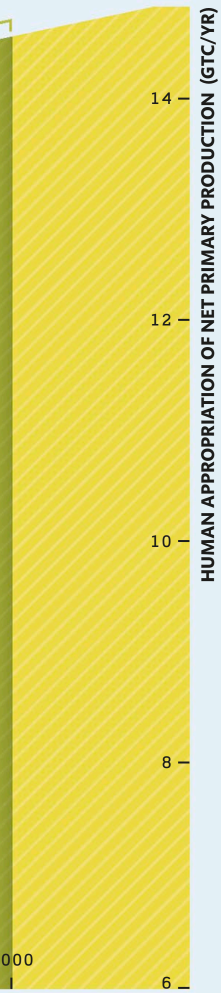
## BIOMASS CHANGE

One of the most dramatic indicators of the scale of human consumption of the planet's productivity is the relative proportion of wild terrestrial vertebrate biomass compared to biomass that is comprised of people and their domesticated animals, such as cattle, sheep, and pigs. Ten thousand years ago, there were very few people, and animal biomass was mostly made up of wild creatures, rather than domesticated animals. Today, 96 percent of terrestrial vertebrate biomass is comprised of people and farm animals.



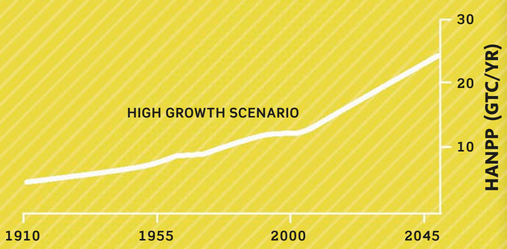

**Because of an average increase in crop yields,** the rate of growth in HANPP levels off, even though population and consumption levels are still increasing.

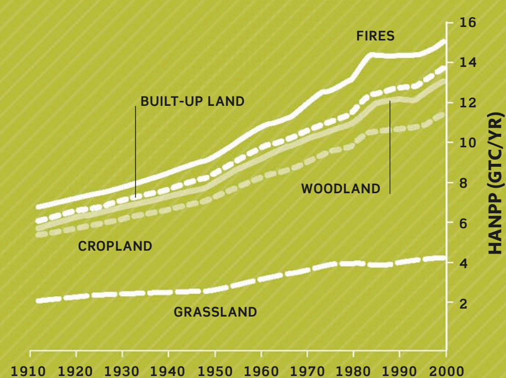
**Rapid population growth** is accompanied by a steep increase in human appropriation of land and plant biomass.




**1990s**
Rapid economic growth in emerging economies leads to more demand for meat and dairy products, and more land to produce them

**1960s**
Despite more productive farming, a population explosion results in more and more land being harnessed to meet human demand




**Future trend**
Projections based on high growth in bioenergy (such as crops for fuel) suggest that HANPP will increase further up to 2050, creating additional pressures on natural habitats and vital ecosystem services.

**Causes for growth**
Most growth in HANPP during the last century is explained by natural habitats being converted to cropland and grazing land. Forest fires also account for a substantial proportion, as does the consumption of forest products.

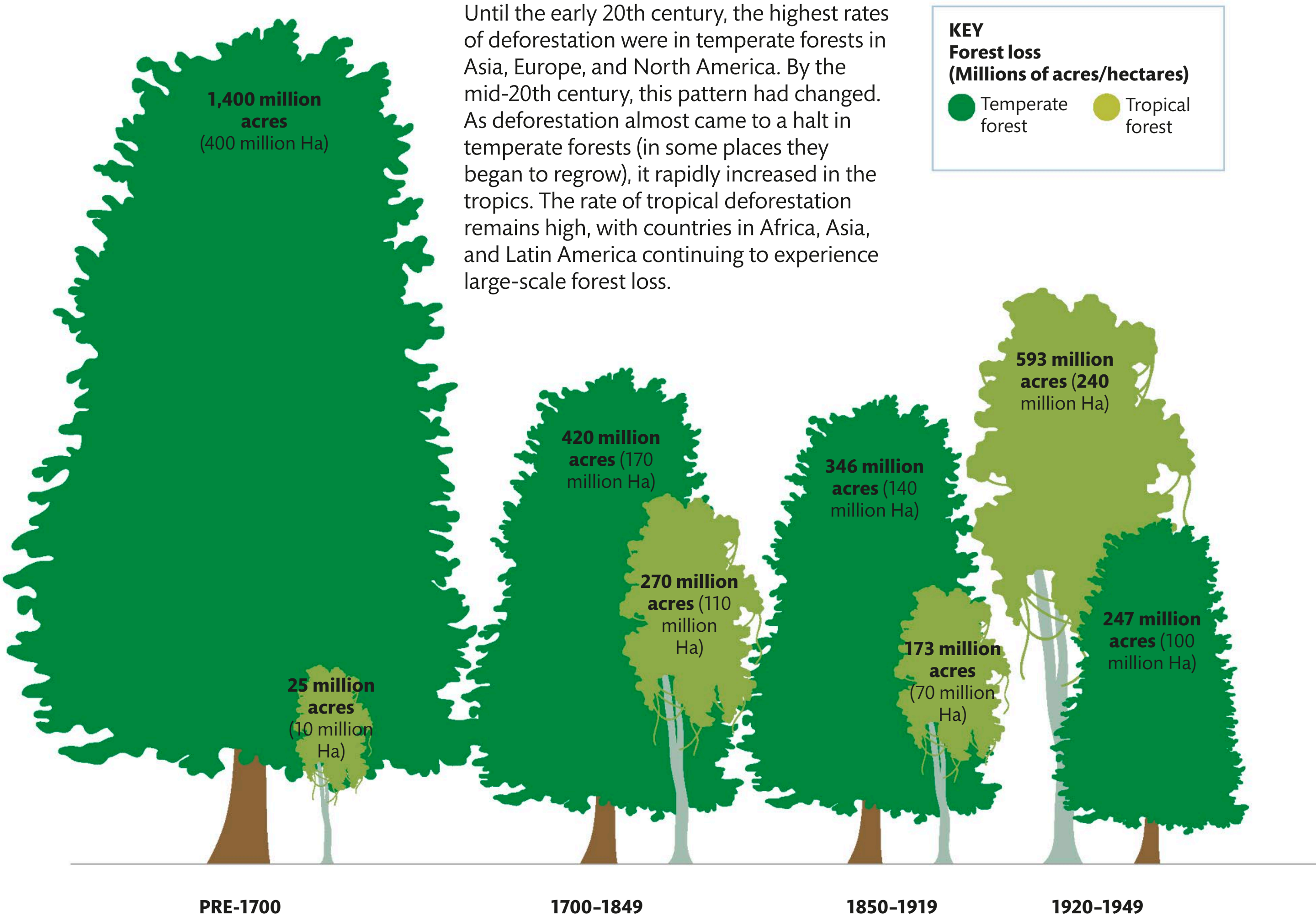
# Forest Clearance

**Most of the world's natural land vegetation has been removed or heavily modified as a result of human activity. The overall global situation is reflected in the drastic reduction in natural forest cover.**

Forests are vital to the health of the planet. They are important in capturing greenhouse gases and for many human needs (see panel, opposite). But, since the beginning of settled agriculture, vast swathes of forest have been lost. Since 1700, the rate of loss has been faster than at any other time in our history. Beginning in Europe and Asia, the process spread to North America and to the tropics. In much of Europe, West Africa, Southeast Asia, and southeastern Brazil, the clearance of natural forests is nearly complete. Agriculture is the main cause of forest loss, often preceded by logging.

## Forest loss over time

Until the early 20th century, the highest rates of deforestation were in temperate forests in Asia, Europe, and North America. By the mid-20th century, this pattern had changed. As deforestation almost came to a halt in temperate forests (in some places they began to regrow), it rapidly increased in the tropics. The rate of tropical deforestation remains high, with countries in Africa, Asia, and Latin America continuing to experience large-scale forest loss.

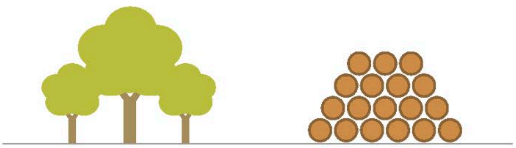


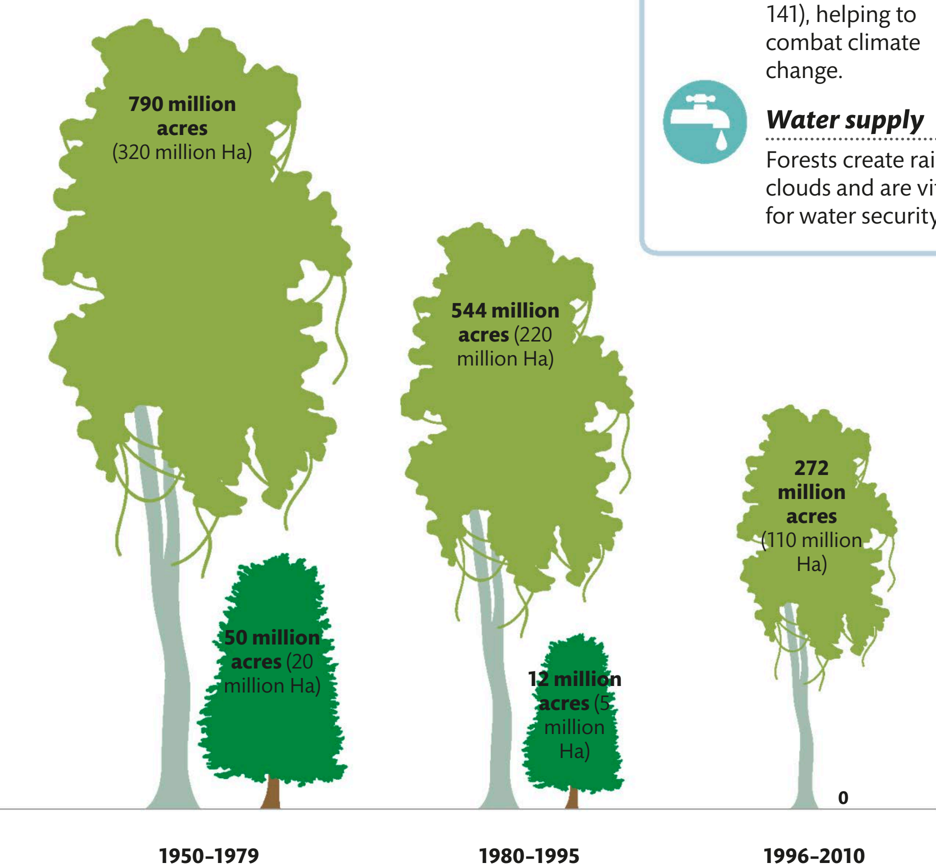
## Winners and losers

In some countries, deforestation is occurring rapidly, but in others, tree cover is expanding on plantations. These are some of the countries to have recently seen the biggest changes in forest cover.

**BIGGEST GAINS**
China
Vietnam
Philippines
India
Uruguay

**BIGGEST LOSSES**
Malaysia
Paraguay
Indonesia
Guatemala
Cambodia






## WHY PEOPLE NEED FORESTS

Forests are plundered for wood and cleared to make way for farming. While societies gain value from these activities, other and even more important forest values are being lost.

***Fuel***

Millions of people depend on forests for wood fuel.

***Carbon storage***

Forests play vital roles in the carbon cycle (see pp140–141), helping to combat climate change.

***Water supply***

Forests create rain clouds and are vital for water security.

***Paper***

Forests supply the world with paper.

***Soil protection***

Woodlands help limit soil erosion and the spread of deserts.

***Flood reduction***

Wooded landscapes hold water and help reduce flood risk.

***Medicines and food***

Many human diseases are treated with drugs first found in forest plants and animals. Forests also provide food.

***Biodiversity***

About 70 percent of wildlife diversity on land is found in forests, especially in the tropics.

## What can I do?

- **Buy wood and paper** products certified by the Forests Stewardship Council.
- **Find out which companies** have adopted "zero deforestation" or "zero net deforestation" policies.
- **Visit and support natural forests** near home or while traveling.

# Desertification

**Across many of the world's semiarid regions, the land is turning to desert. This is mostly caused by the degradation of delicate ecosystems, especially savanna woodlands, leading to soil loss and desertification.**

Desertification is the persistent degradation of semiarid dryland ecosystems, such as grasslands and woodlands. It is caused by variations in climate and human activities. More than one third of the world's land area is vulnerable to desertification, with 10 to 20 percent of all drylands already lost to advancing deserts. The most widespread effects of desertification are seen around the subtropical deserts of North Africa, the Middle East, Australia, southwest China, and western South America. Other areas at risk are the countries surrounding the Mediterranean and Asia's subtropical steppes.

Desertification can cause once-productive land to become useless. It is a global issue that has serious implications for biodiversity, poverty eradication, socioeconomic stability, and sustainable development.

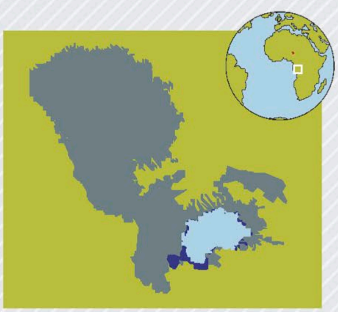

**SEE ALSO...**

- **Threats to Food Security** pp74–75
- **Extreme World** pp130–131


**CASE STUDY**

***Lake Chad***

- In 1963, Lake Chad in Africa was a vast body of water covering 10,000 sq miles (26,000 km²). In 2001, it was a fifth that size and has since shrunk to 500 sq miles (1,300 km²). Millions of people once relied on the lake for fishing and farming.
- Deforestation, overgrazing, and diverting water for irrigation caused desertification to take hold, impoverishing the people living there.



**KEY**

1972 | 1987 | 2007

## Impacts of desertification

Various human activities, such as deforestation and farming practices, can cause deserts to spread and, in the process, bring a series of problems. The consequences are being felt in some of the world's most fragile countries, but also more widely. The effects of climate change are aggravating the situation, with droughts exacerbating the more direct human impacts on the land.

**Causes**

***Growing of cash crops***

Growing crops for export rather than local markets leads to more intensive farming, causing soil damage.

***Incorrect irrigation***

Attempts to boost food production with irrigation can cause salt to rise to the top of the soil, making it harder for plants to grow.

***Cutting down trees***

Felling trees for fuel reduces tree cover, leaving soils vulnerable to erosion.

***Overgrazing***

Too many animals grazing one area for too long remove the vegetation that protects the soil, leading to erosion.

## Dry rivers

Damaged soils hold less water and river flow declines. Fewer plants leads to less moisture evaporation to the air and that means less rainfall.

## Soil damage

- **Sun-baked, cracked soil** Exposed to the punishing heat of the sun, soils become baked and impermeable to the scarce rainfall.
- **Soil erosion** With tree cover removed, the soil becomes dry and vulnerable to erosion by wind and water.

## Loss of plants and animals

As the desert advances, the native wildlife of the dry woodland retreats.

## Extreme weather

- **Flash floods** Instead of penetrating into the ground, rainwater runs off the hardened soil crust to cause flash flooding.
- **Gullying** The land is further damaged as flood water concentrates into streams, stripping away the soil to form deep gullies.
- **More sandstorms** Loosened soil turns to dust. Windy conditions whip it into the air to form blinding sandstorms.

## Impact on people

- **Crops and cattle die** As farm animals and crops die, people are made even poorer.
- **Migrants move to cities** As farming is rendered impossible by the march of deserts, people are forced to move to cities.
- **Unrest** Increased demand for services in urban areas causes social tensions.
- **Death** Reduced food production leads to more widespread malnutrition and people die.

**Desertification**

**Physical impacts**

**Impacts on humans**

### What can we do?

- **Governments can act** by funding programs to achieve the aims of the UN Convention to Combat Desertification (agreed in 1992) to improve the living conditions for people in drylands and maintain and restore the land and soil productivity.

# Land Rush

**Some countries have growing populations but limited potential to grow their own food. Concern about food security has led some governments and investors to seek control of land in other countries.**

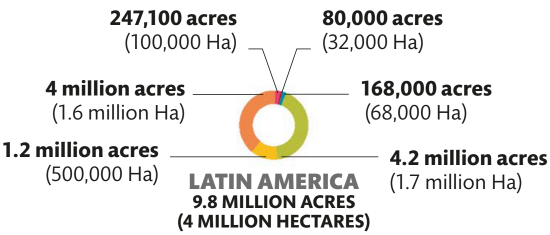
Lack of suitable land to grow plants for food and biofuels, along with water scarcity, are major issues in a growing number of countries. In the past, trade was used as a means to feed countries with limited land, but now direct control of production is seen as more desirable. In some cases, governments have allocated land to foreign interests without consulting local people, leading to disputes and sometimes violence. As well as creating additional pressure on forests and other natural habitats, the large-scale allocation of land to external agricultural interests also undermines food security in host countries. Two-thirds of large-scale land acquisitions have been in countries with a serious hunger problem.

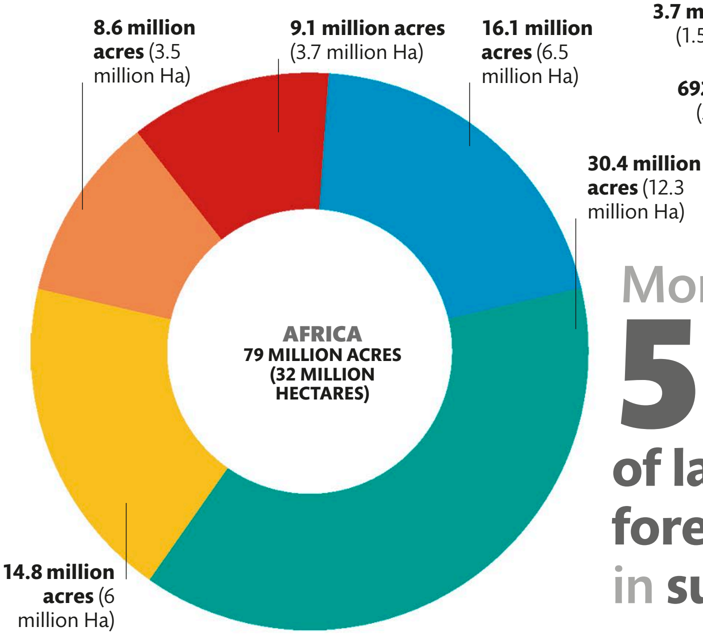
## Land acquisition

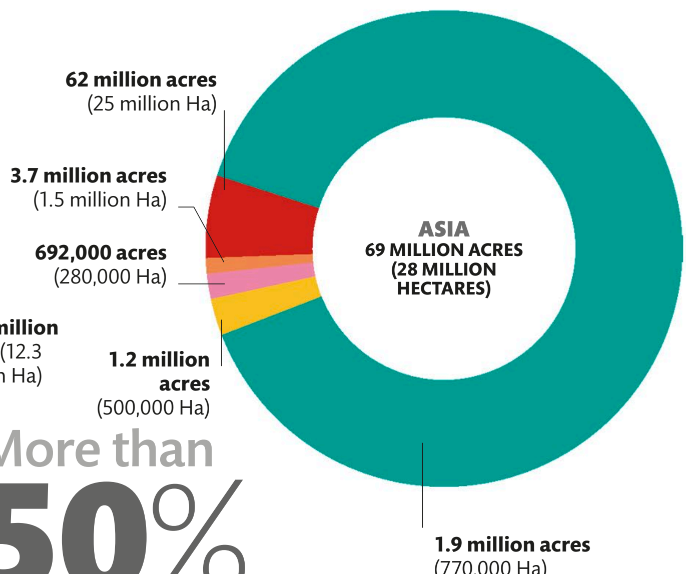
The land rush has been a worldwide phenomenon with finance originating from interests in Europe, Middle Eastern nations, Korea, and China to take control of land in Asia, Latin America, and Eastern Europe. It is Africa, however, to which the vast majority of money has been attracted.

**KEY**
**Regions from which investment originated**

- Africa
- Asia
- Latin America
- Europe
- North America
- Oceania
- Middle East



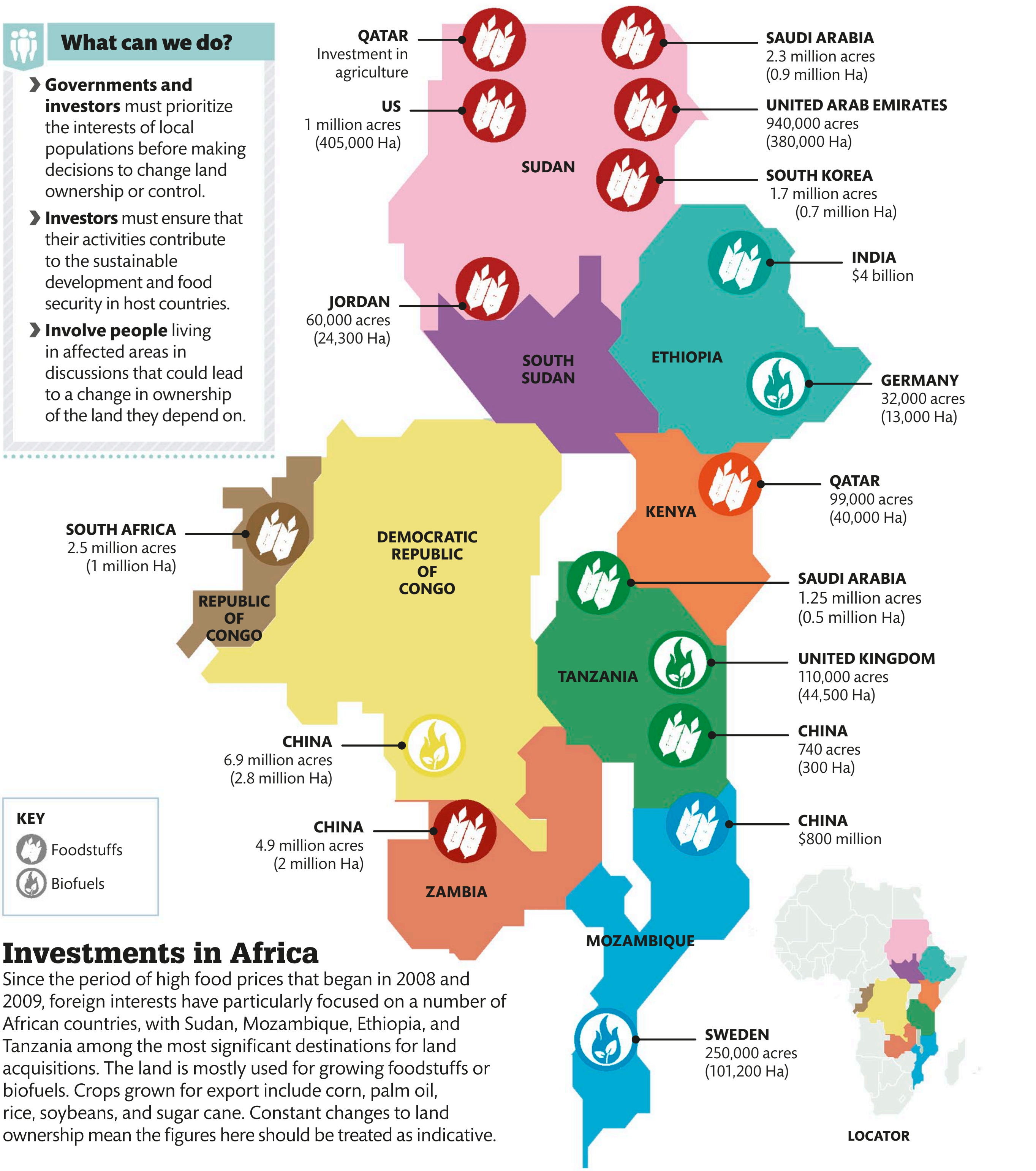




More than **50%** **of land** controlled by **foreign investors** is located in **sub-Saharan Africa**

## What can we do?

- **Governments and investors** must prioritize the interests of local populations before making decisions to change land ownership or control.
- **Investors** must ensure that their activities contribute to the sustainable development and food security in host countries.
- **Involve people** living in affected areas in discussions that could lead to a change in ownership of the land they depend on.




## Investments in Africa

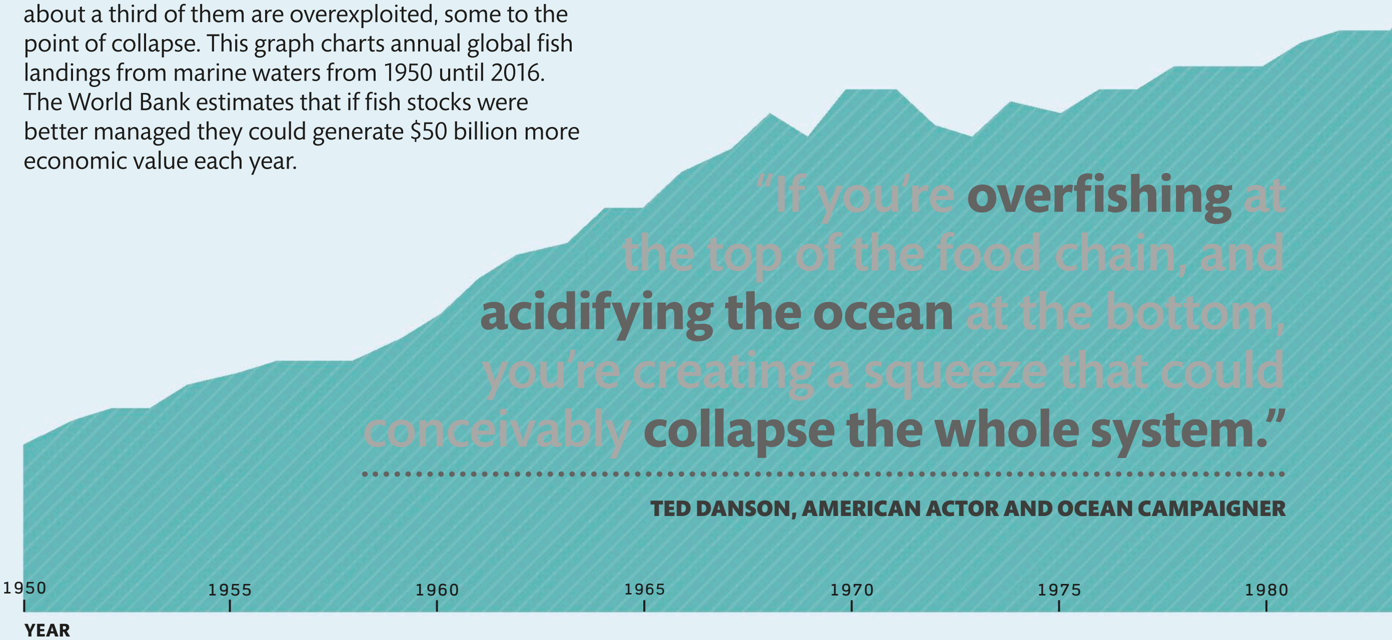
Since the period of high food prices that began in 2008 and 2009, foreign interests have particularly focused on a number of African countries, with Sudan, Mozambique, Ethiopia, and Tanzania among the most significant destinations for land acquisitions. The land is mostly used for growing foodstuffs or biofuels. Crops grown for export include corn, palm oil, rice, soybeans, and sugar cane. Constant changes to land ownership mean the figures here should be treated as indicative.

# Sea Changes

**Fish caught from the seas are a vital source of economic development. Global catches of fish contribute an estimated US$278 billion per year to the global economy, and US$160 billion more comes from boat-building and other related industries. Global wild fish stocks provide employment for hundreds of millions of people, the vast majority of whom live in developing countries. The fishing industry contributes to global food security—about one billion people are reliant on wild-caught fish for their main source of protein. Sustaining these benefits depends on sustaining fish stocks.**

## Plundering the oceans

During the 1950s, marine fish catches grew rapidly. This was due to bigger vessels fishing in greater numbers, as well as the use of new technologies, including sonar equipment. Government subsidies gave incentives for overfishing, so today more than half of stocks are at their maximum sustainable yield—the largest catch that can be taken—and about a third of them are overexploited, some to the point of collapse. This graph charts annual global fish landings from marine waters from 1950 until 2016. The World Bank estimates that if fish stocks were better managed they could generate $50 billion more economic value each year.

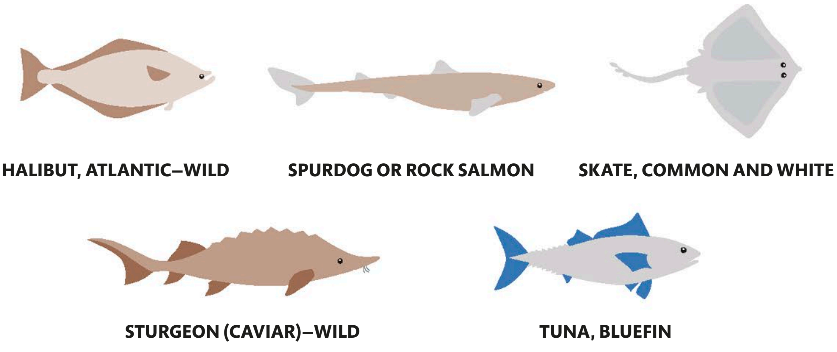



"If you're **overfishing** at the top of the food chain, and **acidifying the ocean** at the bottom, you're creating a squeeze that could conceivably **collapse the whole system.**"

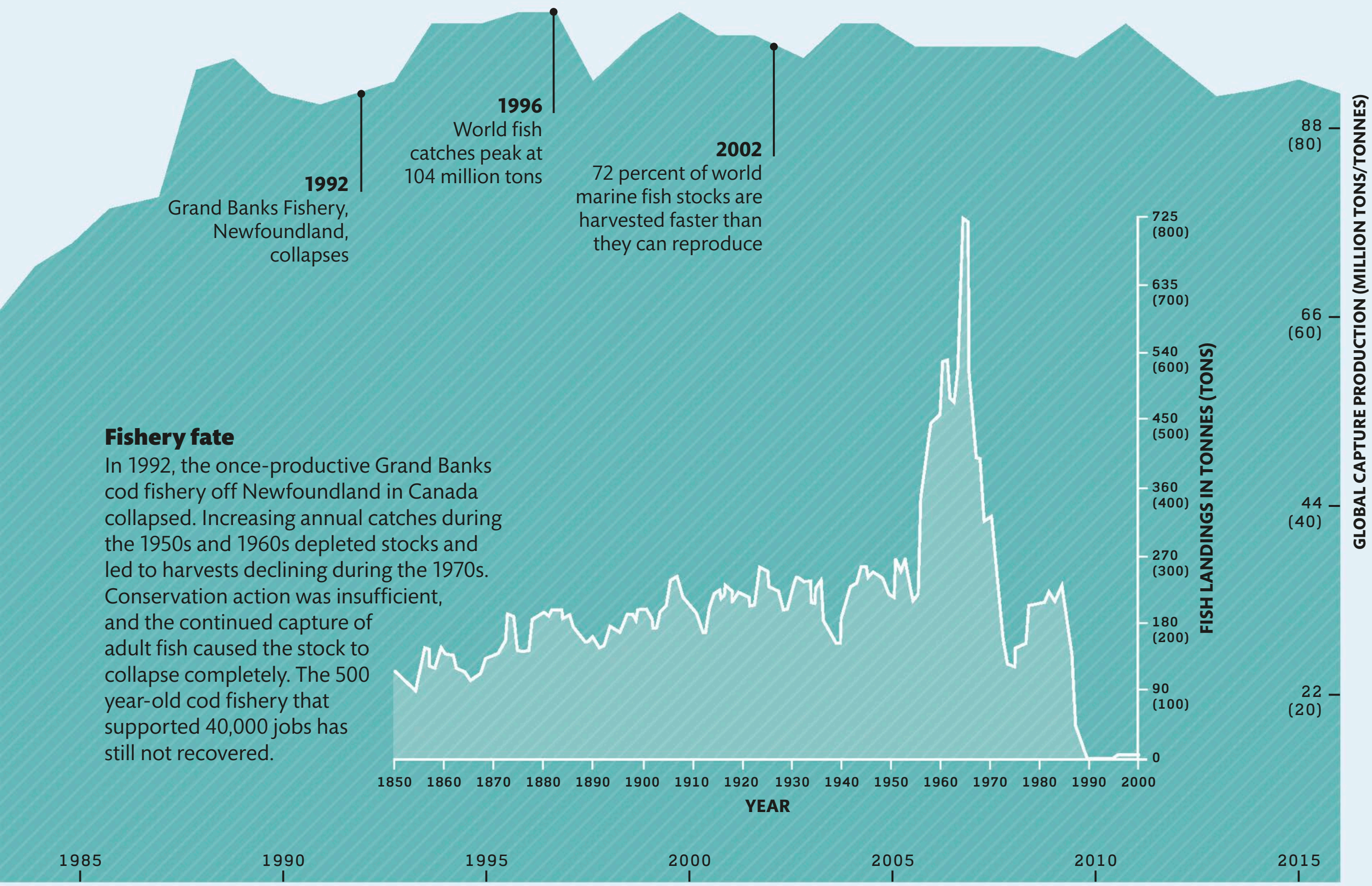
**TED DANSON, AMERICAN ACTOR AND OCEAN CAMPAIGNER**

## FISH UNDER THREAT

Many organizations, including the UK's Marine Conservation Society and the US's Environmental Defense Fund, offer advice on which fish to eat. They discourage consumption of threatened species, such as bluefin tuna and sturgeon, and encourage people to choose herrings, mackerel, and other species from healthy stocks. The Marine Stewardship Council certifies sustainable fish to help consumers make good choices.




FISH TO AVOID EATING




### Fishery fate

In 1992, the once-productive Grand Banks cod fishery off Newfoundland in Canada collapsed. Increasing annual catches during the 1950s and 1960s depleted stocks and led to harvests declining during the 1970s. Conservation action was insufficient, and the continued capture of adult fish caused the stock to collapse completely. The 500 year-old cod fishery that supported 40,000 jobs has still not recovered.

# Farming Fish

**As pressure on wild fish stocks has increased, there has been a rapid expansion in farmed-fish production. While this has made a significant contribution toward meeting nutrition and food security goals, it has also created new challenges.**

During the past 50 years, the expansion of fish farming, also known as aquaculture, has been dramatic. Whereas in 1970 only 5 percent of food fish were sourced from farms, today farmed fish make up about half of all fish eaten in the world. That proportion is expected to rise to nearly two-thirds by 2030.

Fish farming today is a global industry, supplying massive quantities of both marine and freshwater fish, including cod, salmon, bass, and catfish. Aquaculture operations also supply increasing amounts of crustaceans, such as shrimp and lobsters, and mollusks, like mussels.

Growth in farmed fish production between 1980 and 2010 outpaced growth in the wild fish catch—so much so that the average consumer in 2010 ate almost seven times more farmed fish than in 1980. Fish are relatively efficient at converting feed to protein for human consumption, but a number of environmental issues have accompanied the rise of farmed fish.

**60%**

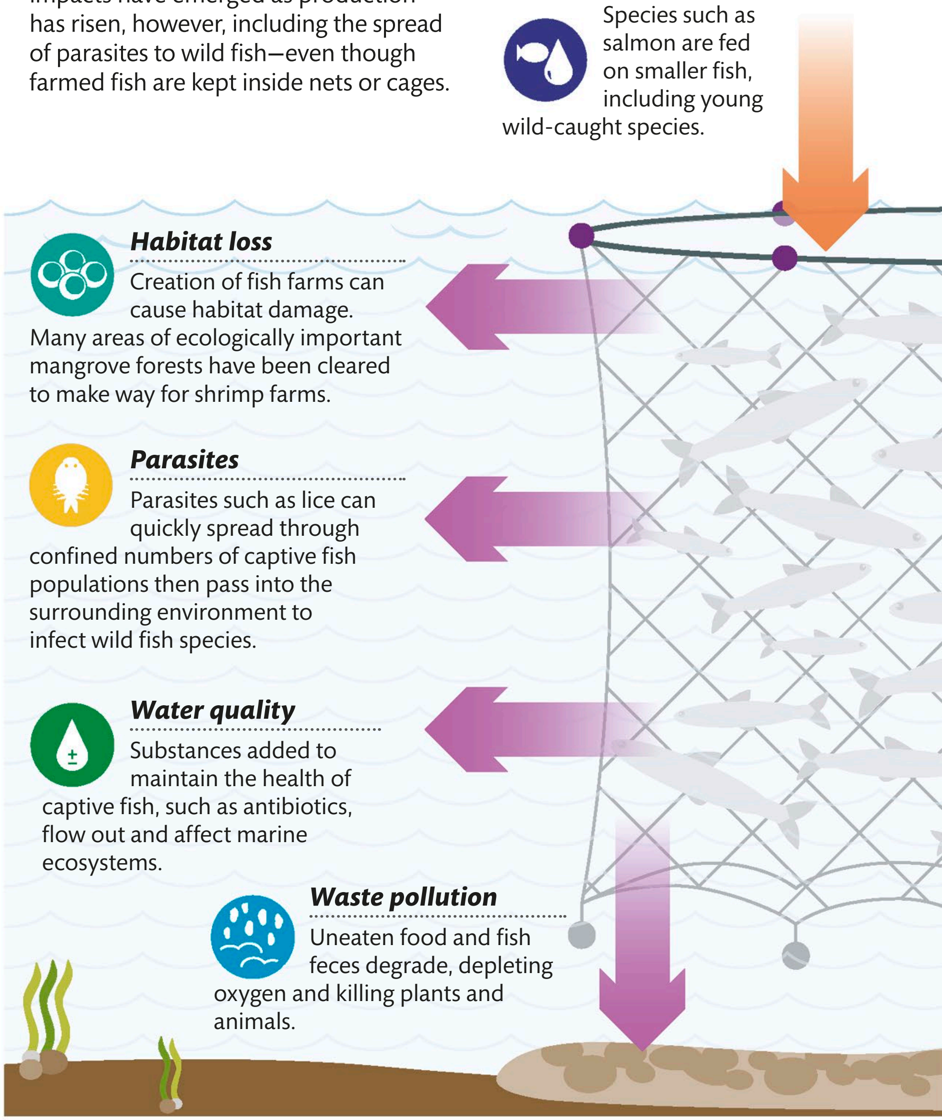
**China's share of the world's farmed fish production**

## Aquaculture's impacts

Fish farming has led to a significant increase in the availability of healthy protein. A number of environmental impacts have emerged as production has risen, however, including the spread of parasites to wild fish—even though farmed fish are kept inside nets or cages.

***Fish and fish oil***

Species such as salmon are fed on smaller fish, including young wild-caught species.



***Habitat loss***

Creation of fish farms can cause habitat damage. Many areas of ecologically important mangrove forests have been cleared to make way for shrimp farms.

***Parasites***

Parasites such as lice can quickly spread through confined numbers of captive fish populations then pass into the surrounding environment to infect wild fish species.

***Water quality***

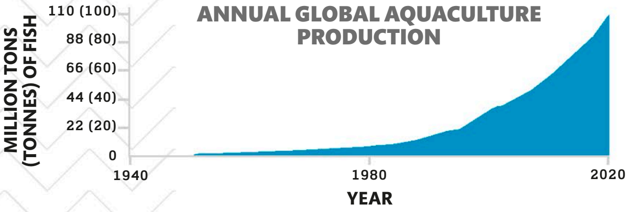
Substances added to maintain the health of captive fish, such as antibiotics, flow out and affect marine ecosystems.

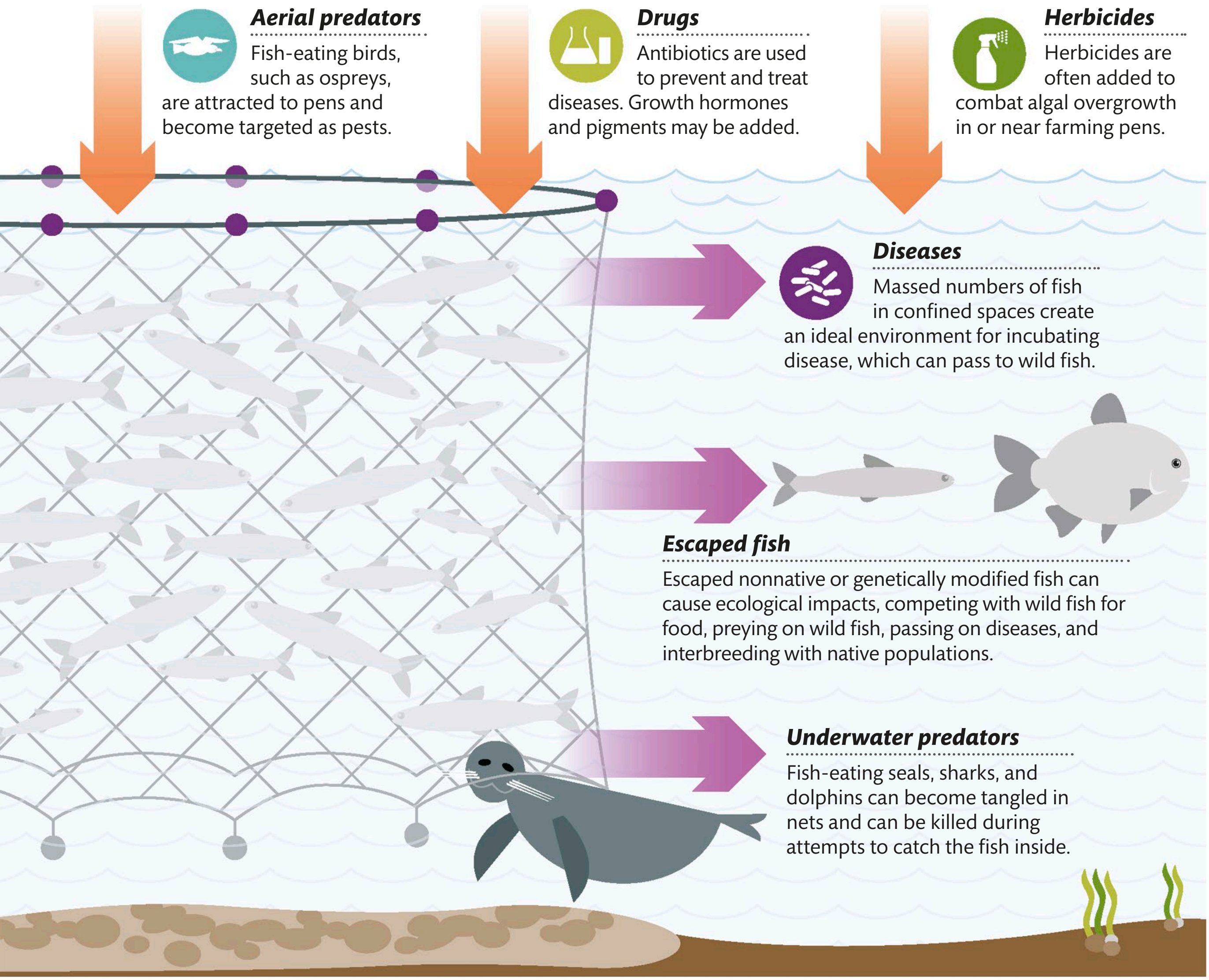
***Waste pollution***

Uneaten food and fish feces degrade, depleting oxygen and killing plants and animals.

## THE RISE OF FARMED FISH

During the last 30 years, the number of wild-caught fish has increased from 76 million to 102.5 million tons (69 million to 93 million tonnes). Farmed fish production rose from 5.5 to 69 million tons (5 to 63 million tonnes). Fish farms will help to meet the increasing demand for food fish, especially in China, which is expected to account for 38 percent of global consumption by 2030.



***Aerial predators***

Fish-eating birds, such as ospreys, are attracted to pens and become targeted as pests.

***Drugs***

Antibiotics are used to prevent and treat diseases. Growth hormones and pigments may be added.

***Herbicides***

Herbicides are often added to combat algal overgrowth in or near farming pens.

***Diseases***

Massed numbers of fish in confined spaces create an ideal environment for incubating disease, which can pass to wild fish.

***Escaped fish***

Escaped nonnative or genetically modified fish can cause ecological impacts, competing with wild fish for food, preying on wild fish, passing on diseases, and interbreeding with native populations.

***Underwater predators***

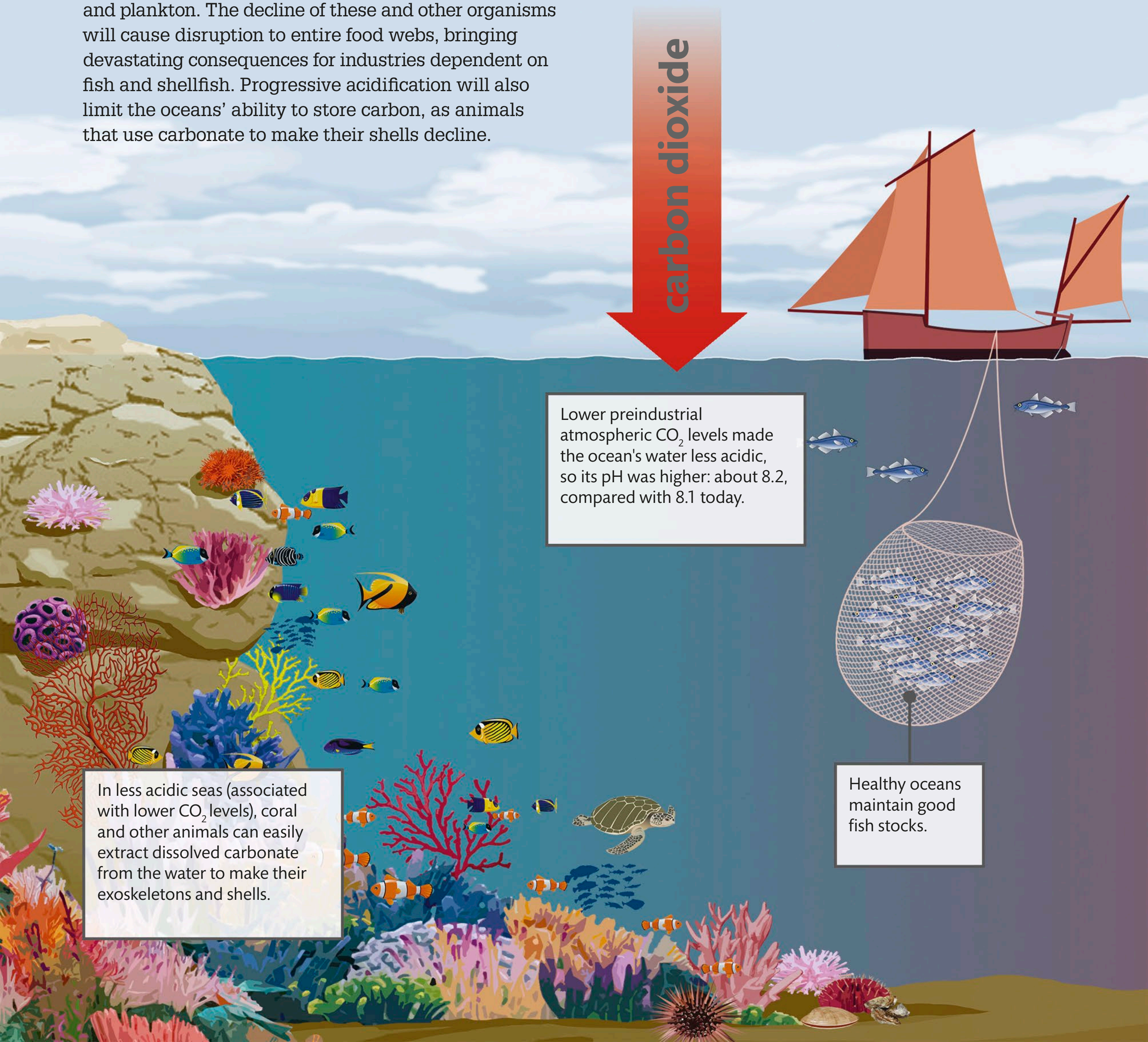
Fish-eating seals, sharks, and dolphins can become tangled in nets and can be killed during attempts to catch the fish inside.

# Acid Seas

Up to half of the carbon dioxide released because of human activities has been absorbed by the oceans. This has caused marine environments to rapidly become more acidic, leading to conditions not experienced on Earth for more than 20 million years. This has had profound impacts on many ecologically vital species, including oysters, clams, urchins, corals, and plankton. The decline of these and other organisms will cause disruption to entire food webs, bringing devastating consequences for industries dependent on fish and shellfish. Progressive acidification will also limit the oceans' ability to store carbon, as animals that use carbonate to make their shells decline.

**Preindustrial world (1850)**

Lower levels of atmospheric carbon dioxide ($CO_2$) were absorbed by seawater in preindustrial times. Since then, its acidity has risen by 30 percent, equivalent to a drop of 0.1 pH unit, caused by emissions from fossil fuels and deforestation.

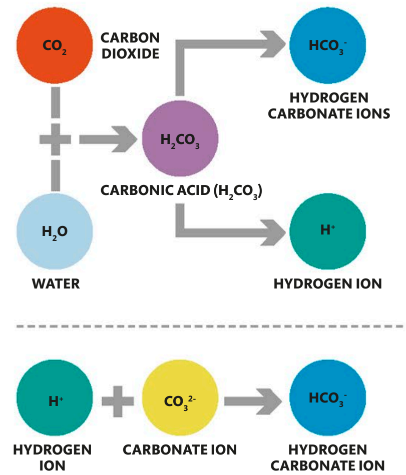


**Future trend (2100)**

If $CO_2$ emissions remain unchecked, by 2100 the acidity of seawater is projected to rise even further: by 150 percent more than it is today—equivalent to another drop of 0.4 pH unit.

## THE CHEMISTRY OF ACIDIFICATION

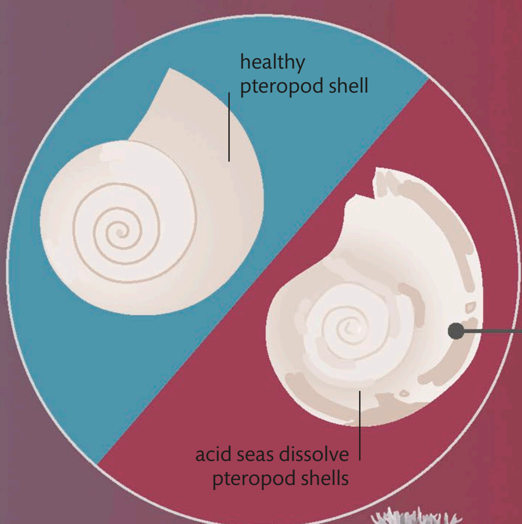
When carbon dioxide ($CO_2$) dissolves in water ($H_2O$), the two molecules react together to form carbonic acid ($H_2CO_3$). Carbonic acid then splits to release hydrogen ions ($H^+$) and hydrogen carbonate ions (top right). The more hydrogen ions in water, the more acidic it is and the lower its pH. Hydrogen ions react with carbonate in the seawater (bottom right), so less carbonate is available for making shells. They also react with carbonate in existing shells, making them corrode.





Higher future atmospheric $CO_2$ levels will make the ocean's water more acidic, so its pH will drop to about 7.7.

Jellyfish are tolerant of warmer and more acid seas. They compete with other sea creatures for food and eat fish eggs. Jellyfish species have spread and numbers have increased dramatically in many areas of oceans.




Pteropods are small free-swimming sea snails. Lab experiments have shown that their shells take little more than six weeks to corrode in seawater with the same acidity as that projected for 2100.

Coral skeletons become fragile, changing shape and crumbling, and are unable to reproduce. Entire reefs may disintegrate in more acidic seas.

# Dead Seas

**High levels of pollutants in the ocean can have a devastating impact on marine life. Substances such as nitrogen and phosphorus act as fertilizers, triggering a process called eutrophication, which removes oxygen from seawater and creates so-called dead zones.**

If nitrogen- and phosphorus-rich agricultural fertilizers, animal waste, detergents, or sewage leak into waterways, contaminated freshwater ends up in the sea, where it can create a dead zone. Dead zones are particularly prevalent in coastal waters, where major rivers discharge and have such low oxygen levels they no longer sustain life. They cause many damaging effects, from loss of wildlife biodiversity to collapse of fisheries. The situation is reversible if the cause is halted and the area is supplied with oxygenated water.

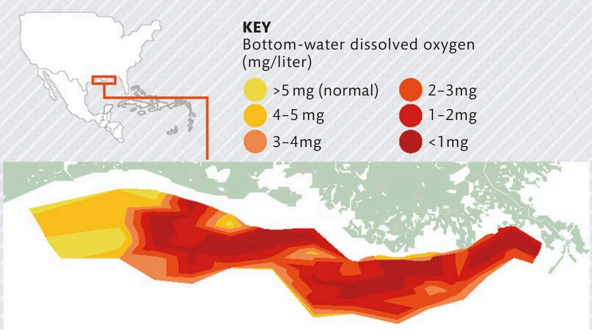
## How dead zones form

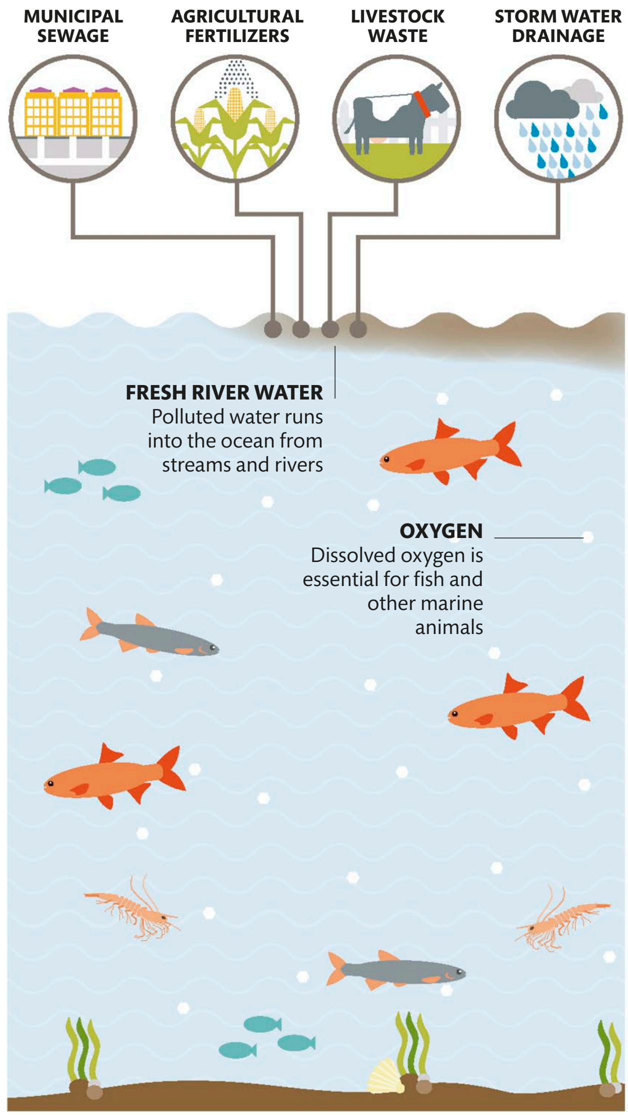
Eutrophication can occur in any water body, including lakes, rivers, or seas. It usually happens when an excess of nutrients runs into the water from surrounding land controlled by human activity, such as farmland, golf courses, and lawns, all of which are heavily fertilized.

### CASE STUDY

***The Gulf of Mexico dead zone***

- Almost half of the continental US drains into the Mississippi River. As it flows into the Gulf of Mexico, the river creates a vast dead zone each spring, due to seasonal runoff of agricultural fertilizer. In 2015, this oxygen-starved area extended almost 6,500 sq miles (17,000 sq km). Marine life cannot survive in waters with oxygen levels below 2 mg/liter (0.5 mg/gallon).




**Contaminated water flows in**

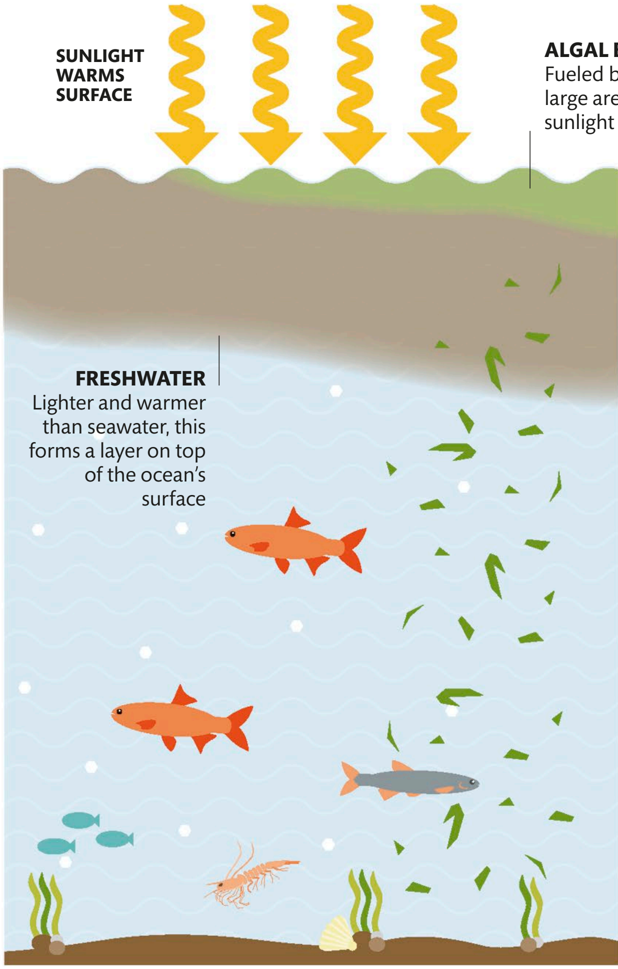
Water rich in nutrients (from sewage and fertilizers, for example) flows into the sea and forms a layer above denser saltwater.

# 405

**The total number of dead zones in coastal waters worldwide**

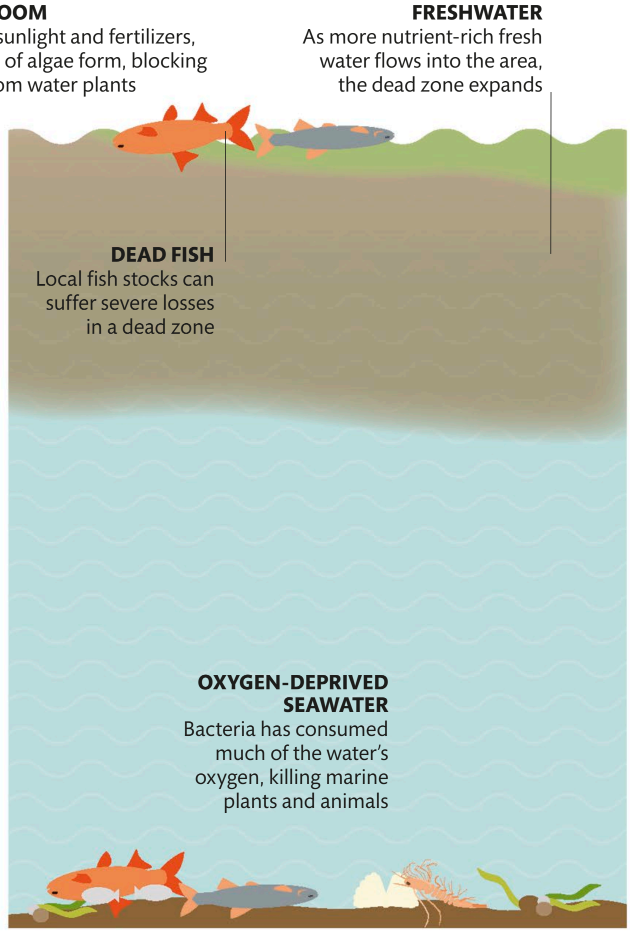
### What can we do?

- **Prevent untreated wastewater** from being channeled into rivers and seas.
- **Limit the use** of industrial fertilizers in problem areas, such as along coastlines and major rivers.
- **Restore wetlands** and natural coastal defenses, which help filter nutrients out of the water before it reaches the sea.




**Algae thrive in freshwater layer**

Warm sun provides perfect conditions for algae to form. At the end of their life cycles, dead algae sink to the sea floor where they decompose. In this process, oxygen is removed from the water.




**Death of the ecosystem**

Low oxygen levels cause marine animals to leave, mutate, or die. Increased decomposition of dead matter exacerbates the lack of oxygen in the water, and the dead zone is formed.

# Plastic Pollution

**Packaging, consumer products, and fishing nets are among the plastic items discarded in the oceans. These kill sea creatures, while plastic particles concentrate pollutants and enter food chains via filter-feeding plankton.**

Most plastic now in the oceans was originally dumped on land and entered the marine environment via rivers. About 88 million tons (80 million tonnes) of plastic litter is already in the seas and about 8 million more plastic items are added each day. The quantity of this plastic debris is rising fast as more people embrace consumer lifestyles. Some wildlife species mistake floating plastic for food, and each year millions of animals and birds die as a result. The United Nations Environment Program estimates that the impact of plastic pollution on marine life costs the global economy $13 billion every year.

## Deadly gyres

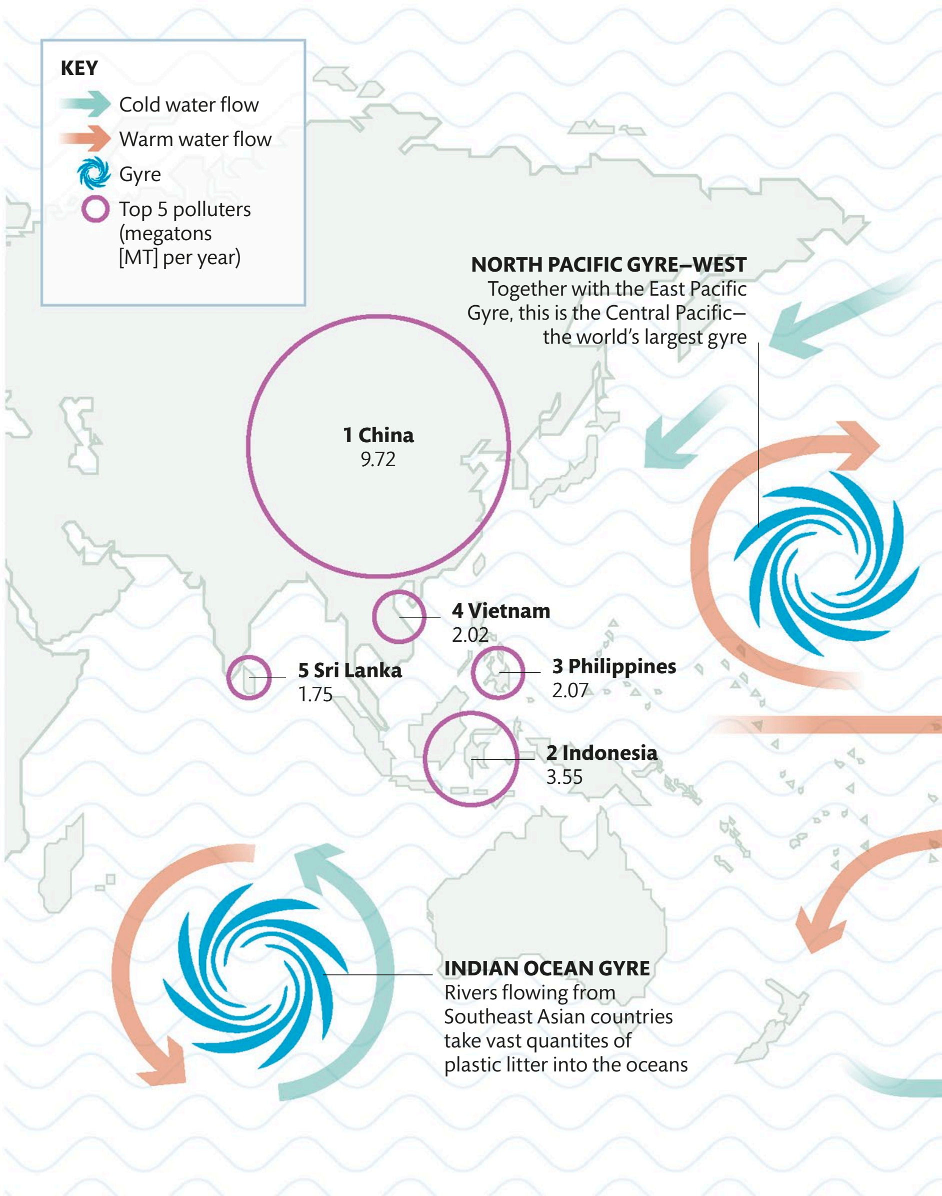
Gyres are large areas of open ocean where slow-moving currents converge. Light plastics are carried on these currents into the gyres, where they are concentrated and held in vast areas of drifting plastic waste. There are five main gyres, including the North Pacific Ocean. A vast quantity of plastic debris drifts in the center of this gyre. Another is in the Bay of Bengal, where plastics are fed into the sea via Asia's largest rivers, including the Ganges.

### What can we do?

- **Restrict the sale** of single-use plastics, such as supermarket bags.
- **Encourage deposit schemes** for plastic bottles.
- **Invest in** solid waste and recycling facilities.
- **Developing countries** should invest in modern recycling.

### What can I do?

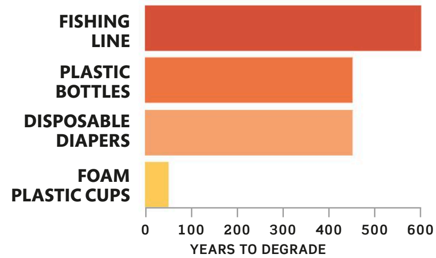
- **Stop buying plastic–** choose reusable alternatives.

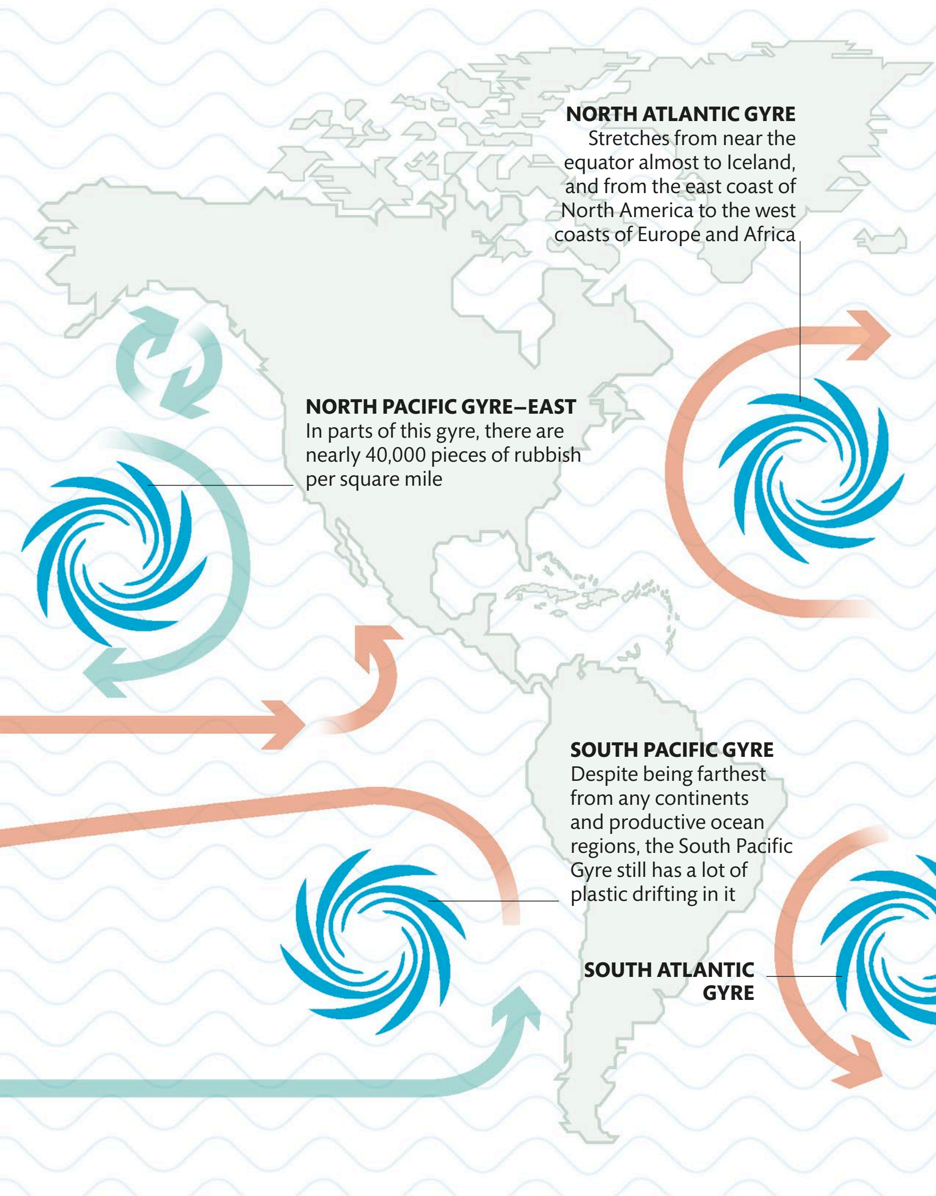


# 90%
## of all litter **floating on the ocean's surface is** plastic

## PLASTIC BREAKDOWN

It can take many years, or even centuries, for plastic debris to break down. Microscopic plastic particles, broken down from larger pieces of litter, attract toxic chemicals that enter the food chain and cause harm.




## EFFECT ON WILDLIFE

Plastic debris has a huge impact on wildlife—either directly or indirectly, as these examples show.

### *Birds*

High mortality among young birds occurs in many albatross colonies because the chicks are fed plastic items, including discarded lighters found drifting in the sea.

### *Turtles*

Some plastic litter, such as fishing nets, lines, and plastic bags, can entangle animals such as turtles, dolphins, and birds, causing them to drown.

### *Plankton*

Microparticles of plastic are taken up both by plankton and by plankton-feeding animals, causing problems for their digestion.

### *Whales and dolphins*

Plastic ingestion has been noted in 56 percent of whale, dolphin, and porpoise species. Whales have also mistaken plastic bags for squid. One whale was found with 37 lb (17 kg) of plastic in its body.

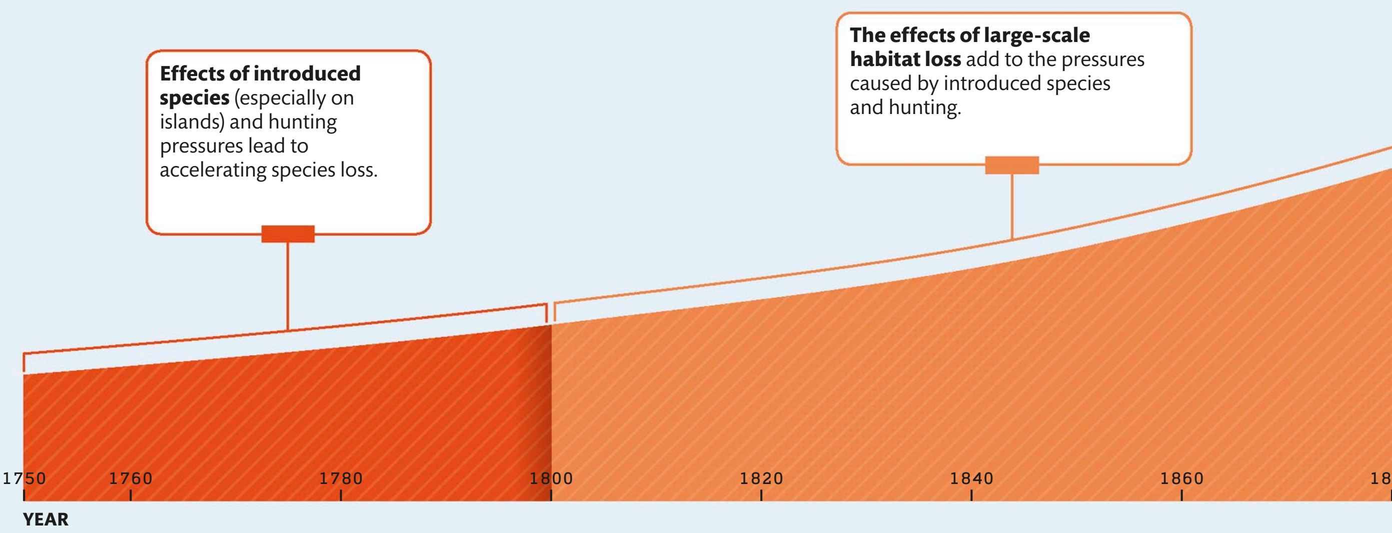
# The Great Decline

**The disappearance of wildlife species is perhaps the most pressing and serious of all environmental problems, threatening the loss of valuable natural "services" (see pp172–173) and, as a result, undermining human well-being. A number of stresses are causing the disappearance of natural diversity on a scale not seen for 65 million years, since the extinction of the dinosaurs. The already accelerating rate of species loss is set to become faster still, as existing pressures arising from human population growth, expansion of farming, and economic development become more intense.**

## Disappearing wildlife

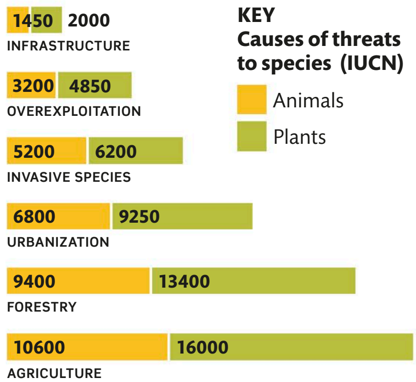
Animal extinctions caused by humans began tens of thousands of years ago, when large mammals, including woolly mammoths and cave lions, were hunted to oblivion by bands of hunter-gatherers. Since then, other pressures have been added to the effects of hunting. During the age of European exploration and colonization, many aggressive invasive species of animals and plants were moved around the world, causing extinctions among native species (see pp170–171). Today, planet-wide degradation of the terrestrial biosphere (see pp148–149) is the main driver of species loss.

> **"We are undoubtedly exterminating species at a speed which has never been known before."**
>
> SIR DAVID ATTENBOROUGH, BRITISH BROADCASTER AND NATURALIST



## CURRENT TOP THREATS TO SPECIES

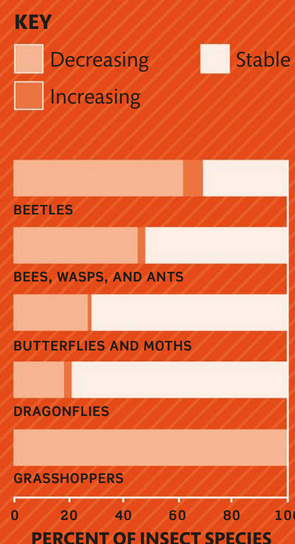
Species considered at risk of extinction are assessed by the International Union for Conservation of Nature (IUCN). The principal pressure on animal and plant species considered at risk of extinction is the expansion and intensification of agriculture. This includes the clearance of more land to grow food, causing ongoing deforestation. Forestry operations are a major threat due to both the logging of natural forests and their replacement with plantations.




**A global mass extinction** is under way, comparable to five other major events evident in the fossil record and now also driven by the impacts of climate change.

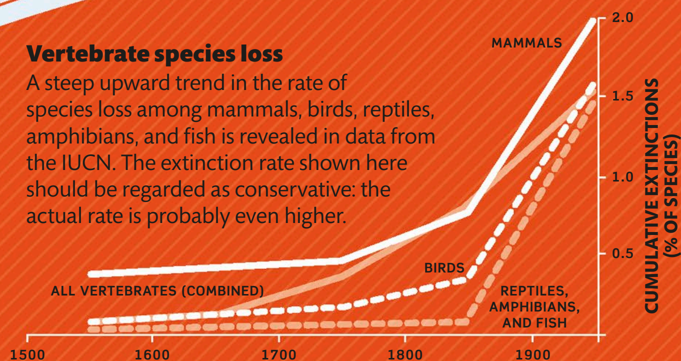
### Invertebrate species loss

Many species of insects are in sharp decline due to pressures arising from habitat loss and chemical pollution as well as the effects of climate change.




### Vertebrate species loss

A steep upward trend in the rate of species loss among mammals, birds, reptiles, amphibians, and fish is revealed in data from the IUCN. The extinction rate shown here should be regarded as conservative: the actual rate is probably even higher.




CUMULATIVE PERCENTAGE DECREASE
30 25 20 15 10 5
80 1900 1920 1940 1960 1980 2000

# Biodiversity Hotspots

**The diversity of wildlife species on Earth is not evenly spread. Some places have a far richer diversity of animals and plants. But many such areas are under threat. These areas are known as biodiversity hotspots.**

Biodiversity hotspots are places where nature is most diverse and unique but also where it is most under pressure. Natural diversity sustains human welfare in a multitude of different ways. All of our food and many of our medicines are derived from wild species. There is also huge potential benefit from the process of biomimicry—this is the idea of copying other life forms to find solutions to, for example, engineering and design challenges. By permitting these unique areas to be damaged through deforestation, for example, and allowing species to become extinct, we risk losing these benefits that nature provides. Conserving the remaining natural habitats in these biodiversity hotspots is therefore vital not only for conserving wildlife but also for protecting humanity's future prospects.

### Caribbean Islands

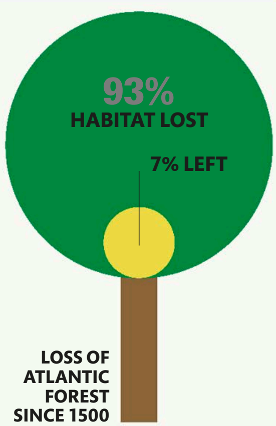
The islands of the Caribbean form a major hotspot with a range of habitats from 10,000 ft (3,000 m) peaks to low-lying deserts. They are home to 6,550 native plant species and more than 200 threatened endemic vertebrates.


## Where nature is most diverse

Conservation International has identified 35 hotspots. Together they cover only 2.3 percent of the Earth's land surface, yet more than 50 percent of the world's plant species and 42 percent of all terrestrial vertebrates are found in these areas. All of these hotspots are threatened by human activities. As a whole, more than 70 percent of the natural vegetation has already been lost. Deforestation is a major pressure, caused by the expansion of farming, logging, and mining.

### Atlantic Forest

The Atlantic Forest stretches along Brazil's coast. Long isolated from other major rain forest blocks in South America, the Atlantic Forest has an extremely diverse and unique mix of vegetation and forest types, including around 8,000 native plant species. Centuries of logging, cattle ranching, mining, and clearance for sugar cane plantations has devastated this unique habitat.




**More than 70% of natural vegetation has been lost** across 35 hotspots

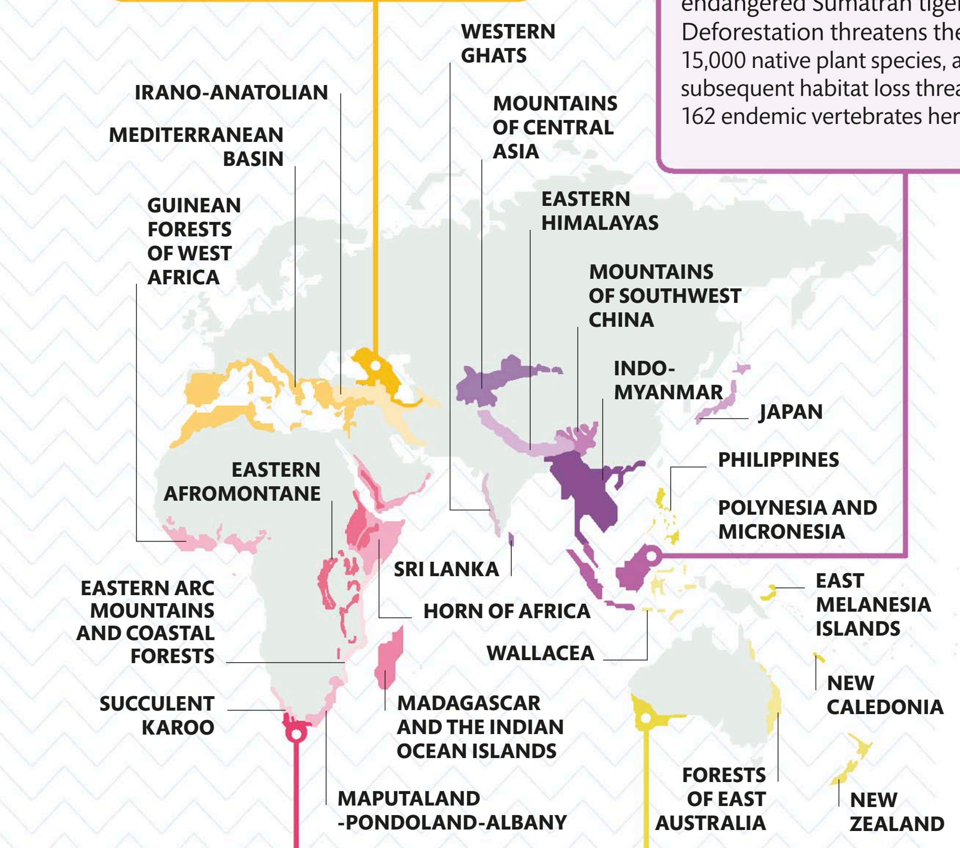
## Caucasus

This region includes a range of important habitats, such as grassland, desert, swamp forests, arid woodlands, broadleaf forests, montane coniferous forests, and shrublands. Together, they are home to around 1,600 native plant species.

## Sundaland

This western half of the Indo-Malayan archipelago has two of the world's largest islands—Borneo and Sumatra. Isolated by sea level rise, the rain forests on these and other islands support many unique species, such as the critically endangered Sumatran tiger. Deforestation threatens the 15,000 native plant species, and subsequent habitat loss threatens 162 endemic vertebrates here.

SUMATRAN TIGER




## Cape Floristic Region

On the southwestern tip of the African continent lies an exceptionally diverse region of shrublands, including the flower-rich fynbos. This unique habitat contains 6,210 native plant species.

## Southwest Australia

In this region of Australia lies a mixture of eucalyptus woodlands, thickets, scrub-heath, and heath. This supports some 2,948 plant and 12 threatened vertebrate species that occur nowhere else.

## What can we do?

- **Retaining natural habitats** in the hotspots will require the legal protection of at least the best-quality areas, with all rules adopted to protect habitats and wildlife fully enforced. It will also be necessary to find ways for farmers to make a living without encroaching into natural areas.

## What can I do?

- **Make regular visits** to areas that are protected for nature, both near to home and when you are traveling. The more that protected areas are used, whether they are diversity hotspots or not, the bigger the incentive for governments and individuals to work to keep them intact.

# Invasive Species

**The spread of species to places where they are not native can cause serious disruption to local ecosystems. The arrival of these invasive alien species can lead to the decline or extinction of native wildlife.**

At the global level, the impact of so-called invasive alien species may be as damaging to ecosystems and wildlife diversity as the effects of habitat loss and degradation. Thousands of species have already been driven to extinction by animals and plants moved around by people. Sometimes species are deliberately introduced, such as rabbits to Australia, where the damage they caused to native vegetation led to the decline of many of that continent's birds and mammals.

Other species were taken to new places inadvertently. Many flightless birds once confined to single islands have been driven to extinction because of predation by rats arriving on ships.

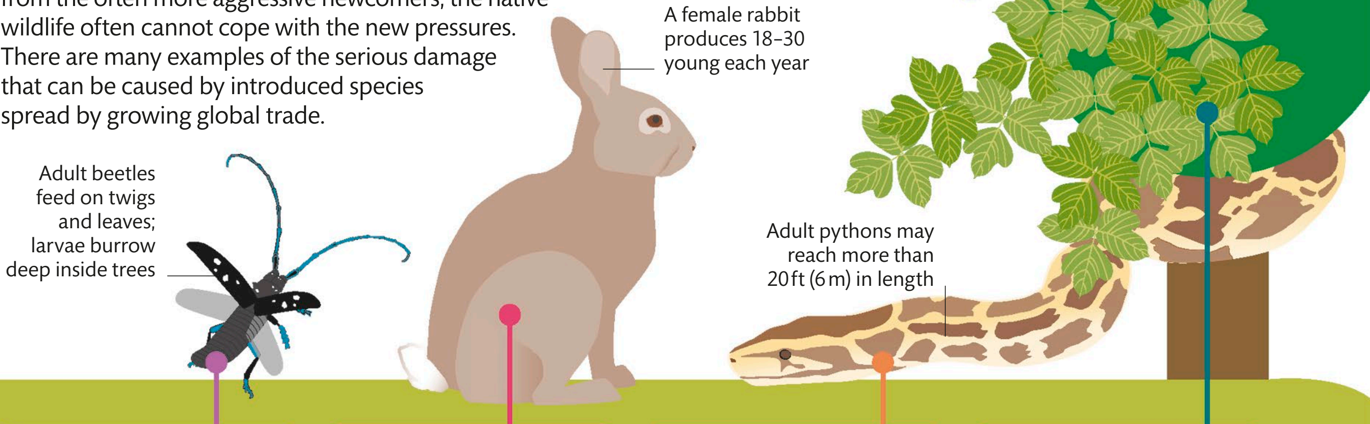

**SEE ALSO...**

› **Biodiversity Hotspots** pp168–169

› **Nature's Spaces** pp190–191


## Invasive species on land

Predation, spread of disease, and competition for food are among factors that lead nonnative species to displace native animals and plants. Evolving in isolation from the often more aggressive newcomers, the native wildlife often cannot cope with the new pressures. There are many examples of the serious damage that can be caused by introduced species spread by growing global trade.




### Asian longhorned beetle

Native to China and Korea, these insects have devastated trees in parts of Europe and in the US—where in 1996–2006 the cost of eradiction attempts was over $800 million.

### European rabbit

Rabbits have changed natural habitats across the world. They breed rapidly—24 rabbits introduced to Australia in 1894 produced 10 billion by the 1920s. They compete with native species for food.

### Burmese python

Originally escaped pets imported from South and Southeast Asia, these huge snakes now threaten rare wildlife across Florida. They predate and outcompete native species.

### Kudzu vine

These climbing vines are native to Southeast Asia but are smothering ecosystems from the US to New Zealand. The vine grows rapidly over plants and trees, creating vast monocultures.

## What can we do?

- **Countries must do more to prevent the importation of invasive species.** This can be achieved through effective trade controls, including on certain kinds of garden plants and marine species carried in ships' ballast tanks.

## What can I do?

- **Never deliberately release pets or garden plants.** Many of the most damaging alien invaders arrived via this route. Once they are out, it is often impossible to stop them from spreading.
- **Take care when disposing of garden waste.**

Every day an estimated **7,000** **species are carried around the world** in ship ballast water

# Aquatic invasive species

Ocean ships move marine wildlife around the world, in their ballast tanks that hold seawater, as well as attached to the outside of their hulls. Many rich and varied freshwater ecosystems have also been seriously damaged by invasive species. This is one reason why freshwater fish are one of the most threatened animal groups.

### Caulpera seaweed

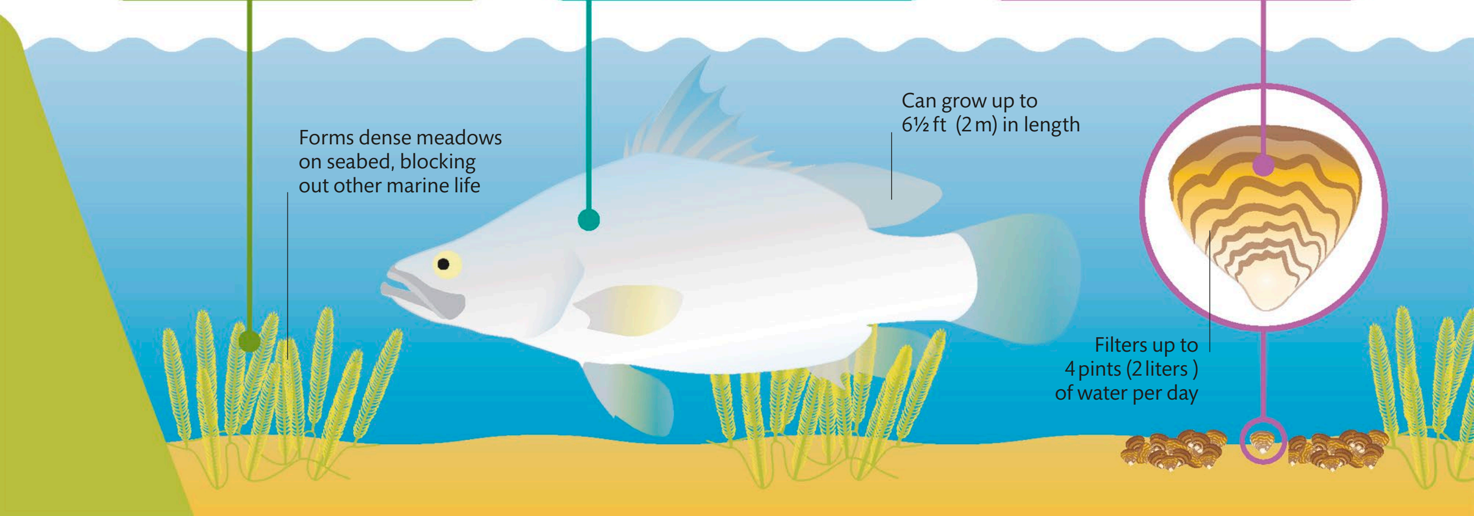
Popular marine aquarium plants, caulpera seaweeds are causing major problems across the Mediterranean, where they smother native seaweed, and invertebrates, causing the decline of many species.

### Nile perch

Native to many African rivers, the introduction of these voracious predators into African lakes caused the extinction of several hundred fish species through direct predation and competition for food.

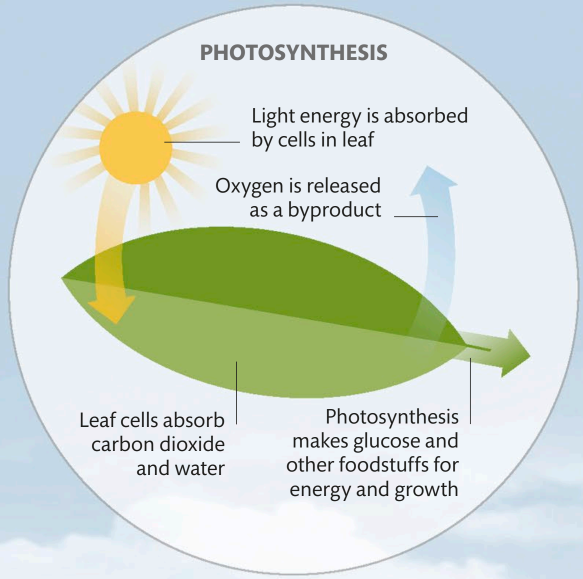
### Zebra mussel

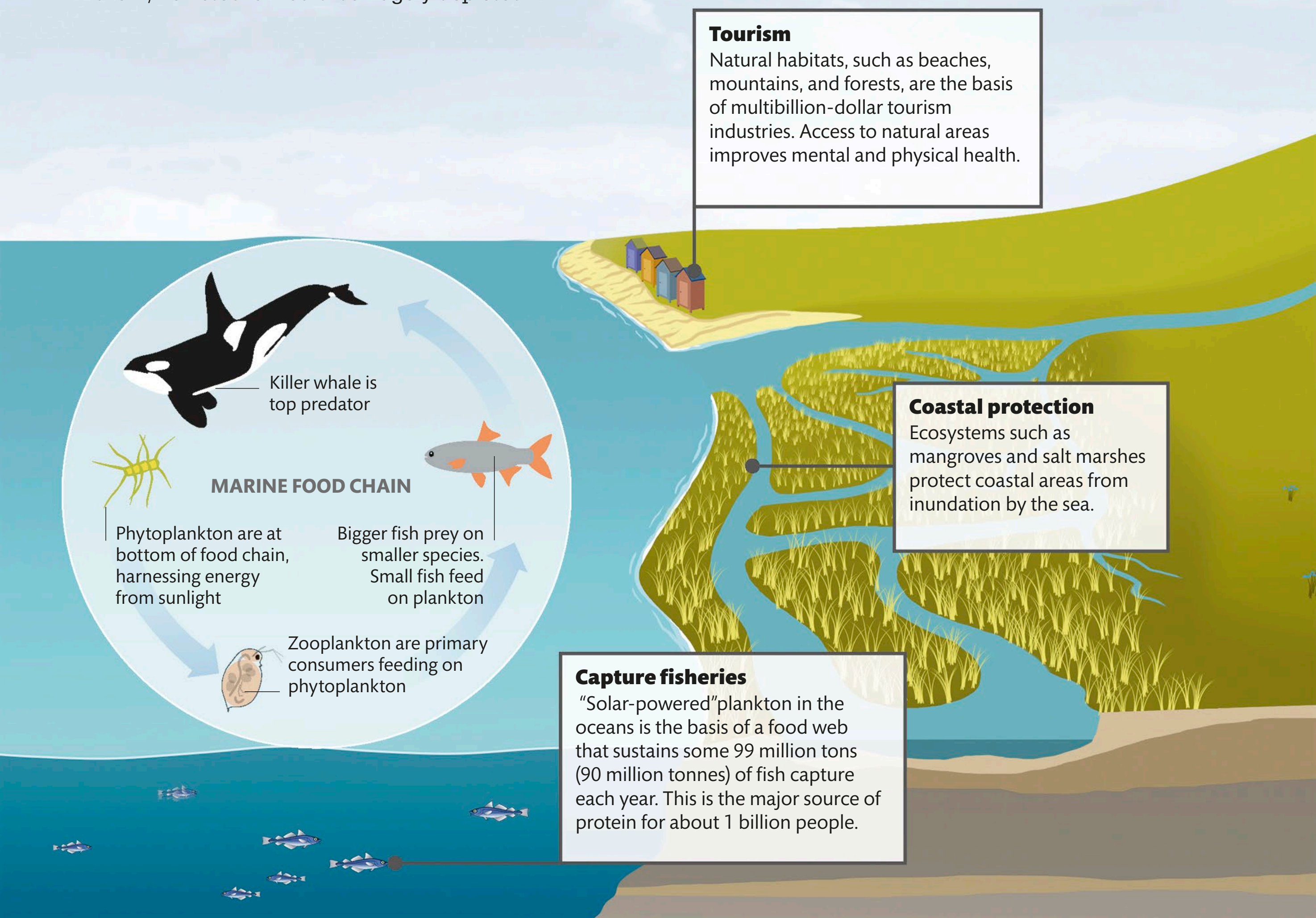
These mollusks spread from western Asia during the 1700s and reached the Canadian Great Lakes in the 1980s. They reduce numbers of phytoplankton available to fish larvae and can devastate entire food chains.

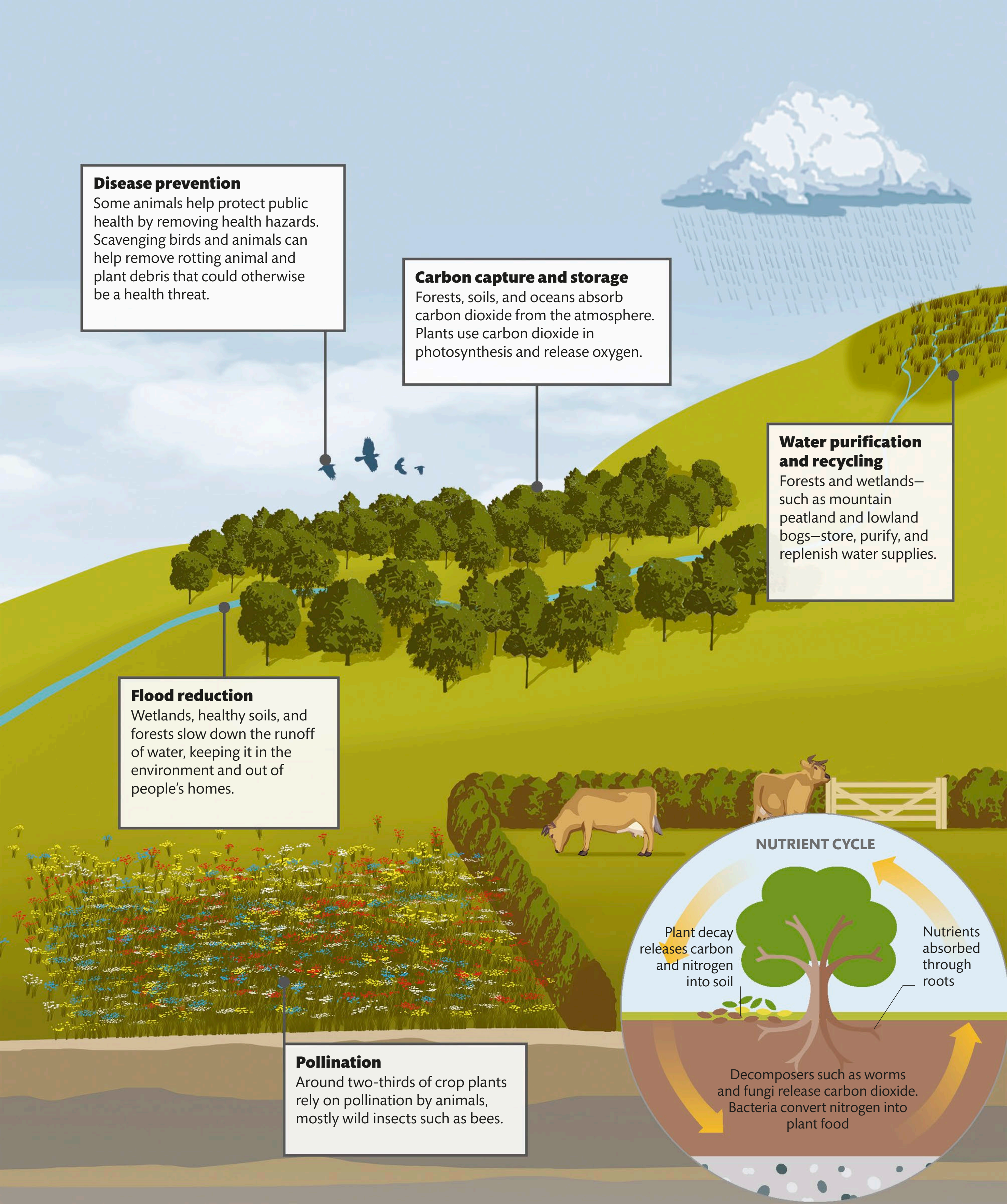


# Nature's Services

Natural systems and wild species are not only beautiful but provide a wide range of essential and economically valuable benefits. These are sometimes referred to as ecosystem services. They range from flood protection given by forests to the storage of carbon in wetlands, and from the pollination of crops by wild insects to the replenishment of freshwater by wetlands. Often, however, economic growth is achieved at the expense of the health of natural systems. For example, all of our food plants and animals, and many of our medicines, are derived from wild species. By permitting extinctions, we are closing down future opportunities for innovation in food and health care. A healthy marine food web depends on plankton—without them, fish stocks would be hugely depleted.





Disease prevention
Some animals help protect public health by removing health hazards. Scavenging birds and animals can help remove rotting animal and plant debris that could otherwise be a health threat.
Carbon capture and storage
Forests, soils, and oceans absorb carbon dioxide from the atmosphere. Plants use carbon dioxide in photosynthesis and release oxygen.
Water purification and recycling
Forests and wetlands—such as mountain peatland and lowland bogs—store, purify, and replenish water supplies.
Flood reduction
Wetlands, healthy soils, and forests slow down the runoff of water, keeping it in the environment and out of people's homes.
NUTRIENT CYCLE
Plant decay releases carbon and nitrogen into soil
Nutrients absorbed through roots
Decomposers such as worms and fungi release carbon dioxide. Bacteria convert nitrogen into plant food
Pollination
Around two-thirds of crop plants rely on pollination by animals, mostly wild insects such as bees.

# Insect Pollination

**Almost 9 in 10 species of land plants—including most crop varieties—rely on pollination by animals, especially insects, to complete their life cycles. But wild insect populations are declining, posing a risk to food security.**

Bees, wasps, hoverflies, butterflies, and beetles are among the insects that pollinate flowers, enabling plants to produce seeds and fruit. Most of the fruits and vegetables we eat rely on insects. In some parts of the world, the loss of wild pollinators has already disrupted food production, forcing farmers to resort to extreme measures, including pollinating plants by hand using paint brushes. Such cases reveal not only the crucial role of pollinators in the food chain but also their huge economic value. Their annual contribution has been estimated to be worth about $190 billion globally, including $14.6 billion in the US and $600 million in the UK.


**SEE ALSO...**

› **Nature's Services** pp172–173


## TYPES OF POLLINATORS

Insect pollination first evolved about 140 million years ago, and it plays a vital role in ecosystem function. There are several types of pollinators. Some are highly specialized, visiting just one species of plant; others are very general, feeding on a wide range of flowering plants.

***Bees***

A variety of bees undertake pollination, including bumblebees, solitary bees, mason bees, carpenter bees, and honeybees.

***Wasps***

Many of the 75,000 wasp species pollinate one particular species of plant. Some live in colonies; others are solitary.

***Hoverflies***

Adults feed on nectar and pollen while the larvae are aphid predators, making them both pollinators and pest controllers.

***Butterflies and moths***

These insects use their long proboscis to feed on nectar deep inside flowers and, in doing so, transfer pollen between blossoms.

## Threats to pollinators

In many areas of the world, wild pollinators have undergone drastic decline, mainly as a result of agriculture. Habitat loss due to farming deprives insects of food plants and breeding areas, and many pesticides are toxic to pollinators. In common with other wildlife, many pollinators are also being affected by climate change, as well as other threats, such as housing and infrastructure developments and pollution. Shown here are the principal threats to bees in Europe.

**AGRICULTURE**
The progressive intensification of farming has led to more and more species disappearing from farmed land. Pesticides have devastated some populations of insect pollinators, while herbicides have killed wildflowers, depriving pollinators of food

**POLLUTION**

Nitrogen deposition arising primarily from fertilizers causes plant diversity to decline in grasslands, wetlands, and other habitats, depriving pollinators of their food sources

**LIVESTOCK**
More intensive livestock rearing has involved the replacement of traditional hay meadows with silage production. In some countries, such as the UK and Sweden, more than 95% of flower-rich grasslands have been lost, depriving pollinators of vital habitats

### What can we do?

- **Governments could ban the most damaging pesticides**, including the neonicotinoids that are harmful to bumblebees and birds (see p69).
- **Subsidies to farmers** could be paid only on condition that farmers protect or restore pollinator habitats.

### What can I do?

- **Grow pollinator-friendly flowering plants** in your garden and leave wilder patches where insects can hibernate and breed.
- **Buy organic fruit and vegetables;** these are produced without any pesticides that can poison pollinators.

**The estimated economic value of bees and other pollinators per year is $190 billion**

**RESIDENTIAL AND COMMERCIAL DEVELOPMENT**

Urban expansion and infrastructure development reduce wild and semi-wild areas while fragmenting and further isolating those that remain

**FIRE AND FIRE SUPPRESSION**

Fire has its greatest impact on species in drier areas. Land management intended to reduce the fire risk can also reduce plant diversity

**CLIMATE CHANGE**

Heavy rainfalls, droughts, heatwaves, and alterations in the timing of seasons can adversely affect populations of insect pollinators

**OTHER ECOSYSTEM CHANGES**

Sea defenses that affect coastal habitats can impact species that are specially adapted to those habitats

**RECREATIONAL DISTURBANCES**

Tourism in wild or semi-wild areas, such as ski tourism in the Alps, can disturb natural habitats, threatening bees and other pollinators

**MINING AND QUARRYING**

Mineral extraction leads to loss of vegetation, but rehabilitated mines and quarries can provide excellent habitats for insects

**POLLINATION**

Bees and other pollinators transfer pollen from one flower to another, enabling the plants to reproduce

## The importance of bees

Healthy diets include a diverse range of fruit and vegetables. Maintaining a secure supply of such produce into the future will depend on healthy insect populations. Domesticated honeybee hives can play some role, but many crops rely primarily on other species, such as wild bumblebees; in the UK, for example, at least 70 percent of crop pollination is carried out by wild insects.

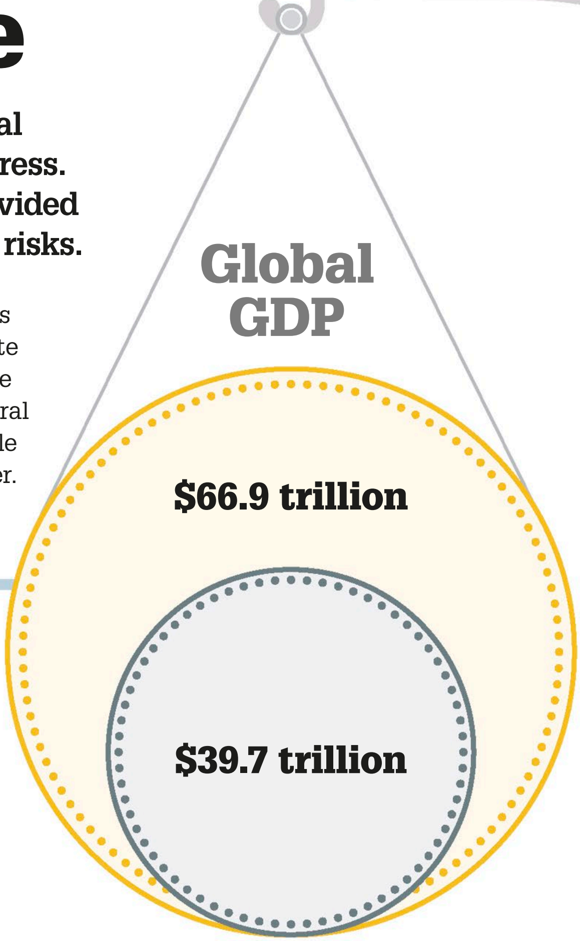
**Pollinating by hand**

In parts of southwestern China, the destruction of wild pollinators with pesticides means that fruit growers must pollinate blossoms by hand.

# Value of Nature

**It is often assumed that environmental damage is an inevitable price of progress. However, the loss of free services provided by nature is creating major costs and risks.**

Nature provides a wide range of essential services that sustain development. It is possible to estimate the financial value of these, such as the work done by bees in pollinating crops, the importance of coral reefs in protecting coasts from storms, and the role of wetlands and forests in replenishing freshwater. The economic value of natural services is vast and estimated to be worth more than global GDP.




## Nature's bounty

Work by US environmental economist Robert Costanza and colleagues has revealed the value of nature and how the financial value of ecosystem services changed between 1997 and 2011. A range of valuation methods were used, but this research demonstrates how nature's annual contribution is bigger than world GDP. These findings reveal that the continuing development of human societies depends directly on the health of nature. The more we damage ecosystems, the bigger the costs to human societies in replacing what nature once did for free.

### What can we do?

- **Governments and companies** can gather information on their impact on and their dependence upon natural assets. This information can shape economic decisions to improve, rather than decrease, the health of vital ecosystems.

> **"Without land, the rivers, the oceans,** the forests... and thousands of natural resources **we would have no economy whatsoever."**
>
> **SATISH KUMAR, INDIAN ECOLOGICAL CAMPAIGNER**

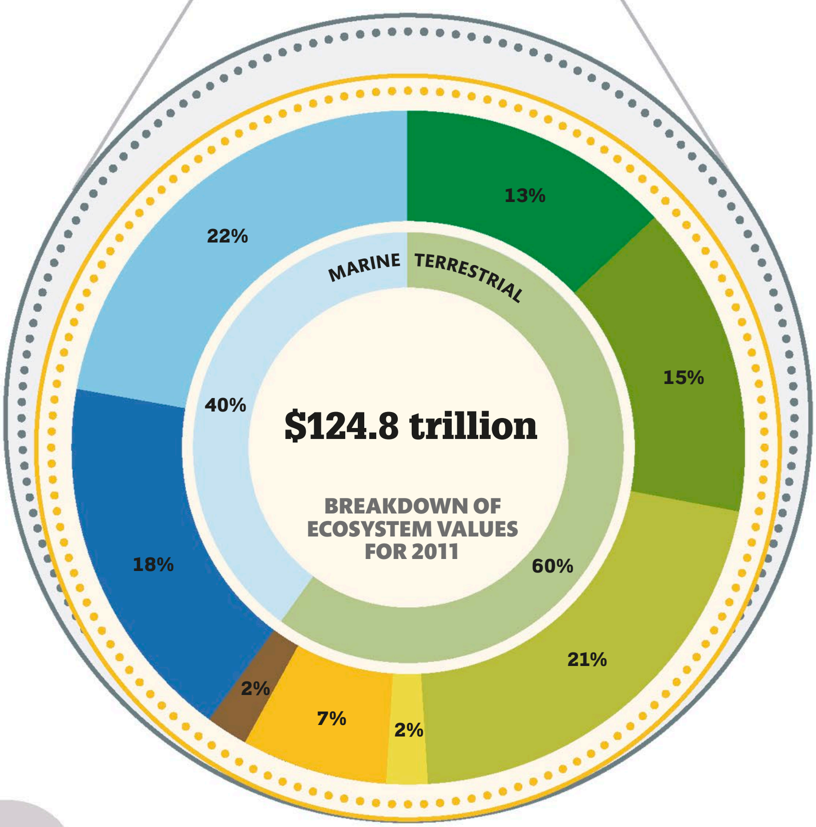
## Natural systems

All around us ecosystems and wild species help sustain human welfare. Carbon dioxide is removed from the air by forests, which helps slow climate change. Wild fish stocks are replenished by solar-powered food webs that begin with plankton and provide nutrition and jobs. New drugs and crop varieties are being developed with genetic material found in wild species. The contribution of nature is shown in estimates by Costanza and his team.

**Value of GDP**
While countries seek growth in GDP, the declining health of nature is absent from economic calculations. As ecosystems are destroyed and degraded, the value we get from them is declining.

**KEY (2007 US$)**
1997
2011

# Global value of nature




**KEY**

**FOREST**
The economic value of forests is more than $16 trillion per year. Forests replenish oxygen, supply water, and are home to most land species.

**GRASSLANDS**
Different kinds of grasslands are estimated to deliver more than $18 trillion in value, through sustaining most of the world's livestock.

**WETLANDS**
These help reduce flood risk, capture carbon, and purify water. Wet ecosystems deliver more than $26 trillion in value.

**LAKES AND RIVERS**
Our water supplies depend on lakes and rivers being replenished: an annual economic contribution in excess of $2 trillion per year

**CROPLAND**
The croplands that grow our food depend on soils supplying nutrients to plants. They provide services worth more than $9 trillion per year.

**URBAN**
Seminatural environments in towns and cities provide valuable services. The global value of these per year is more than $2 trillion.

**OPEN OCEAN**
This global asset provides services worth nearly $22 trillion per year, including ocean plants that produce much of Earth's oxygen.

**COASTAL**
Ecosystems lying where sea meets the land provide $28 trillion worth of services, such as tourism and protection from storms.

“**The core values** that underpin sustainable development—**interdependence, empathy, equity, personal responsibility, and intergenerational justice**—are the only foundation upon which any **viable vision of a better world** can possibly be constructed.”

SIR JONATHON PORRITT, BRITISH ENVIRONMENTALIST AND WRITER

**The Great Acceleration**

**What’s the Global Plan?**

**Shaping the Future**

# 3 BENDING THE CURVES

A wide range of initiatives is in place to address interrelated global challenges, but if we are to achieve a secure and sustainable future, far more will be needed.

# The Great Acceleration

**The pressures exerted by humankind on planet Earth have led to fundamental changes to the atmosphere, ecosystems, and biodiversity while depleting many resources. Further population and economic growth are driving the demand that is behind continuing changes, many of which are interconnected. The scale of human activity is so big as to become the most influential factor shaping life on Earth. Scientists believe that we have entered a new geologic era—the Anthropocene—a period in which people have become a defining global force.**

## A new era: the Anthropocene

The point at which the Anthropocene began is subject to debate. Some suggest it began during the Pleistocene, up to 50,000 years ago, when humans caused the extinction of many large mammals. Others suggest that it coincides with the rise of agriculture. There is a strong argument for the industrial revolution as the point from which to start the new epoch, since it ushered in an unprecedented global impact on the planet. Equally, some argue it began when the first atomic bomb was detonated, leaving a global radioactive human fingerprint. There is increasing agreement, however, that the 1950s is the best place to mark the start of the Anthropocene. This was the start of a unique period, called the Great Acceleration, when many human activities reached takeoff points and sharply accelerated toward the end of the century.

**50,000 YEARS AGO**
**Groups of hunter-gatherers target large mammals for food and other resources, including skins and bones.**
Although climate changes that accompanied the end of the last Ice Age played a part, it has been estimated that about two-thirds of the many large mammal extinctions that took place in this period were caused by humans.

**8,000 YEARS AGO**
**The near simultaneous rise of agriculture and cities marked a sudden change in human impacts.**
Hunter-gatherer societies lived close to nature in the ecosystems they depended upon. Farmers feeding urban populations made fundamental changes to their environment, including forest clearance, which caused carbon dioxide ($CO_2$) levels to rise, while the builders of cities relied on systematic large-scale resource extraction.

**5,000–500 YEARS AGO**
**Soil changes created by human activity spread widely across the world with the rise of agriculture.**
Some changes were deliberate and aimed at improving soil quality. Other impacts were inadvertent and led to soils being damaged to the point where they stopped producing crops.

**1610**
**A drop in atmospheric $CO_2$ concentration coincides with forest regrowth.**
The mass mortality of indigenous peoples in tropical rain forest regions, caused by slavery and diseases brought by newly arrived Europeans, meant fields reverted to forests, which removed $CO_2$ from the air.

## Rising trends

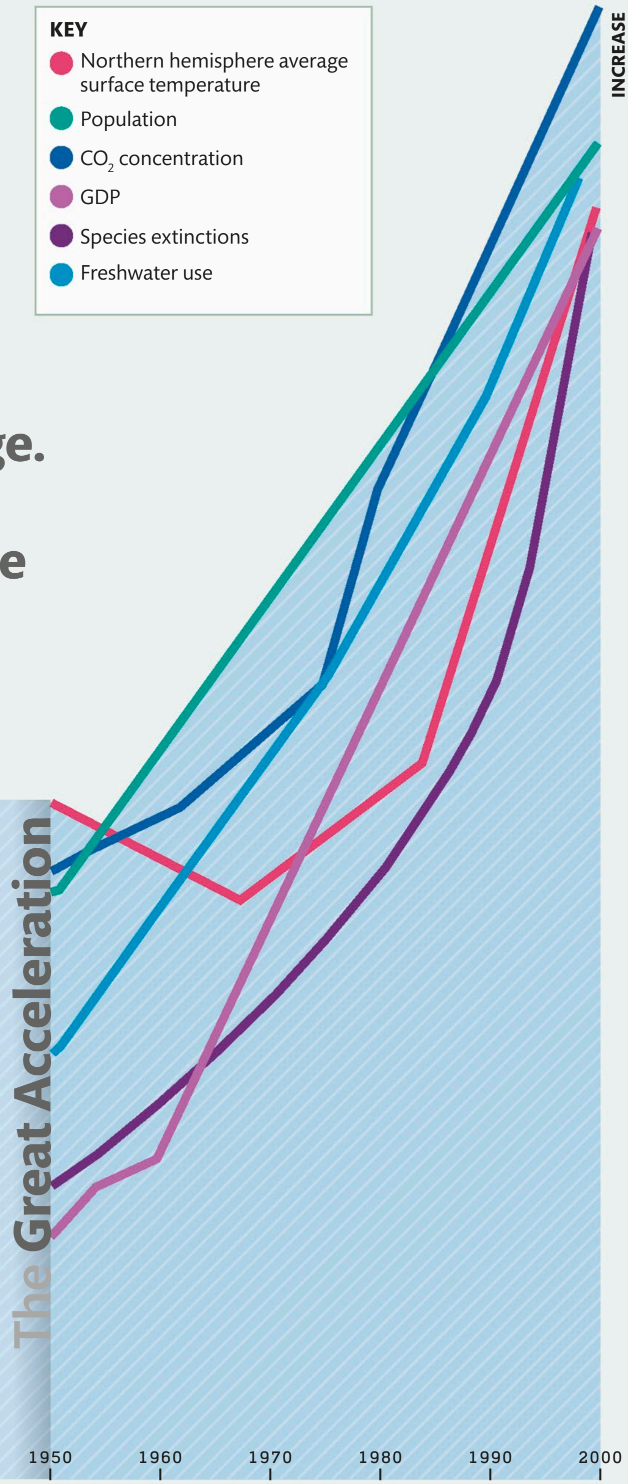
When researchers plotted various trends reflecting rising human demands and impacts, they expected the curves to begin going up sharply from the start of the industrial age, during the 1700s or 1800s. They found, however, that all these and many other trends really took off during the middle of the 20th century. The Great Acceleration that began in the 1950s and continues today is perhaps the correct point from which to mark the start of the Anthropocene.

> "It is difficult to overestimate the **scale and speed of change.** In a single lifetime, **humanity** has become a **planetary-scale geological force.**"

**WILL STEFFEN, EXECUTIVE DIRECTOR OF THE INTERNATIONAL GEOSPHERE-BIOSPHERE PROGRAMME**

**LATE 1700s**
**The industrial revolution begins in England but soon spreads across Europe and to North America.**
The large-scale combustion of fossil fuels begins, and there is a sharp increase in demand for other natural resources. Industrialized farming follows in its wake. It took more than 200 years for industrialized development to spread across the globe.

**1950**
**The Great Acceleration: the beginning of rapid growth in many areas.**
Following the first nuclear bomb detonation, the Great Acceleration marks the rise of truly global impacts caused by people on planet Earth. In addition to leaving a radioactive marker in sediments across the world, climate change, ocean acidification, widespread soil damage, and a mass extinction of species accompany the sharp increase in human influence.



# Planetary Boundaries

**The degradation of the Earth's systems poses increasing risk to human societies. Scientists have identified a number of planetary "boundaries" that if breached could lead to potentially disastrous consequences.**

## Crossing boundaries

An international team led by scientists at the Stockholm Resilience Centre has set out nine "planetary boundaries" that are believed to be key to the health of our planet. The boundaries relate to global trends, including climate change, ozone depletion, ocean acidification, freshwater use, and biological diversity. The colors depicted here represent the level of risk for each area. Green indicates that to date the risk falls below the boundary—in other words, not presently a globally systemic threat. Yellow is the zone of uncertainty where risk is increasing. Red has gone beyond uncertainty and shows a high risk. Gray is an aspect that has not yet been quantified.

### EARTH BUDGET

Human demand is now far larger than what the Earth can indefinitely sustain. Many large economies use more resources than can be provided within their own borders. For example, Japan needs five times its own area to sustain current consumption. China and the UK are also among countries demanding more than can be provided from their own territory.

**CHINA** 2.7

**UK** 3

**WORLD AVERAGE** 1.6

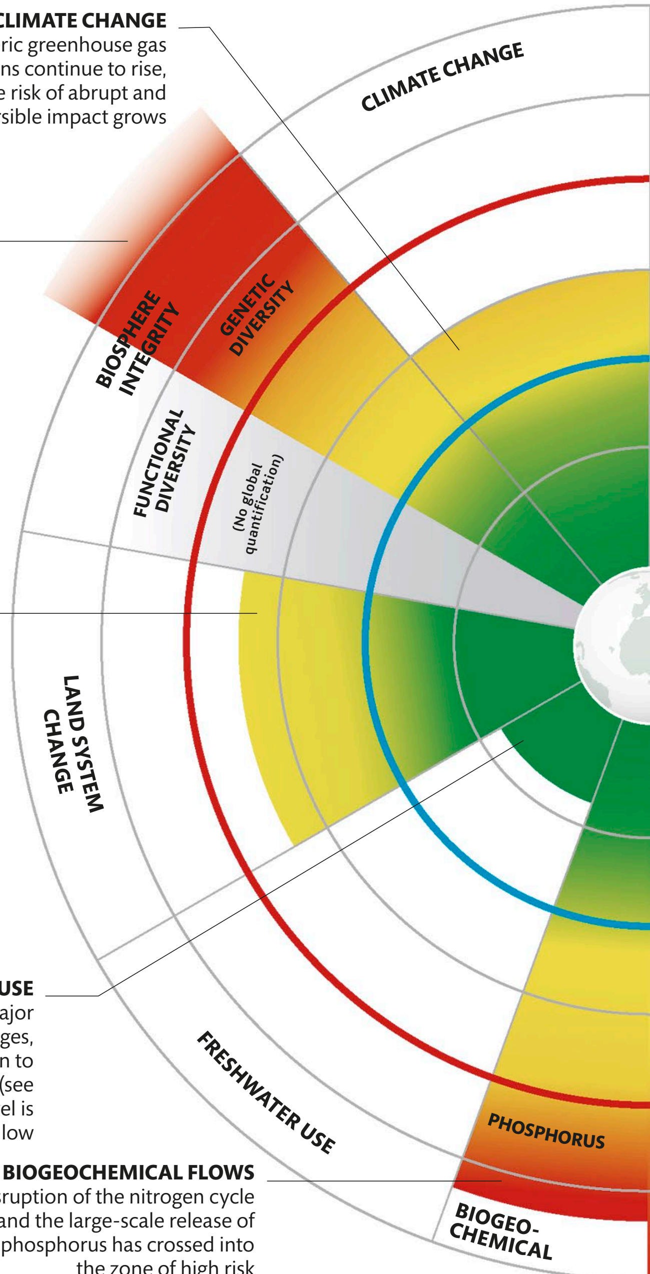
**CLIMATE CHANGE**
Atmospheric greenhouse gas concentrations continue to rise, and the risk of abrupt and irreversible impact grows

**BIOSPHERE**
Ecosystem damage has taken on global proportions, in the process increasing the risk of abrupt and irreversible impact (see Genetic diversity panel, opposite)

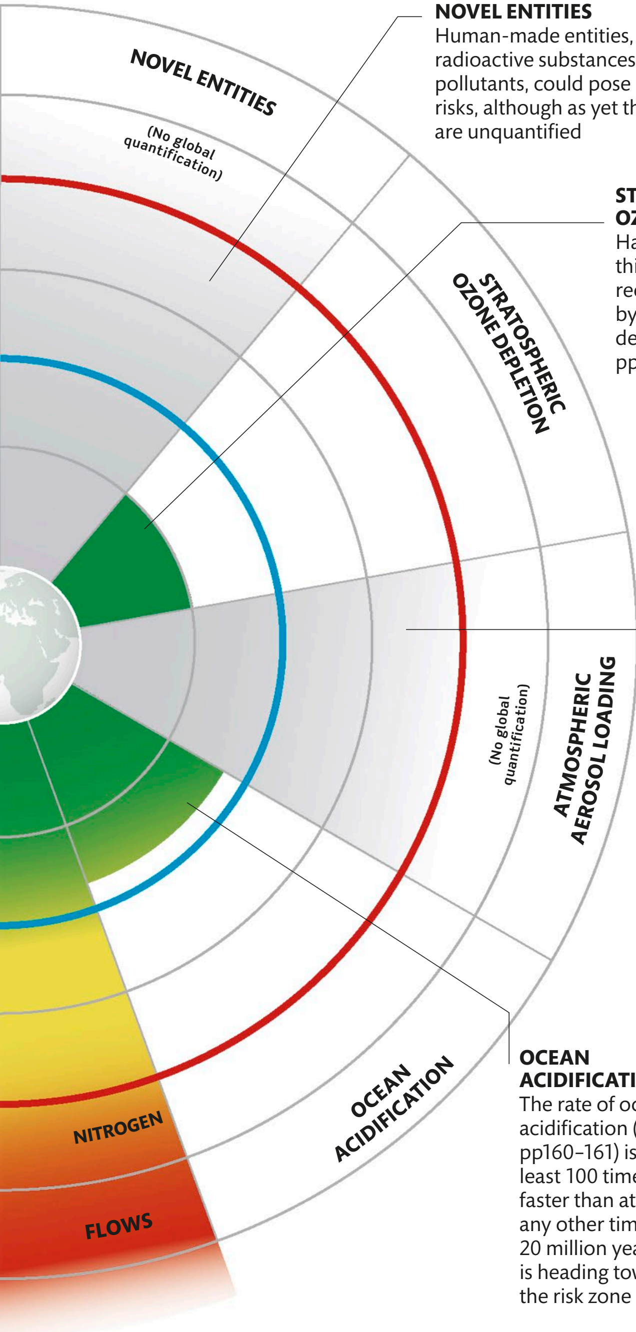
**LAND SYSTEM CHANGES**
The global-scale conversion of natural habitats, especially deforestation to make way for farming (see pp150–151), has pushed us into the zone of increasing risk

**FRESHWATER USE**
Although there are major local and regional challenges, the current risk of disruption to the freshwater cycle (see pp80–81) at a global level is regarded as low

**BIOGEOCHEMICAL FLOWS**
Disruption of the nitrogen cycle and the large-scale release of phosphorus has crossed into the zone of high risk (see panel, opposite)



It is important to identify those planetary pressures that have become most acute and pose potentially catastrophic risks to humankind. This can help us prepare for significant change and prioritize resources toward meeting the most pressing challenges. The nine key areas shown here relate to global changes. In many places, local changes are already into the zone of high risk.




**NOVEL ENTITIES**
Human-made entities, such as radioactive substances and persistent pollutants, could pose global risks, although as yet these are unquantified

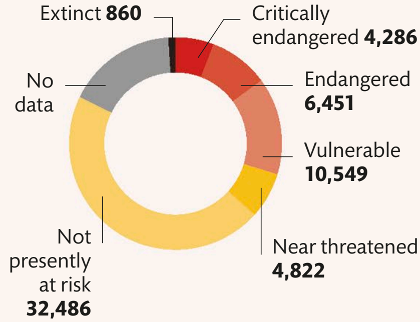
**STRATOSPHERIC OZONE DEPLETION**
Having previously crossed this boundary, humankind reentered the low risk zone by phasing out ozone depleting chemicals (see pp122–123)

**AEROSOLS**
Particles in the atmosphere that impact on climate and human health could have global implications; as yet not quantified

**OCEAN ACIDIFICATION**
The rate of ocean acidification (see pp160–161) is at least 100 times faster than at any other time for 20 million years; it is heading toward the risk zone

## Genetic diversity

Ecosystems have been changed more rapidly in the past 50 years than at any other time in human history. One indicator is the rising number of species threatened with extinction. More than a quarter so far assessed are deemed at risk.




## Fertilizer use

Human interference with the nitrogen cycle and phosphorus "flows" has brought change to many lakes and marine environments, causing ecological collapse. The main source of these nutrients is fertilizer application in agriculture (see pp66–67). This map shows the link between high nitrogen application and agricultural zones.

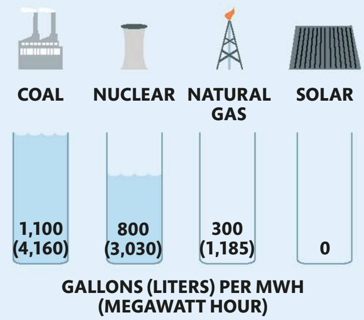
# Interconnected Pressures

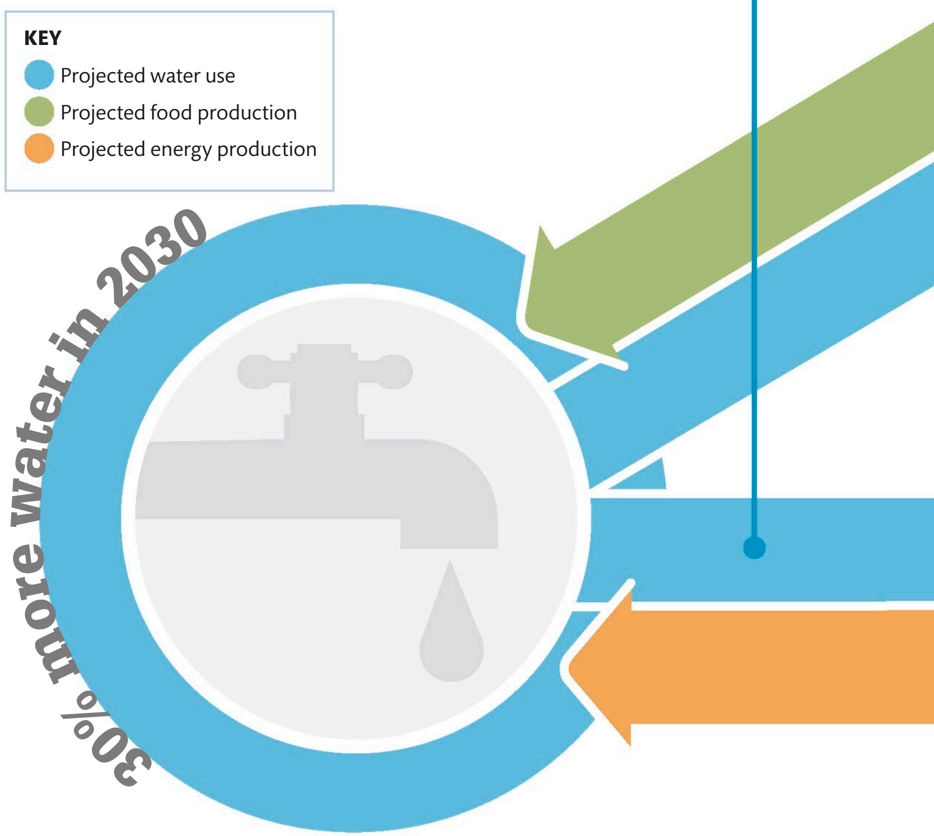
**Rising demand for food, energy, and water presents great challenges, but less obvious are the connections between them. Energy and water produce food, water produces energy, and energy cleans and supplies water.**

During 2008, food prices rose significantly, increasing the number of hungry people in the world by an estimated 100 million. This sparked social unrest and led many countries to restrict exports of staple foods. Two of the main reasons for this situation were the unprecedented high price of oil and gas and the droughts affecting major food-producing areas. The future security of human societies depends on finding solutions that recognize the clear links between food, water, and energy. The avoidance of waste and the efficient use of energy, food, and water are essential.

### Water for power

Water is vital for many different sources of power production, especially coal and nuclear, where it is used for cooling. Renewable technologies, such as solar photovoltaic, do not need any water.




## Linked demands

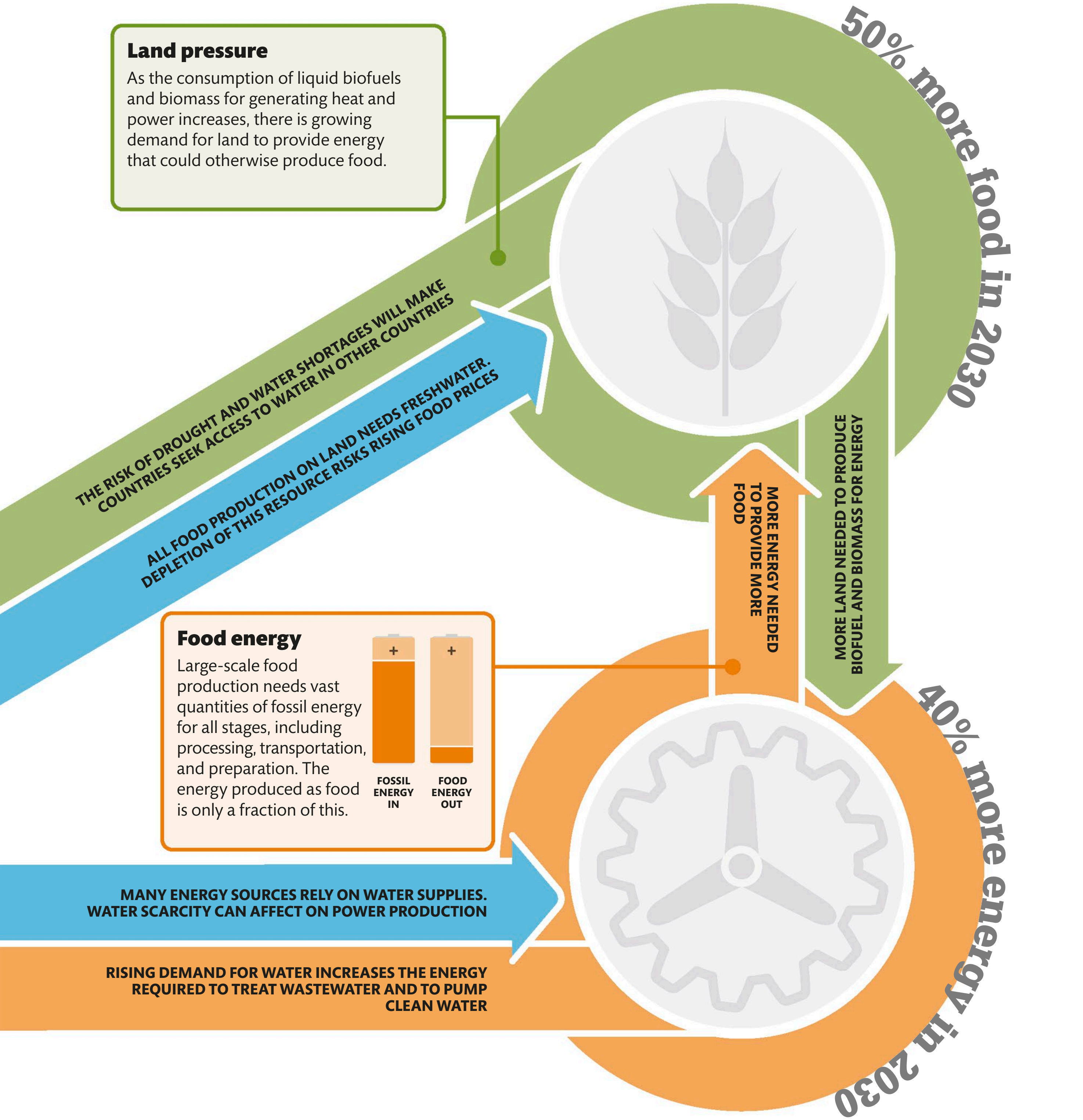
It is estimated that by 2030 the world will need 30 percent more water, 40 percent more energy, and 50 percent more food. Meeting these rising demands will be individually challenging, but the pressures emerging between them have been described as potentially creating a "perfect storm." This graphic shows some of the implications of the growing demand for food, energy, and water and how the increased consumption of one has implications for the others.

### Land pressure

As the consumption of liquid biofuels and biomass for generating heat and power increases, there is growing demand for land to provide energy that could otherwise produce food.

### Food energy

Large-scale food production needs vast quantities of fossil energy for all stages, including processing, transportation, and preparation. The energy produced as food is only a fraction of this.



# What's the Global Plan?

**Recognizing the limited ability of individual countries to solve many environmental problems, intensive efforts have been devoted to negotiating and implementing various multilateral environmental agreements (MEAs). These are formal legal accords between countries to manage collective challenges that no one country can meet on its own. Countries signing multilateral agreements undertake to implement commonly agreed rules and meet targets linked with different environmental challenges.**

## Rise in MEAs

During the last century, the number of international environmental treaties, protocols, and other agreements has grown, especially during the 1970s, '80s, and '90s. While some agreements have been highly successful in galvanizing coordinated responses, many have struggled to meet their aims. Some have attracted support steadily over time, but others have achieved very rapid sign-up from countries. For example, when countries realized the serious risks and threats posed by the loss of the Earth's natural diversity, support for the Convention on Biological Diversity quickly grew.

**KEY**

**World Heritage Convention**
Adopted at UNESCO's General Conference in 1972 to stem threats to natural and cultural heritage sites.

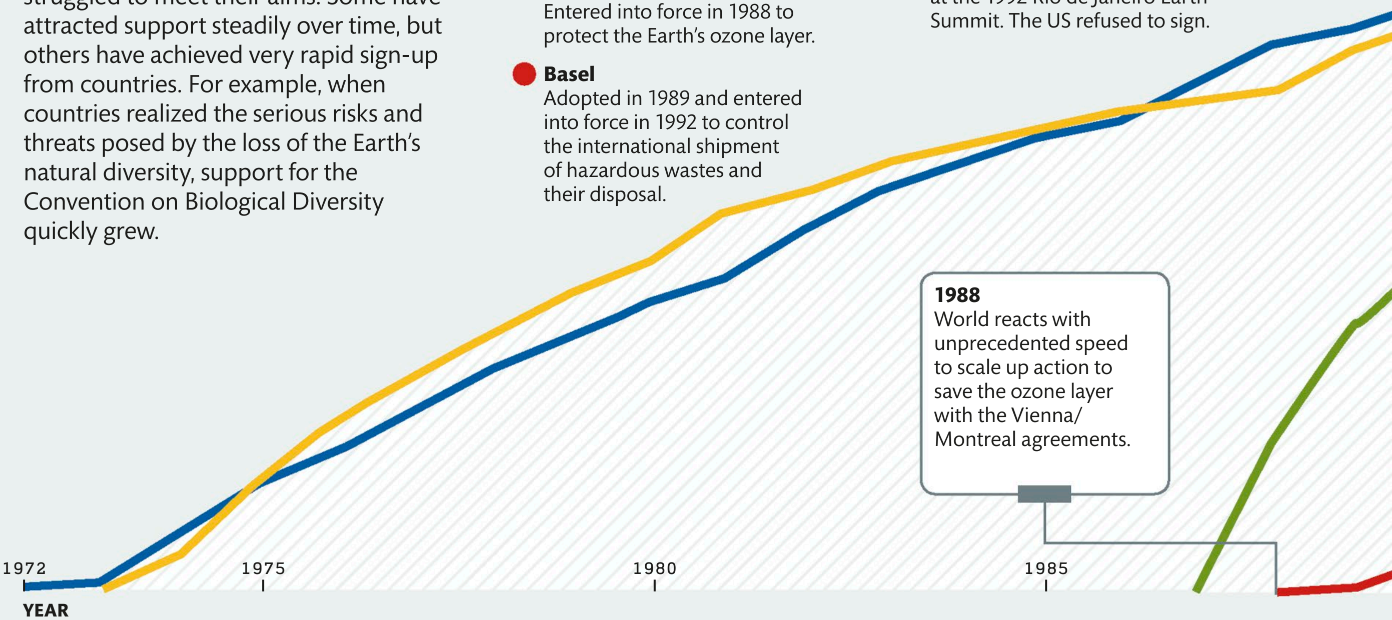
**CITES**
Agreement adopted in 1973 and entered into force in 1975. Aims to protect species that are traded.

**Vienna/Montreal**
Entered into force in 1988 to protect the Earth's ozone layer.

**Basel**
Adopted in 1989 and entered into force in 1992 to control the international shipment of hazardous wastes and their disposal.

**UNFCCC**
United Nations Framework Convention on Climate Change (UNFCCC) and Kyoto Protocol. Convention agreed in 1992 and Protocol in 1997. Paris Agreement 2015.

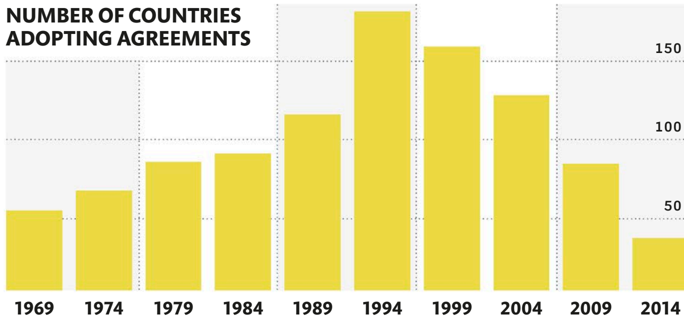
**CBD**
United Nations Convention on Biological Diversity (CBD). Agreed at the 1992 Rio de Janeiro Earth Summit. The US refused to sign.

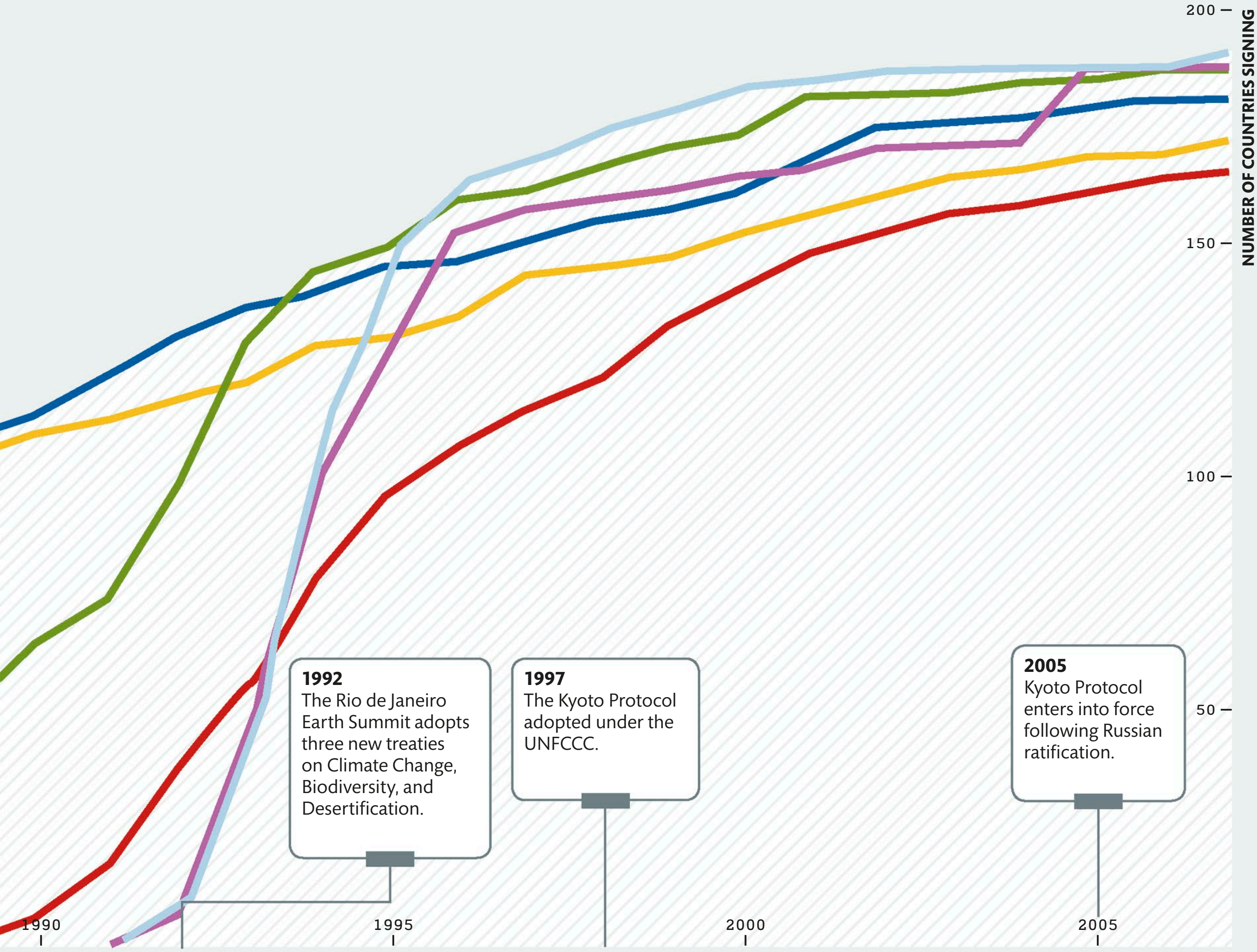


## MULTILATERAL ENVIRONMENTAL AGREEMENTS

During the last century, hundreds of new international environmental agreements have been reached. Most are technical amendments to existing plans; others are major new treaties. Over time, as more and more MEAs have been adopted, the rate of new ones being agreed has gone down. It is not for want of new agreements that the world struggles to make progress but more the effective implementation of what is already there.

**NUMBER OF COUNTRIES ADOPTING AGREEMENTS**



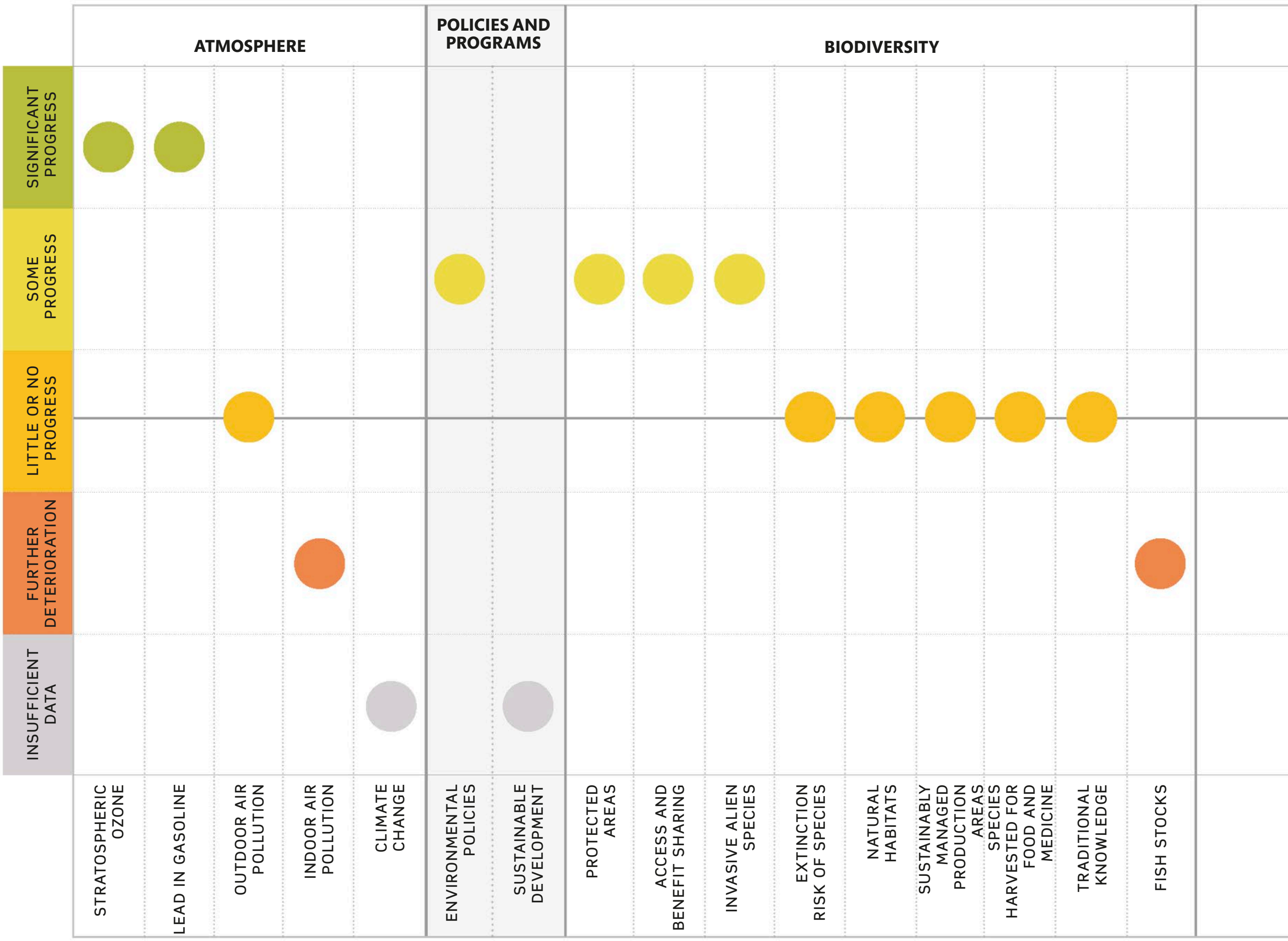
# What Is Working?

**Hundreds of different environmental and social treaties and agreements have been adopted internationally. However, more progress has been made in relation to social goals than environmental ones.**

Plans to bring about the well-being of people have resulted in environmental measures taking a back seat. Improving health and nutrition have so far, for example, been more successful than action on climate change and conservation. The disparity in the performance of different treaties is linked to a wide range of factors, including the demands of the core aims, mixed political backing, available funding for implementation, and possible conflict with wider economic goals.

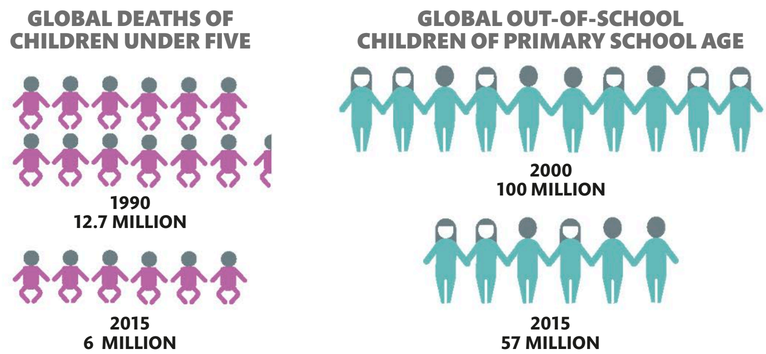
## Limits of progress

In 2012, the United Nations Environment Program (UNEP) published an assessment on the effectiveness of environmental treaties. This chart reveals the successes and failures. Only three environmental aims made significant progress—to phase out ozone-depleting substances (see p123), remove lead from vehicle fuel, and improve access to clean drinking water.



## MILLENNIUM DEVELOPMENT GOALS

Progress toward meeting international social targets has been more successful. The Millennium Development Goals agreed by the United Nations in 2000 set out to reduce extreme poverty, give more children an education, promote gender equality, and reduce child mortality. Across the developing world, political cooperation and international assistance have pursued these targets with impressive results.




# Nature's Spaces

**The last 50 years have seen a huge increase in the number of national parks, nature reserves, and other protected areas. While this is a positive trend, there are still many challenges to overcome.**

Investment in large, high-quality, and connected areas of natural habitat on land and in coastal and marine areas is vital to minimize the extinction of wild species. In 2010, world governments pledged to increase protected areas as part of the Aichi Biodiversity Targets. However, this will not be enough on its own. Other steps—for example, sustainable farming, enforcement of antipoaching laws, pollution prevention, and effective action on climate change—are critical for nurturing nature's spaces. Protected areas must also be managed effectively. One recent survey found that only 24 percent were under "sound management." Experts also conclude that the current protection is insufficient to safeguard the full range of species and ecosystems. Little of the open ocean is protected, and habitats including tropical coral reefs, seagrass beds, and peat lands need particular attention.

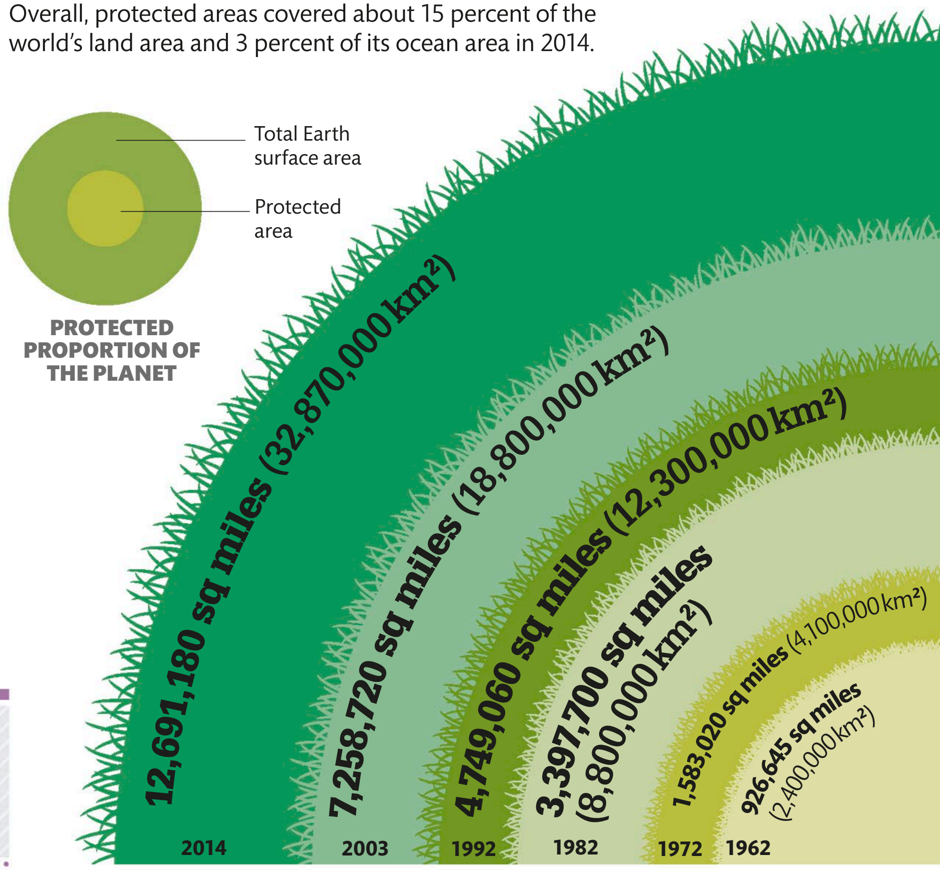

**SEE ALSO...**

❯ **Nature's Services** pp172–173

❯ **The Value of Nature** pp176–177


## Growth of protected areas

Since 1962, the number of protected sites has increased more than 20-fold globally and the total protected area has increased about 14-fold, to more than 209,000 sites covering an area of nearly 13 million sq miles (nearly 33 million sq km) in 2014. Overall, protected areas covered about 15 percent of the world's land area and 3 percent of its ocean area in 2014.




**Protection timeline**

The legal protection of land for conservation purposes started in the mid-19th century. Countries have also enacted progressively stronger laws for the protection of individual species.

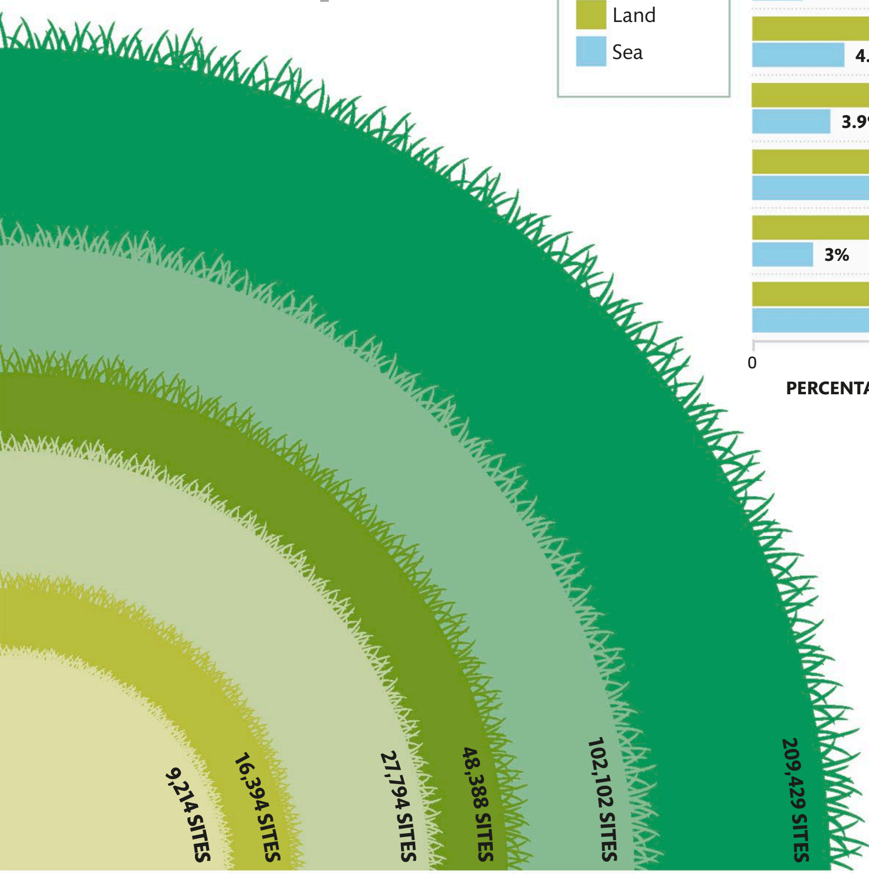
**1864** Yosemite Grant Act passed by US President Abraham Lincoln establishing first major modern protected area

**1872** Yellowstone National Park, California, the world's first national park, established

**1948** The IUCN, then called the International Union for the Protection of Nature (IUPN), founded

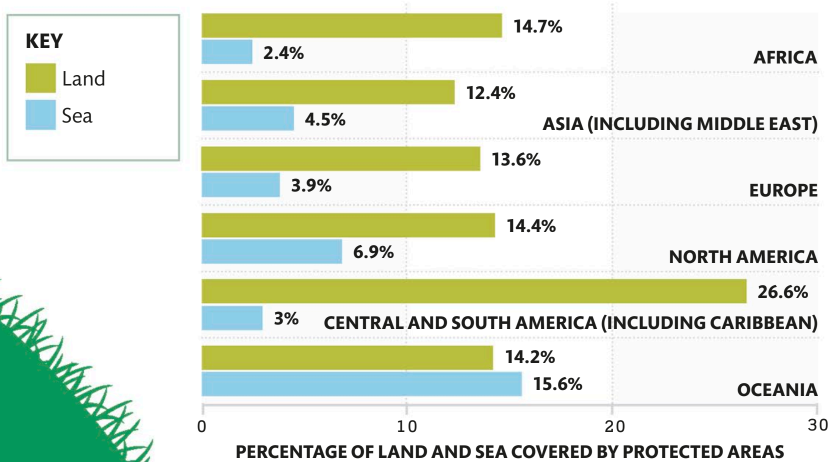
**1958** The IUCN establishes provisional National Parks Commission

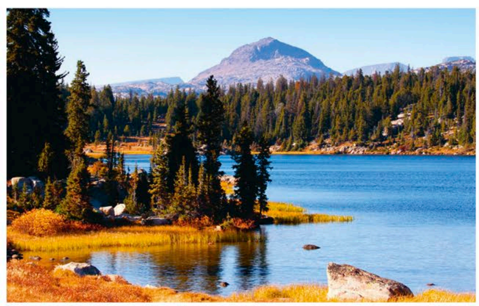
# 15%
## of Earth's land surface is in some form of nature reserve or national park




## The regional picture

All regions of the world have designated protected areas, but many are not properly implemented. Scientists have determined that it would cost about 0.12 percent of global GDP to rectify this, as well as to enforce other conservation measures. Meanwhile, the global cost of environmental damage is estimated at about 11 percent of global GDP.



**First in the world**
The iconic Yellowstone National Park was established in 1872. Today it protects one of the last remaining nearly intact temperate zone ecosystems on Earth.

**1962** First World Parks Congress, a global forum on protected areas, held in Seattle, Washington

**1972** United Nations Environment Program and World Heritage Convention established

**1982** Third World Parks Congress focuses on protected areas and sustainable development

**1992** UN Convention on Biological Diversity (CBD) treaty agreed at Rio de Janeiro Earth Summit

**2010** CBD adopts Aichi Biodiversity Targets to halt loss of biodiversity

**2015** UN Sustainable Development Goals adopted (see pp198–199), including targets for the protection of nature

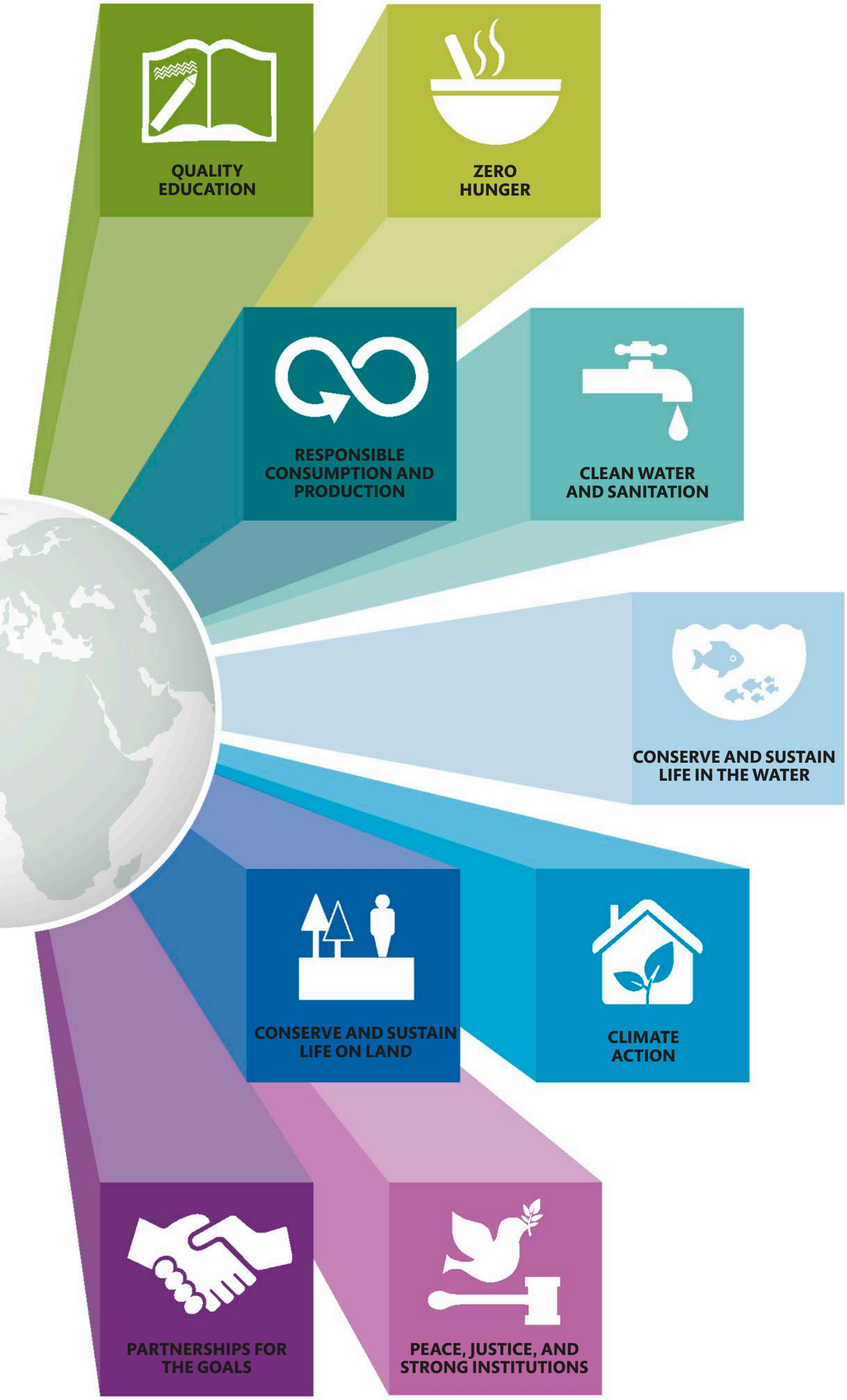
# New Global Goals

**The Millennium Development Goals (see p189) expired in 2015. New action was needed to set out a framework for meeting environment and development challenges until 2030 and to lay the foundations for a more secure future.**


The world first committed to the goal of sustainable development at the Earth Summit in Rio in 1992, but societies everywhere struggled to embed its central idea of meeting the needs of the present without compromising the needs of future generations. Instead, economic growth and progress toward social goals were promoted at the expense of environmental assets and climatic stability. Then, in 2000, a set of Millennium Development Goals (MDGs) were adopted (see p189). These aimed to reduce poverty and hunger but did not address the causes of poverty, and they made no mention of human rights or economic development. In 2012, countries—with the support of campaign groups and major international companies—agreed to embark on a process to establish a new set of goals.

This culminated in a new framework agreed at the United Nations General Assembly in 2015. A key challenge for the new Sustainable Development Goals (SDGs) will be to achieve social and environmental outcomes at the same time, rather than advancing one at the expense of the other.

**193 nations** have signed on to the **Sustainable Development Goals**




## What are the goals?

The 17 SDGs focus on discrete challenges but are all linked. They are concerned with human well-being, envisaging a world free of poverty and hunger, where everyone has access to education, health care, and social protection, and to affordable and sustainable energy. They also address human rights and human dignity. The goals are designed to build a more just, equitable, tolerant, and socially inclusive world. Above all, they are concerned with sustainability and the building of a world in which every country enjoys inclusive and sustainable economic growth and decent work for all, while also protecting the environment and conserving biodiversity.

### What can we do?

- **Urge governments** across the world to adopt ambitious plans for full implementation of the new Sustainable Development Goals.

### What can I do?

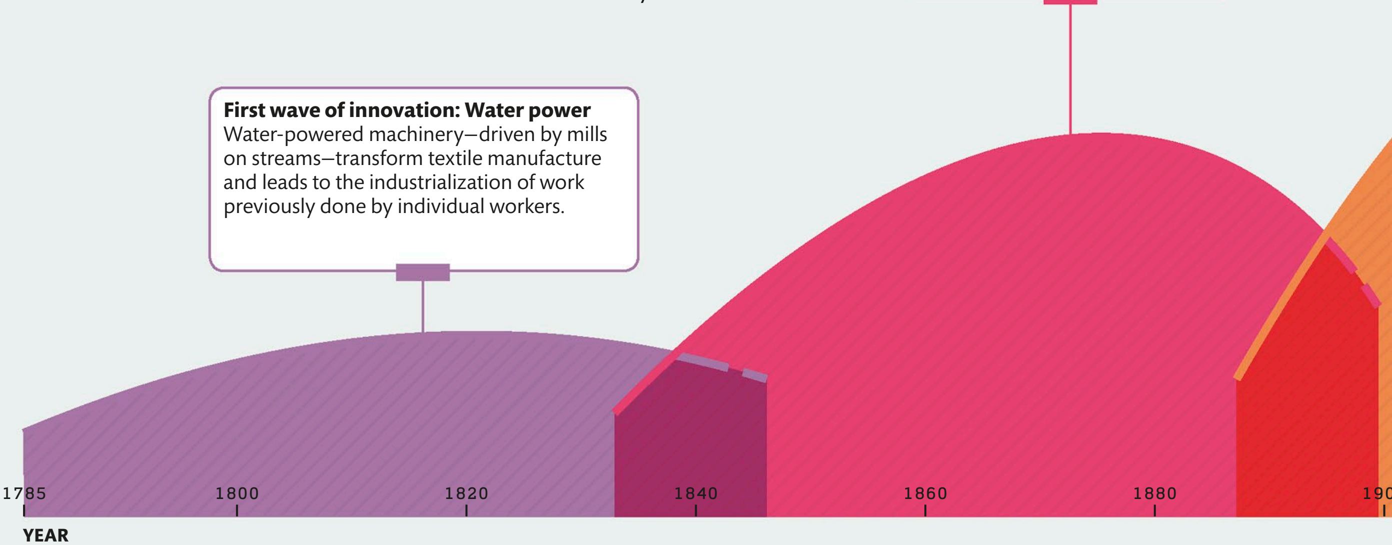
- **When buying products and services** from international companies, choose those whose policies support the achievement of the goals.

# Shaping the Future

**Since the start of the first industrial revolution, successive waves of invention have driven economic development and led to improved living conditions for billions of people. Many factors have shaped innovation. These include access to natural resources, the strength of the societies that develop new technologies, the role of government in encouraging innovation, levels of education, and how existing technologies provide springboards for new invention. A new wave of innovation is breaking and could be vital in enabling development that respects the planet.**

## Waves of innovation

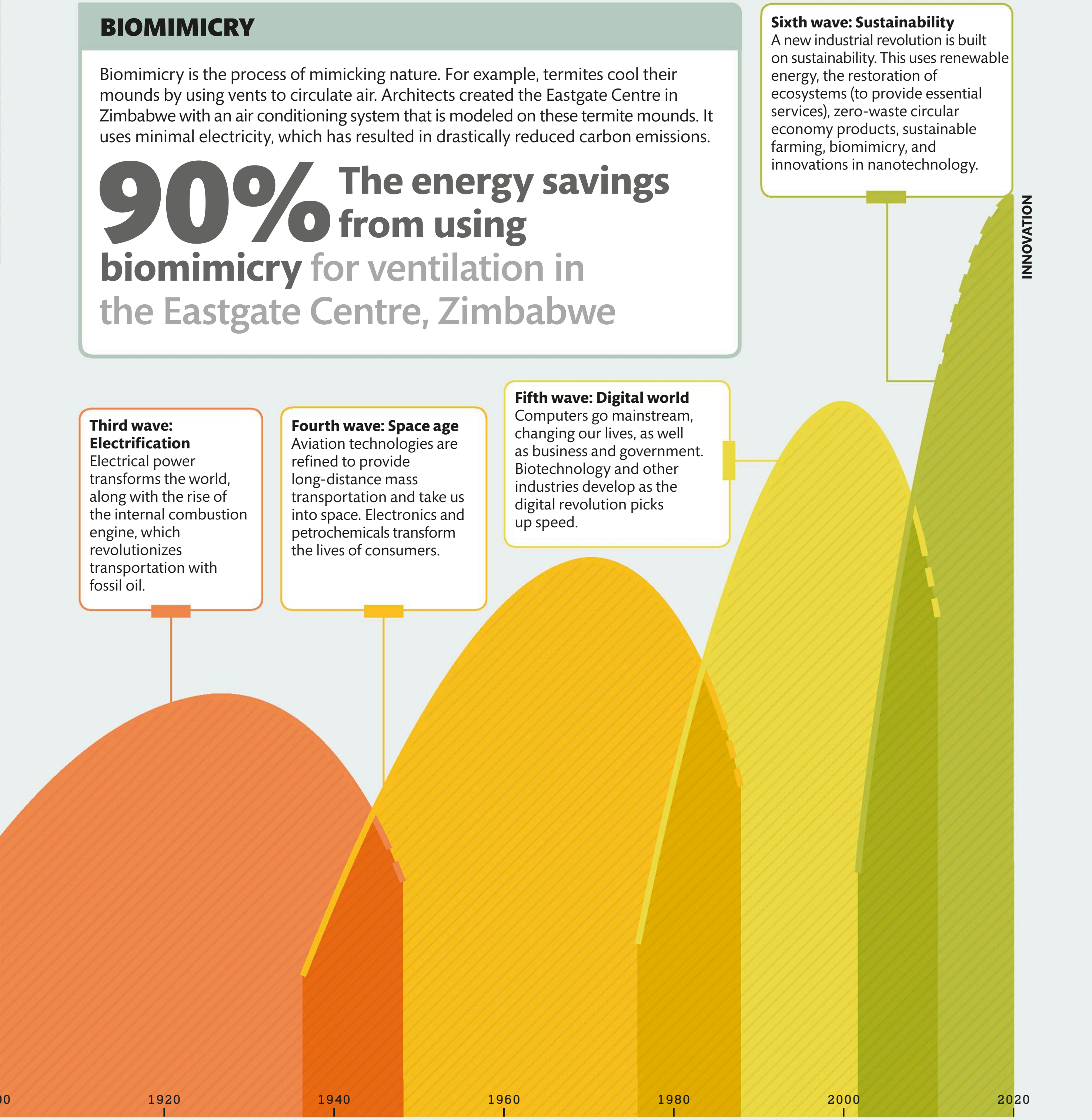
Since the middle of the 18th century, there have been a number of new industrial revolutions. Each of these has reshaped every aspect of the economy and society, and they have all followed a similar pattern, with the initial invention creating a period of boom and rising wealth. In the process, this gave rise to secondary economies based on core inputs, such as coal for steam engines and computer chips for the computers that drive the digital economy. Each time the technology reaches maturity, it is subject to a period of adjustment before, ultimately, being replaced. History reveals successive waves of progress driven by new technologies that last for about 50 years each. We could be at the start of a new one—the sustainability revolution.



## BIOMIMICRY

Biomimicry is the process of mimicking nature. For example, termites cool their mounds by using vents to circulate air. Architects created the Eastgate Centre in Zimbabwe with an air conditioning system that is modeled on these termite mounds. It uses minimal electricity, which has resulted in drastically reduced carbon emissions.

**90% The energy savings from using biomimicry for ventilation in the Eastgate Centre, Zimbabwe**



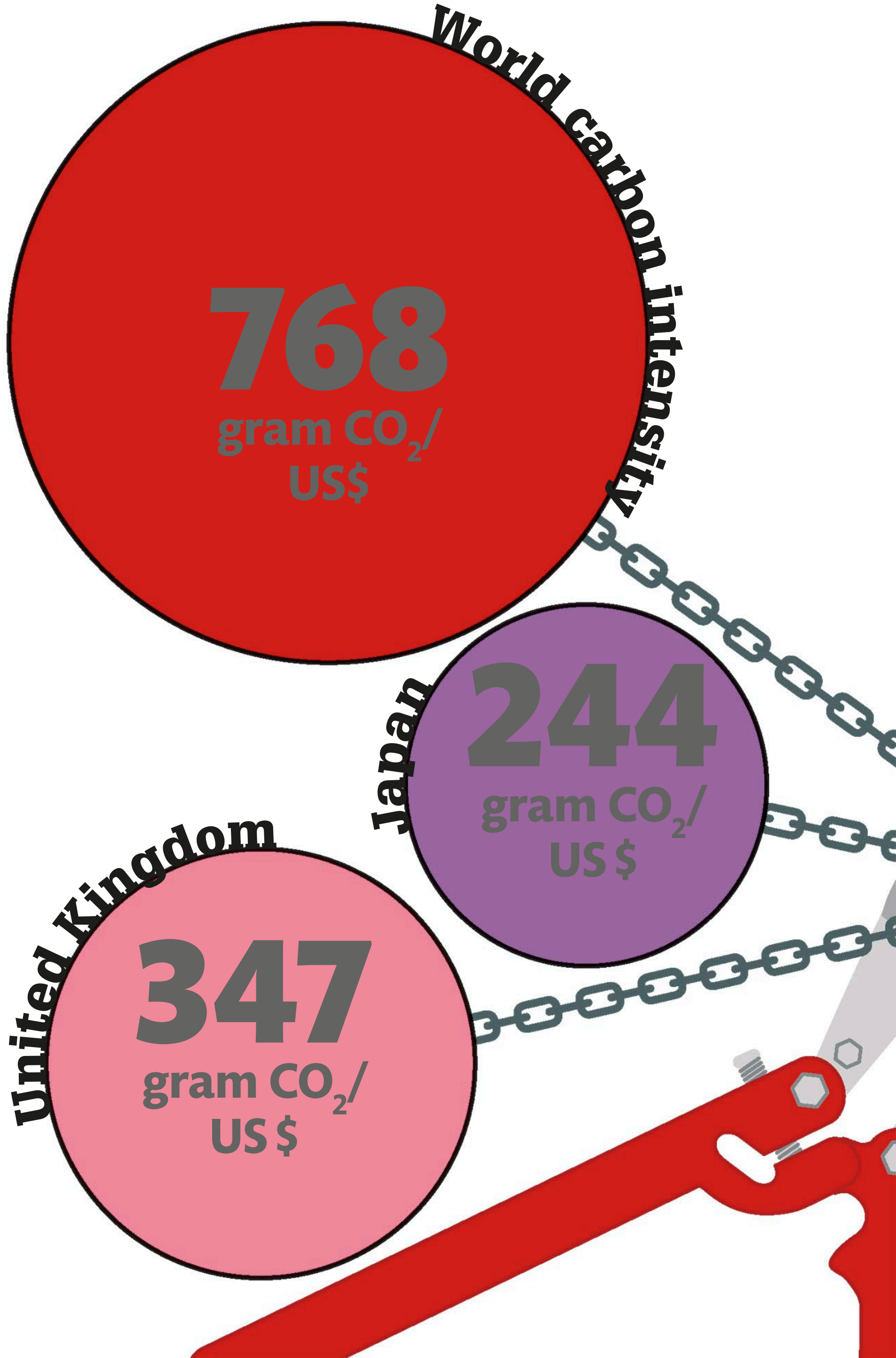
# Low-Carbon Growth

**The sustainability revolution will need to meet the demands of more people while achieving a drastic reduction in environmental impact. Carbon emissions provide an illustrative case in point.**

Present patterns of economic development are carbon intensive. In other words, for every unit of economic output, we are producing high levels of carbon dioxide ($CO_2$). The strategy going forward needs to be toward a less carbon-intensive society—a world where we can continue to grow in wealth but are less dependent on factors (like fossil fuel energy production) that increase $CO_2$ emissions. This "delinking" of economic growth from carbon emmisions is vital if we are to have any reasonable chance of ensuring the average global temperature increase does not exceed two degrees.

## Carbon intensity

This graphic shows the carbon intensity of each dollar of GDP in 2007 in the UK and Japan, as well as the world's average levels. The relatively efficient use of energy, gas generation, and some nuclear power leads the UK to emit at about half the global GDP average. Lacking fossil energy resources, Japan's economy is quite efficient. The country uses a great deal of nuclear power and generally has a low level of emissions per unit of GDP compared with the world average. However, both countries are far off the much lower global carbon target that is needed by 2050—from 6 to 36 grams $CO_2$ per dollar (see Scenarios 1–4, opposite).



## Future scenarios

We need to reduce carbon intensity significantly to prevent global temperatures rising more than two degrees above preindustrial levels. Economist Tim Jackson came up with four possible scenarios to reveal the scale of the challenge ahead. Each scenario uses variations on population number and average income. These predict how much carbon emissions must be reduced compared with 2007. With economic growth, incomes will rise. If the world achieves the income levels forecast in scenario 4, the carbon intensity of each dollar of GDP must drop to six grams. Even with continued inequality, but some growth (scenario 1), emissions per unit of GDP must be less than one-twentieth of the 2007 average.

**6.2%**

The amount that the **global economy** needs to cut carbon intensity **each year**

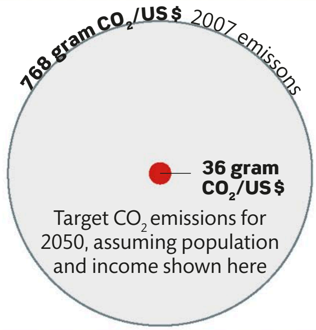

### 2050 Scenario 1

Assumes that population grows to 9 billion. Per capita income growth continues at the 2007 level, but inequalities remain.

**WORLD POPULATION**

**9 BILLION**

**PER CAPITA INCOME GROWTH**



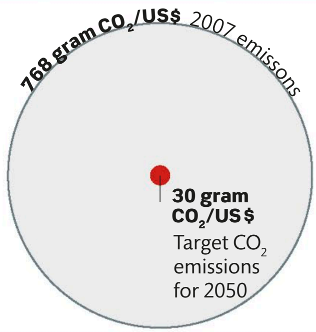

### 2050 Scenario 2

Assumes population grows to 11 billion. As in scenario 1, per capita income growth continues at the 2007 level, but inequalities remain.

**WORLD POPULATION**

**11 BILLION**

**PER CAPITA INCOME GROWTH**



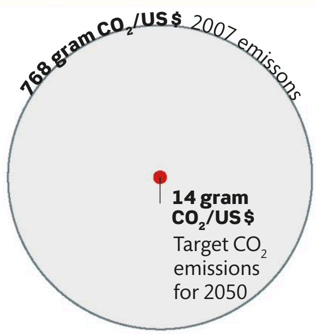

### 2050 Scenario 3

Population grows to 9 billion (as in scenario 1). Everyone enjoys per capita income at the equivalent of the EU average in 2007.

**WORLD POPULATION**

**9 BILLION**

**PER CAPITA INCOME GROWTH**



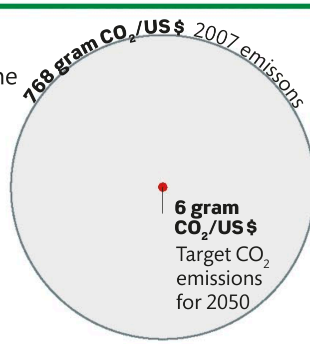

### 2050 Scenario 4

Population grows to 9 billion. Everyone enjoys high living standards because of economic growth above those of the EU today.

**WORLD POPULATION**

**9 BILLION**

**PER CAPITA INCOME GROWTH**



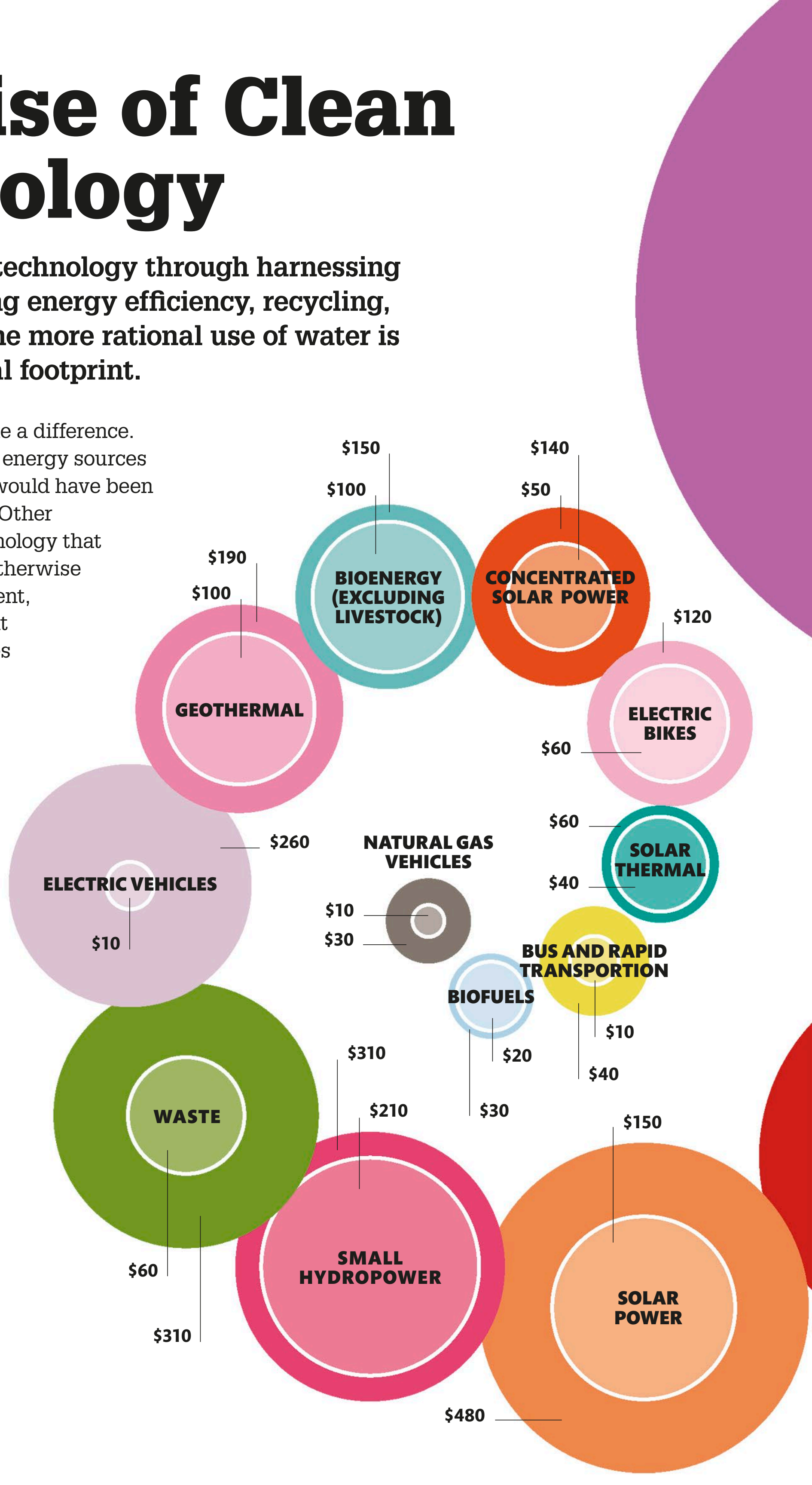
# The Rise of Clean Technology

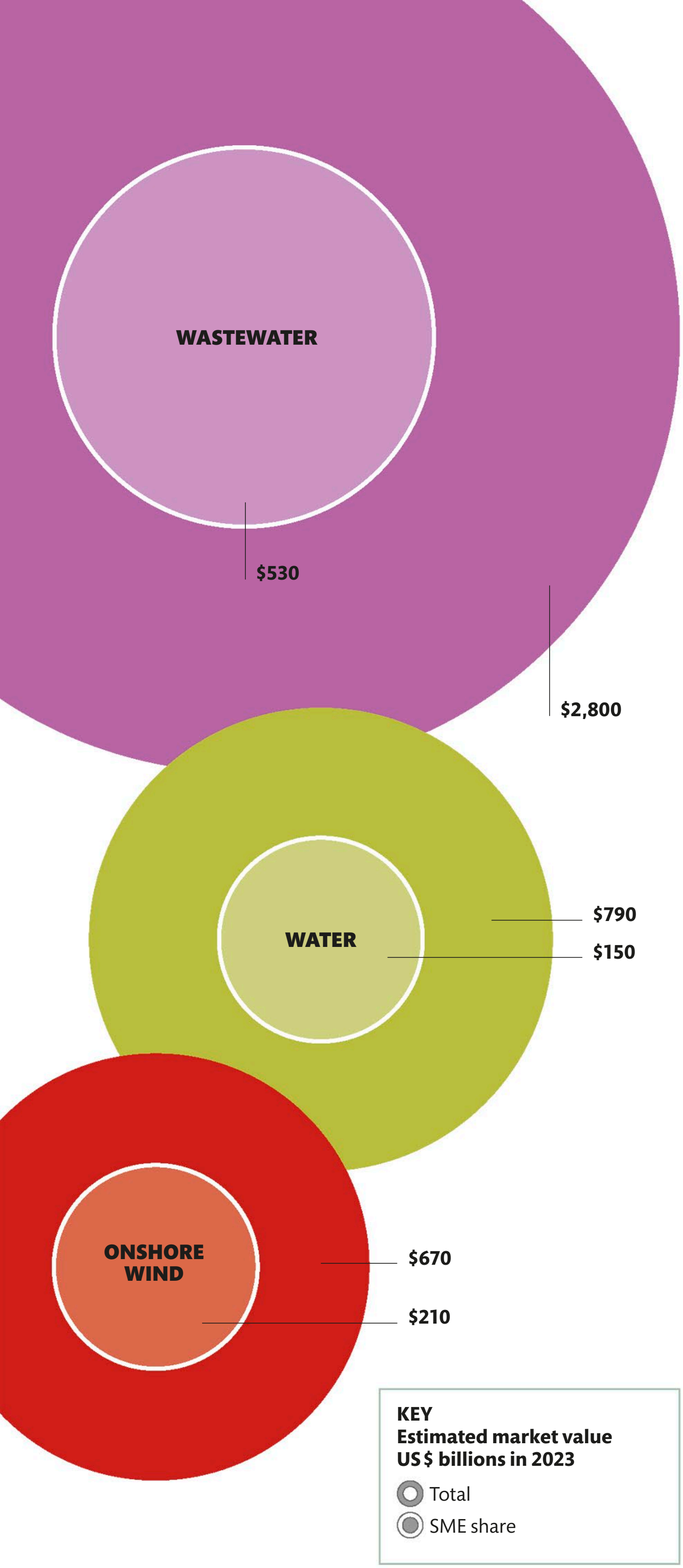
**Increasing our use of clean technology through harnessing renewable energy, promoting energy efficiency, recycling, green transportation, and the more rational use of water is vital to reduce our ecological footprint.**

Clean technology is beginning to make a difference. Most notably, switching to renewable energy sources decreases the amount of carbon that would have been released through burning fossil fuels. Other promising developments include technology that extracts resources from what would otherwise be waste, more efficient water treatment, nutrient recovery facilities that prevent pollution, and information technologies that enable buildings to run more efficiently. Clean technology companies are attracting increased investment as they become more efficient and competitive, which is helping them grow. From 2007–2010, the clean technology sector expanded by, on average, 11.8 percent per year, and in 2011–2012, it comprised a market worth around $5.5 trillion.

## Developing a clean future

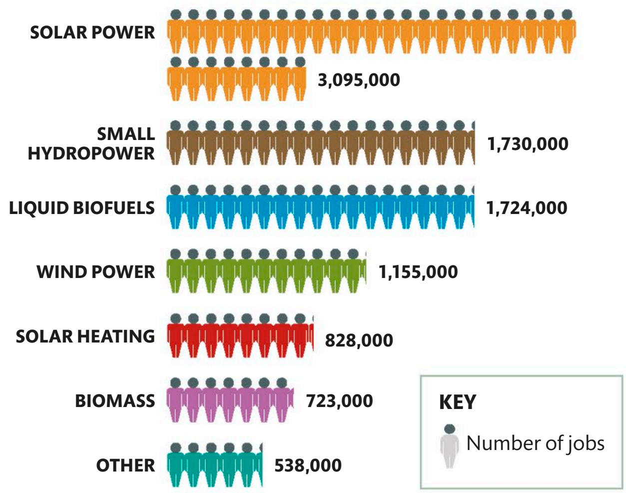
Clean technology is driving growth in developing countries, including among small- and medium-sized enterprises (SMEs). A World Bank study estimated that from 2014 to 2024, $6.4 trillion will be invested in clean technology in developing countries, with $1.6 trillion of that accessible to SMEs. South America and sub-Saharan Africa are predicted to be major growth areas in developing-world clean technology.





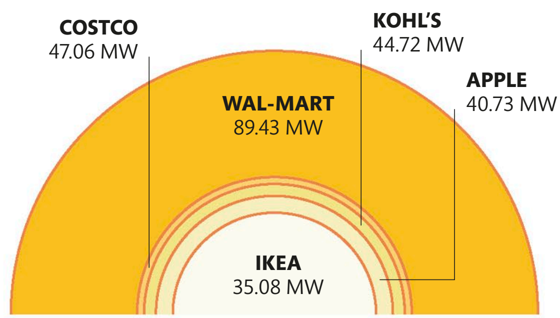

## Clean, green jobs

According to the International Renewable Energy Agency, there were 9.8 million jobs in renewable energy in 2016, up from 5.7 million in 2012. The largest concentrations are in China, Brazil, the USA, India, and Germany. Solar power, hydroelectric power and biofuels are the biggest employers.




### COMPANIES GOING GREEN

The nonprofit organization The Climate Group identified Ikea, Apple, Kohl's, Costco, and Wal-Mart as among those US companies deploying a significant amount of renewable energy in 2013. The total amount of solar energy these companies deployed in the US in 2013 is measured below in megawatts (MW).



# A Sustainable Economy

**If the world is to achieve the Sustainable Development Goals (see pp198–199) to raise living standards while avoiding the worst impacts of climate change, resource depletion, and ecosystem degradation, then economic change is needed.**

## Rewiring the economy

In 2015, the University of Cambridge Institute for Sustainability Leadership (CISL) in the UK proposed a plan to "rewire" the economy. The plan sets out 10 tasks for governments, business, and financial institutions to place our economic system more in line with social and environmental priorities. The tasks (right) relate to changes in government policy and the world of business while harnessing the massive power of finance. The changes are deliberately geared to promoting the achievement of the Sustainable Development Goals, which cannot be reached through traditional environmental and development programs on their own. A more fundamental shift is needed. That shift goes to the heart of our economy.

"If there is waste or pollution, **someone along the line pays for it.**"

**LEE SCOTT, FORMER CHIEF EXECUTIVE, WAL-MART**

### Government

- **Set the right targets and measures**
  For example, official goals to cut greenhouse gas emissions and protect ecosystems must be backed by policies to meet them.
- **Introduce new tax systems**
  Show the true cost of different choices—such as taxing waste and pollution to promote cleaner production and energy sources.
- **Positive influence**
  Drive positive change by harnessing the power of public spending, subsidies, planning rules, education, and research.

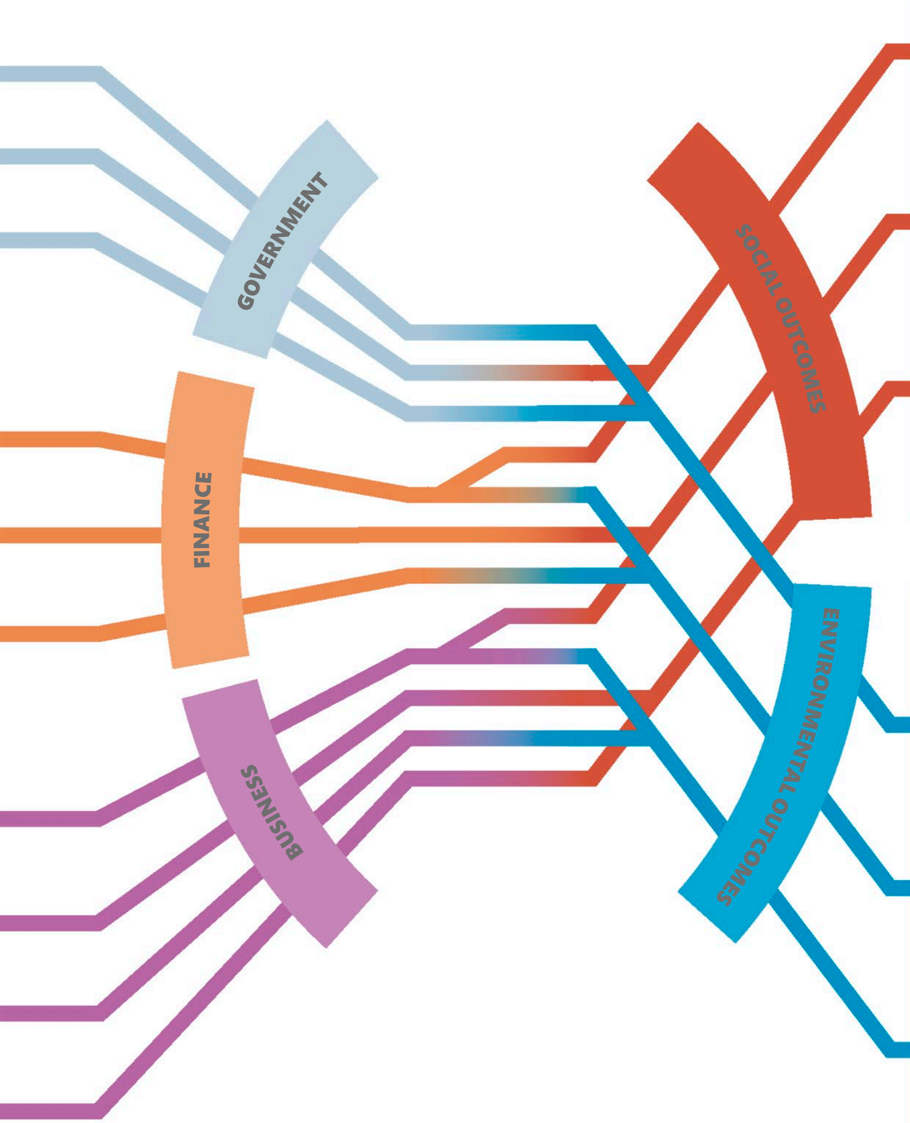
### Finance

- **Ensure that capital acts for the long term**
  Extend the timeframes over which financial risks and returns are modeled, thereby reducing short-term decisions while protecting investors.
- **Value the true costs of business activity**
  Identify strategies that encourage companies to meet social and environmental goals while they pursue financial profitability.
- **Innovate financial structures**
  Make finance work for social benefit, including fighting climate change and protecting the planet's ecosystems.

### Business

- **Set bold ambitions**
  Transform company activities to embrace goals for low-carbon energy, zero deforestation, and zero waste.
- **Broaden measurement and disclosure**
  Ensure that companies report on the full range of impacts they create, including social and environmental performance.
- **Grow capability and incentive**
  Harness companies' talent and money by, for example, linking executive bonuses with reduced carbon emissions.
- **Harness the power of communications**
  Change advertising to avoid messages that undermine social and environmental progress.

Despite the many social and environmental pressures facing our world today, the achievement of the Sustainable Development Goals could lay the foundations for a very positive future. This requires a change in mindset, however, and moving beyond the view that environmental protection brings unaffordable financial costs. In reality, social progress cannot be achieved if the natural environment continues to degrade. That is why environmental damage must be minimized through the way the economy operates. There is evidence from around the world that this is beginning to happen, as policies, investment patterns, and business practices begin to change.




## Social outcomes

**Basic needs**
Lead to stronger drivers for meeting basic needs, including food, water, shelter, sanitation, security, and basic freedoms.

**Health and well-being**
Investment in health and education enhances well-being, contributing to economic development and environmental goals.

**Decent work**
Economic strategies generate many more socially inclusive jobs with good working conditions.

## Environmental outcomes

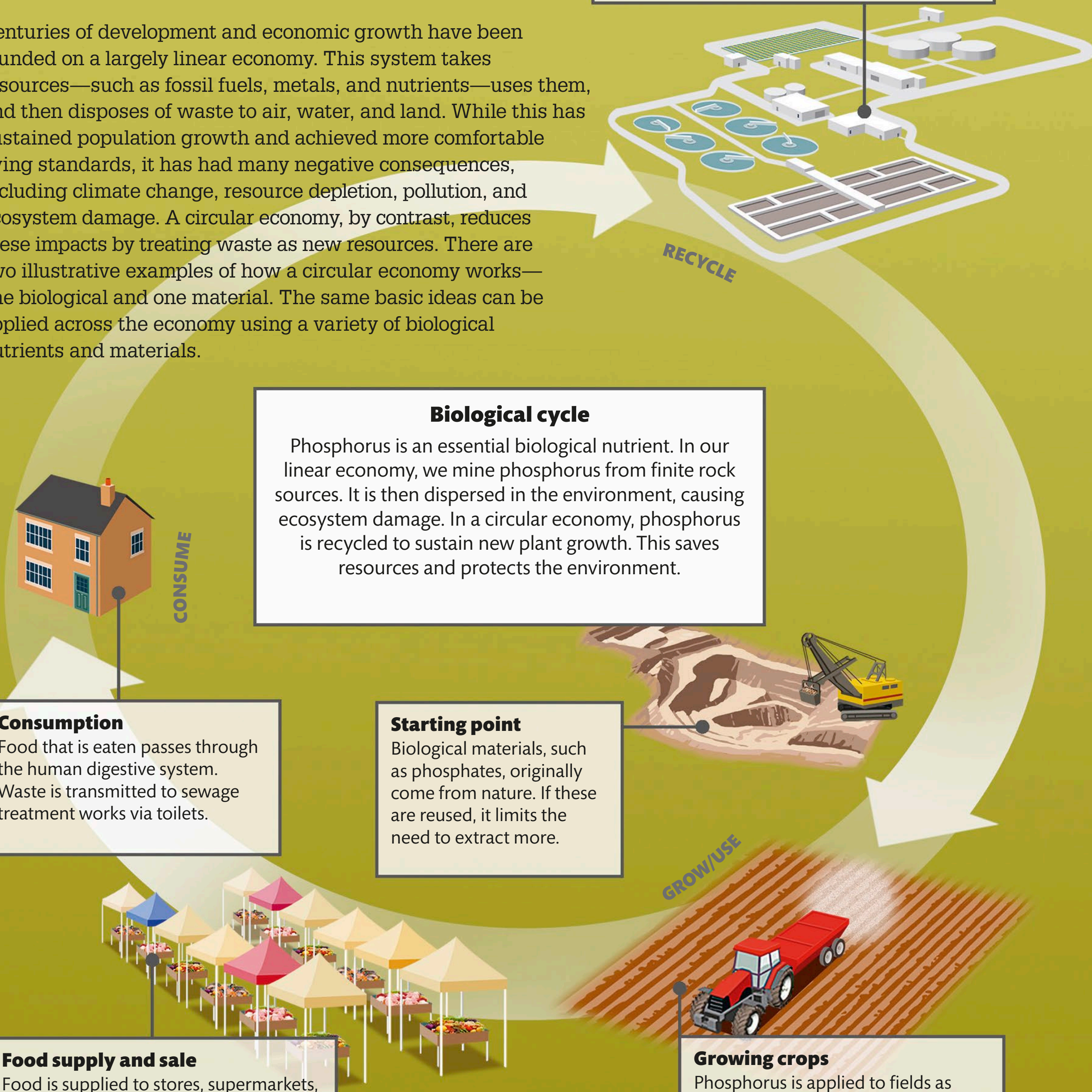
**Preserving resources**
Economic plans lead to the cleaner and more efficient use of natural resources and the development of a "circular economy" (see pp202–203).

**Ecological maintenance**
Economic planning leads to the promotion of ecosystem health, not least because this is essential for future economic development.

**Temperature target**
Economic development strategies embrace low-carbon outcomes, stabilizing greenhouse gases in the atmosphere so as to limit average global temperature increase to well below two degrees Celcius (3.6°F).

# Circular Economy

Centuries of development and economic growth have been founded on a largely linear economy. This system takes resources—such as fossil fuels, metals, and nutrients—uses them, and then disposes of waste to air, water, and land. While this has sustained population growth and achieved more comfortable living standards, it has had many negative consequences, including climate change, resource depletion, pollution, and ecosystem damage. A circular economy, by contrast, reduces these impacts by treating waste as new resources. There are two illustrative examples of how a circular economy works—one biological and one material. The same basic ideas can be applied across the economy using a variety of biological nutrients and materials.




**Sewage treatment plant**
New technology is already fitted to some sewage works. Phosphorus is captured from waste and turned into a high-quality fertilizer.

## Biological cycle

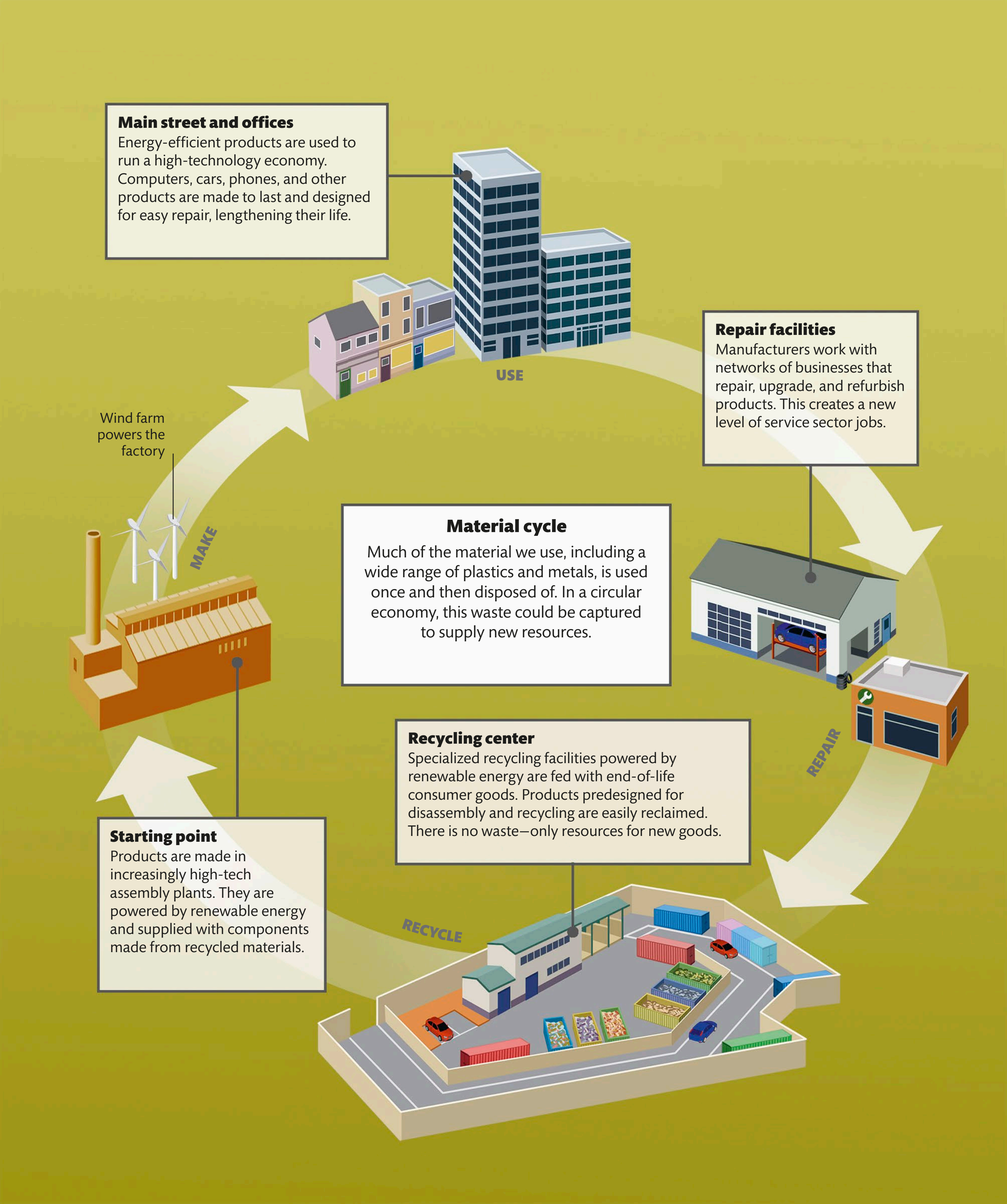
Phosphorus is an essential biological nutrient. In our linear economy, we mine phosphorus from finite rock sources. It is then dispersed in the environment, causing ecosystem damage. In a circular economy, phosphorus is recycled to sustain new plant growth. This saves resources and protects the environment.

**Consumption**
Food that is eaten passes through the human digestive system. Waste is transmitted to sewage treatment works via toilets.

**Starting point**
Biological materials, such as phosphates, originally come from nature. If these are reused, it limits the need to extract more.

**Food supply and sale**
Food is supplied to stores, supermarkets, and markets. Part of the cost of the produce is determined by the price of fertilizer, such as phosphorus.

**Growing crops**
Phosphorus is applied to fields as fertilizer to promote plant growth and increase the crop yields needed to feed a growing population.


Main street and offices
Energy-efficient products are used to run a high-technology economy. Computers, cars, phones, and other products are made to last and designed for easy repair, lengthening their life.
USE
Repair facilities
Manufacturers work with networks of businesses that repair, upgrade, and refurbish products. This creates a new level of service sector jobs.
Wind farm powers the factory
MAKE
Material cycle
Much of the material we use, including a wide range of plastics and metals, is used once and then disposed of. In a circular economy, this waste could be captured to supply new resources.
REPAIR
Recycling center
Specialized recycling facilities powered by renewable energy are fed with end-of-life consumer goods. Products predesigned for disassembly and recycling are easily reclaimed. There is no waste—only resources for new goods.
Starting point
Products are made in increasingly high-tech assembly plants. They are powered by renewable energy and supplied with components made from recycled materials.
RECYCLE

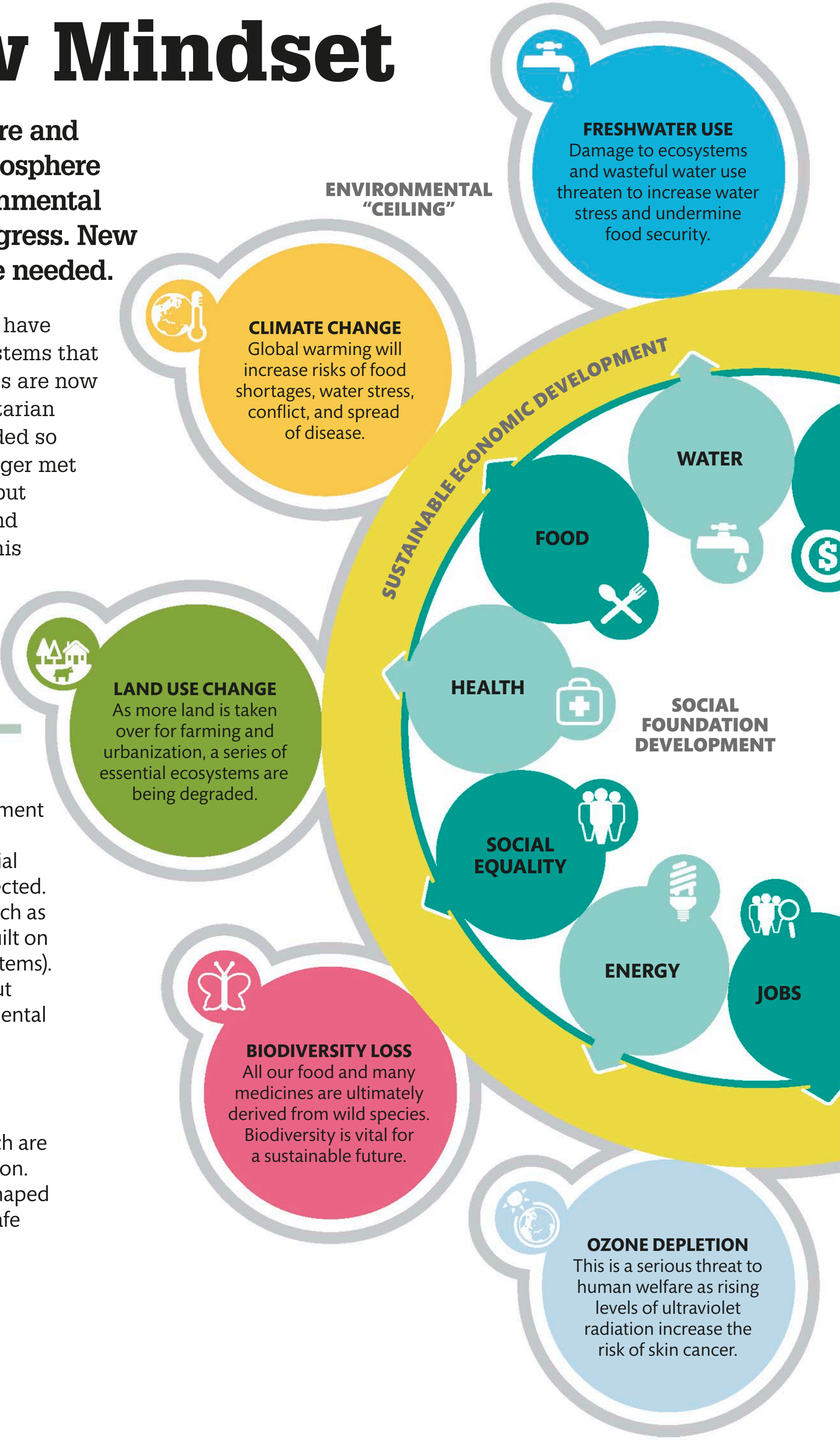
# A New Mindset

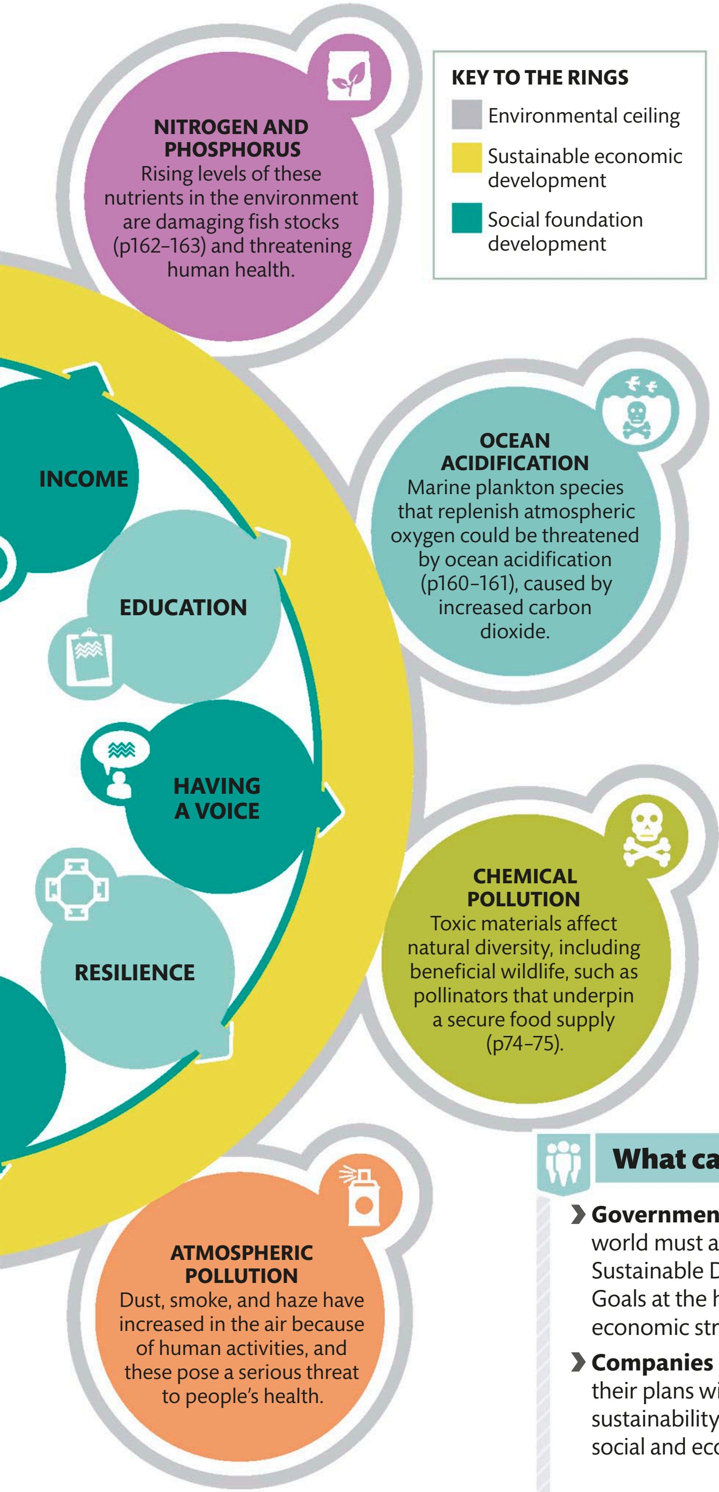
**Taking resources from nature and releasing wastes into the biosphere is causing mounting environmental pressures that threaten progress. New patterns of development are needed.**

Our growing demands upon nature have caused profound changes to the systems that sustain life on Earth. These changes are now having huge economic and humanitarian impacts. A shift in approach is needed so that rising human demand is no longer met at the expense of the environment but instead embraces the restoration and protection of ecological systems. This in turn leads to the need for an approach that achieves sustainable economic development and improved social conditions while respecting ecological limits.

## The safe zone

UK economist and sustainable development expert Kate Raworth proposes the idea of "doughnut economics," whereby social and ecological factors are equally respected. At the moment, one (social progress, such as better health, jobs, and education) is built on the sacrifice of the other (ecological systems). This graphic demonstrates the doughnut concept. The outer ring is the environmental "ceiling," made up of nine planetary boundaries (see pp180–181). Beyond these limits are unacceptable levels of environmental damage. The inner ring consists of 10 social factors, below which are unacceptable levels of human deprivation. Between the two rings is a doughnut-shaped space, which is both environmentally safe and socially just: the space where all of humanity can thrive.






**KEY TO THE RINGS**

- Environmental ceiling
- Sustainable economic development
- Social foundation development

## PLANETARY STRESS

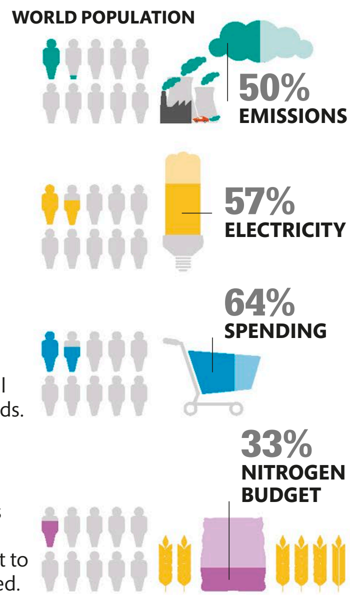
Oxfam estimates that one-tenth of the population is most responsible for factors that result in planetary stress, such as greenhouse gas emissions and energy use. It is their consumption, and the production methods of the companies producing the goods and services these wealthiest people buy, that drives most of the environmental damage threatening human security.

**EMISSIONS**
Half of the world's carbon dioxide emissions are generated by 11 percent of the world's population.

**ENERGY**
High-income countries are home to 16 percent of the world's population but use 57 percent of all electricity.

**PURCHASING POWER**
The same 16 percent of the global population also account for 64 percent of all spending on consumer goods.

**NITROGEN (FOOD)**
The EU has 7 percent of the world's population but uses 33 percent of the planet's sustainable nitrogen budget to grow and import animal feed.




### What can we do?

- **Governments** across the world must adopt the 2015 Sustainable Development Goals at the heart of their economic strategies.
- **Companies** must align their plans with long-term sustainability, protecting social and ecological values.

### What can I do?

- **Elect politicians** who are supporters of "doughnut economics."
- **Buy from firms** building "doughnut economics" into their business strategies.
- **Support campaigns** promoting human welfare within planetary limits.

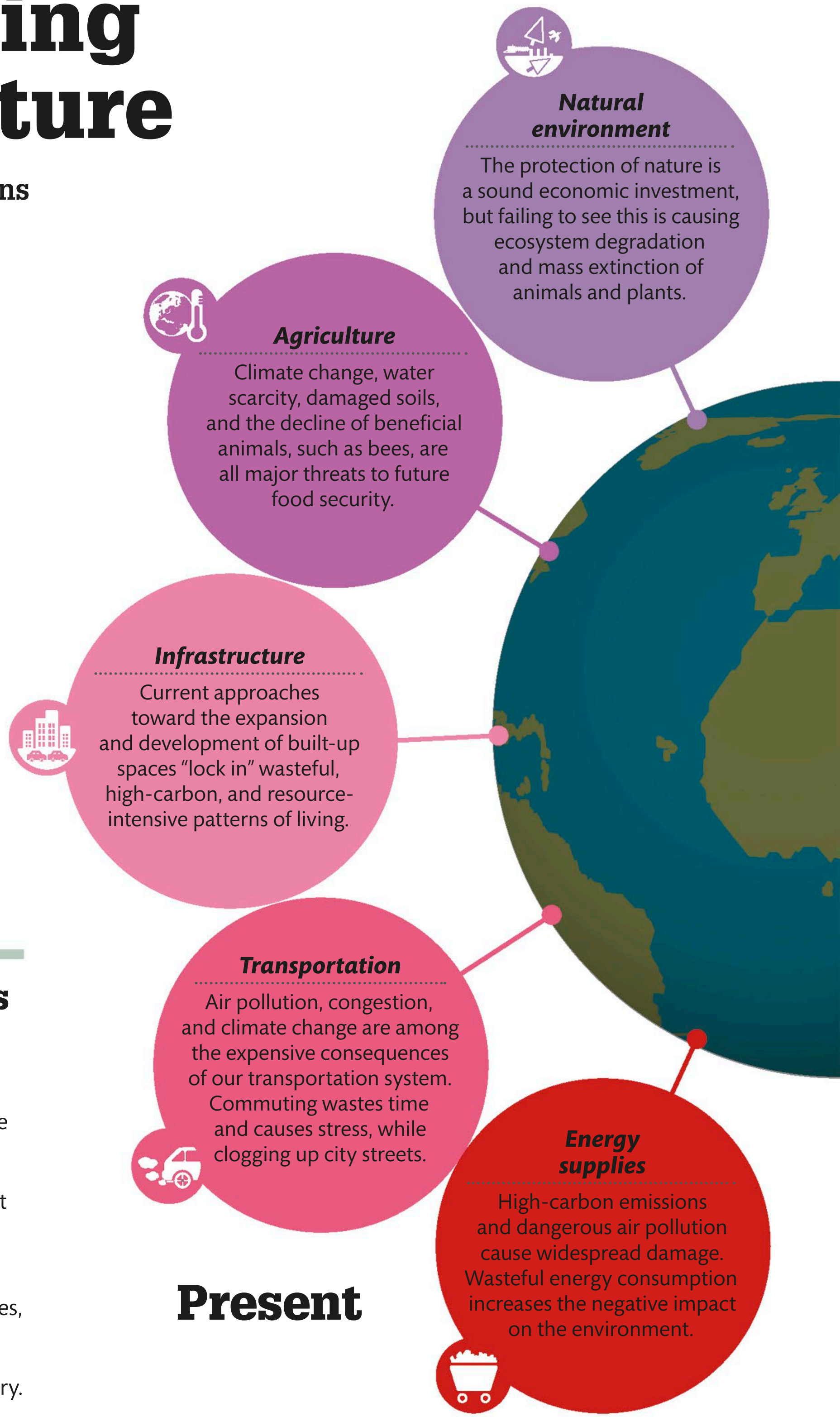
# Restoring the Future

**If we are to lay the foundations for a secure future, then the centuries of environmental degradation must be halted and reversed. This is both an economically rational and an achievable priority.**

Our approach to development and economic growth so far has assumed that the sacrifice of environmental ecosystems and the pollution of air and water are inevitable prices of progress. While this growth has brought comfort, convenience, and security to billions of people around the world, we are in a period of diminishing returns. The damage caused by climate change, air and water pollution, depletion of resources, and ecosystem deterioration threatens to exceed all the benefits of growth. But it is still possible to restore environmental health through sustainable development.

## Restoration in progress

Continuing environmental degradation is not inevitable, and it can be reversed if we decide to build on positive examples from around the world that already demonstrate what is possible. From Brazil to Denmark, and from Uruguay to Bhutan, there are hundreds of inspirational examples of what can be done across a range of sectors, including farming, transportation, conservation, infrastructure, and energy supply. Governments, international agencies, businesses, and individual citizens all need to play their part in the sustainability transformation necessary in the 21st century.



### *Natural environment*

The realization that thriving nature is essential for healthy people, a strong society, and a sound economy brings an end to environmental damage and leads to restored ecosystems.

### *Agriculture*

Sustainable farming that protects soil, water, and wildlife, and changes in the wider food system, including a huge reduction in food waste, result in secure nutrition, which causes less environmental damage.

### *Infrastructure*

The cities of the future are designed to be efficient and pleasant places to live. Engineering and ecology combine to create truly sustainable, healthy cities.

### *Transportation*

Biycling and walking improve public health, cut pollution, and reduce emissions. Digital technologies allow "telecommuting," which reduces actual commuting. Electric vehicles allow cleaner transportation.

### *Energy supplies*

Greenhouse gas emissions are reduced by the efficient use of renewably generated heat and power. Clean electricity charges the batteries of electric vehicles.

## Future

"Ours is a world of looming **challenges and ... limited resources.** Sustainable development offers the **best chance to change our course."**

**BAN KI-MOON, FORMER UNITED NATIONS SECRETARY-GENERAL**

### What can we do?

- **Investors can adopt strategies** that direct finance toward positive solutions, such as renewable energy and sustainable farming.
- **Governments can introduce incentives** to adopt clean technology, including subsidies to encourage the protection and restoration of ecosystems.

### What can I do?

- **Choose products and services** from companies offering solutions for sustainability challenges. This rewards market leaders and puts pressure on those companies that lag behind.
- **Urge your bank** and pension fund to lend and invest only in enterprises that back a secure and sustainable future.

# Glossary

## UNITS

**MTOE—million tons of oil equivalent** The amount of energy released by burning one million tons of oil; used as a measure of energy production or consumption.

**MWh—megawatt hour** A measure of electrical energy use. 1 megawatt is 1 million watts; 1 MWh is the power of 1 million watts used or produced constantly for 1 hour.

**TWh—terawatt hour** A measure of electrical energy use. 1 terawatt is 1 trillion watts; 1 TWh is the power of 1 trillion watts used or produced continuously for 1 hour. See also MWh.

**BTU—British thermal unit** The amount of heat required to raise the temperature of 1 lb of water by 1°F at sea level. Used to measure the heat output of heating and cooling systems and machines.

**DU—Dobson unit** A unit used for measuring the concentration of trace gases, notably ozone, in the atmosphere.

**gigatons (billions of tons) of $CO_2$** A unit of measurement used for carbon dioxide or carbon emissions. A similar unit, $GtCO_2$-eq (gigatons of $CO_2$ equivalent), may be used to measure other greenhouse gases in the "common currency" of the warming caused by carbon dioxide. To convert carbon dioxide to carbon, divide by 3.67. For example, 1Gt of $CO_2$ is equivalent to 272 million tons of carbon.

**Ej—**Exajoule A unit of energy equivalent to 1 billion gigajoules. (A gigajoule is 1 billion joules.)

**ng (nanogram)** One billionth of a gram.

## GENERAL

**acid rain** Rain, sleet, or snow contaminated with air pollutants such as sulfur dioxide and nitrogen oxides. Acid rain pollutes soil and water and damages buildings.

**acidification** A process by which oceans, lakes, or rivers gradually become more acid. Acidification of oceans is largely due to increased uptake of $CO_2$ from the air. In lakes and rivers, it may be due to acid rain entering the water.

**algal bloom** Rapid growth of algae in a lake or ocean, often due to an excess of nutrients such as nitrogen or phosphorus. Algae can block out sunlight and use up oxygen. Some algal blooms produce toxins harmful to animals or humans.

**atmosphere** The layer of gases surrounding the Earth (or any other planet). Earth's atmosphere consists mainly of nitrogen (78%) and oxygen (21%).

**biodegradable** A term used for materials that can be broken down naturally by microorganisms into constituent molecules or elements.

**biodiversity** Variety in living things. Species biodiversity is the variety of species in an environment. Genetic biodiversity is the variation in genes within one species. Ecological diversity is the range of ecosystems and habitats.

**bioenergy** Renewable energy extracted from biological materials such as wood, straw, manure, and sewage.

**biofuels** Generally used to describe liquid fuels derived from plants and other organic material, such as food waste, providing alternatives to gasoline, diesel, and kerosene. Biogas is an alternative to fossil gas, also made from organic material, such as animal waste or food waste.

**biogeochemical flow** The circulation of a chemical substance, such as carbon or nitrogen, through the atmosphere, soil, biosphere (plants and animals), and water.

**biomagnification** The process by which a chemical (such as a pesticide) becomes more concentrated as it passes through a food web, for example as filter-feeding organisms are eaten by bigger creatures and finally top carnivores.

**biomass** The mass of living organisms (plants, animals, and microorganisms) in a given ecosystem or community.

**biome** An area of land surface, freshwater, or ocean characterized by particular types of vegetation, as well as by physical features such as climate or water depth.

**biomimicry** Imitation of natural structures and processes to help meet challenges in the human world.

**bioproductivity** The rate of production of biomass from a specific ecosystem over a given time period.

**biosphere** The zone of the Earth containing all living organisms; comprises the Earth's surface, oceans, and the lowest layer of the atmosphere.

**carbon** A common chemical element (symbol: C) that binds with other elements such as hydrogen (H) and oxygen (O) to form compounds such as carbon dioxide. Carbon is found in all living organisms.

**carbon capture and storage (CCS)** A process in which carbon dioxide from burning fossil fuels is captured before it reaches the atmosphere, then deposited deep inside rocks.

**carbon dioxide** A gas with molecules formed from one carbon atom and two oxygen atoms (formula: $CO_2$); produced by respiration from living organisms, fermentation of dead matter, and combustion (fires, or burning of biofuels or fossil fuels).

**carbon intensity** A measure of greenhouse gas emissions calculated as the mass of carbon emitted per unit of energy consumed. One example is grams of carbon dioxide-equivalent gases per megajoule of energy ($gCO_2e/MJ$). Carbon intensity can also be calculated in relation to emissions per unit of GDP. In this case, the concept can also embrace emissions from deforestation as well as energy.

**carbon pricing** A tax or market price levied on emissions of carbon dioxide to incentivize changed behavior, such as more efficient energy use or the expansion of renewable energy.

**carbon sink** An ecological system that absorbs and stores carbon dioxide from the atmosphere. Oceans and forests are the Earth's two main carbon sinks.

**carrying capacity** The maximum population size of a species that an ecosystem or habitat can support indefinitely.

**chlorofluorocarbons (CFCs)** Chemical compounds formed from chlorine, fluorine, and carbon. CFCs were widely used in refrigeration, as propellants for aerosols, and as solvents, but it was found that they damaged the ozone layer so their use is now restricted.

**climate** The average atmospheric conditions in an area over a long period of time. It is influenced by the latitude and elevation of an area, plus factors such as average temperatures and rainfall.

**$CO_2$ emissions** Release of carbon dioxide by natural means (as in forest fires and volcanic eruptions) or artificial means (such as burning of fossil fuels).

**consumption (economic)** The purchase and use of goods and services by individuals or households.

**convection** The transfer of heat through movement of a fluid (such as air or water). For example, in convection cells in the atmosphere (see pp128–29), warmer air expands and rises, while cooler air sinks, creating air currents.

**dead zone** An area of a lake or ocean where the water is so low in oxygen that many animals cannot survive there. Dead zones can result from *algal blooms* caused by water pollution.

**deforestation** Destruction and/or removal of trees from an area of forest, to leave open land. Major causes include logging or clearance of forest for ranches or plantations of crops. Deforestation can lead to soil erosion and loss of *biodiversity*.

**desalination** Removal of salt and other minerals from water to make the water suitable for drinking or irrigation.

**desertification** The spread of desert conditions to areas that were previously covered with vegetation; caused by factors that include reduced rainfall and overgrazing by domesticated animals

**developed country** A country with a relatively stable industrial or postindustrial economy, established political security, advanced level of technology, and generally high standard of living compared to other nations.

**developing country** A country with a weak infrastructure and insufficient public services, and in which the majority of people have relatively low income, lower life expectancy, and limited access to comprehensive modern health care and education.

**dieback** In trees and shrubs, the progressive death of twigs, then branches, then the whole plant. Possible causes include infection, pest infestation, drought, and pollution.

**dioxin** A group of persistent chemicals that may be emitted via industries such as paper bleaching and processes such as waste incineration. These chemicals are toxic and can pose risks to animal and human health through bioaccumulation in food chains.

**DUs—Dobson units** See *Units*

**E7 countries** A group of seven powerful countries with emerging market economies: China, India, Brazil, Russia, Mexico, Turkey, and Indonesia. The E7 now accounts for around 30 percent of world *GDP*.

**ecology** The science that deals with interrelationships between organisms and each other and their nonliving environment, including air, water, and geology.

**ecosystem** A self-sustaining community of living things interacting with each other and with the air, water, and soil of their environment.

**El Niño** A large-scale climate disturbance occurring about every 3–7 years in the central and eastern equatorial Pacific Ocean, in which warming of ocean surface currents gives rise to changes in prevailing weather patterns around the world, but especially along the coasts of North and South America and north of Australia. See also *La Niña*.

**emerging market** A national economy that is growing, developing, and industrializing rapidly from a relatively low income and economic base compared to the already developed nations. Many of these countries are becoming increasingly powerful in industry, trade, and technology.

**emissions** Discharges of gases, liquid vapors, and tiny particles into the atmosphere; usually refers to discharges from human sources such as vehicles, power stations, and deforestation.

**energy storage** The collection and storage of electrical or mechanical energy for use at a later time, either on a small scale (as in a rechargeable battery) or a large scale (as with a reservoir for a hydroelectric plant).

**erosion** A process in which soil or rock is broken down and carried away by wind, flowing water, or ice. Erosion processes may be mechanical (in which rock or soil is physically worn away) or chemical (in which the rock or soil is dissolved in water).

**eutrophication** Ecological change resulting from the rising concentration of nutrients, such as nitrates and phosphates, in an ecosystem such as a body of water. Eutrophication can give rise to *algal blooms* and *dead zones*.

**evaporation** The process in which molecules from the surface of a liquid change to a vapor, usually due to increased temperature, as when water evaporates from a sea or lake on a warm day.

**extinction** The disappearance of a species, subspecies, or group of organisms marked by the the death of the last individual.

**flood plain** A flat area of land beside a river that naturally floods whenever the water level rises above the level of the river banks.

**food chain or food web** A hierarchy (chain) or network (web) of organisms in which those at one level eat others; for example, a bird of prey species may eat insect-eating birds, which in turn eat insects, which in turn eat plants.

**food miles/food kilometers** The distance that food has traveled from the place where it was produced to reach the consumers. Longer distances involve higher fuel use, so cutting food miles/km can help reduce emissions from transportation.

**food security** The state that exists when people have access to, and can afford, enough nutritious food to maintain a healthy life.

**fossil fuel** A fuel produced from the remains of plants and animals that died tens or hundreds of millions of years ago, such as coal, oil, or *natural gas*. These fuels contain *carbon* captured from the *atmosphere*, so when they are burned they release *carbon dioxide* into the atmosphere.

**fracking (hydraulic fracturing)** Injection of a high-pressure mix of water, sand, and chemicals into oil- or gas-bearing rock to create cracks (fracturing) and release the oil or gas. Fracking can lead to contamination of groundwater and may even trigger small earthquakes.

**G7 countries** A group of seven major industrialized countries—the US, Canada, UK, France, Germany, Italy, and Japan—whose leaders and finance ministers meet annually to discuss global economic policy and international security.

**GDP per capita** A measure of economic performance; it is calculated by dividing a country's GDP by the number of people in the population.

**GDP—Gross Domestic Product** The monetary value of all the finished goods and services produced in a country over a specific time (usually a year). See also *Real GDP*.

**geothermal energy** Energy derived from heat generated naturally within the Earth, for example obtained from hot springs in areas of volcanic activity.

**global warming** The increase in the average temperature of the *atmosphere* and/or oceans, that in turn affects the extent of ice on earth, sea levels, and *weather*, including rainfall. Human activities have recently played a fundamental role in raising global temperatures.

**green revolution** A set of advances in crop cultivation, starting in the 1940s, that vastly increased food supplies, especially in developing countries.

**greenhouse effect** The process by which the Earth's atmosphere traps more energy from the Sun, thus warming the atmosphere and oceans.

**greenhouse gas** A gas that traps heat in the *atmosphere*. The main gas is *carbon dioxide*; other major gases are *methane* and *nitrous oxide*. Greenhouse gas emissions from human activities such as burning fuels contribute to *global warming*.

**groundwater** Water held within the spaces in soil and rock, notably in water-saturated rocks called aquifers.

**gyre** A large system of ocean currents rotating in a spiral.

**Haber-Bosch process** A synthetic process in which nitrogen from the air is combined with hydrogen to form ammonia. Mainly used to manufacture fertilizer.

**habitat** An *ecosystem* such as woodland or grassland that supports characteristic communities of animals and plants.

**HANPP–**Human appropriation of net *primary production* A measure of human use of the Earth's photosynthetic productivity. Net primary production is the net amount of solar energy converted to plant matter. HANPP is seen in, for example, the use of net primary production as food, wood, paper, and plant fibrers.

**hydro energy** Energy obtained from falling or flowing water; for example, in hydroelectric power, where water is used to turn a turbine and generate electricity.

**hydropower** Electrical energy obtained from falling or flowing water; for example as produced by turbines in a hydroelectric dam.

**ice sheet** A mass of glacial land ice covering more than 20,000 sq miles (50,000 sq km). Earth's two main ice sheets lie over Greenland and Antarctica.

**infrared** A form of electromagnetic energy whose waves are just longer than those of visible light. Some of the Sun's energy, and some of the heat from Earth's surface, is in the form of infrared radiation.

**inundation** The overflow of water to cover normally dry land, as when a river floods or a storm surge occurs on a coast.

**invasive alien species** A species that is not native to a particular ecosystem and causes harm when introduced to that system.

**invertebrate** An animal with no backbone. Such animals include insects, mollusks, crustaceans, and worms.

**IUCN red list** The register of animals, plants, and fungal species across the world that are deemed to be at some risk of extinction.

**La Niña** A large-scale change in temperature occurring about every 3–7 years in the central and eastern equatorial Pacific Ocean, during which the ocean surface is cooler than normal, causing disruption to weather, especially in the Americas, Australia, and Southeast Asia. Counterpart of *El Niño*.

**Latin Americ**a The countries of Central and South America, primarily those where the populations mainly speak Spanish, Portuguese, or French.

**least developed country (LDC)** A country with very low per capita incomes; LDCs are the poorest of the *developing countries*.

**literacy** The ability to read and write. Literacy, especially for women and children, is a key indicator of economic and social development in a country.

**malnourishment** Having a diet that does not contain the right balance of nutrients: for example, too little vitamin C or too little protein. See also *Undernourishment*.

**megacity** A city and its surrounding area that has more than 10 million people, such as Tokyo, New York, or São Paulo.

**methane** A colorless, highly flammable, gaseous hydrocarbon. Methane is the main component of natural gas and a very powerful *greenhouse gas*. Globally, more than 60 percent of human-induced emissions arise from industry, agriculture, and landfills.

**millennium development goals** A set of eight development goals (including one relating to the environment) set out by the United Nations (UN) in 2000, to be achieved by 2015. Now superseded by the UN's 17 Sustainable Development Goals.

**monoculture** The agricultural practice of producing a single crop, plant, or livestock species, variety, or breed in a field or farming system at a time.

**monsoon** A seasonal change in weather, often associated with the Indian subcontinent, in which changes of wind direction and air pressure cause strong sea breezes bringing torrential summer rains.

**MTOE**–Million tons of oil equivalent (See *Units*).

**multilateral environmental agreement (MEA)** A legally binding agreement between three or more states relating to environmental issues. There are currently more than 250 MEAs in force.

**MWh–**Megawatt hour (See *Units*).

**natural gas** A fossil fuel comprised mainly of *methane*. Extracted from rocks, it is often associated with oil deposits. It is extracted by drilling or *fracking*.

**nitrous oxide** A pollutant and greenhouse gas. The atmosphere naturally holds a tiny amount of nitrous oxide, but levels have markedly increased due to human activity.

**nuclear power** Splitting of atoms of certain elements (nuclear fission) to release energy, which is used to generate electricity. Nuclear power produces low *carbon dioxide* emissions, but the waste is highly toxic for many years.

**nutrient cycle** The circulation of biological and chemical matter, such as carbon or nitrogen, between the physical environment and living organisms and back again in a particular *ecosystem*.

**OECD countries** Countries belonging to the Organization for Economic Cooperation and Development, a body set up by the most developed countries in 1968 to promote economic development and social progress. There are 34 OECD countries.

**organic farming** A method of agriculture in which farmers avoid the use of manufactured pesticides and fertilizers, instead relying on more natural processes to maintain soil fertility, including animal manure and nitrogen-fixing plants.

**ozone** A colorless gas that can be harmful to plants and animals in the air we breathe, but in the upper atmosphere it protects the Earth from the Sun's ultraviolet radiation. Ozone concentration is measured using *Dobson units*.

**ozone layer** A layer of the atmosphere, 12–31 miles (20–50 km) from the Earth's surface, that contains relatively high concentrations of ozone. Thinning of the ozone layer can expose organisms (including humans) to dangerous levels of ultraviolet radiation.

**permafrost** Soil or rock that has remained continuously frozen for more than 2 years. In some areas, such as Alaska and Siberia, permafrost has existed for thousands of years.

**persistent organic pollutants (POPs)** Chemical compounds that resist being broken down and remain in the environment for a long time. Some POPs, such as DDT, are harmful to wildlife and human health.

**petrochemicals** Chemical compounds derived from petroleum or *natural gas*. They are used in thousands of products, such as solvents, detergents, plastics, and synthetic fibers.

**photochemical smog** A form of air pollution that occurs when sunlight reacts with nitrogen oxide and *volatile organic compounds*, making the air foggy or hazy. The smog can contain *ozone* and be harmful to breathe.

**photosynthesis** The process by which plants and some microorganisms use the energy from sunlight to convert *carbon dioxide* and water into glucose, releasing oxygen as a waste product.

**photovoltaic system** A technology in which photovoltaic cells or panels convert sunlight into electricity. PV systems produce clean and renewable power.

**phytoplankton** Tiny forms of *plankton* that live in the sunlit upper layers of oceans and lakes and use *photosynthesis* to take in *carbon dioxide* and release oxygen, thus playing a vital part in the carbon cycle.

**plankton** Small organisms, ranging from single-celled algae and bacteria to jellyfish, that spend part or all of their lives drifting in seas or lakes. Plankton plays vital roles in aquatic food chains. See *phytoplankton* and *zooplankton*.

**polychlorinated biphenyls (PCBs)** A group of manmade chemicals that were widely used in the past in products such as electrical equipment, adhesives, and paints. PCBs are *persistent organic pollutants (POPs)* that can damage health, and are now banned in many countries.

**preindustrial world** The world as it was before 1750, when the Industrial Revolution began. Humans lived mainly by agriculture or small-scale industries. Pressures on the environment were much lower than they are today.

**primary production** The rate of conversion of solar energy into new plant *biomass* by means of *photosynthesis*.

**pteropods** A group of free-swimming marine snails. Pteropods have been recognized as victims of ocean *acidification*, which causes thinning of their shells.

**rain forest** A dense forest in a tropical or temperate area with high annual rainfall. Many rain forests are notable for their *biodiversity* and are major oxygen producers and *carbon sinks*.

**real GDP** A measure of the value of all goods and services produced in a given year, adjusted for inflation.

**recycling** The conversion of domestic, agricultural, or industrial waste products into new usable materials. Recycling helps save energy and reduce pollution.

**renewable energy** A term for an energy source (for power, heat, or transportation) that can be constantly replenished instead of being progressively depleted. Examples include solar, wind, and hydropower.

**savanna woodland** A form of tropical vegetation consisting mainly of open grassland together with scattered trees and bushes.

**seabed** The floor of a sea or ocean.

**sulfur dioxide** An air pollutant primarily emitted by burning *fossil fuels* such as coal. Sulfur dioxide can mix with water vapor to form *acid rain*; it is also a health hazard to animals and humans.

**sustainability** The term to describe the circumstances in which a human activity can continue indefinitely into the future, for example in relation to farming, energy generation, waste management, forestry, or materials consumption.

**TWh–**Terawatt hour (See *Units*).

**turnover** The total amount that an organization earns, before taxes and other costs, from selling goods or services during a specific time period.

**ultraviolet light** A form of electromagnetic energy whose waves are just shorter than those of visible light. Some of the Sun's energy is in the form of ultraviolet (UV-A and UV-B) radiation, most of which is blocked by the Earth's *atmosphere* before it reaches the surface.

**undernourishment** A consequence of consuming too few essential nutrients or using or excreting them more rapidly than they can be replaced. See also *Malnourishment*.

**urbanization** The process by which large numbers of people come together to live and work in relatively small areas, forming towns and cities.

**urban density** A measure of the intensity of human land use in an urbanized area, such as the number of people or the total floor area of buildings per sq mile/$km^2$.

**UV radiation** See Ultraviolet light.

**vertebrate** An animal with a backbone and an internal skeleton. Vertebrates include fish, amphibians, reptiles, birds, and mammals.

**volatile organic compounds (VOCs)** Carbon-based chemical compounds that evaporate readily. Found in manmade substances such as fuels, pesticides, and solvents, VOCs are air pollutants that can cause *photochemical smog*.

**water table** In soil or rock below the ground surface, the level below which the rock is saturated with *groundwater*.

**weather** The day-to-day atmospheric conditions in a particular place; aspects include air temperature and pressure, hours of sunshine, cloud cover, humidity, and rainfall or snowfall.

**weathering** The breakdown of rock in situ (in a specific place) at the ground surface, by wind, water, temperature changes, or chemical reactions. See also *Erosion*.

**zooplankton** Animals that live part or all of their life as *plankton*. They include amebae, the larvae and juveniles of fish, and the larvae of mollusks, crustaceans, and jellyfish. Zooplankton feed on *phytoplankton* and in turn are a vital food source for larger animals.

# Index

Page numbers in **bold** indicate main references

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**Dr. Tony Juniper**, Cambridge, January 2016

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