

EV20001: ENVIRONMENTAL SCIENCE



Lecture #1

Environmental Problems, Their Causes and Sustainability

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Global Environmental Issues



Global Environmental Issues



TOP ENVIRONMENTAL CONCERN



41%
CLIMATE
CHANGE



38%
AIR
POLLUTION



32%
WATER
SCARCITY



24%
WATER
QUALITY



24%
DEPLETION OF
NATURAL RESOURCES



20%
FOOD
SAFETY

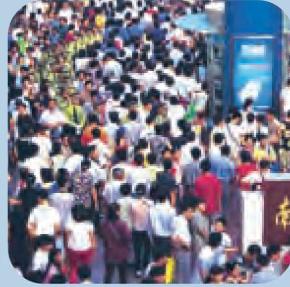


19%
POPULATION
GROWTH

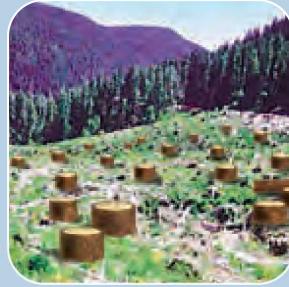
Sources: Cotton Council International & Cotton Incorporated 2017 Global Environment Survey --- survey of 7,365 women and men in the U.S., U.K., India, China, Mexico, Germany and Italy.

Causes of Modern Environmental Concerns

Causes of Environmental Problems



Population
growth



Unsustainable
resource use



Poverty

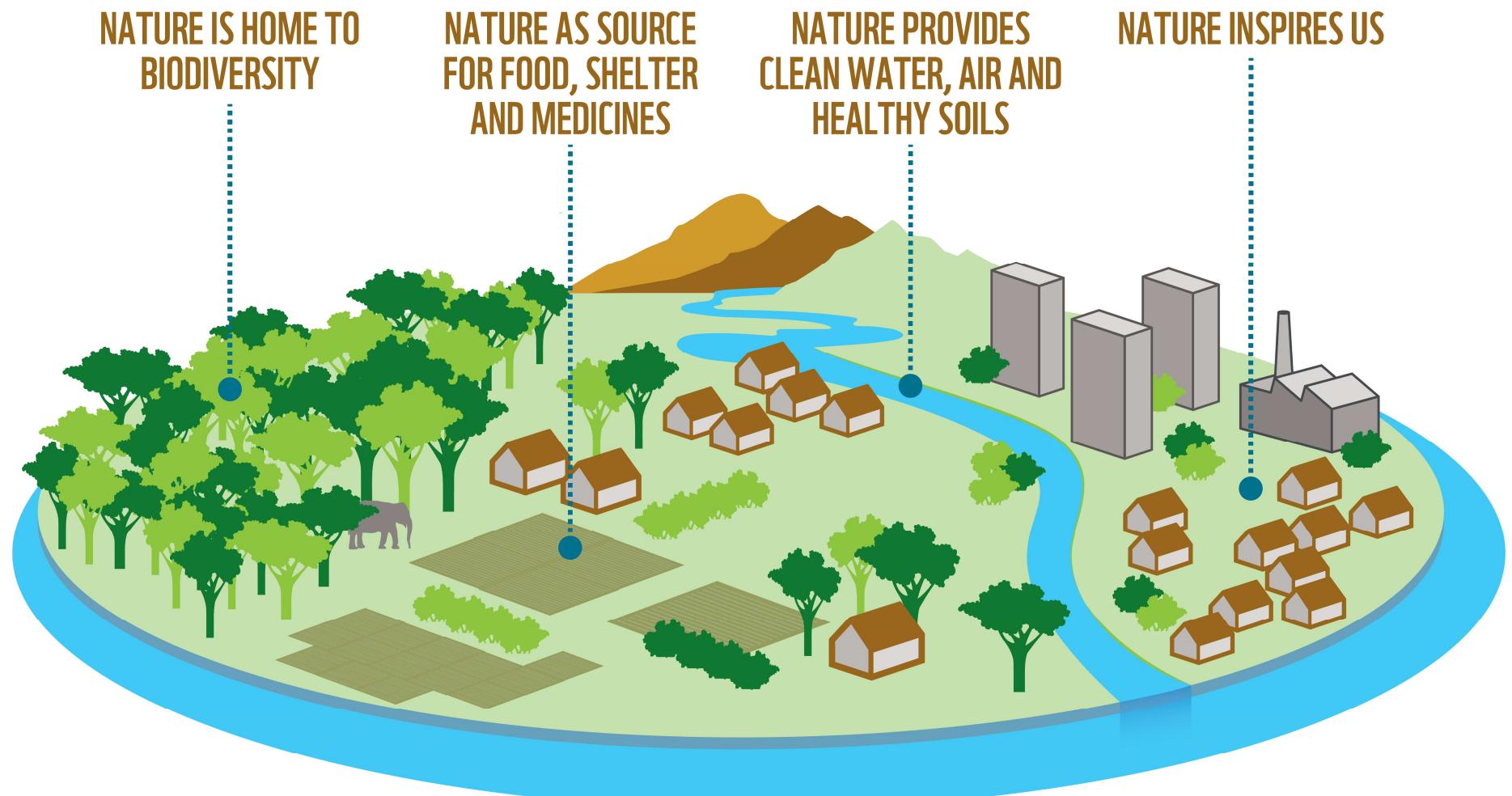


Excluding
environmental costs
from market prices



Importance of Natural Capital

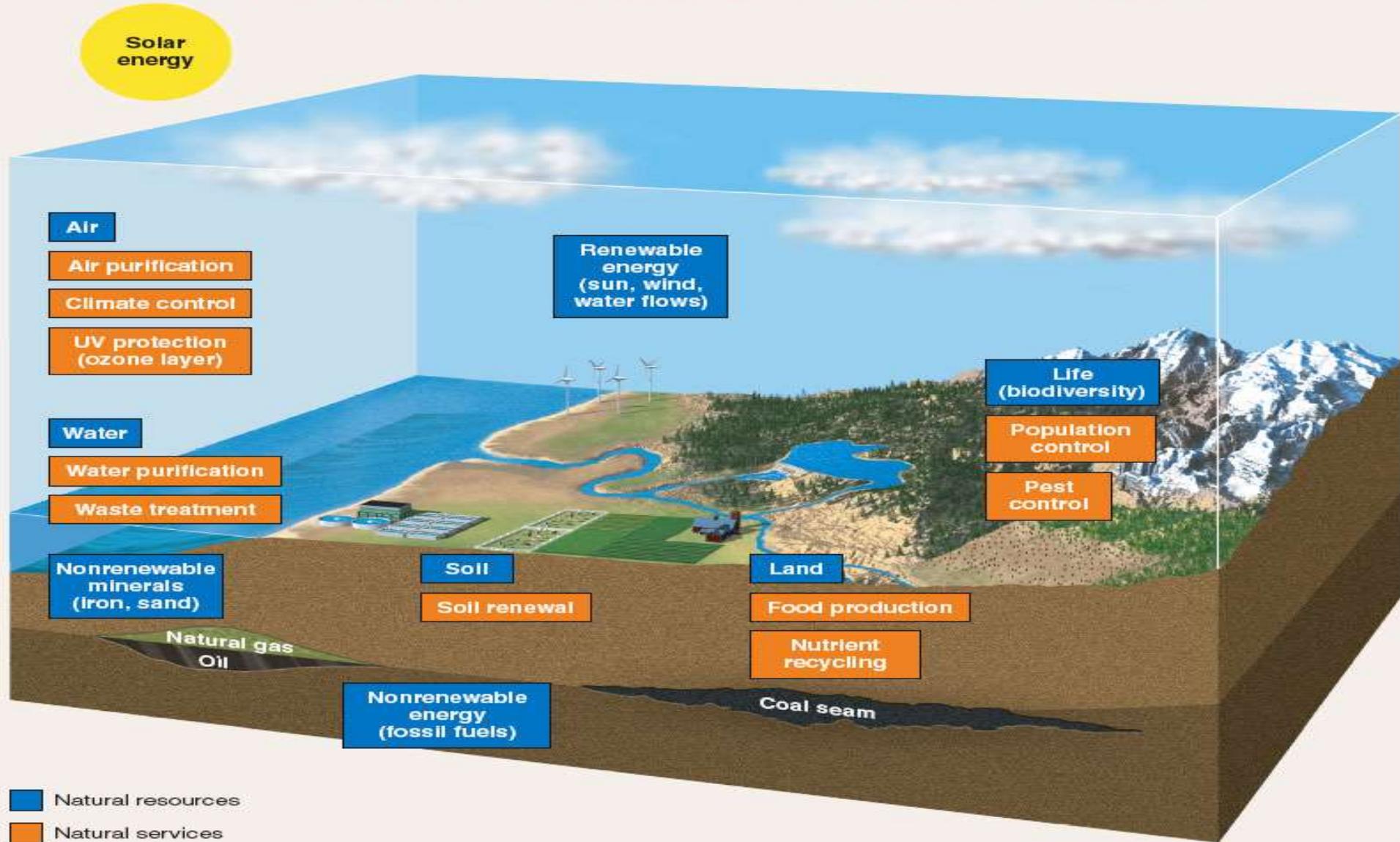
- Nature provides us with vital goods and services. To sustain modern human society we will continue to need the resources of nature that, throughout history, have allowed us to thrive.



Importance of Natural Capital

Natural Capital

Natural Capital = Natural Resources + Natural Services



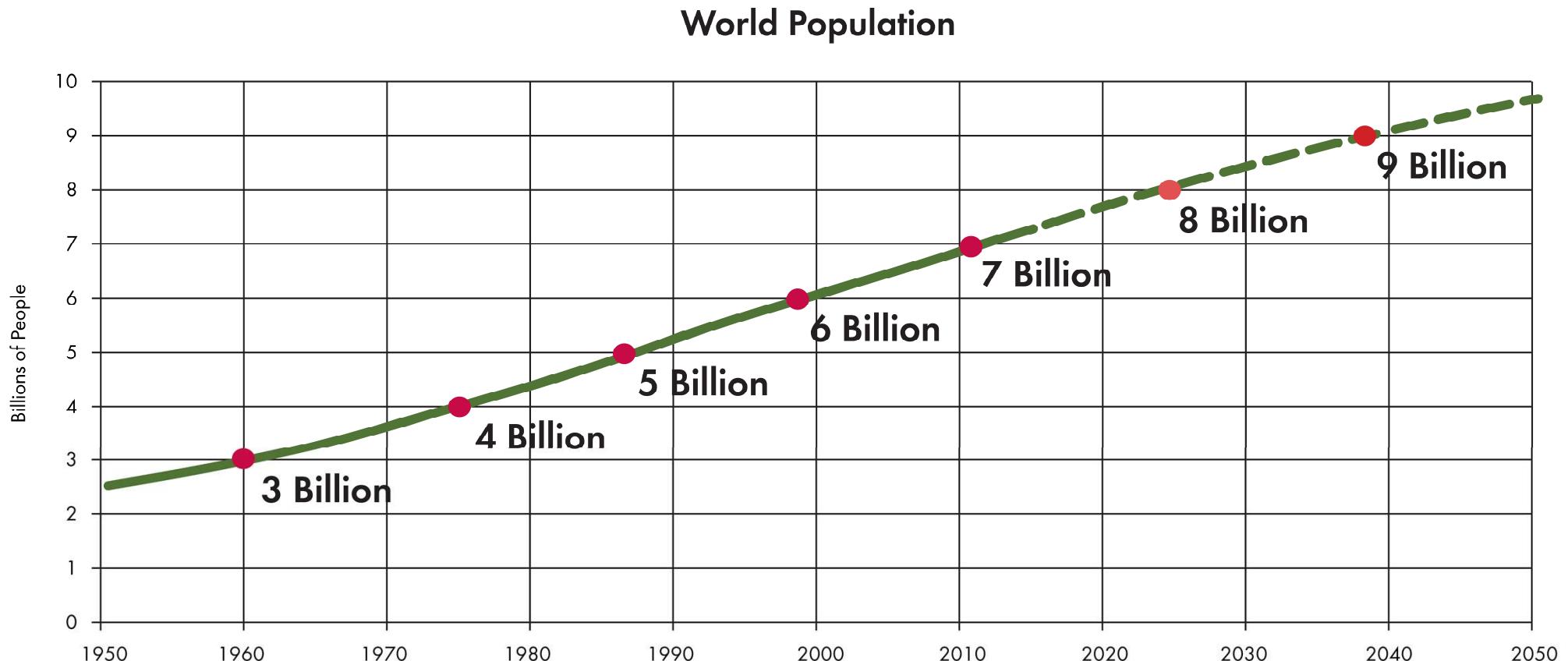


An aerial photograph of a large, crowded boat filled with people, sailing on a dark blue sea. The boat is packed tightly with individuals of various ages and backgrounds, illustrating a scene of overpopulation. The wake of the boat is visible in the water behind it.

Overpopulation

Exponential Population Growth

- As the future of the fossil fuel economy is increasingly uncertain, the world's population is still on the rise, and so are people's material expectations.



Overpopulation: Why Does it Matter?

■ Environment

- Overuse of non-renewable natural resources
- Habitat destruction and loss of biodiversity
- Pressure on land and soil degradation

■ Economy

- Strain on infrastructure
- Widespread poverty and unemployment
- Inequitable distribution

■ Social

- Lack of education to large population
- Social unrest due to limited resources
- Poor coverage of healthcare





Earth offers many natural resources that help us to live.
Some of them are essential for our survival while most are used for satisfying our needs.

Renewable

Replenished in days to several hundred years through natural processes as long as it is not used up faster than it is renewed.

e.g., solar energy, air, water, soil, plants

Non-Renewable

Exist in a fixed quantity in the Earth's crust and can be depleted much faster when their rate of consumption exceeds the rate than they are formed.

e.g., coal, oil, metals, non-metals

Our resources are limited...and it matters!



Tragedy of the Commons

- A common-property or free-access resource, which is owned by no one but is available to all users free of charge.
- Degradation occurs because the user reasons: “**If I do not use it someone else will. The little bit I use or pollute is not enough to matter.**”
- Example: Nobody really owns the groundwater; it is technically up for grabs. However, individual pumping of too much groundwater can result in the exhaustion of the resource. Eventually, depletion by a few means depletion for all. That is the ‘**tragedy**’.
- Solution:
 - ✓ Use shared renewable resources at rates well below their estimated sustainable yields.
 - ✓ Convert open-access renewable resources to private ownership.



Ecological Footprint

MEASURES

how fast we consume resources and generate waste



Energy

Settlement

Timber & Paper

Food & Fiber

Seafood

COMPARED TO

how fast nature can absorb our waste and generate new resources



Carbon Footprint

Built-up Land

Forest

Cropland & Pasture

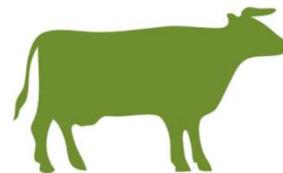
Fishing Grounds

Components of Ecological Footprint



CARBON

Represents the amount of forest land that could sequester CO₂ emissions from the burning of fossil fuels.



GRAZING LAND

Represents the amount of grazing land used to raise livestock for meat, dairy, hide and wool products.



FOREST

Represents the amount of forest required to supply timber products, pulp and fuel wood.



BUILT-UP LAND

Represents the amount of land covered by human infrastructure, including transportation, housing, industrial structures and reservoirs for hydropower.



CROPLAND

Represents the area used to grow crops for food and fibre for human consumption as well as the area for animal feed.

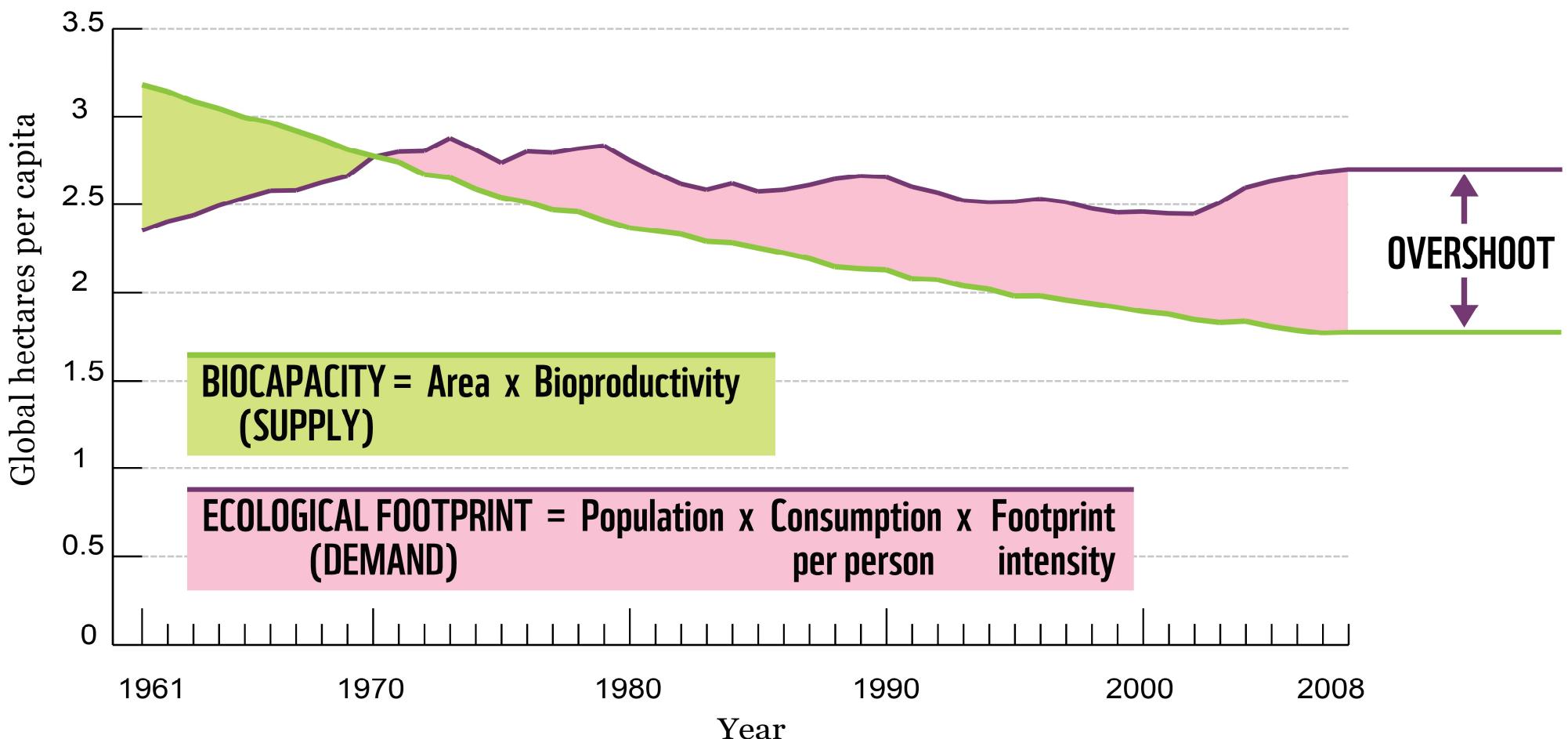


FISHING GROUNDS

Calculated from the estimated primary production required to support the fish and seafood caught.

Biocapacity & Bioproductivity

- **Biocapacity** quantifies nature's capacity to produce renewable resources, provide land for built-up areas and provide waste absorption services such as carbon uptake.
- **Bioproductivity** is the amount and rate of production which occur in a given ecosystem over a given time period.



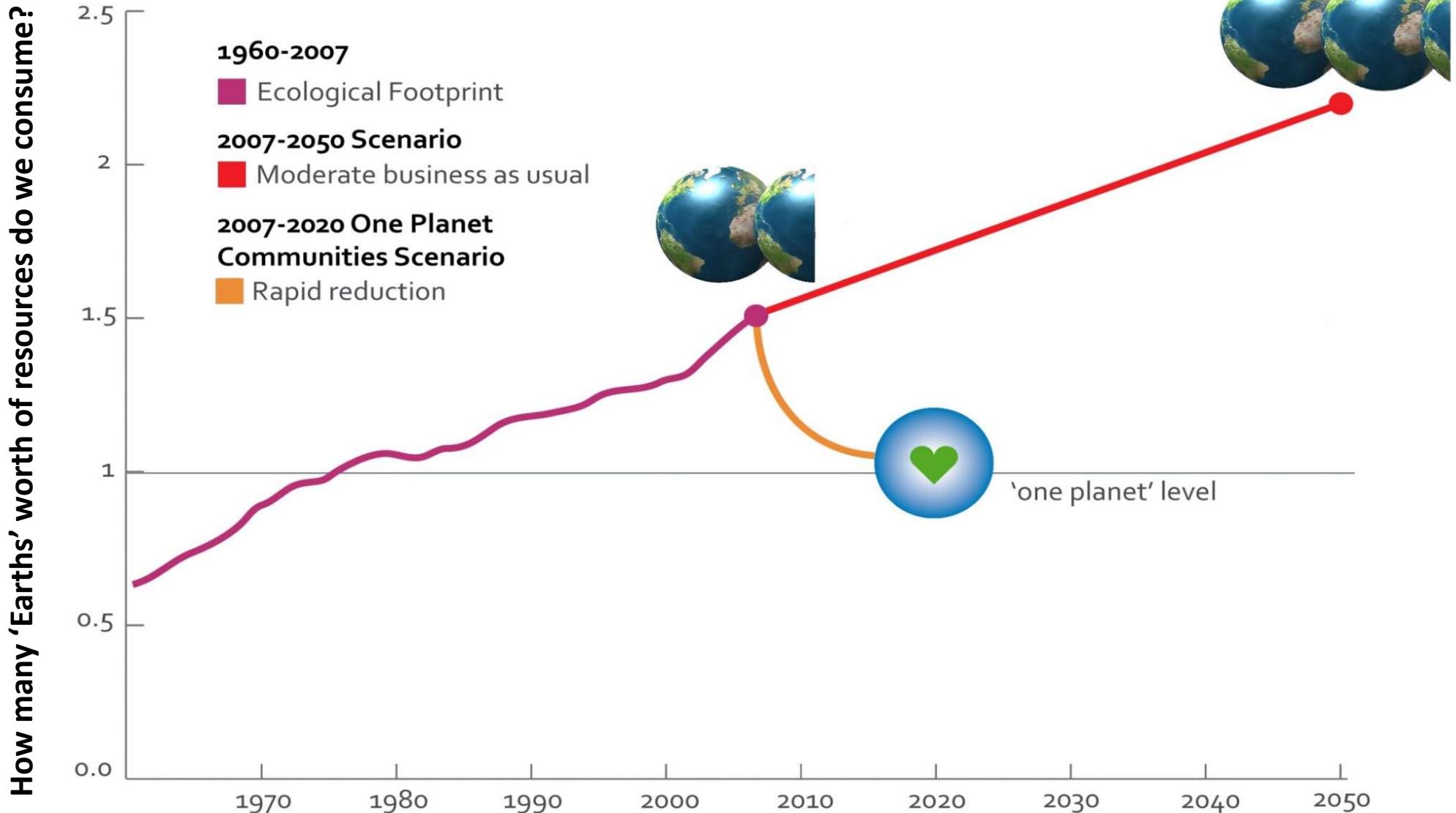
Ecological Deficit

- If a region's (country's, or the world's) total ecological footprint is larger than its biological capacity to replenish its renewable resources and absorb the resulting wastes and pollution, it is said to have an **ecological deficit**.
- A region in ecological deficit meets demand by importing, liquidating its own ecological assets (such as overfishing), and/or emitting carbon dioxide into the atmosphere.
- If a region's biocapacity exceeds its Ecological Footprint, it has an **ecological reserve**.



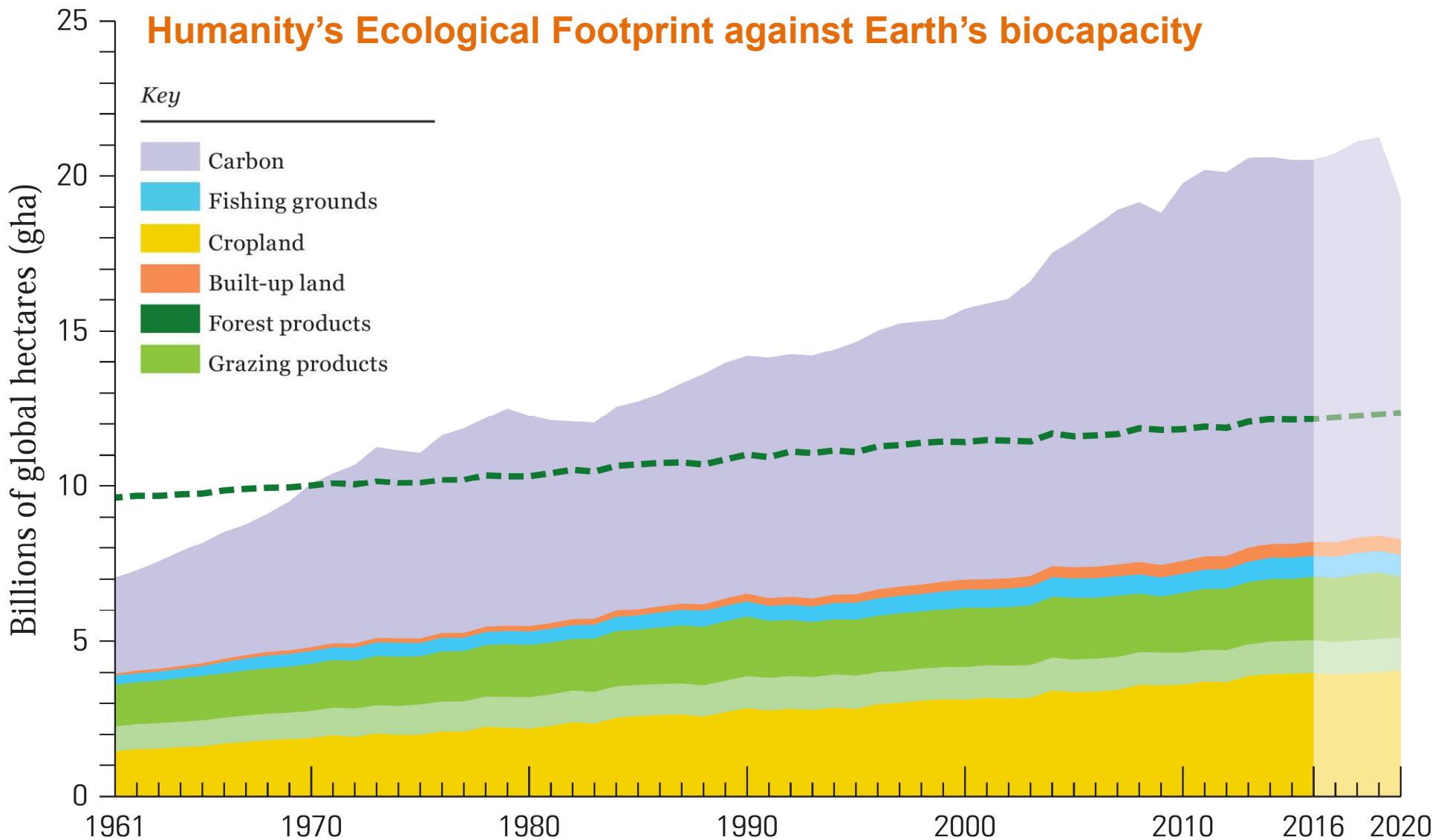
Overstepping Ourselves

- Today humanity uses the equivalent of 1.6 Earths to provide the resources we use and absorb our waste.

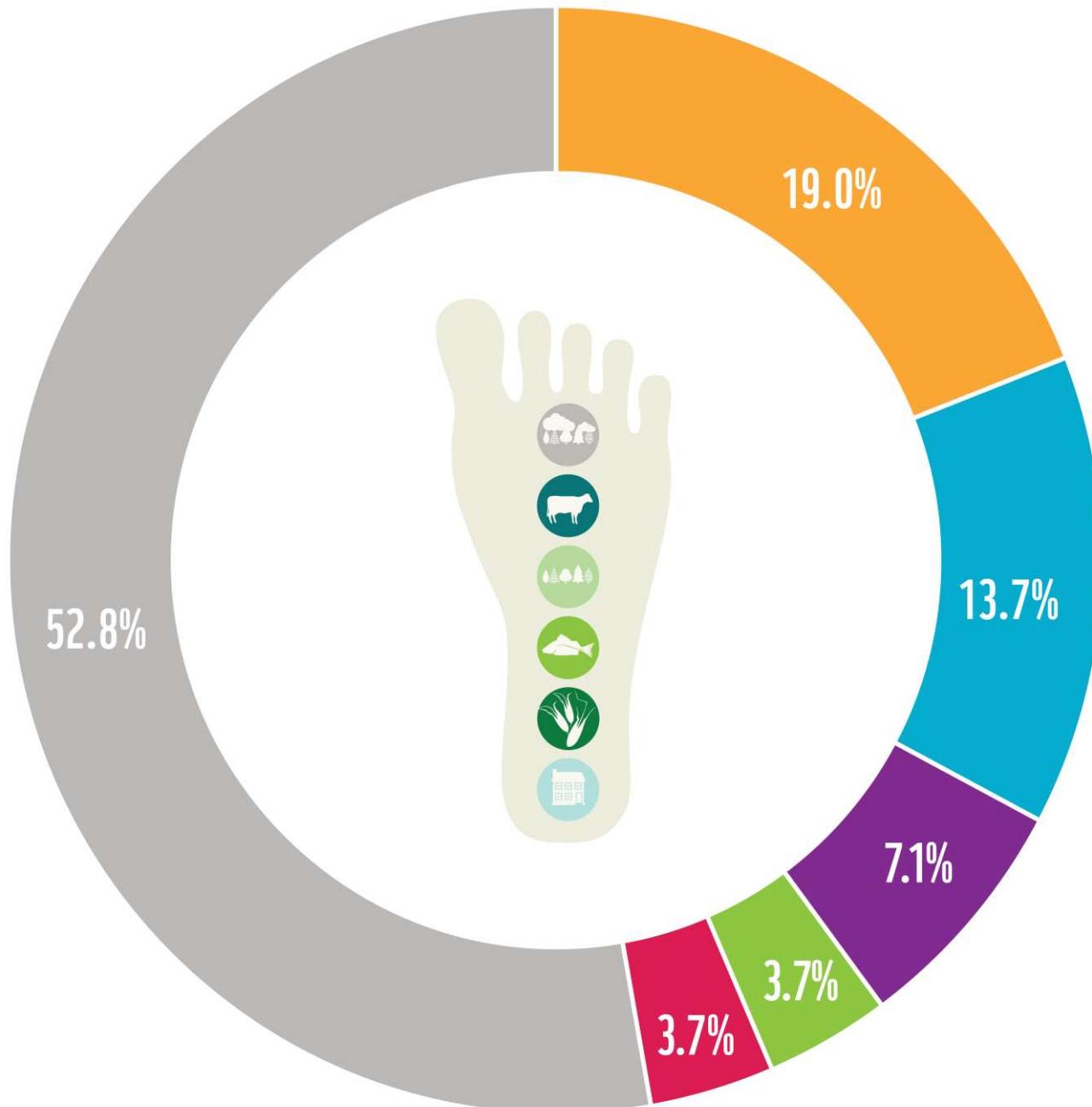


Overstepping Ourselves

- For more than 40 years, humanity's demand on nature has exceeded what our planet can replenish.



Overstepping Ourselves



Share of total ecological footprint among the top five countries with the highest demand and the rest of the world. If everyone lived like an average resident of the USA, a total of four Earths would be required to regenerate humanity's annual demand on nature.

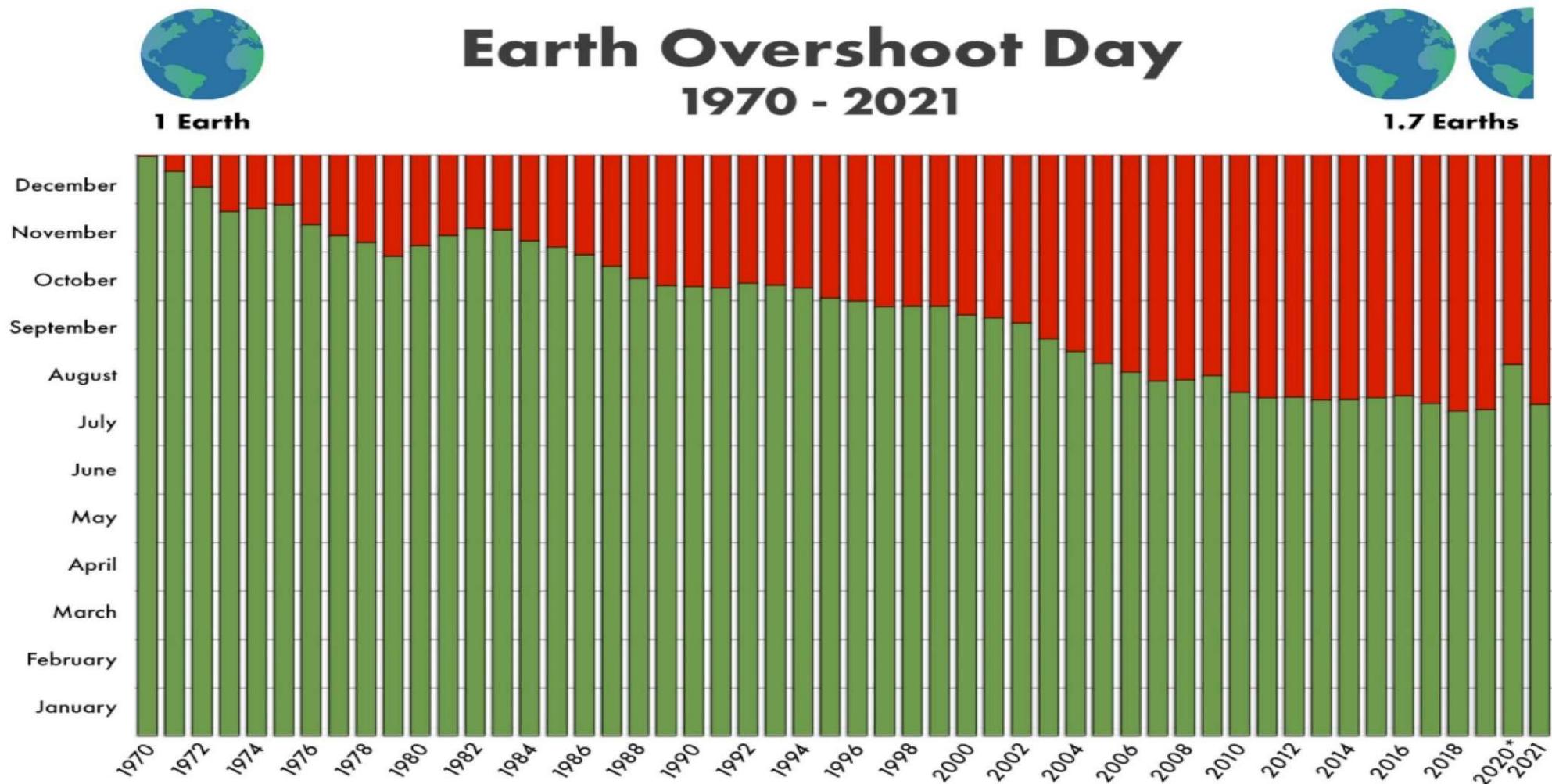
Key

- █ China
- █ United States of America
- █ India
- █ Brazil
- █ Russia
- █ Rest of world

Earth Overshoot Day

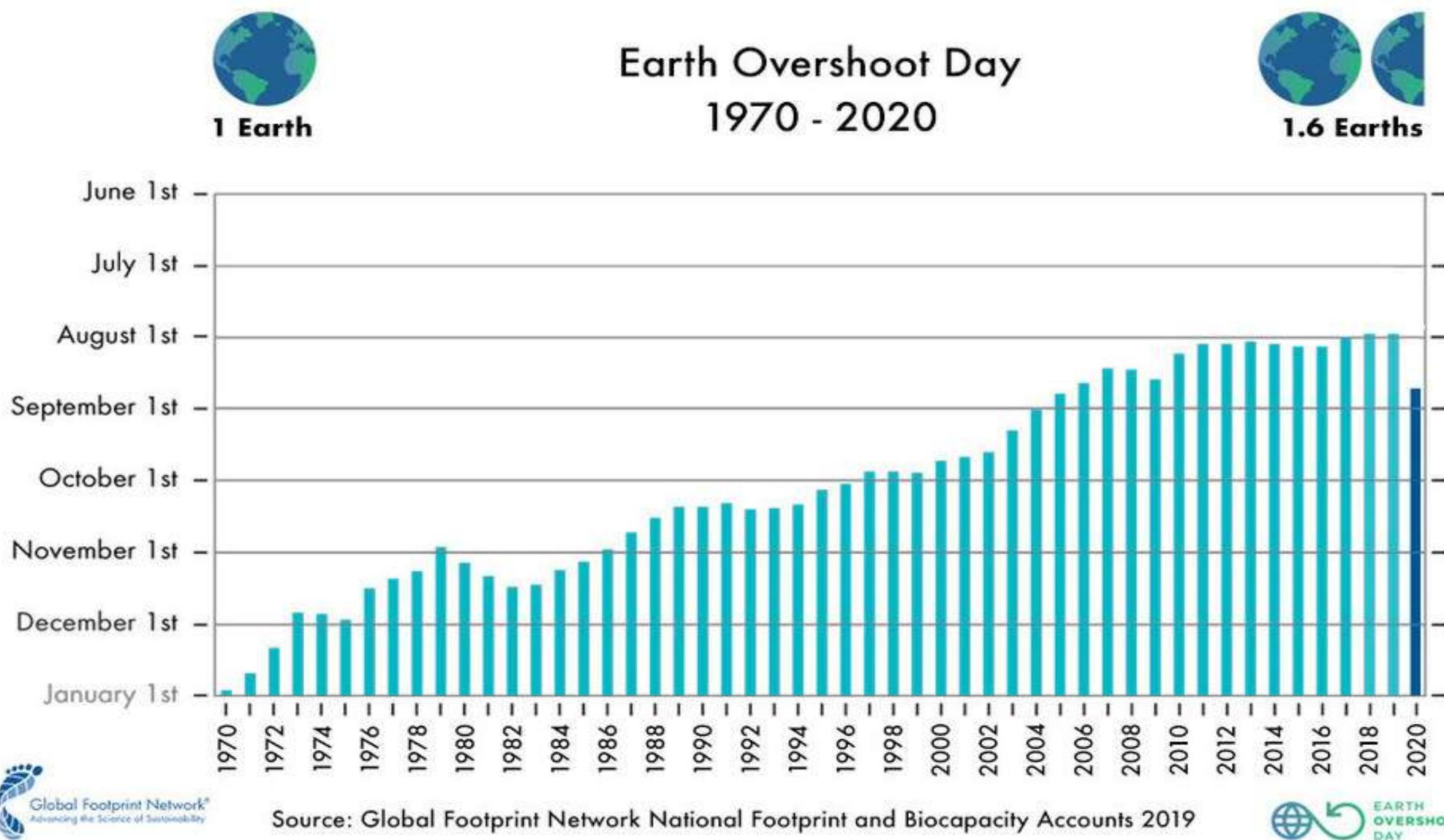
- Earth Overshoot Day marks the date when humanity's demand for ecological resources and services in a given year exceeds what the Earth can regenerate in that year.

(Planet's Biocapacity / Humanity's Ecological Footprint) x 365 = Earth Overshoot Day



2020 Earth Overshoot Day: 22 August

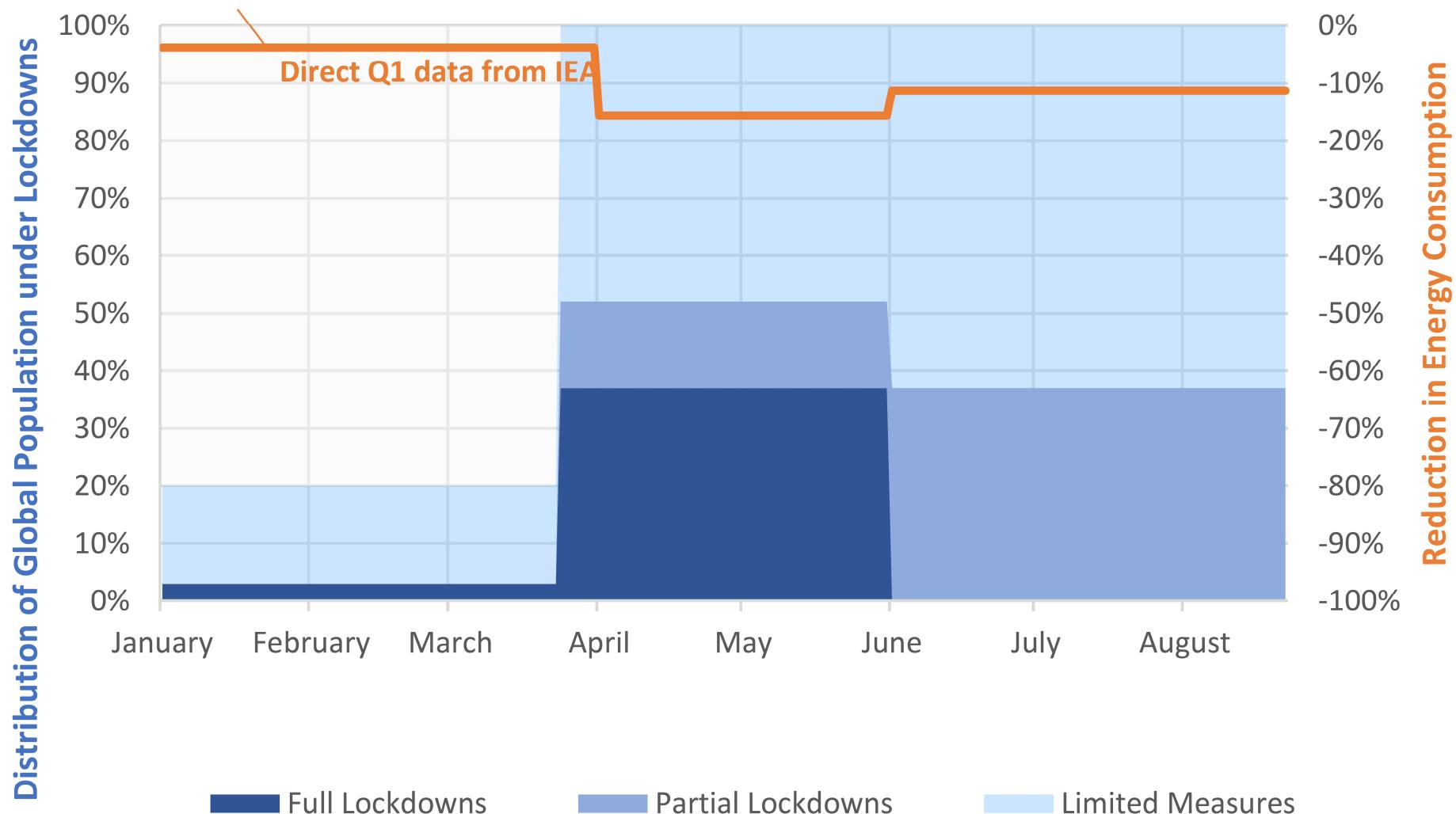
- In 2020, Earth Overshoot Day fell on 22 August. The ongoing COVID-19 pandemic has caused humanity's ecological footprint to contract.



2020 Changes to Ecological Footprint

- Change in Carbon Footprint: 14.5% reduction

Visualising the distribution of lockdowns and their effects
on energy consumption



2020 Changes to Ecological Footprint



■ Forests Product Footprint: 8.4% reduction

- Reduced demand for forest products due to economic slowdown
- Increased pressure on forests from COVID-19 induced internal migration

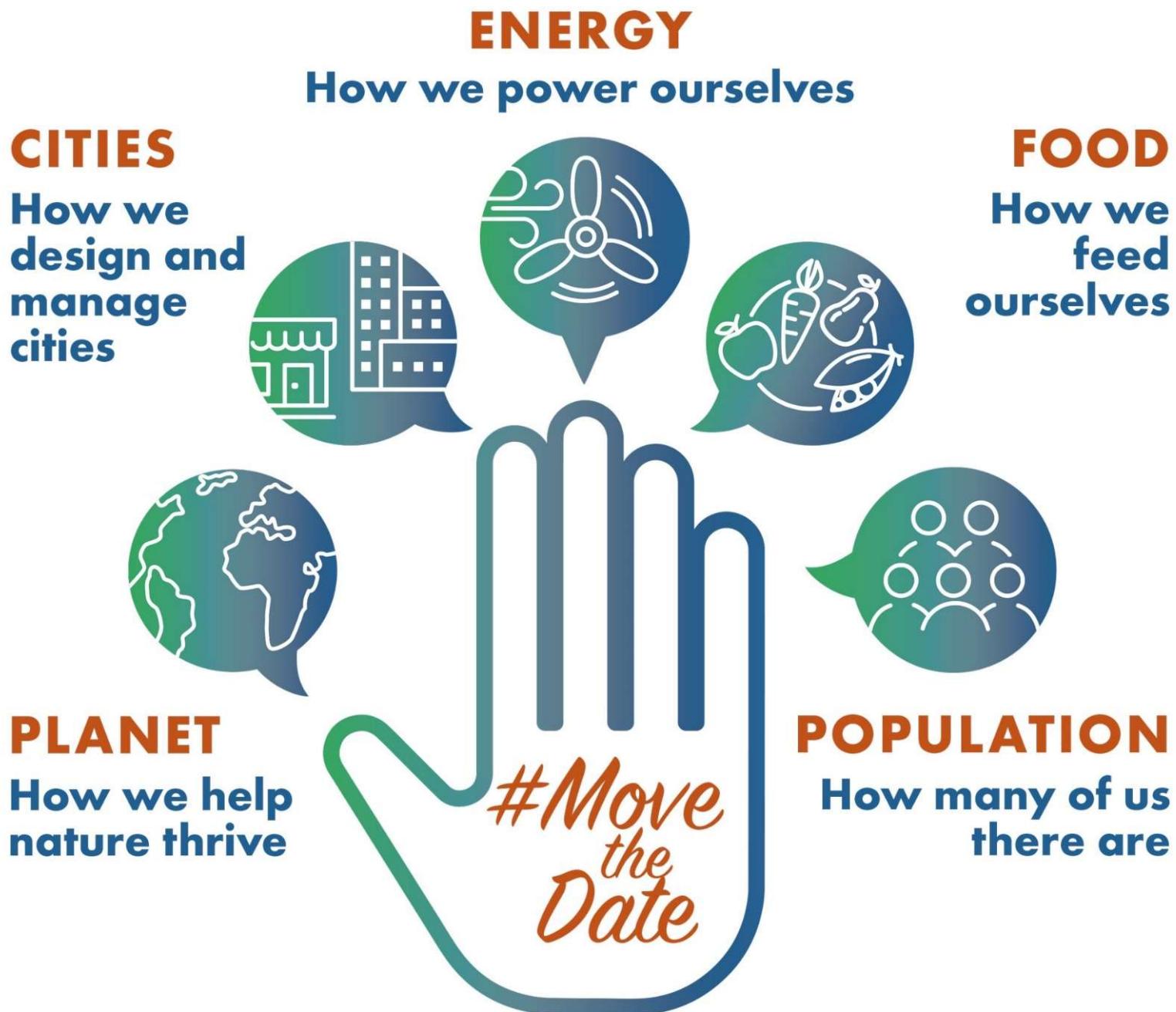


Lessons from COVID-19

- Governments are capable of acting swiftly, both in terms of regulations and spending, when they put human lives above all else.
- Humanity is one biology and is stronger when we act together:
 - Businesses and individuals alike can effectively align and collaborate in the pursuit of a shared goal when people recognize that their own lives, and that of the people they love, may be at risk.
 - The necessary actions required to protect oneself, one's household, and one's community also protect others; one's decisions at all levels have consequences for all.



#MoveTheDate





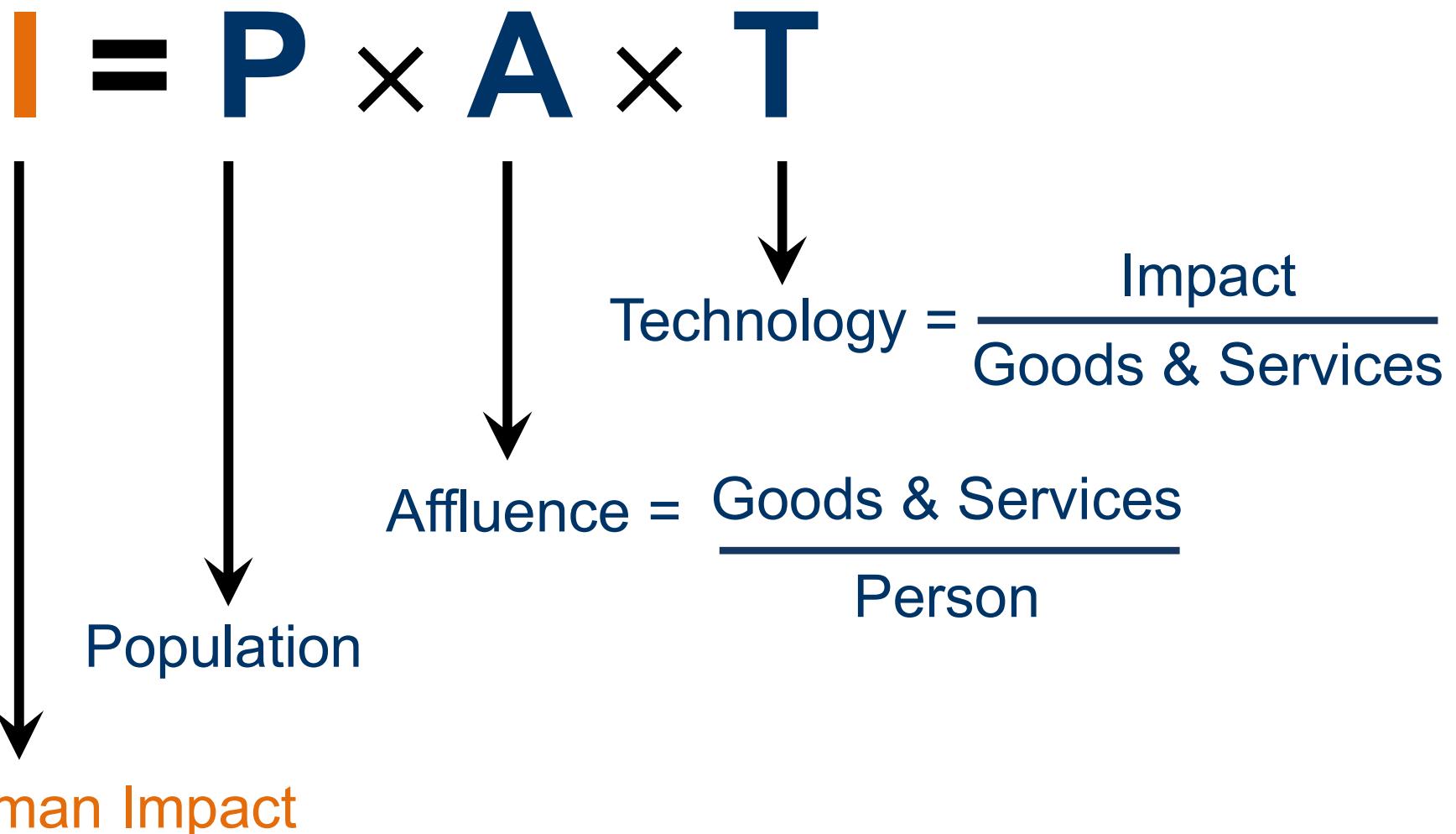
Overconsumption



IPAT Environmental Impact Model



- Proposed by Paul Ehrlich and John Holdren in the early 1970s, the IPAT model determines the environmental impact of human activities.



IPAT Environmental Impact Model



- What are the factors that influence the amount of gasoline we burn in automobiles?

$$\text{gasoline} = \text{number of cars} \times \frac{\text{miles driven}}{\text{car}} \times \frac{\text{gasoline}}{\text{mile}}$$

Impact "I" population "P" service provided technology "T"

car
"A"

```
graph TD; I[Impact "I"] --> P[population "P"]; P --> C[service provided  
---  
car]; C --> T[technology "T"]; T --> G[gasoline / mile]
```



IPAT Connections

Developing Countries



Population (P)



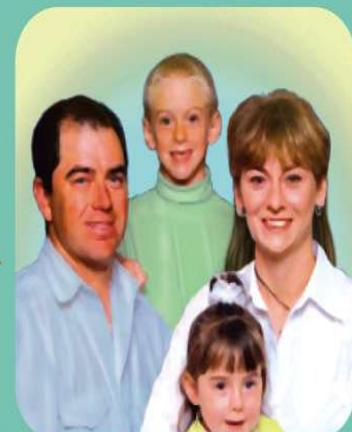
Consumption per person (affluence, A)



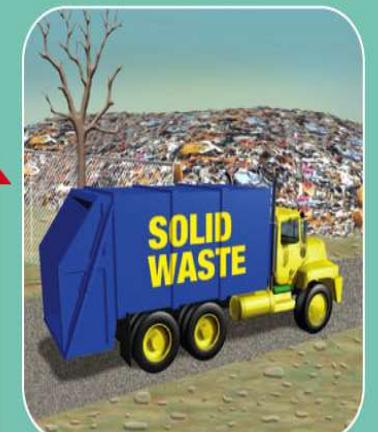
Technological impact per unit of consumption (T)



= Environmental impact of population (I)



Developed Countries

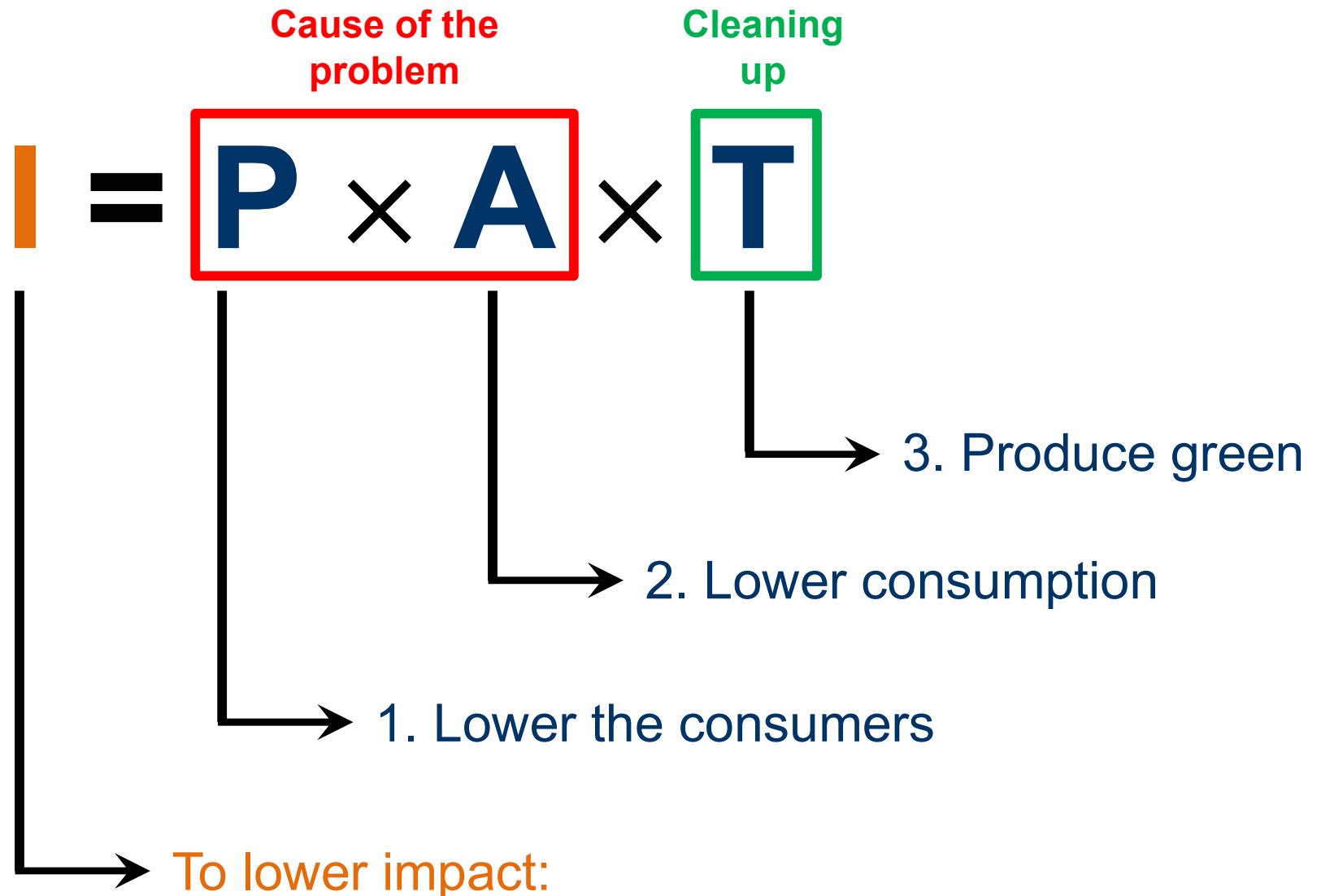


Affluence has harmful and beneficial effects

- ❖ Many consumers in developed countries have become addicted to buying more and more stuff in their search for fulfilment and happiness.
- ❖ **Affluenza** is the unsustainable addiction to overconsumption and materialism exhibited in the lifestyles of affluent consumers in the developed countries.
- ❖ Affluence have harmful environmental impact due to
 - high levels of consumption.
 - high levels of pollution.
 - unnecessary waste of resources.
- ❖ Affluence can, however, provide funding for developing technologies to reduce
 - pollution.
 - environmental degradation.
 - resource waste.



Reducing Environmental Impact





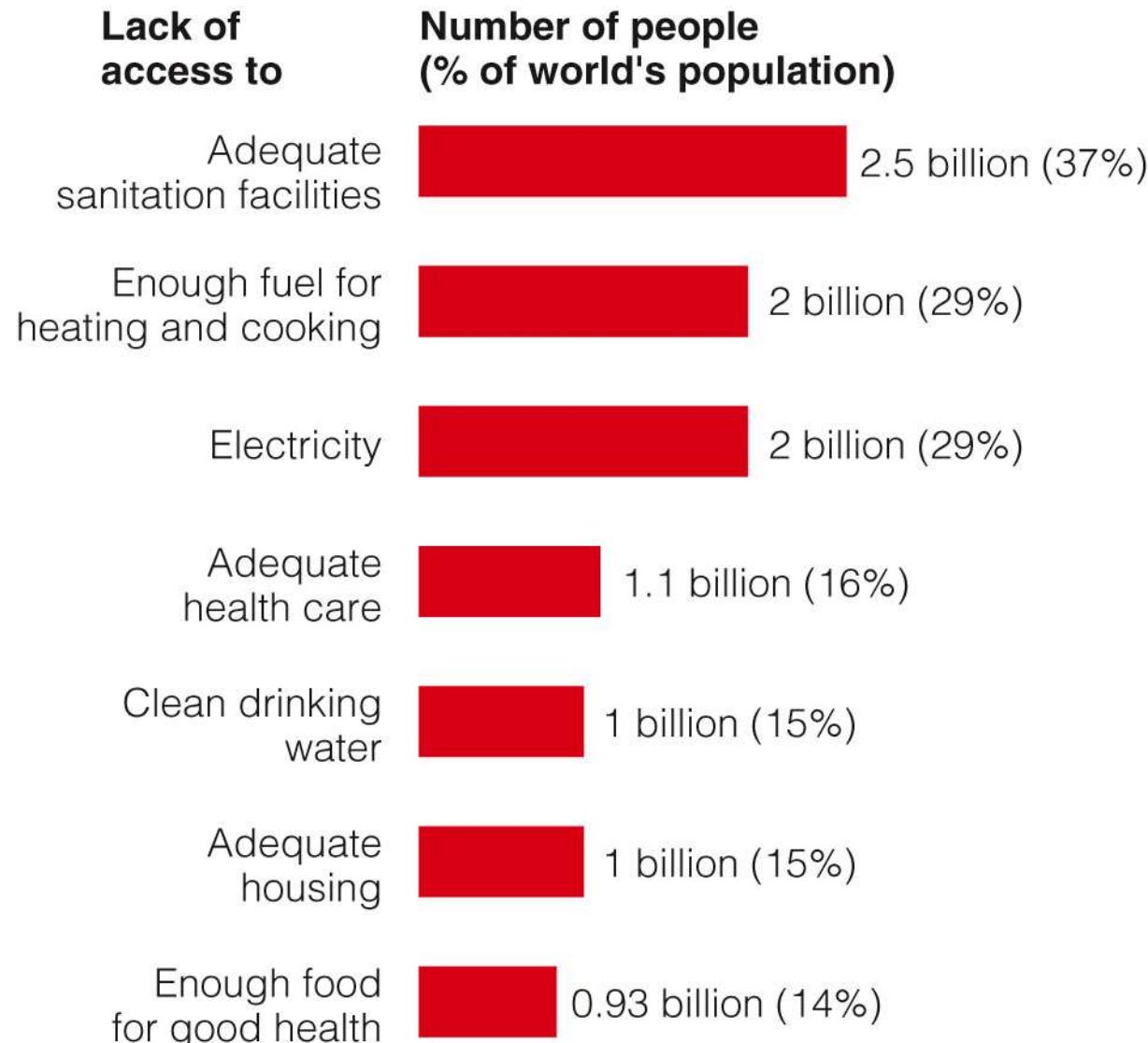
Poverty





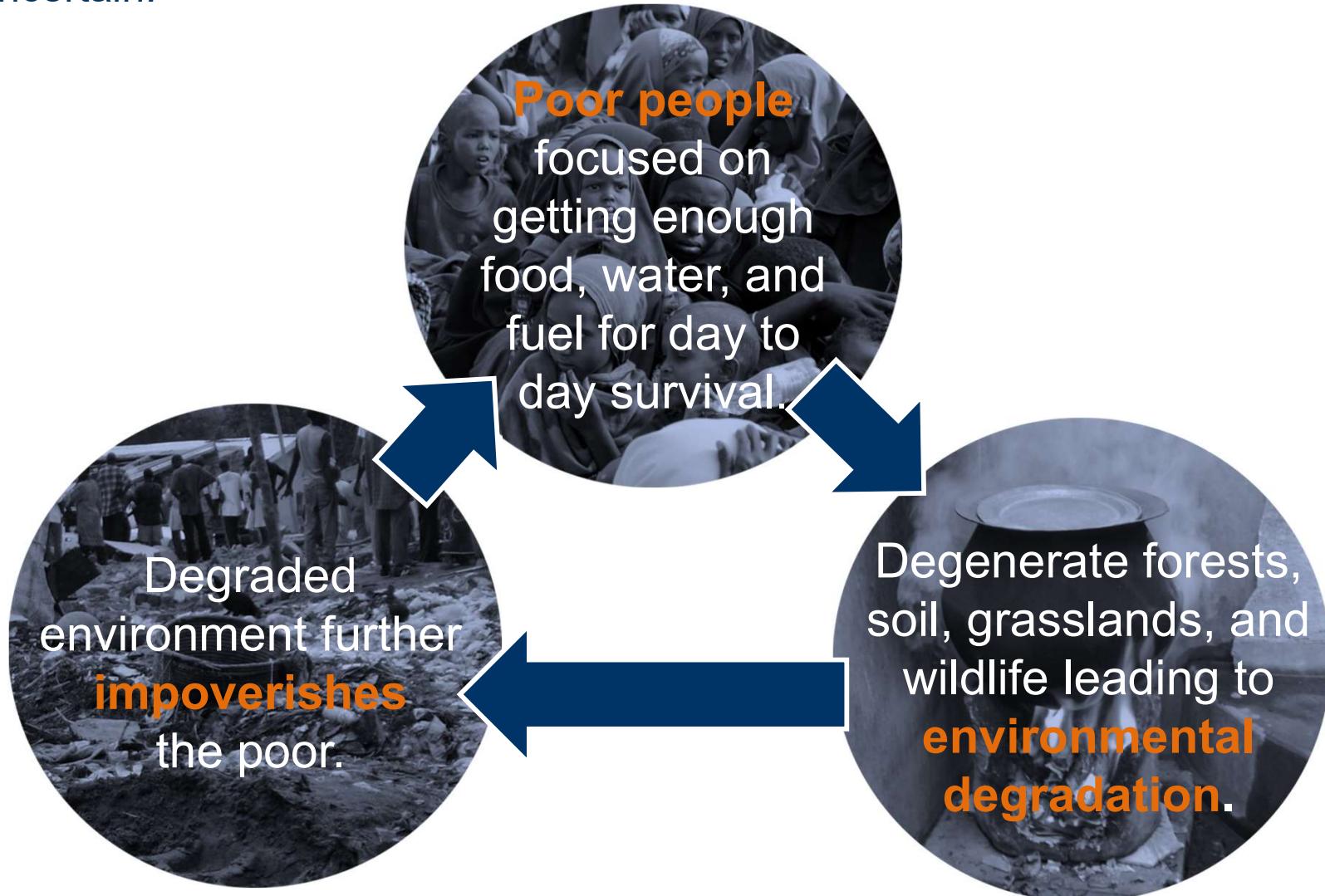
Poverty Has Many Harmful Effects

- Many of the world's poor do not have access to the basic necessities for a healthy, productive, and decent life.



Poverty Has Many Harmful Effects

- Poverty and environment are linked in a **downward spiral**; poor people are forced to overuse environmental resources to survive from day to day, and their impoverishment of their environment further impoverishes them, making their survival ever more difficult and uncertain.





Excluding Environmental Costs





Prices Do Not Include Value of Natural Capital

- Nature provides resources at no cost. Human activities degrade these resources but do not pay the cost.
- Example:
 - ❖ Timber companies pay the cost of clear-cutting forests but do not pay for the resulting environmental degradation and loss of wildlife habitat.
 - ❖ Fishing companies pay the costs of catching fish but do not pay for the depletion of fish stocks.
- Taxes and fines aim to fix this problem but it is not enough.



People Have Different Views



Planetary Management

- We are apart from the rest of nature and can manage nature to meet our increasing needs and wants.
- Because of our ingenuity and technology, we will not run out of resources.
- The potential for economic growth is essentially unlimited.
- Our success depends on how well we manage the earth's life-support systems mostly for our benefit.

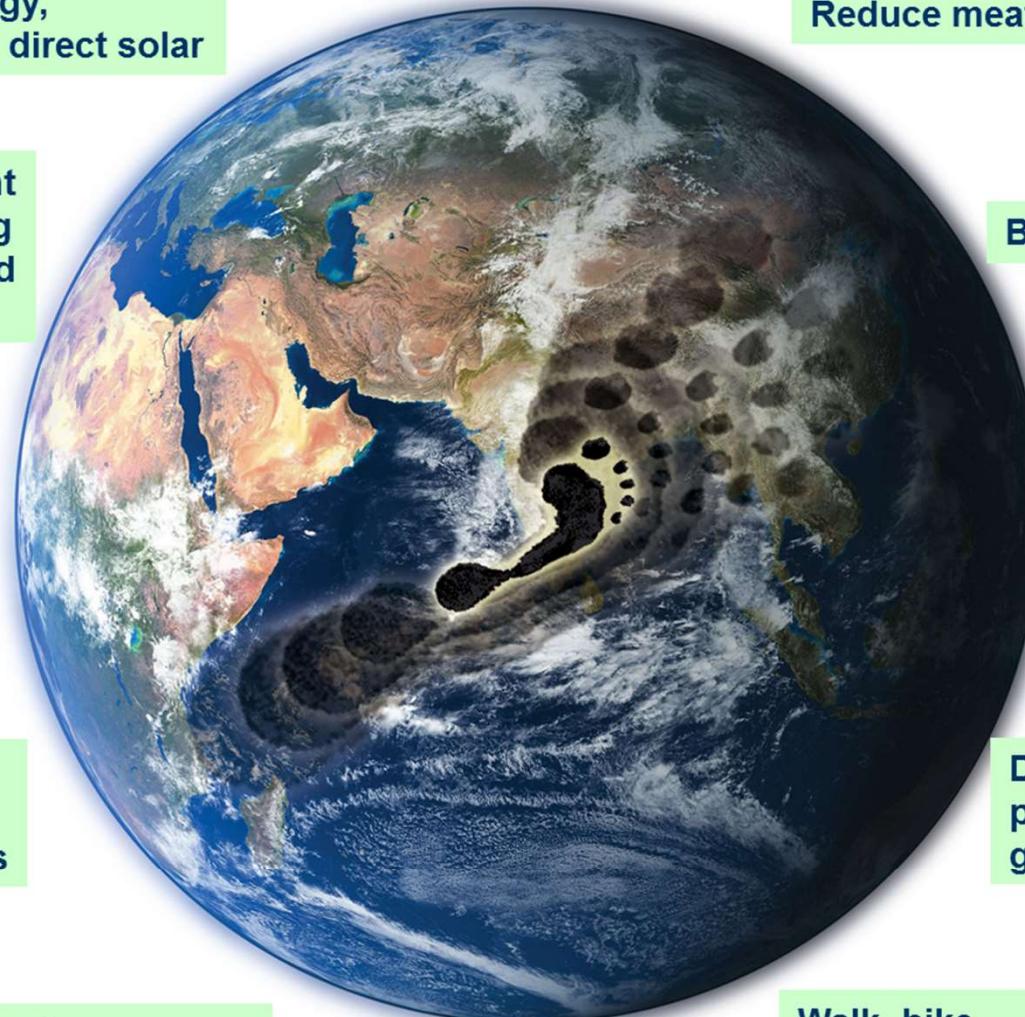
Stewardship

- We have an ethical responsibility to be caring managers, or stewards, of the earth.
- We will probably not run out of resources, but they should not be wasted.
- We should encourage environmentally beneficial forms of economic growth and discourage environmentally harmful forms.
- Our success depends on how well we manage the earth's life-support systems for our benefit and for the rest of nature.

Environmental Wisdom

- We are a part of and totally dependent on nature, and nature exists for all species.
- Resources are limited and should not be wasted.
- We should encourage earth-sustaining forms of economic growth and discourage earth-degrading forms.
- Our success depends on learning how nature sustains itself and integrating such lessons from nature into the ways we think and act.

We Can Solve Environmental Problems



Use renewable energy,
especially wind and direct solar

Insulate your house
and plug air leaks

Reduce meat consumption

Use energy-efficient
heating and cooling
systems, lights, and
appliances

Buy locally grown food

Reduce, reuse,
and recycle

Buy or grow
organic food

Use water-saving
appliances and
irrigation methods

Don't use
pesticides on your
garden or lawn

Reduce car use

Drive an
energy-efficient
vehicle

Walk, bike,
carpool, or take mass
transit whenever possible

Sustainable Development

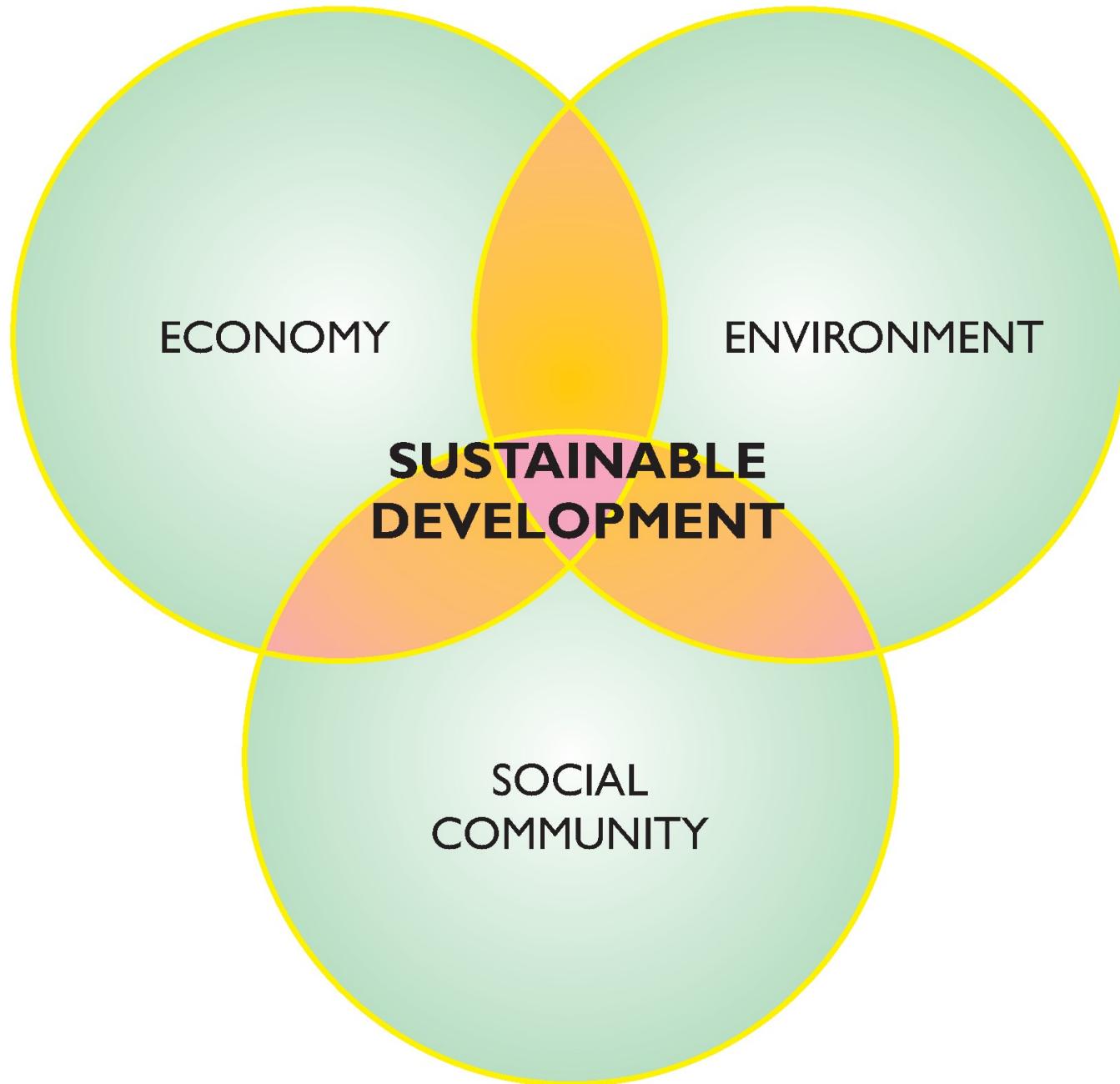


“Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs.”

definition by the Brundtland Commission
of the overall goal of sustainable development
1987



3 Pillars of Sustainability



Historical Roots of the Concept

AN ESSAY ON



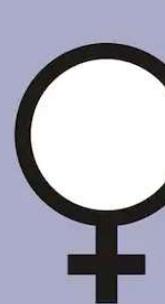
1

ERADICATE
EXTREME POVERTY
AND HUNGER



2

ACHIEVE UNIVERSAL
PRIMARY EDUCATION



3

PROMOTE GENDER
EQUALITY AND
EMPOWER WOMEN



4

REDUCE
CHILD MORTALITY



5

IMPROVE MATERNAL
HEALTH



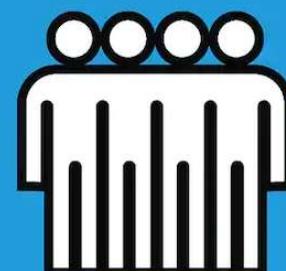
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COMBAT HIV/AIDS,
MALARIA AND OTHER
DISEASES



7

ENSURE
ENVIRONMENTAL
SUSTAINABILITY



8

A GLOBAL
PARTNERSHIP FOR
DEVELOPMENT

ON ENVIRONMENT
AND DEVELOPMENT

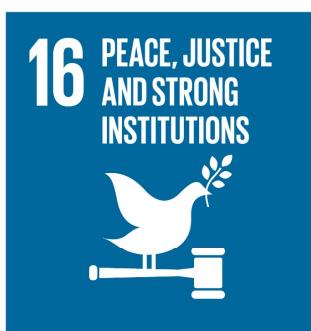
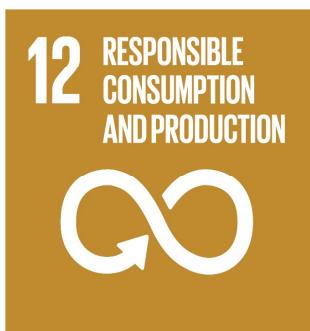
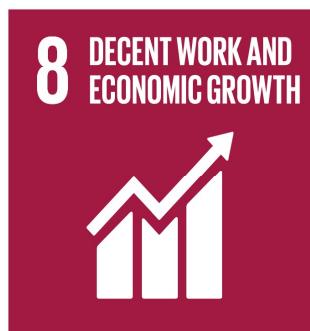


PROGRESS

THOSE CONSIDERED EXTREMELY POOR ACCOUNTED FOR ALMOST HALF OF THE DEVELOPING WORLD'S POPULATION IN 1990, TEN YEARS BEFORE THE MDGS WERE ESTABLISHED. IN 2005, 5 YEARS INTO THE MDGs, THEY ACCOUNTED FOR JUST OVER A QUARTER.

2030 Agenda for Sustainable Development

- The Sustainable Development Goals (SDGs) are a set of 17 objectives set forth by the United Nations in 2015 to define the global development agenda for the next 15 years until 2030.





Goal #1: No Poverty



End poverty in all its forms everywhere

See the globally adopted targets for this goal on the UN website:

<https://sustainabledevelopment.un.org/topics>

Edmonton, Canada

The role of cities in ending poverty

More than 100,000 Edmontonians live in poverty, which costs Edmonton up to \$7.1 billion each year in healthcare and social services. The EndPovertyEdmonton initiative seeks to eliminate poverty in Edmonton within a generation, based on economic arguments, the human rights case and a public opinion approach. Through strong public participation, multiple stakeholders are engaged in development of a long-term plan against poverty.

Tshwane, South Africa

Poverty reduction and community development conference, Tshwane Vision 2055 'Remaking South Africa's Capital City'

In Tshwane, approximately 27.9 percent of the population live in poverty. Since 2008, the local government has been developing an integrated poverty reduction and community development strategy. Based on community-driven approaches, over ten poverty alleviation programs are being delivered in the city, targeting housing facilities, grants-in-aid and support for the orphans.



Goal #2: Zero Hunger

2 ZERO
HUNGER



End hunger, achieve food security and improved nutrition

See the globally adopted targets for this goal on the UN website:
<https://sustainabledevelopment.un.org/topics>

Almada, Portugal

Promoting local food production

Agriculture in Almada has strong cultural traditions, as about 23% of land is used agriculturally. With the goal to become self-sufficient in its horticulture needs, the City of Almada promotes agriculture activity in local urban and peri-urban areas. The initiative enhances green infrastructure and the agricultural parks network, wastewater recycling for horticulture, are targets, master plans and information activities.

Dar es Salaam, Tanzania

Demonstrating the Urban NEXUS approach to link water, energy and food resources in schools

Through cross-institutional collaboration, two schools in Dar es Salaam operationalized the Urban NEXUS approach as a new design process towards resource-efficient and productive service delivery. The project serves as an example of integrated solutions for optimizing energy, water and food to be scaled up throughout the metropolitan region.

Goal #3: Good Health & Well Being



3 GOOD HEALTH
AND WELL-BEING



Ensure healthy lives and promote well-being for all at all ages

See the globally adopted targets for this goal on the UN website:
<https://sustainabledevelopment.un.org/topics>

Santa Monica, USA

Define, measure and actively improve wellbeing

Santa Monica's Wellbeing Project followed the city's 2013 success in the Bloomberg Philanthropies' inaugural Mayors Challenge, which encouraged the city to develop a local measure of well-being. A new wellbeing index brought together a global consortium of experts to develop a framework, which can be practically applied for local policy-making based on developmental progress beyond GDP measures.

Thimpu, Bhutan

Toward a new development paradigm

In March 2014, the city of Thimphu hosted local forums on the concept of a New Development Paradigm (NDP), a holistic and sustainable approach to development which prioritizes the happiness and well-being of humans and all life. The NDP draws on the Gross National Happiness Index and guides institutions to create policies that can deliver the conditions for sustainability and dynamic contributions to people's health and happiness.



Goal #4: Quality Education

4 QUALITY EDUCATION



Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all

See the globally adopted targets for this goal on the UN website:

<https://sustainabledevelopment.un.org/topics>

Helsingborg, Sweden:

Environmental education and participation for local sustainable development

The city of Helsingborg established the Environment Workshop and Sustainable School Campus as long-term educational projects in a collaboration between the municipal departments for School and Youth Services, and City Planning and Technical Services. By engaging young students, the city is promoting quality education and a long-term behavioral change towards sustainability.

Beijing, China

An experienced learning city in a new phase of development

Beijing officially launched its “learning city” agenda in 1999 in order to promote innovation, sustainability and inclusiveness in preparation for the 2008 Olympic Games. The strong leadership of the Beijing Municipal Government has led to strengthened community education and the creation of websites that serve as lifelong learning platforms for citizens. The Learning Beijing initiative has grown rapidly over the last fifteen years.

Goal #5: Gender Equality



5 GENDER EQUALITY



Achieve gender equality and empower all women and girls

See the globally adopted targets for this goal on the UN website:

https://sustainabledevelopment.un.org/topics/gender_equality

Växjö, Sweden

Women leaders transforming cities

Under the lead of the Mayor of Växjö, a discussion on how local governments can foster women's leadership and participation at all levels - from the citizen on the street to the mayor's office is underway. The example of Sweden helps to explore the opportunities for the entire political engagement process, which is necessary if governments are to better foster effective women leaders for climate and sustainability.

Rosario, Argentina

Gender inclusive cities program

The Equal Opportunities Plan is the most important policy developed by the municipality of Rosario to achieve gender equity. Its formulation and implementation, including gender mainstreaming, interventions directed at women's strategic interests, not only their basic needs and transformative gender policies. It intends to act upon the causes that create inequalities between men and women.



Goal #6: Clean Water & Sanitization

6 CLEAN WATER AND SANITATION



Ensure availability and sustainable management of water and sanitation for all

See the globally adopted targets for this goal on the UN website:
<https://sustainabledevelopment.un.org/topics>

Melbourne, Australia

Total watermark program invests in stormwater harvesting

In the decade known as the Millennium Drought, the State of Victoria experienced rainfall 14 per cent below average. This drought, combined with severe water restrictions affected the health of Melbourne's urban forest sending many trees into decline. The City implemented several large stormwater harvesting schemes across the city, invested \$20 million in their stormwater harvesting network, which is now delivering 25% of the city's annual landscape water requirements and is reducing the reliance on potable water.

Nashik, India

An Urban NEXUS approach to optimize water, energy and land resources in peri-urban agriculture

The Nashik Municipal Corporation adopted an Urban NEXUS approach to improve resource productivity at the local and regional level in India, and to avoid consequences of narrow sectoral approaches causing unsustainable water management. The Urban NEXUS pilot project introduced a collaborative design and implementation of innovative solutions and programs for optimizing water, energy and land resources in peri-urban agricultural practices in Nashik.



Goal #7: Affordable & Clean Energy

7 AFFORDABLE AND CLEAN ENERGY



Ensure access to affordable, reliable, sustainable and modern energy for all

See the globally adopted targets for this goal on the UN website:

<https://sustainabledevelopment.un.org/topics>

Vancouver, Canada

100% Renewable Energy Target

ICLEI Member Vancouver recently took a huge step towards becoming a fully sustainable city, with its City Council voting for the long-term goal of deriving 100 percent of the city's energy from renewable sources. Vancouver joins a number of other cities, including San Francisco, Copenhagen and Sydney, in making this ambitious target a part of its urban planning.

Balikpapan, Indonesia

Multi-faceted stakeholder approaches for a low-carbon city

Urban-LEDS Model City Balikpapan used its first GHG inventory, to define emission reduction targets for the community by 2020 with 15.6% based on 2010 levels. Among other areas, the city works on protection and expansion of a protected city forest area, energy-efficient lighting, a waste-to-energy landfill methane capture facility, and is involved in the Corporate Social Responsibility forum working with businesses.

Goal #8: Decent Work & Economic Development



8 DECENT WORK AND ECONOMIC GROWTH



Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all

See the globally adopted targets for this goal on the UN website:
<https://sustainabledevelopment.un.org/topics>

Bristol, United Kingdom

UK's first city-wide local currency

The Bristol Pound is a form of community currency with a goal to support local businesses and employment in Bristol. It emerged as a not-for-profit partnership between Bristol Pound Community Interest Company (CIC) and Bristol Credit Union and is governed in line with the model of a stakeholder cooperative, thereby giving Bristol Pound account holders a say in the development of the company and representation on the board.

Ehlanzeni, South Africa

The Integrated Water Harvesting Project for food security and income generation

Ehlanzeni district has a high unemployment rate of 76%, with four out of five people living below the government's official poverty line on less than \$US 60 cents per day. The Ehlanzeni district Integrated Water Harvesting Project targets four of the poorest communities in Mpumalanga Province, sustainably improving local livelihoods through a water-food-health NEXUS that aims to boost agricultural production and community income.

Goal #9: Infrastructure, Industry & Innovation



9 INDUSTRY, INNOVATION AND INFRASTRUCTURE



Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation

See the globally adopted targets for this goal on the UN website:
<https://sustainabledevelopment.un.org/topics>

Tokyo, Japan

Urban Cap-and-Trade Programme and Reducing emissions through green building

The Tokyo Metropolitan Government (TMG) launched the Cap and Trade Program in 2000 to establish total emission reduction obligations for existing commercial buildings (those that use over 1,500 kiloliters of crude oil annually). Together with the Green Building Programs, the Cap and Trade concept contributes to TMG's policy goal to reduce CO₂ emissions by 25 percent below 2000 levels by 2020.

Dezhou, China

Green economic development with renewable energy industries

In 1997, the municipality and local government of Dezhou elaborated a Development Plan for the Dezhou Economic Development Zone to bring together solar technology research, manufacturing, education and capacity building. Dezhou now hosts over 120 solar energy businesses generating an annual turnover of USD 3.46 billion. The plan showed how local governments are essential to stimulate renewable energy industry and can catalyze economic development in the region.



Goal #10: Reduced Inequalities

**10 REDUCED
INEQUALITIES**



Reduce inequality within and among countries

See the globally adopted targets for this goal on the UN website:

<https://sustainabledevelopment.un.org/topics>

Paris, France

A plan to stop housing displacement

In December 2014, the city of Paris announced a housing plan to stop displacement in central, predominantly gentrified, neighborhoods. With its plan to support rental options to lower- and middle-income residents, the city published a list of over 200 addresses with over 8,000 apartments that the city would have a 'right of first-refusal' to buy as subsidized housing for poor and marginalized dwellers.

Bogotá, Colombia

Bogotá Humana

In June 12, 2012, the city of Bogota officially introduced the Human Development Plan Bogota, a city project that is the roadmap for the four year administration period. The core idea of the plan is to combat social segregation and build an inclusive, dignified and equitable city, while tackling corruption and insecurity. One of the actions is the creation of an environmental district (57 km) around the rivers Fucha, Salitre, Tunjuelo, and Torca with a strong community involvement.

Goal #11: Sustainable Cities & Communities



11 SUSTAINABLE CITIES AND COMMUNITIES



Make cities and human settlements inclusive, safe, resilient and sustainable

See the globally adopted targets for this goal on the UN website:

<https://sustainabledevelopment.un.org/topics>

New York City, USA

#OneNYC for a strong and just city

In 2007, the city of New York introduced The Plan for a Strong and Just City "#OneNYC" (originally called 'PlaNYC') as a groundbreaking concept to address the city's long-term challenges: 9 million citizens by 2040, changing climate and economy, and aging infrastructure. The #OneNYC plan sets a number of goals and targets, including elevating 800,000 people out of poverty by 2025, and introducing a zero-waste concept.

Mexico City, Mexico

Plan Verde

Also in 2007, the Mexico City embarked on a 15-year Green Plan (Plan Verde). The plan, which is supported by the United Nations and the World Bank aims to invest approximately 8% of the city's annual budget into a wide range of sustainability initiatives, with particular emphasis on reducing traffic and improving air quality.

Goal #12: Sustainable Consumption & Production



12 RESPONSIBLE CONSUMPTION AND PRODUCTION



Ensure sustainable consumption and production patterns

See the globally adopted targets for this goal on the UN website:

<https://sustainabledevelopment.un.org/topics>

Helsinki, Finland

The Global Lead Cities Network

In 2015, the City of Helsinki set a goal to achieve 100 percent sustainable public procurement by 2020. To attain this goal, Helsinki implements policies to support the transition to sustainable procurement, including medium-term and long-term environment policies. Currently, the city aims at reducing the volume of communal waste by 10% compared to 2013 levels, and increasing the amount of materials reused from communal waste by 10%.

Cape Town, South Africa

The Global Lead Cities Network

The City of Cape Town will be undertaking a review of its spending to assess where the greatest environmental impact can be achieved, including the role that sustainable public procurement (SPP) can play. With changes in procurement, the city's green procurement efforts can contribute to a total saving of approximately R120 million is expected by 2018.



Goal #13: Climate Action

13 CLIMATE ACTION



Take urgent action to combat climate change and its impacts

See the globally adopted targets for this goal on the UN website:

<https://sustainabledevelopment.un.org/topics>

Seoul, Republic of Korea

The Promise of Seoul - Taking Actions against Climate Change

Recognizing the need to engage the public, Seoul Metropolitan Government decided to engage with its citizens to create an action plan to tackle climate change. This plan marks a promise from Seoul Metropolitan Government to change lifestyles of the 10 million Seoul citizens, while living up to and enhancing the city's reputation as environmental, cultural and global leader.

Mexico

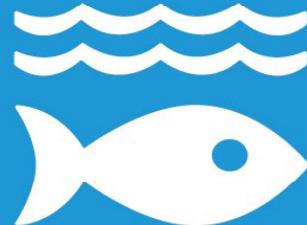
Municipal Climate Action Planning and Implementation for Mexican Cities

In Mexico, the Municipal Climate Action Plan (Plan de Acción Climática Municipal, short PACMUN) strengthens local capacity by training local government officials to develop and implement municipal climate change policies and development plans. To increase multi-level government action, the PACMUN program supports with GHG emissions inventories, mitigation and adaptation guidance, and raising climate change vulnerability awareness.



Goal #14: Life Below Water

14 LIFE
BELOW WATER



Conserve and sustainably use the oceans, seas and marine resources for sustainable development

See the globally adopted targets for this goal on the UN website:

<https://sustainabledevelopment.un.org/topics>

Rotterdam, Netherlands

The Delta Cities network

City of Rotterdam is an active member of the Connecting Delta Cities (CDC) network. Within this network, Rotterdam implements a number of sustainability projects on water quality and recreation. One of such projects includes the introduction of lush greenery and a healthy cover of riparian vegetation to the river banks and the tide-influenced estuary. Work is currently underway at the Nieuwe Waterweg and the Nieuwe Maas.

Sriracha, Thailand

Balancing development and conservation with integrated coastal management

Since 1999, Sriracha Municipality, together with other local governments of Chonburi province, has developed an Integrated Coastal Management (ICM) project. By late 2008, 26 local government units were part of the Chonburi ICM network, which covers the entire 157 km coastline of Chonburi province. One of the focus areas of the project, the Blue Swimming Crab conservation activities, has resulted in increasing crab-related eco-tourism.



Goal #15: Life on Land

15 LIFE
ON LAND



Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss

See the globally adopted targets for this goal on the UN website:

<https://sustainabledevelopment.un.org/topics>

Winnipeg, Canada

An Urban Forest: Valuable to Both Ecosystem and the Community

The Bois-des-esprits (or Spirit Forest) is an urban forest on the Seine River and is the largest remaining riverbank forest in Winnipeg. Rapid urban sprawl has threatened the forest. The City has established a Forest Management Planning Process to protect the entire forest from harmful urban development in a partnership between various municipal departments, community development groups and the Province of Manitoba.

Walvis Bay, Namibia

Pioneer in Local Action for Biodiversity Programme and URBIS

The Walvis Bay Lagoon is considered one of the richest and most important wetlands in southern Africa, with approx. 20 bird species regularly occurring in numbers greater than 1% of their world population. Walvis Bay established the Walvis Dune Belt Management Plan to protect the dune ecosystems from disturbances from irresponsible recreational activities such as off-road driving. Zoning the area for specific uses is one of the key strategies employed by the plan.



Goal #16: Peace, Justice & Strong Institutions

16 PEACE, JUSTICE
AND STRONG
INSTITUTIONS



Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable and inclusive institutions at all levels

See the globally adopted targets for this goal on the UN website:
<https://sustainabledevelopment.un.org/topics>

Paderborn, Germany

New Neighbours (*Neue Nachbarn*) – Paderborner Help Refugees Initiative

In June, 2015, the City of Paderborn established a new initiative to strengthen the positive attitude of Paderborn shows to its new citizens, and to support civic engagement for refugees. Its main goals are to strengthen the inclusiveness of the local society, encourage cross-cultural projects and avoid the formation of ghettos. The initiative is supported by a broad coalition which includes multiple religious institutions and social service organizations in Paderborn.

São Paulo, Brazil

Promoting Open Government action

The City of São Paulo introduced a municipal open government agenda. It is one of the first cities in the world to embrace issues of transparency, social participation, technological innovation and integrity in public policies. Open Government has become one of the priorities for this administration and the municipal initiative, entitled São Paulo Aberta, was established by Official Decree in January, 2014.

Goal #17: Partnerships for Achieving the Goals



17 PARTNERSHIPS
FOR THE GOALS



Strengthen the means of implementation and revitalize the global partnership for sustainable development

See the globally adopted targets for this goal on the UN website:
<https://sustainabledevelopment.un.org/topics>

Bonn, Germany

[Decentralized cooperation for Renaturalization of Fosu Lagoon, Cape Coast, Ghana](#)

Since 2012, Cape Coast and the City of Bonn have been partners in a project to restore the Fosu Lagoon, funded by the German Ministry for Economic Cooperation and Development as one of the “50 Municipal Climate Partnerships until 2015”. The four year project has increased knowledge of the sensitive ecosystem and contributed to the protection of this natural resource.

Shimla, India

[Addressing future climate change by building institutional capacity](#)

Shimla Municipal Corporation seized the opportunity to pilot the ICLEI-ACCRN Process (IAP) of climate resilience planning during 2012. The IAP pilot was an innovative approach to climate resilience planning that draws on the ACCRN experiences of the previous years. As a result, Shimla now has a better understanding of the future climate scenario the city may face.



Dimensions of the Agenda

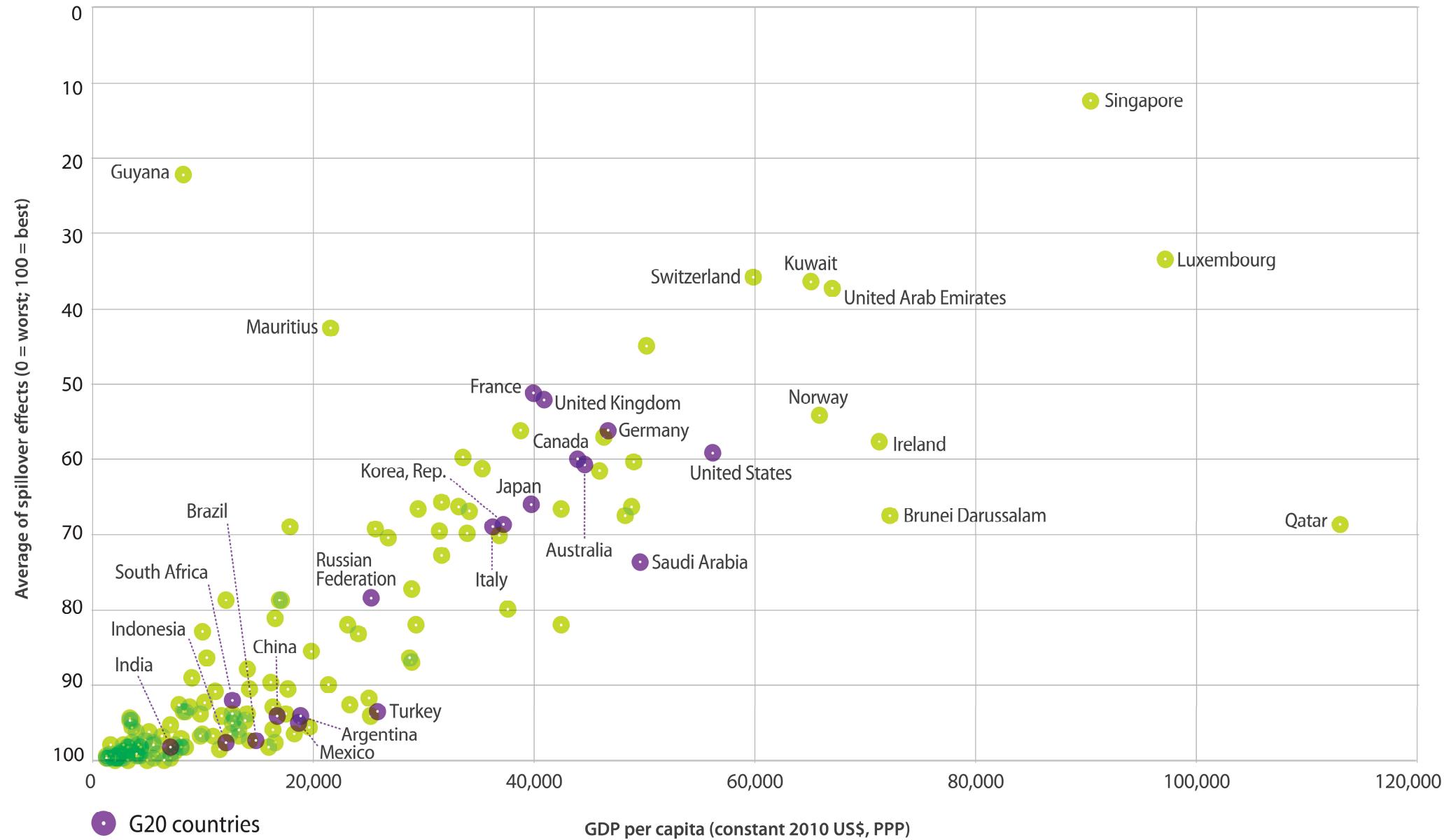




International Spillovers

- Strategies to achieve the SDGs need to be implemented domestically without generating negative impacts on other countries (“**spillovers**”).
- The **Spillover Score** measures transboundary impacts generated by one country on others, which undermine their ability to achieve the SDGs. It covers financial spillovers, environmental and social impacts embodied into trade and consumption, and security/development cooperation.
- **Environmental spillovers** cover international spillovers related to the use of natural resources and pollution: (i) transboundary effects embodied in trade and (ii) direct cross-border flows in air and water.
- **Spillovers related to the economy, finance, and governance** cover international development finance, unfair tax competition, banking secrecy, and international labor standards.
- **Security spillovers** include negative externalities, such as the trade in arms and organized international crime, which can have a destabilizing impact on poor countries. Among the positive spillovers are investment in conflict-prevention and peacekeeping.

Spillover Score



Average spillover score against gross domestic product per capita (GDP per capita, constant 2010 US\$, PPP)

COVID-19 and the SDGs

- COVID-19 will have severe negative impacts on most SDGs.
- All countries need to strengthen the resilience of their health systems and prevention programs.
- The SDGs can inform the recovery from COVID-19.
- Asian countries have made the progress towards the SDGs since the adoption of the goals in 2015. Asian countries have also responded most effectively to the COVID-19 outbreak.
- Solidarity and partnerships are critical to address and prevent health, economic, and humanitarian crisis.
- Data gaps and time lags in official statistics require urgent investments in statistical capacity and increased coordination between governments and the private sector.



EV20001: ENVIRONMENTAL SCIENCE



Lecture #2

Human Population & Urbanization

Dr. Shamik Chowdhury

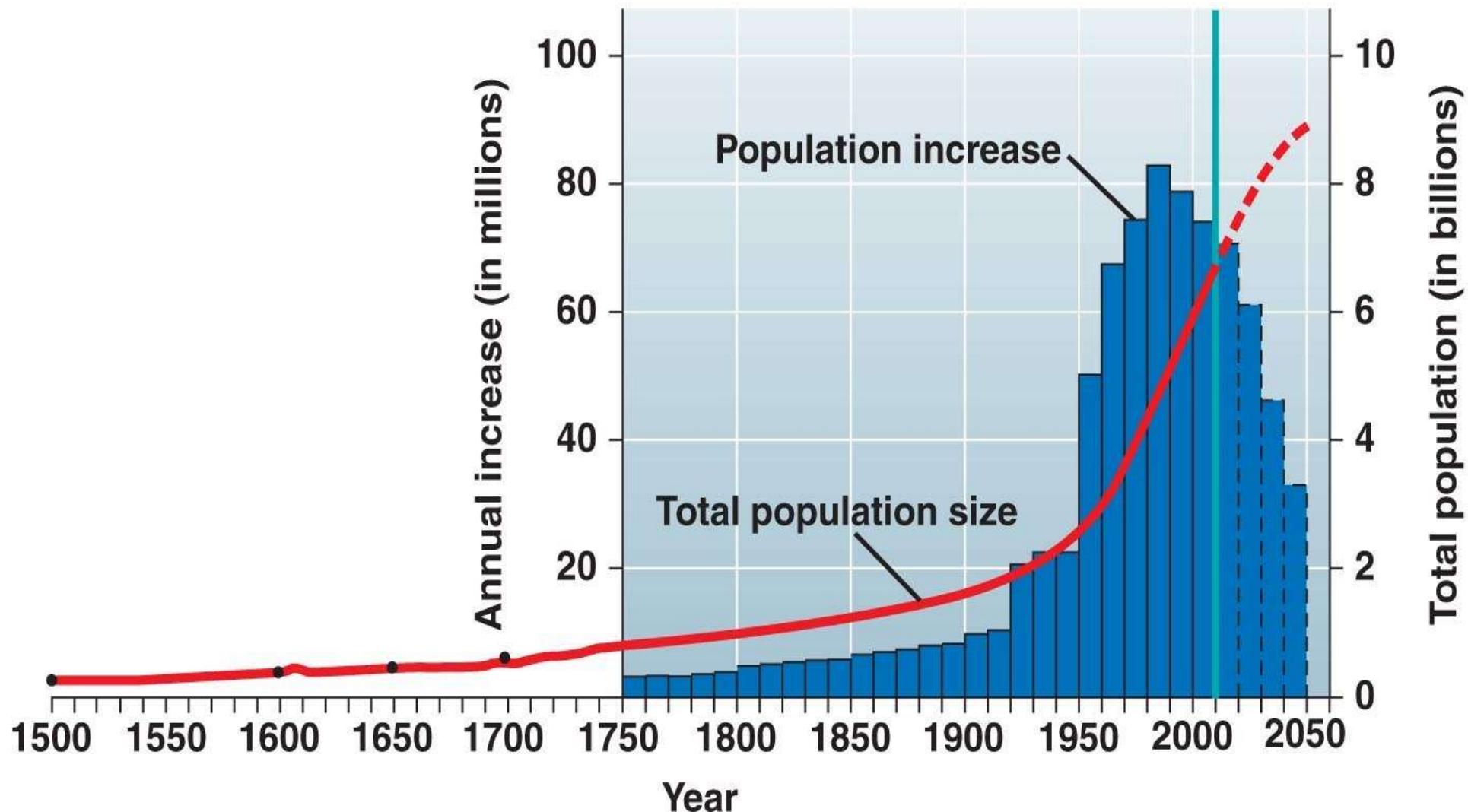
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09 February 2022

Are There Too Many of Us?

- Currently, there are about **7.8 billion** of us. Each year, we add about **83 million** more people to the world's population. If such growth continues, the number of people on Earth is projected to increase to **8.5 billion** by **2030**.



Population Growth Affect Ecosystem Services

Natural Capital Degradation

Altering Nature to Meet Our Needs

Reduction of biodiversity



Increasing use of the earth's net primary productivity



Increasing genetic resistance of pest species and disease-causing bacteria



Elimination of many natural predators



Introduction of potentially harmful species into communities



Using some renewable resources faster than they can be replenished



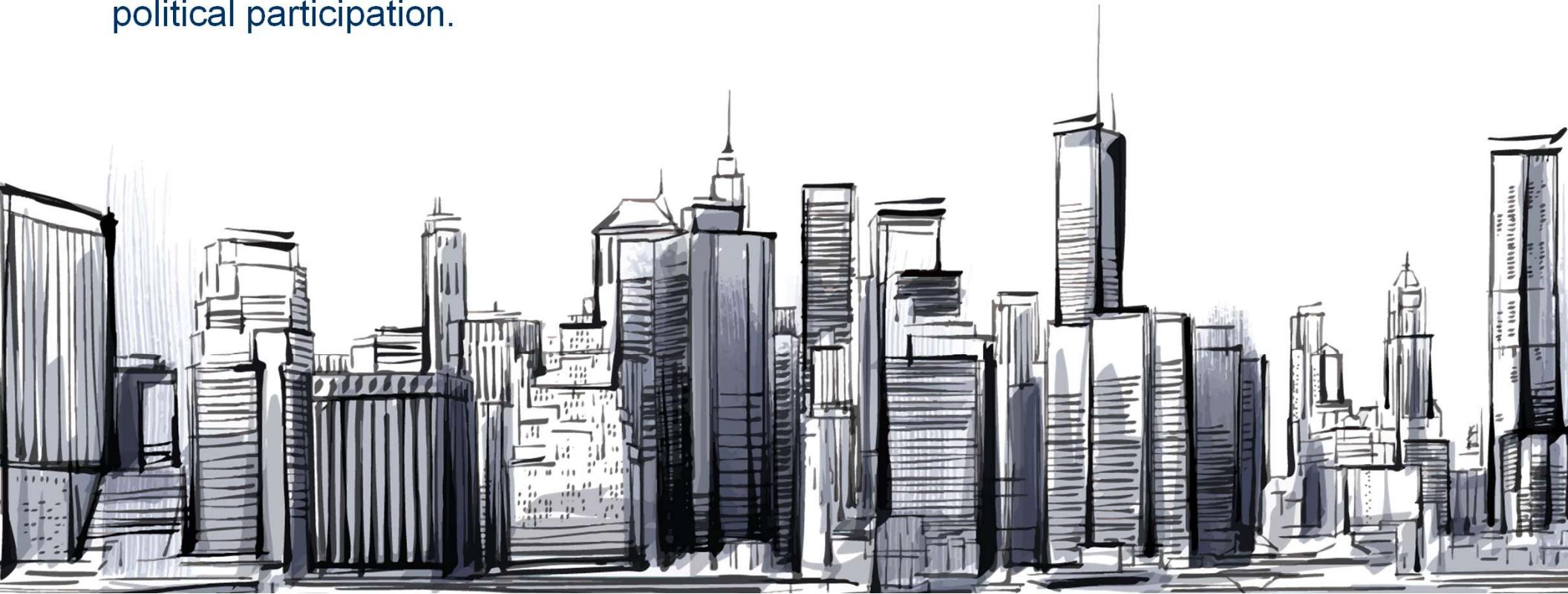
Interfering with the earth's chemical cycling and energy flow processes



Relying mostly on polluting and climate-changing fossil fuels

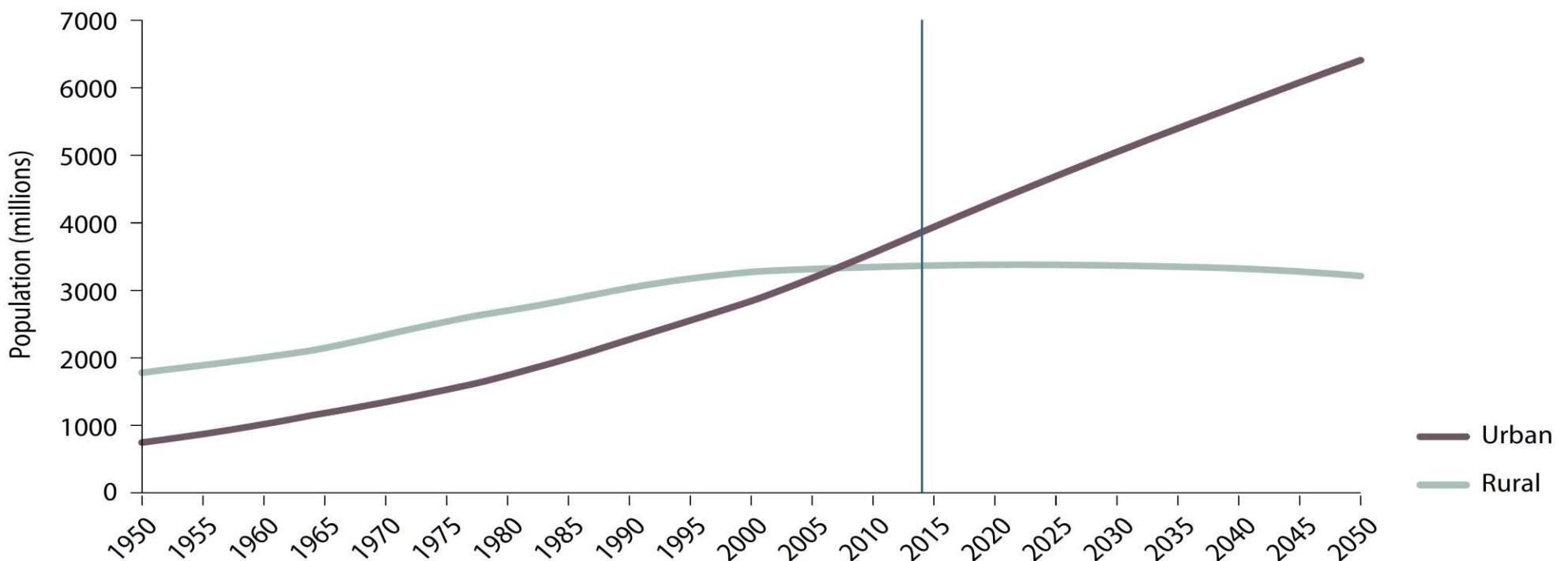
Urbanization

- As the world is undergoing the largest wave of population growth in history, urbanization – the process of transition from a rural to a more urban society – is inevitable.
- More than half of the world's population now lives in cities.
- Urban living is often associated with higher levels of literacy and education, better health, greater access to social services, and enhanced opportunities for cultural and political participation.



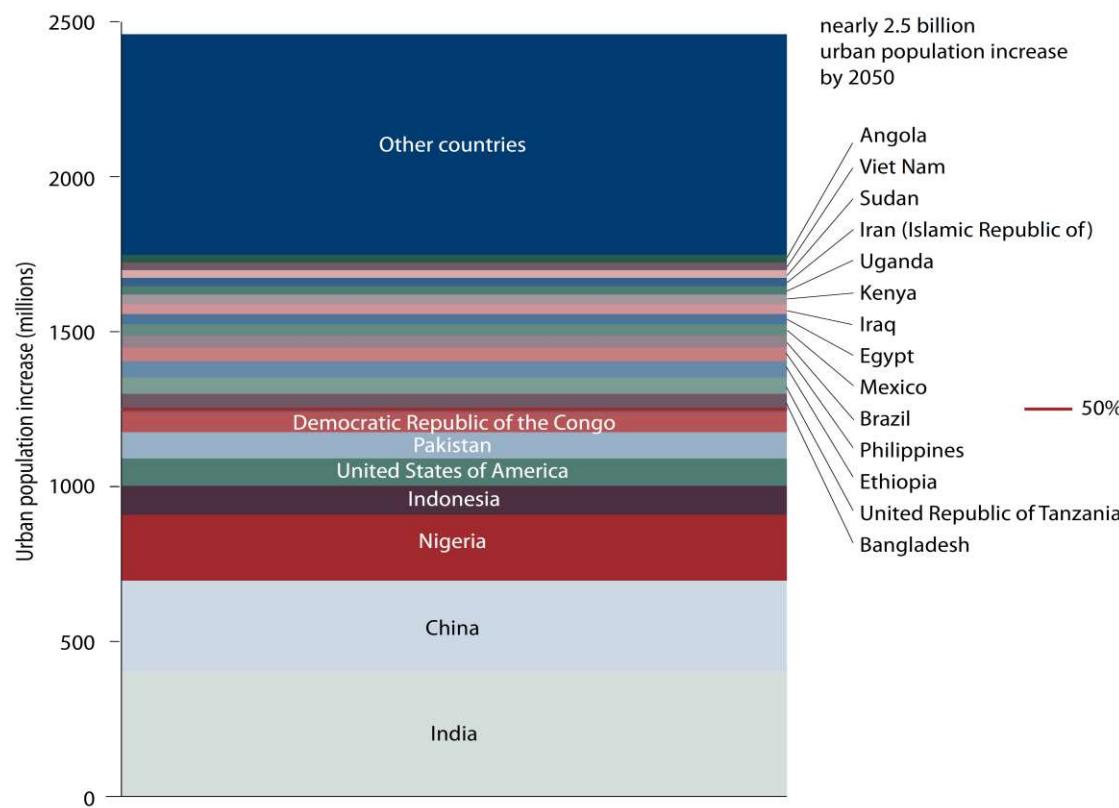
Trends in Urbanization

- Globally, more people live in urban areas than in rural areas, with 55% of the world's population residing in urban areas in 2018.
- In 2007, for the first time in history, the global urban population exceeded the global rural population, and the world population has remained predominantly urban thereafter.
- Growth in the urban population is driven by overall population increase and by the upward shift in the percentage living in urban areas.

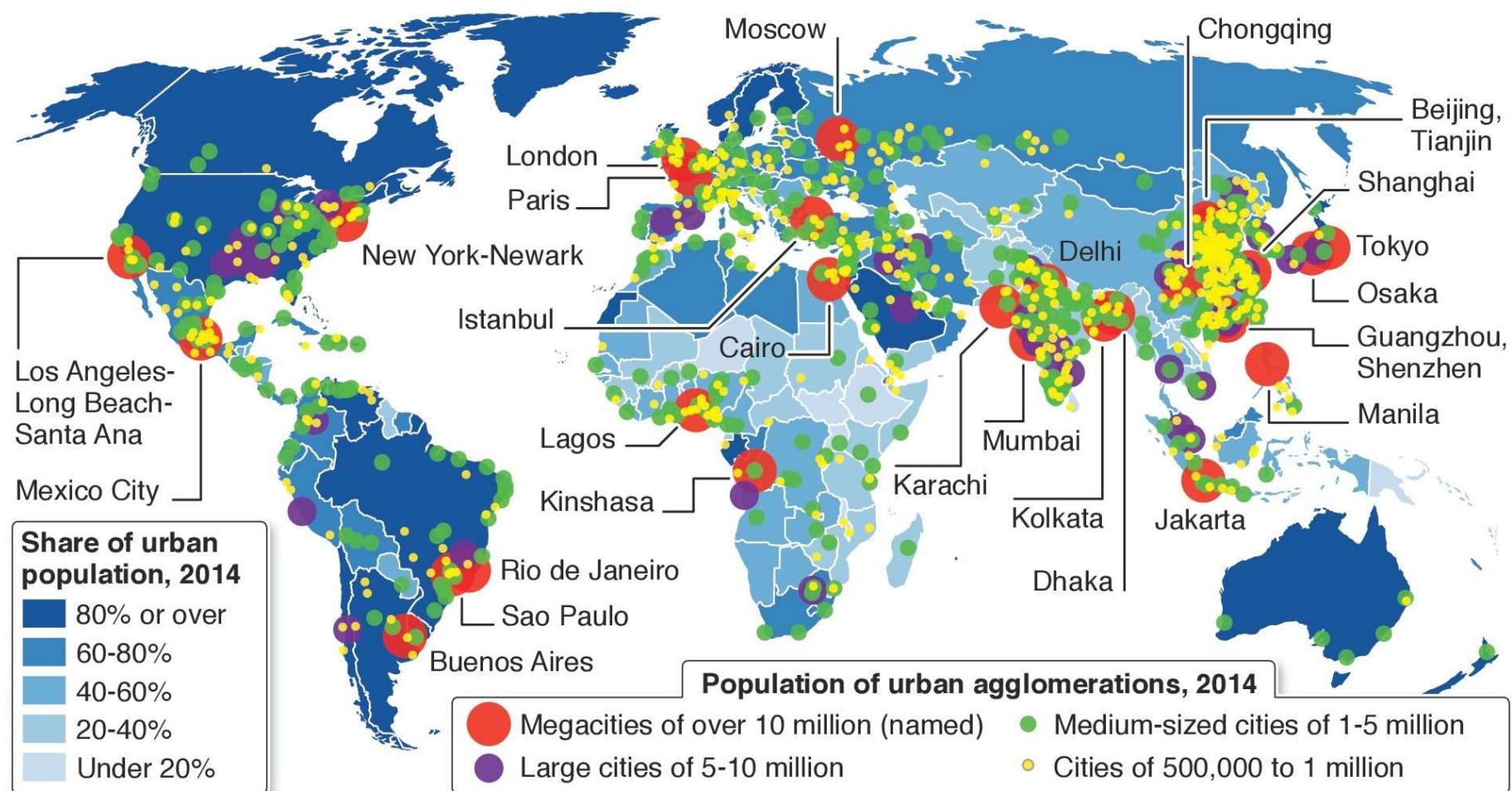




- Just a few countries are home to half of the world's urban population. China has the largest urban population (758 million), followed by India (410 million).
- Future increases in the world's urban population are also expected to be highly concentrated in just a few countries. India, China and Nigeria – together are expected to account for 35% of the growth in the world's urban population between 2018 and 2050. India is projected to add 416 million urban dwellers, China 255 million and Nigeria 189 million.



- Tokyo is the world's largest city with an agglomeration of 37 million inhabitants, followed by Delhi with 29 million, Shanghai with 26 million, and Mexico City and São Paulo, each with around 22 million inhabitants.
- Today, Cairo, Mumbai, Beijing and Dhaka all have close to 20 million inhabitants.



Benefits of Urbanization

- Urban areas are global economic platforms for **production, innovation and trade**, and offer significant **opportunities** for both **formal** and **informal** employment.
- Urbanization has helped millions escape poverty through increased productivity and employment opportunities; improved quality of life *via* better education and health; large-scale public investment and access to improved infrastructure and services.



Challenges of Urbanization

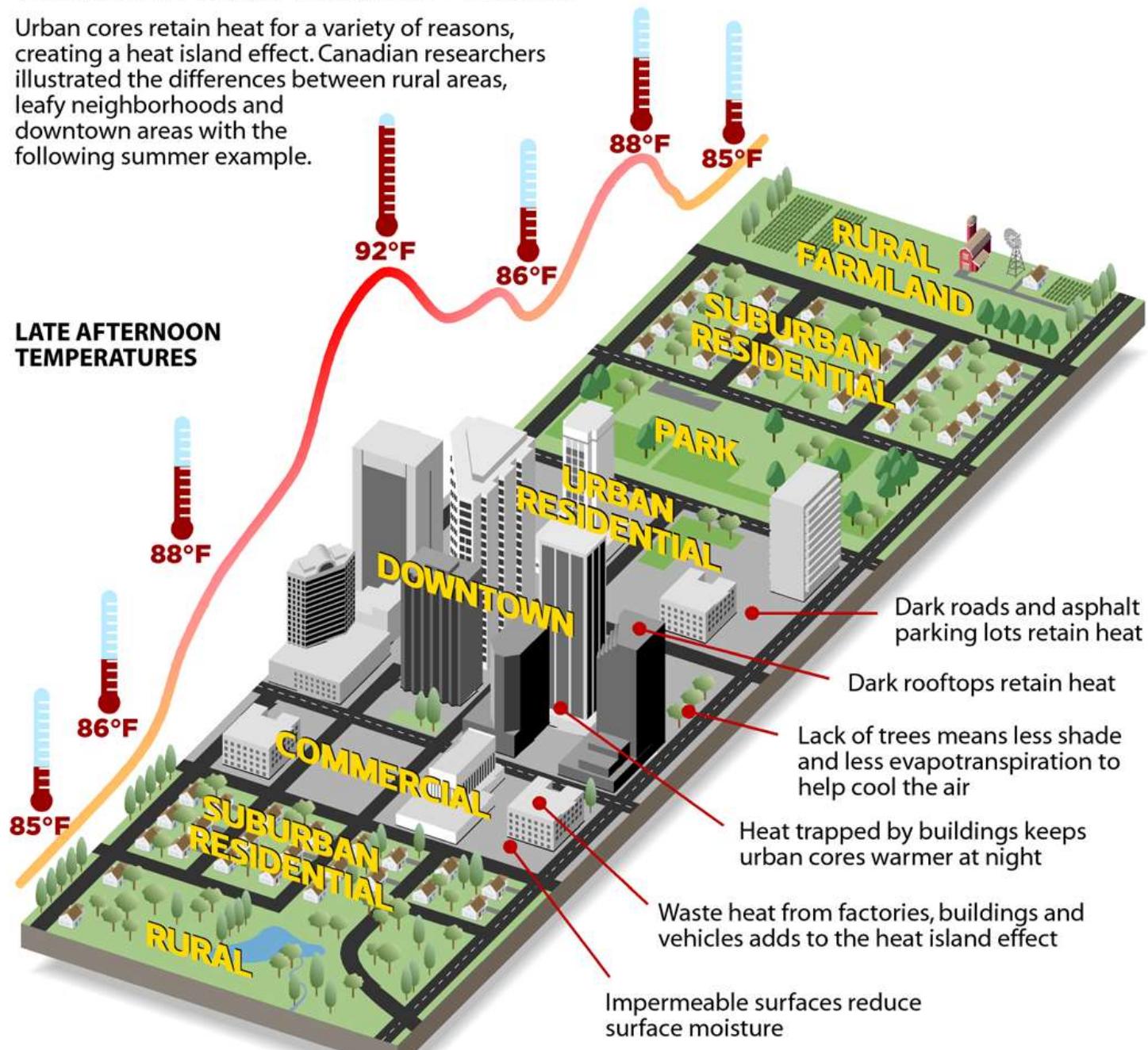
- Urbanization does not necessarily result in a more equitable distribution of wealth and wellbeing. Today, urban areas are more unequal than rural areas: 75% of the world's cities have higher levels of **income inequalities** than two decades ago.
- Inadequately managed urban expansion leads to **rapid sprawl**, **pollution**, and **environmental degradation**, together with **unsustainable production and consumption patterns**.





Urban Heat Island Effect

Urban cores retain heat for a variety of reasons, creating a heat island effect. Canadian researchers illustrated the differences between rural areas, leafy neighborhoods and downtown areas with the following summer example.



Cities Can Grow Outward or Upward

■ Compact cities

- Limited land area with high population density, thus growing vertically
- Most people get around by walking, biking, or using mass transit
- Example: Hong Kong, Singapore, Tokyo

■ Dispersed cities

- Ample land area available for outward expansion
- Residents mostly depend on motor vehicles for transportation
- Example: Cities in Australia, Canada, China, India and the United States



Transport and Urban Environment



- Road transport contributes significantly to **urban air pollution** in many countries.
- A common feature across road networks in many urban regions in the developing world is the presence of critical **congestion** areas. Traffic congestion worsens the emissions of both local and global pollutants.
- Besides, each year, **automobile accidents** kill approximately 1.2 million people and injure another 15 million people, globally. They also kill about 50 million wild animals and family pets every year. **Car accidents have killed more Americans than have all the wars in the country's history!**



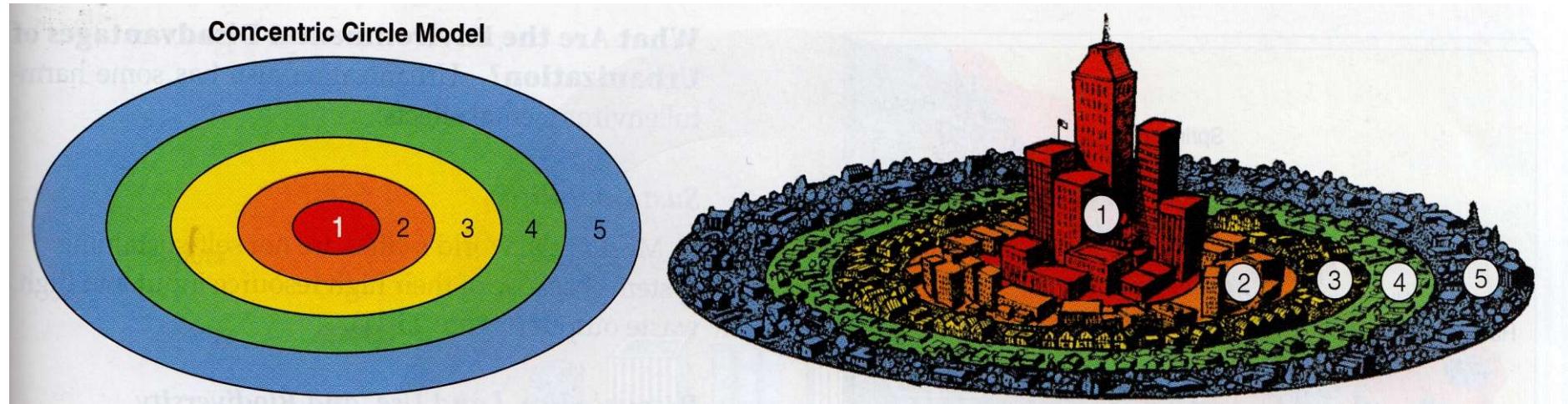
Transport and Urban Environment

- Some cities promote **alternatives** to motor vehicles, each with its own advantages and disadvantages.



Spatial Patterns of Urbanization

- A **concentric circle city**, such as Kolkata, develops outward from its central business district (CBD) in a series of rings as the area grows in population and size.
- Typically, industries and businesses in the CBD and poverty-stricken inner-city housing areas are ringed by housing zones that usually become more affluent toward the suburbs.

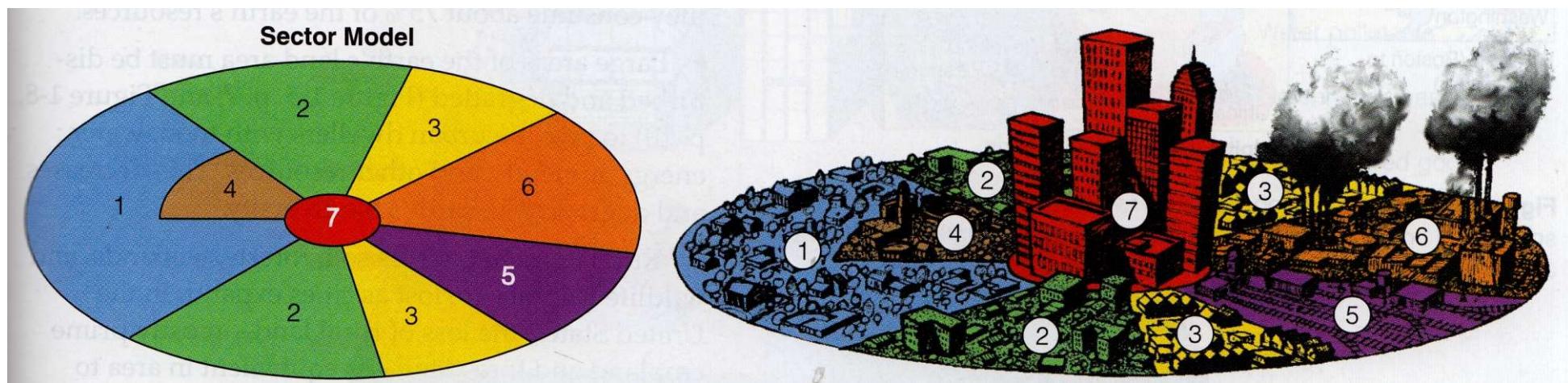


- | | |
|--|---|
| 1. Central business district (CBD)
2. Deteriorating transition zone
3. Worker's home | 4. Middle-class suburbs
5. Commuter's zone |
|--|---|





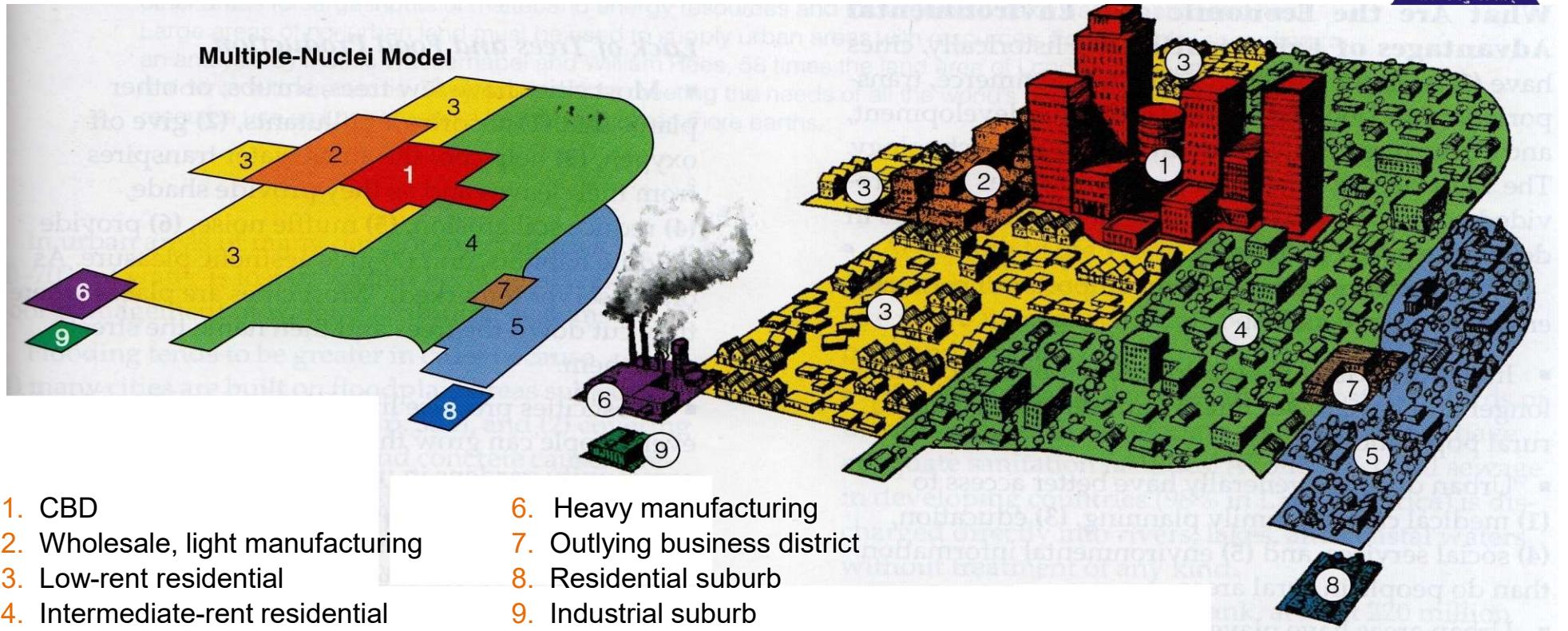
- A **sector city** grows in pie-shaped wedges or strips when commercial, industrial, and housing districts push outward from the CBD along major transportation routes. An example is the large urban area extending from Mumbai to Navi Mumbai.



- 1. High-rent residential
- 2. Intermediate-rent residential
- 3. Low-rent residential
- 4. Education and recreation
- 5. Transportation
- 6. Industrial
- 7. CBD



- A **multiple-nuclei city** develops around a number of independent centres, or satellite cities, rather than a single centre. Singapore comes fairly close to this pattern.



Urban Sprawl

- Rapid expansion of the geographic extent of cities, often characterized by low-density residential housing, single-use zoning, and increased reliance on private automobile for transportation.
- The end result is the spreading of a city and its suburbs over more and more rural land.
- Urban sprawl is a complex phenomenon, which goes beyond average population density.





Causes of Urban Sprawl

- Urban sprawl is driven by **demographic, economic, geographic, social and technological** factors.
- As number of people in a city grows beyond capacity, the local communities continues to spread farther and farther from the core of the cities.
- Increased affluence, attractive land and housing prices, and the desire for larger homes with more amenities (such as yards, swimming pools, storage space, lower noise levels, better air quality, and privacy) play significant roles at the level of the individual.
- Most importantly, sprawl is also **policy-driven**. Maximum density restrictions, specific zoning regulations, tax systems that are misaligned with the social cost of low-density development, the underpricing of car use externalities and the massive investment in road infrastructure contribute to this phenomenon.



Consequences of urban sprawl

Natural Capital Degradation

Urban Sprawl



Land and Biodiversity

- Loss of cropland
- Loss of forests and grasslands
- Loss of wetlands
- Loss and fragmentation of wildlife habitats



Water

- Increased use of surface water and groundwater
- Increased runoff and flooding
- Increased surface water and groundwater pollution
- Decreased natural sewage treatment



Energy, Air, and Climate

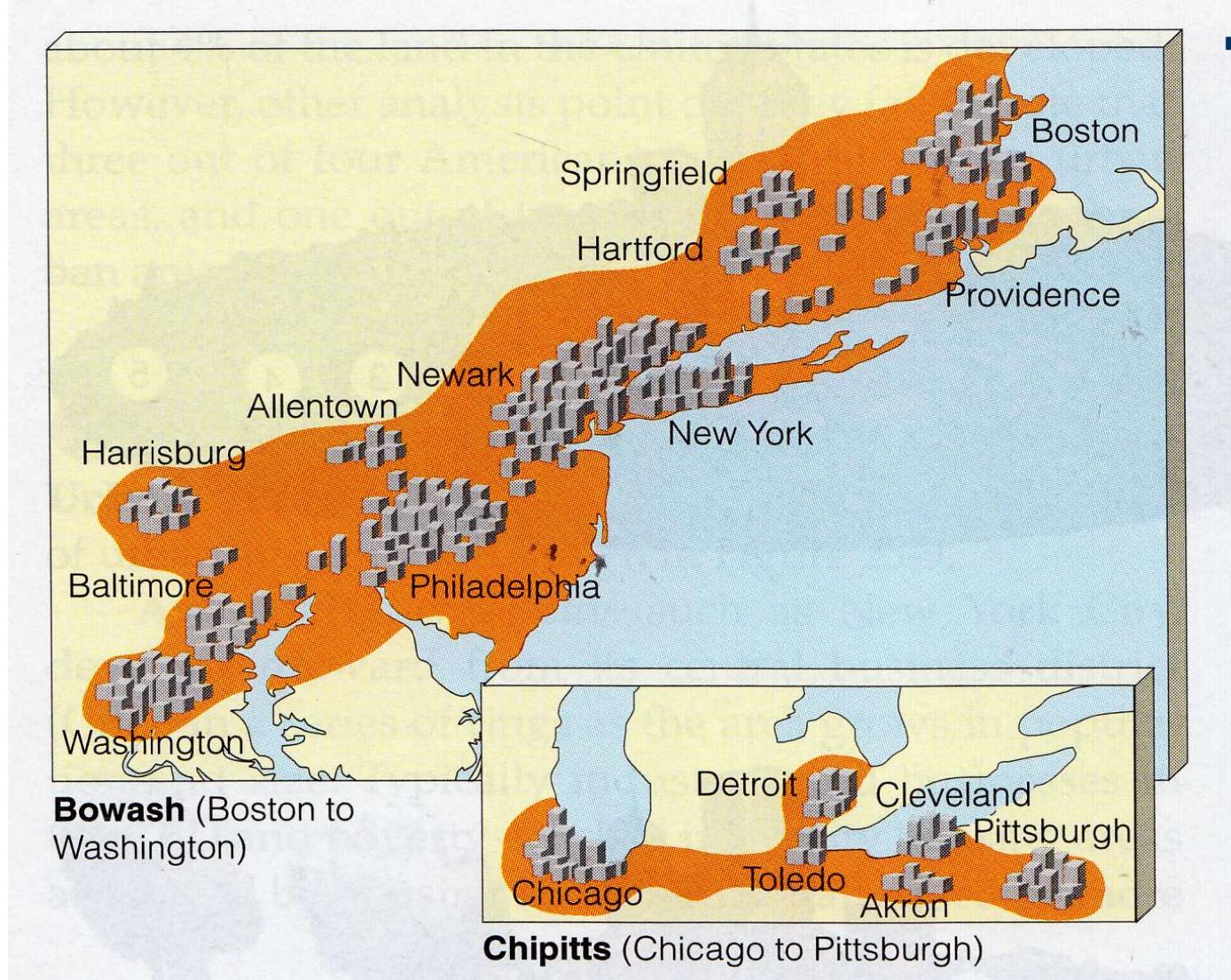
- Increased energy use and waste
- Increased air pollution
- Increased greenhouse gas emissions
- Can enhance climate change



Economic Effects

- Decline of downtown business districts
- Increased unemployment in central city
- Loss of tax base in central city

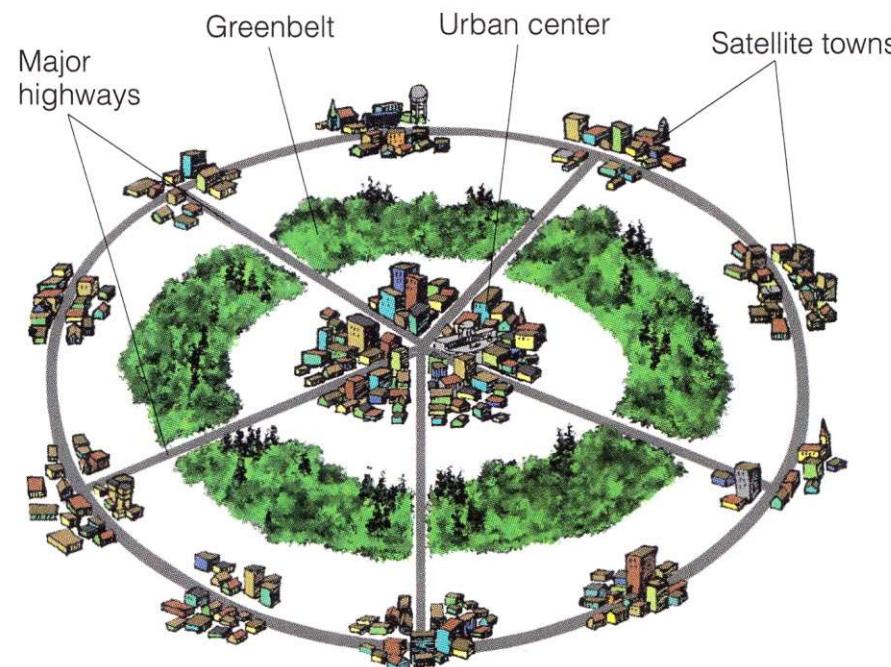
- As they grow and sprawl outward, separate urban areas may merge to form a **megapolis**. For example, the remaining open space between Boston, Massachusetts, and Washington D.C., is rapidly urbanizing and coalescing.



- Two megapolises: *Bowash*, consisting of urban sprawl and coalescence between Boston and Washington, D.C., and *Chipitts*, extending from Chicago to Pittsburgh.

Regulating Urban Sprawl

- Some cities provide open space and control urban sprawl by surrounding a large city with a **greenbelt**: an open area used for recreation, sustainable forestry, and or other nondestructive uses.
- **Satellite towns** (smaller metropolitan areas which are located somewhat near to, but are mostly independent of larger metropolitan areas) can be built outside the belt.
- Highways or rail systems can be used to transport people around the periphery and into the central city.



Regulating urban sprawl

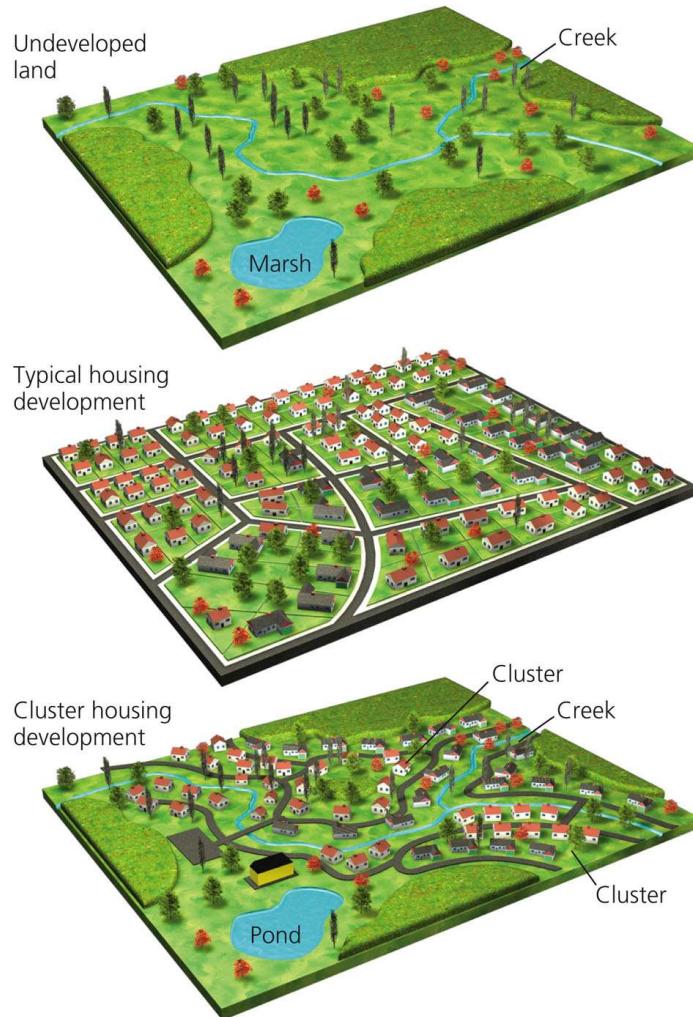
- Another increasingly popular approach to preserving open space outside a city is to set up an **urban growth boundary**: a line surrounding a city beyond which new development is not allowed.



- The sharp demarcation between the metropolitan area of Portland, Oregon (on the left), and the rural acreage that falls outside the city's urban growth boundary determines where, precisely, land can be developed — and where it cannot.

Regulating Urban Sprawl

- In recent years, builders have increasingly used a new pattern, known as **cluster development**, in which high-density housing units are concentrated on portion of a parcel, with the rest of the land (often 40–50%) used for commonly shared open space.

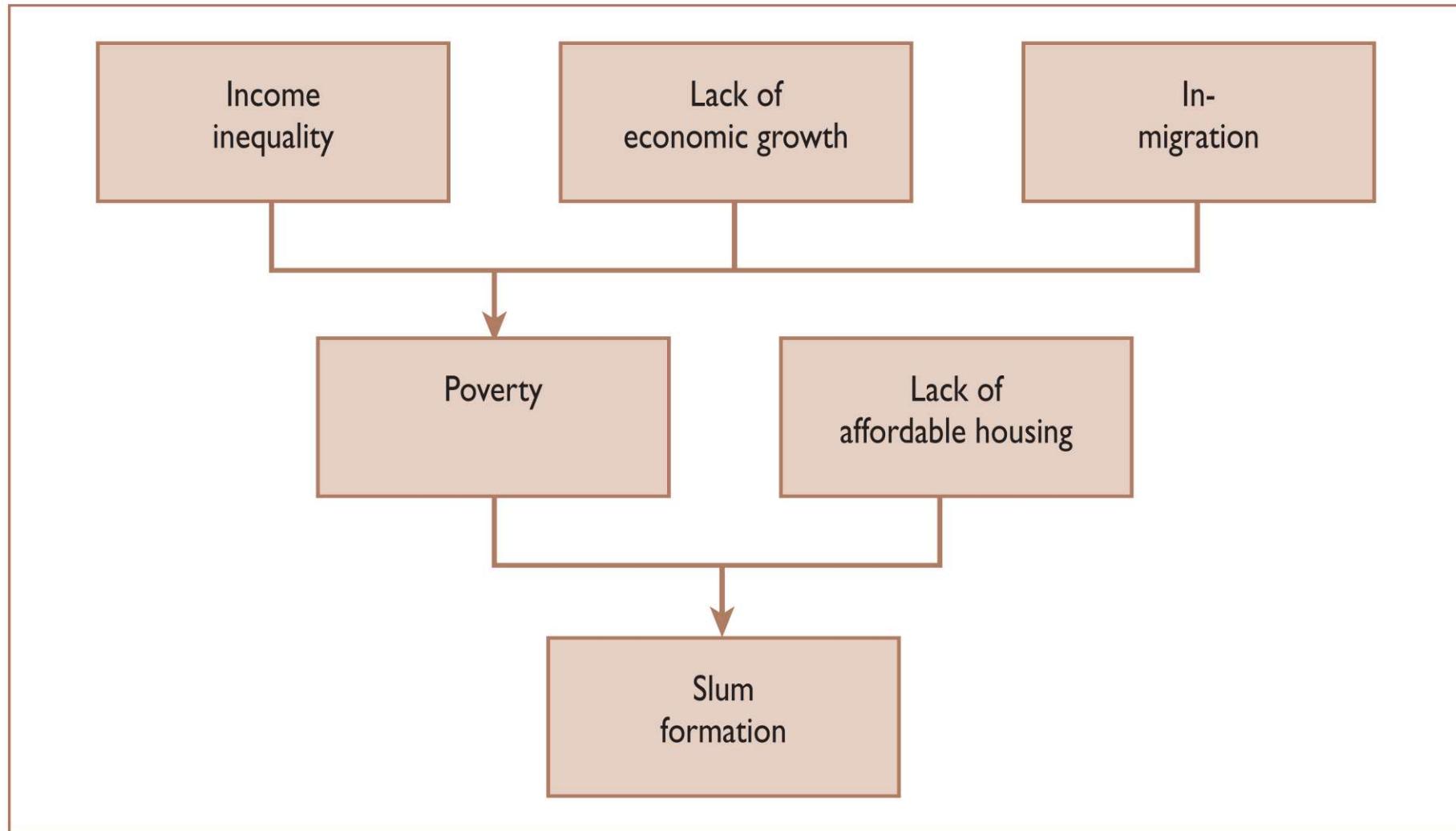


Urban Poverty

- With uncontrolled migration and rapid urban growth, the redistribution of wealth and opportunities across diverse individual abilities and cultural backgrounds that historically characterizes urban dynamics seems to have stalled in many regions of the world.
- At least 1 billion people live under crowded and unsanitary conditions.
- Some live in **slums** – areas dominated by tenements and rooming houses where several people might live in a single room.
- Others live in improvised **shanty towns** or **squatter camps** – housing developments often made up of corrugated metal, plywood, cardboard boxes and sheets of plastics.
- People in slums live under the most deplorable conditions, with little access to effective social and health care services, potable water, sanitation facilities and are therefore more vulnerable to epidemics and developmental challenges.



- The numbers of urban poor are, to a large extent, outside the control of city governments, and are swelled by a combination of **economic stagnation**, **increasing inequality**, **population growth** (especially growth through **in-migration**), and **inadequate and expensive accommodation**.



Sustainable urbanization: Eco-cities

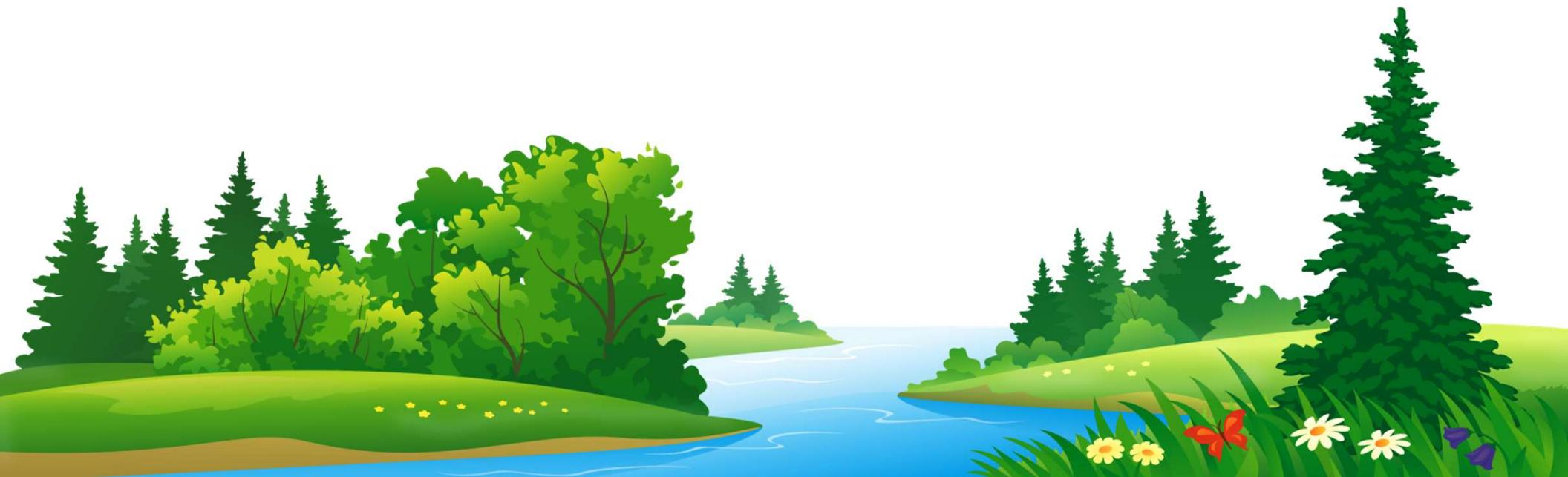
- An eco-city is
 - an ecologically healthy human settlement modelled on the self-sustaining resilient structure and function of natural ecosystems and living organisms.
 - an entity that includes its inhabitants and their ecological impacts.
 - a subsystem of the ecosystems of which it is part — of its watershed, bioregion, and ultimately of the planet.
 - a subsystem of the regional, national and world economic system.
- The ultimate goal of eco-cities is to eliminate all carbon waste, to produce energy entirely through renewable sources, to incorporate the environment into the city, reduce poverty, organize cities to have higher population densities, and therefore higher efficiency, and improving health.



Sustainable urbanization: Eco-cities

■ Eco-cities

- centralize the population within a given area.
- use renewable energy as much as possible.
- use energy and matter efficiently.
- prevent pollution and reduce waste.
- recycle, reuse, and compost.
- protect and encourage biodiversity.
- promote urban gardens and farmers markets.



Case study: Vauban, Freiburg

- The Vauban district of Freiburg in southern Germany is the world's best example of sustainable urban living.
- Pedestrian and bicycle paths form a highly-connected, efficient, green transportation network with every home within walking distance of a tram stop. Trains appear every 7.5 minutes during rush hours with ticket costs subsidized to encourage use.
- Public energy and heat are generated by a highly efficient woodchip-powered combined heat and power generator connected to a district heating grid.
- Organic household waste is treated with an anaerobic digester. The city has an unique ecological sewage system in one pilot project: sucked by vacuum pipes, faeces are transported into this digester; generating biogas, which is used for cooking.
- Grey-water is cleaned in biofilm plants and returned to the water cycle.





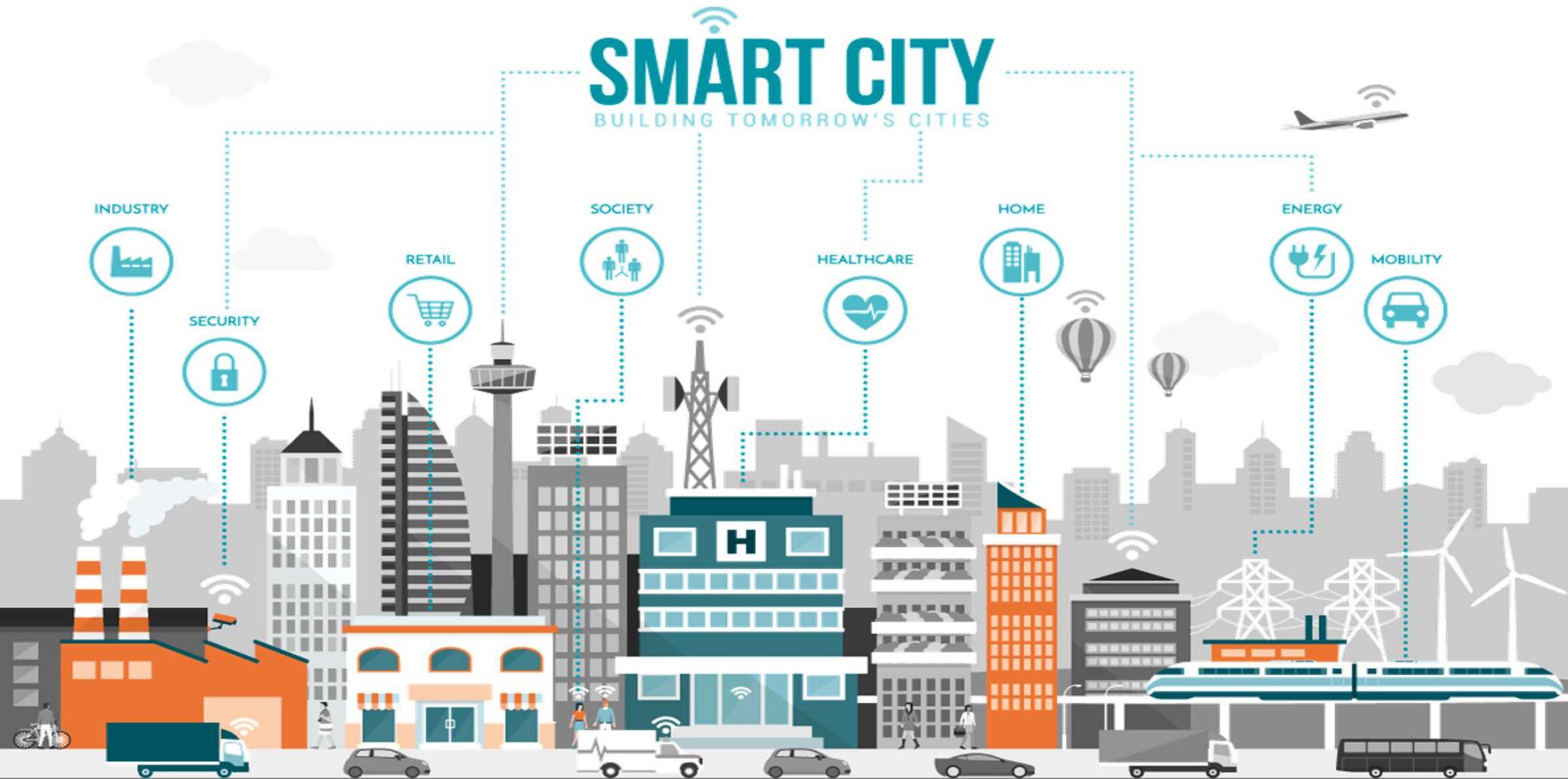
Case study: Vauban, Freiburg

- The city contains over 600 hectares of parks and 160 playgrounds providing greenery, recreation, and biodiversity.
- 3,800 small privately owned garden allotments for the inhabitants to grow their own food lie on the outskirts of the city.
- Local food is also supplied by farm shops, a farmers' market, a local winery and distillery, beekeeping, butchers, bakers and plant nursery.
- Shops and offices are located on the ground floor of the apartment buildings, allowing residents easy access, on foot or bicycle, to their daily needs.
- Renewable energy production is encouraged with tax credits from the federal government and subsidies from the regional utility.



Sustainable urbanization: Smart cities

- A **smart city** is a municipality that uses information and communication technologies to increase operational efficiency, share information with the public and improve both the quality of government services and citizen welfare.



Sustainable urbanization: Smart cities

FROM GREEN TO SMART

CLEVER ROUND THE CLOCK

Apart from being energy-efficient, these intelligent structures centralise and automate all operations and management systems – including lighting, temperature, air quality and security – making surveillance and maintenance a breeze.

See how a smart building works by following Sam through a typical work day. You might wish for the future to come a little sooner.

WHY SMART BUILDINGS?

Capital efficient

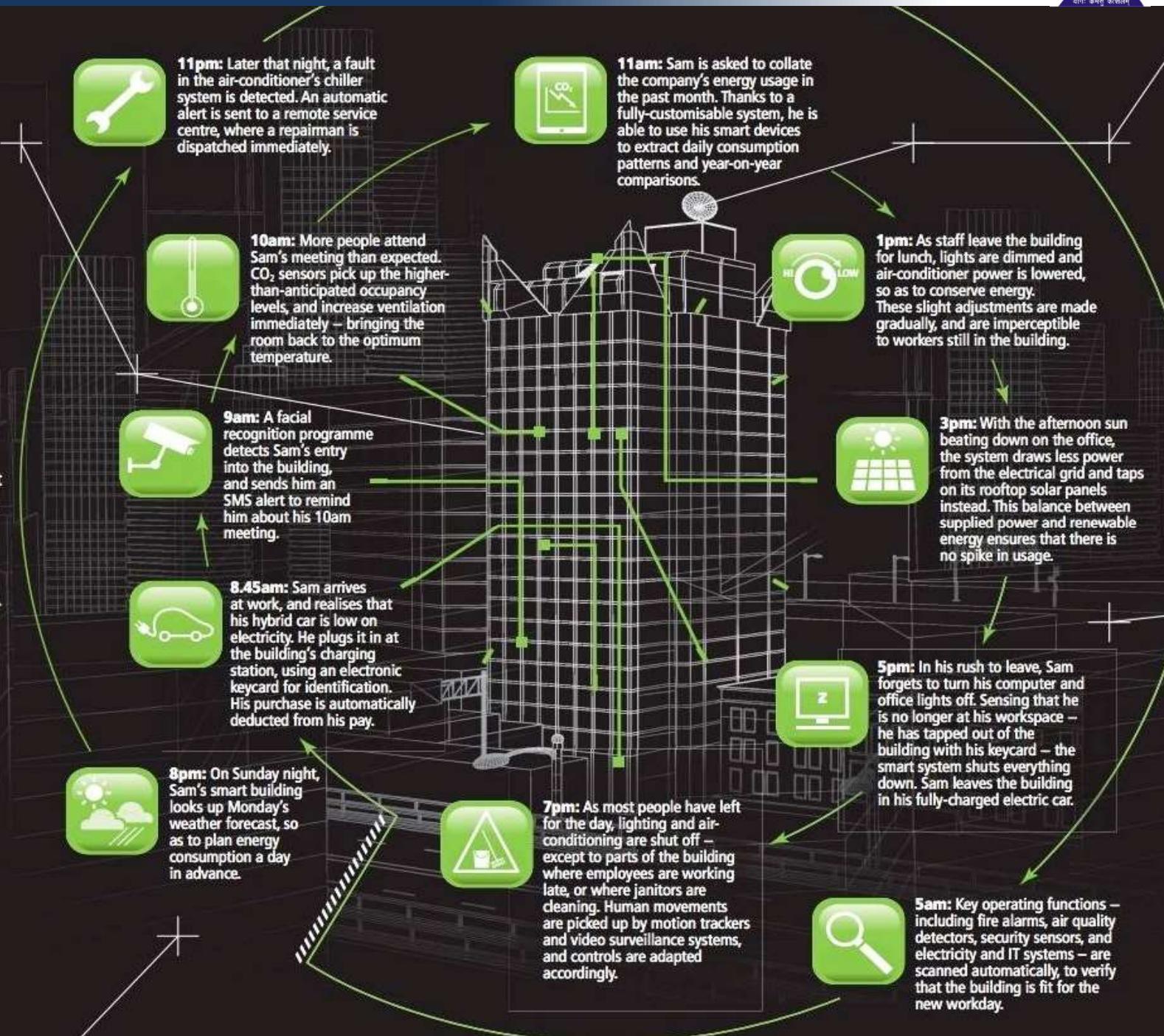
- 24% reduction in capital costs
- Return on investment (ROI) in 10 years

Cost-saving

- 20% lower energy bills
- 36% decrease in running costs

Sustainable

- 15% reduction in carbon emissions



Sustainable urbanization: Smart cities

TOP 10 SMARTEST CITIES IN 2019

- 1 Singapore, Singapore
- 2 Zurich, Switzerland
- 3 Oslo, Norway
- 4 Geneva, Switzerland
- 5 Copenhagen, Denmark





Lecture #3

Understanding Air Pollution

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15 September 2021



Air Pollutants

- Any substance found in the ambient air that is not part of its natural composition or any substance whose concentration is higher than the concentration found in the air's natural composition.
- Air pollutants come from natural activities, such as volcanic eruptions, or human activities, such as burning of fossil fuels.
- Can be in the following two physical forms:
 - particulate matter (e.g., ash, dust, smoke, etc.)
 - gases (e.g., sulfur dioxide, carbon monoxide, etc.)

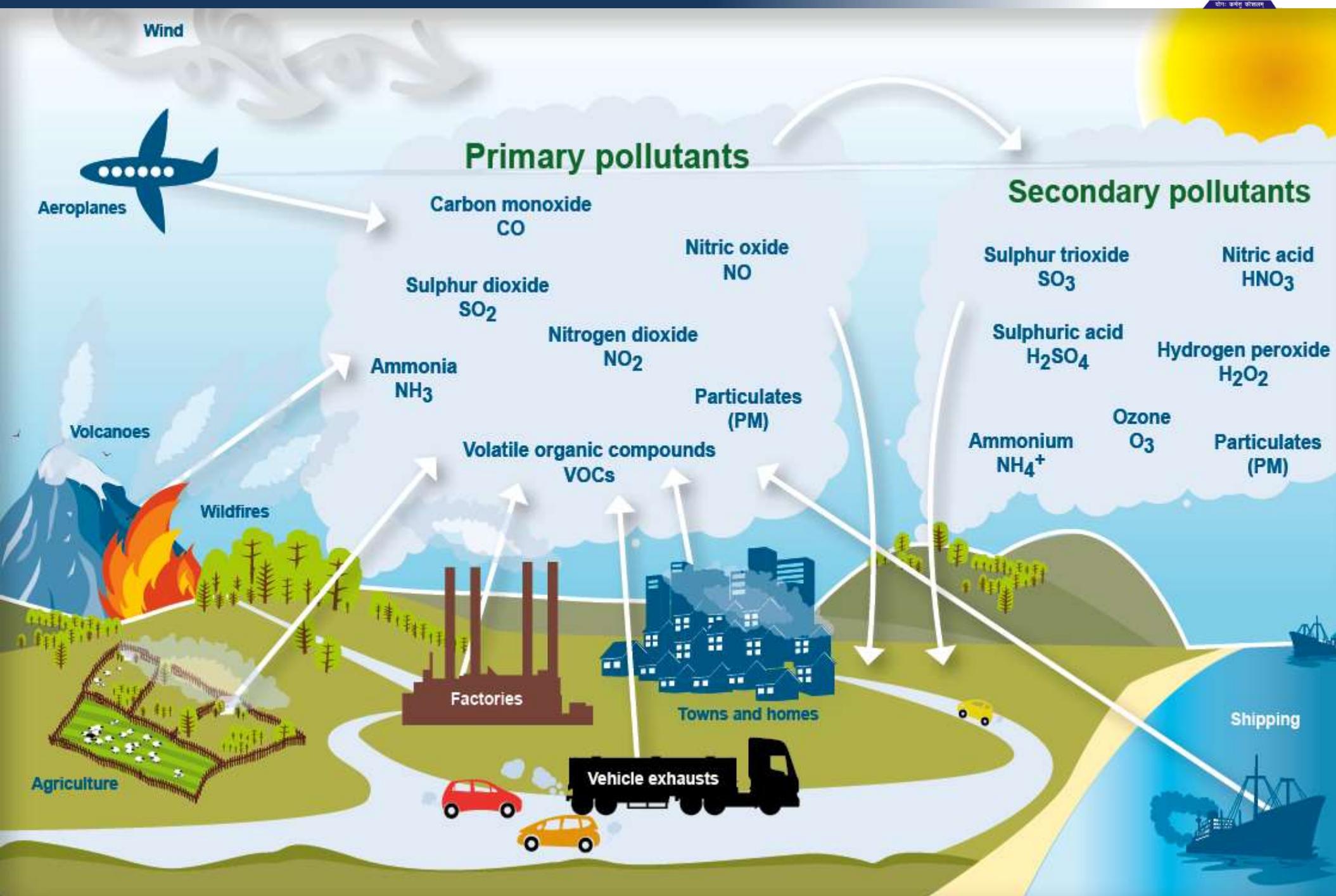




Classification of Air Pollutants

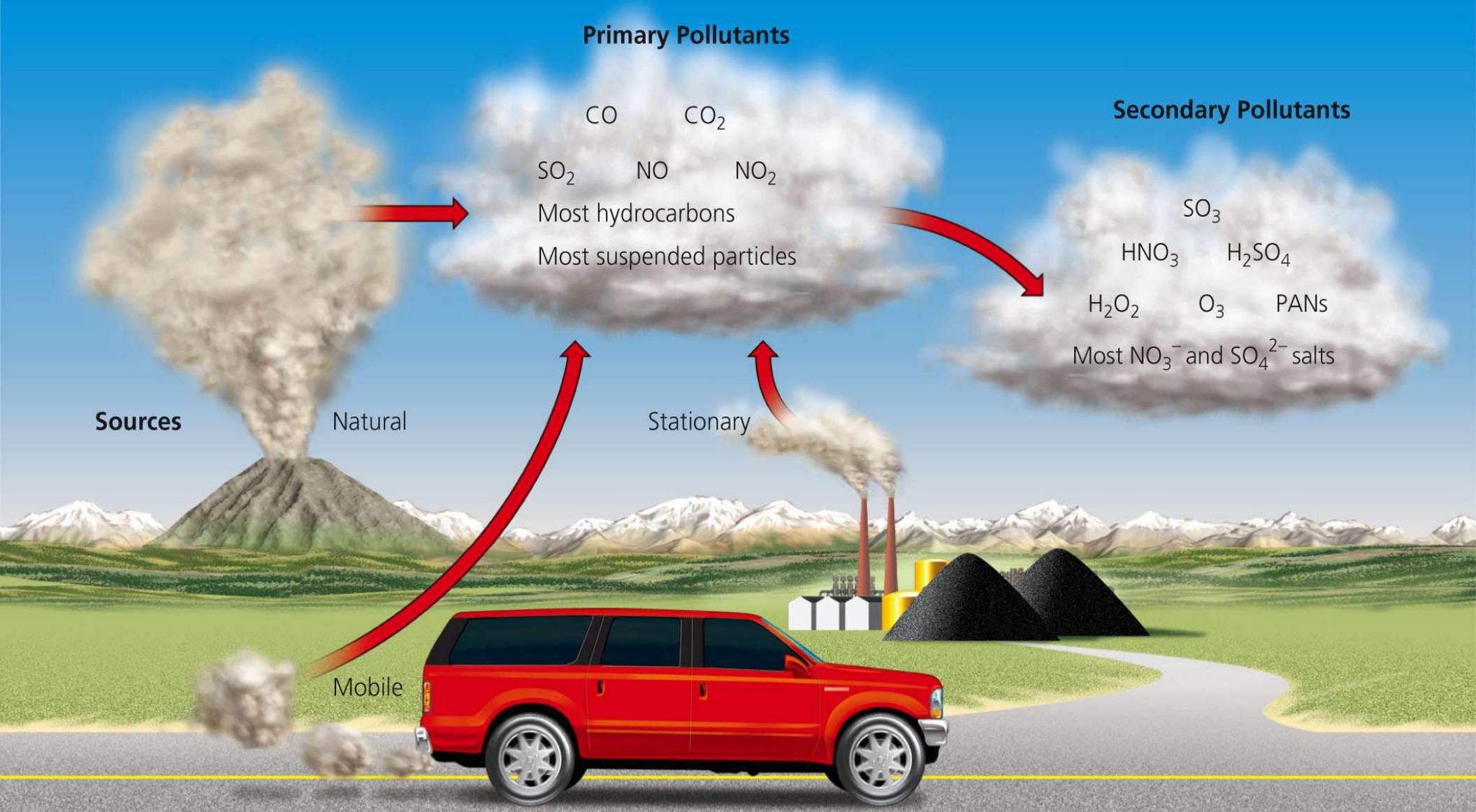
- Primary pollutants
 - Found in the atmosphere in the same chemical form as when it was emitted from its source.
 - Example: carbon monoxide, nitric oxide, nitrous oxide, hydrogen sulfide, sulfur dioxide, halogen compounds such as chlorides, fluorides, bromides, particulate matter.
- Secondary pollutants
 - Not directly emitted into the atmosphere but formed in the air as a result of chemical transformation of other primary pollutants.
 - Example: nitrogen dioxide formed from nitric oxide, ozone formed from photochemical reactions of nitrogen oxides and volatile organic compounds, sulfuric acid droplets formed from sulfur dioxide.

Classification of Air Pollutants

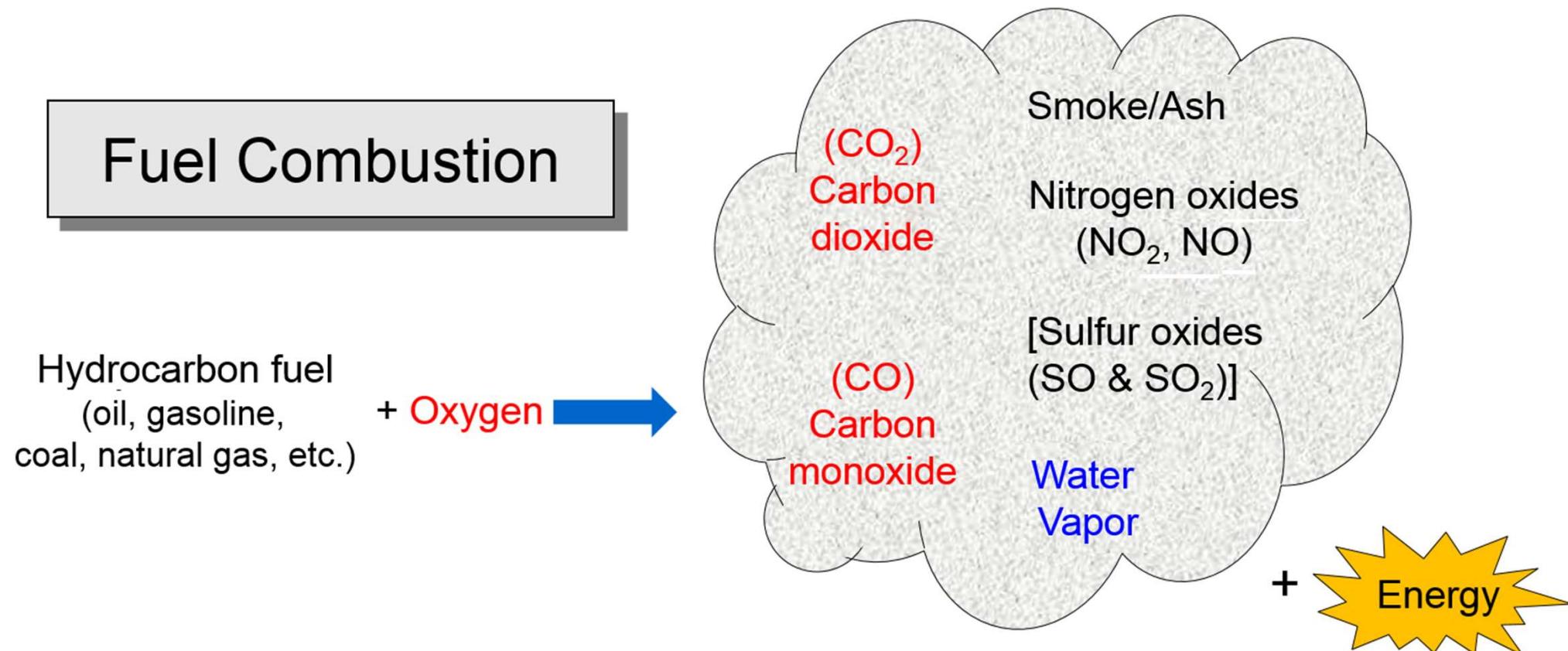


Sources of Air Pollutants

- Human inputs of air pollutants come from **mobile** sources (such as cars) and **stationary** sources (such as industrial and power plants).



Anthropogenic Sources of Air Pollution





Clean Air Act

- The Environmental Protection Agency (EPA) was created in December 1970 in the United States to address the Nation's environmental problems. In the same year the Clean Air Act (CAA) was passed to safeguard public health.
- The CAA is the comprehensive federal law that regulates air emissions from stationary and mobile sources.
- It authorizes the EPA to set standards to protect public health and public welfare and to regulate emissions of hazardous air pollutants.
- The CAA is one of the United States' first and most influential modern environmental laws, and one of the most comprehensive air quality laws in the world.
- Numerous countries around the globe have enacted similar legislation to achieve healthy air quality.





Criteria Pollutants

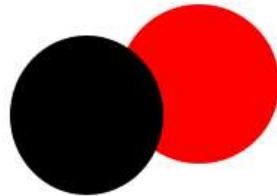
- A group of six common air pollutants that are the most prevalent and the most harmful to human health and the environment.
- Harmful to humans if concentration in ambient air is above certain levels.
- In the United States, the **National Ambient Air Quality Standards (NAAQS)** sets limits for each pollutant based on health and welfare standards.



Criteria Pollutants

- NAAQS have been established for the following six 'criteria pollutants'.

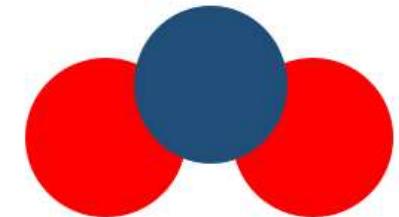
Carbon Monoxide



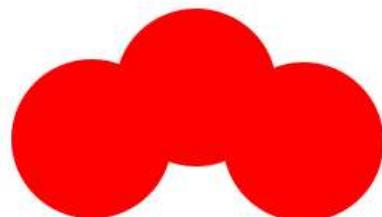
Lead



Nitrogen Dioxide



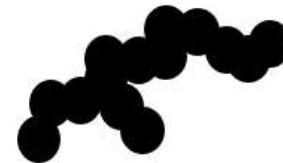
Ozone



● C

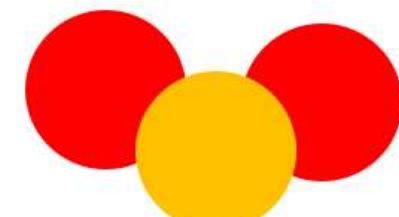
● O

Particulate Matter



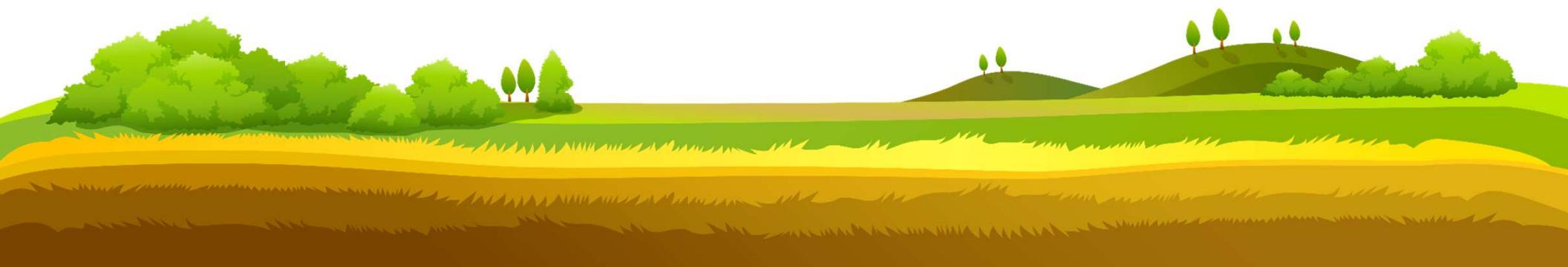
● Pb

Sulfur Dioxide



● N

● S



Carbon Monoxide (CO)

- **Description:** Colorless, odorless gas; forms during incomplete combustion of carbon-containing fuels.
- **Major human sources:** Cigarette smoking, incomplete burning of fossil fuels. About 77% (95% in cities) comes from motor vehicle exhaust.
- **Health effects:** Reacts with hemoglobin in red blood cells and reduced the ability of blood to bring oxygen to body cells and tissues. This impairs perception and thinking; slows reflexes; causes headaches, drowsiness, dizziness, and nausea; can trigger heart attacks and angina; damages the development of fetuses and young children; and aggravates chronic bronchitis, emphysema, and anemia. At high levels, it causes collapse, coma, irreversible brain cell damage, and death.



Nitrogen Dioxide (NO_2)

- **Description:** Reddish brown irritating gas; can be converted to nitric acid (HNO_3), a major component of acid deposition.
- **Major human sources:** Fossil fuel burning in motor vehicles (49%), and power plants and industries (46%).
- **Health effects:** Lung irritation and damage; aggravates asthma and chronic bronchitis; increases susceptibility to respiratory infections such as the flu and common colds (especially in young children and older adults).
- **Environmental effects:** Reduces visibility; acid deposition of HNO_3 can damage trees, soils, and aquatic life in lakes.
- **Property damage:** HNO_3 can corrode metals and eat away stone on buildings; statues, and monuments; NO_2 can damage fabrics.

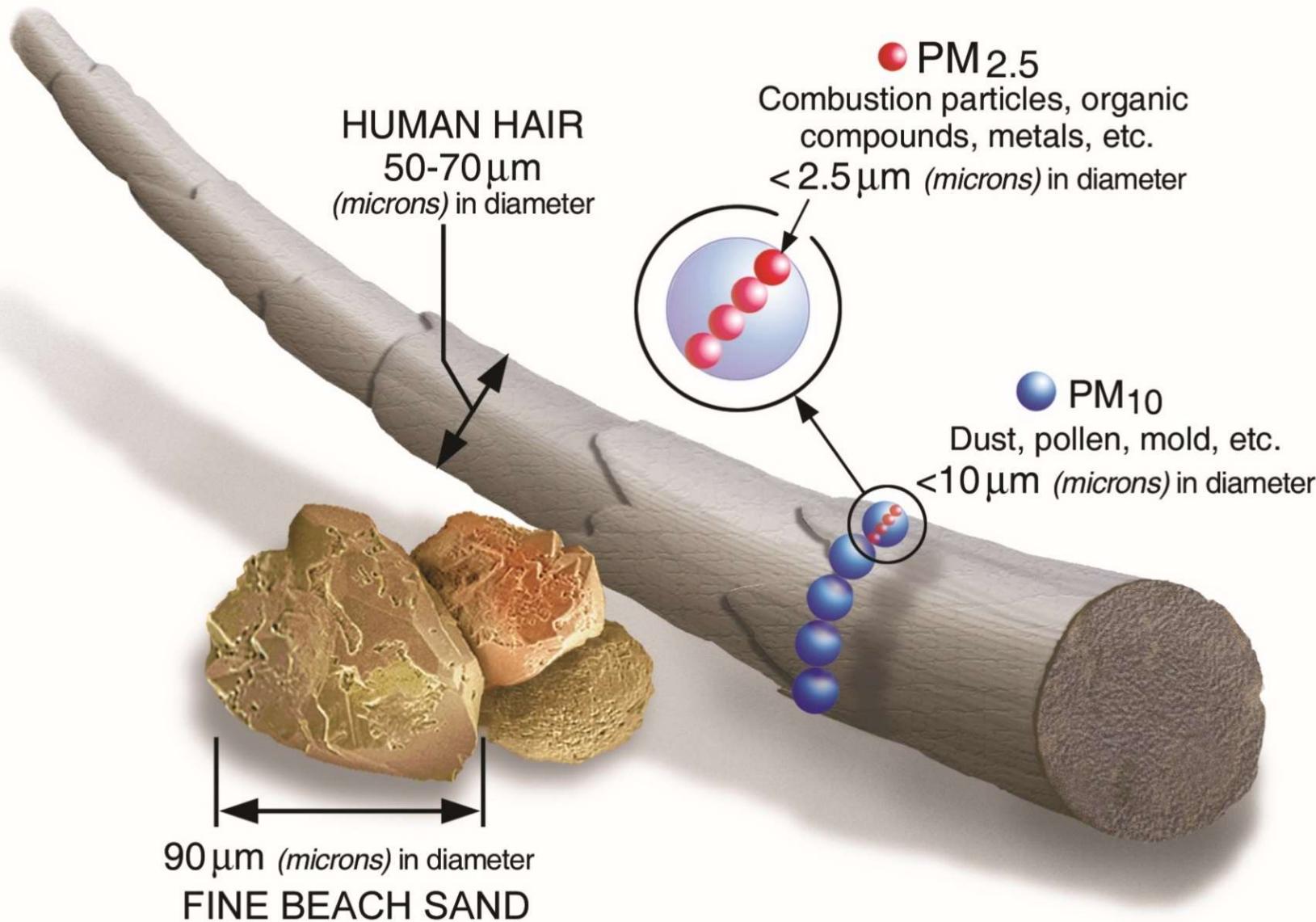
Sulfur Dioxide (SO_2)

- **Description:** Colorless, irritating; forms mostly from the combustion of sulfur containing fossil fuels such as coal and oil; in the atmosphere can be converted to sulfuric acid (H_2SO_4), a major component of acid deposition.
- **Major human sources:** Coal burning in power plants (88%) and industrial processes (10%).
- **Health effects:** Breathing problems for healthy people; restriction of airways in people with asthma; chronic exposure can cause a permanent condition similar to bronchitis.
- **Environmental effects:** Reduces visibility; acid deposition of H_2SO_4 can damage trees, soils, and aquatic life in lakes.
- **Property damage:** SO_2 and H_2SO_4 can corrode metals and eat away stone on buildings; statues, and monuments; SO_2 can damage paint, paper and leather.

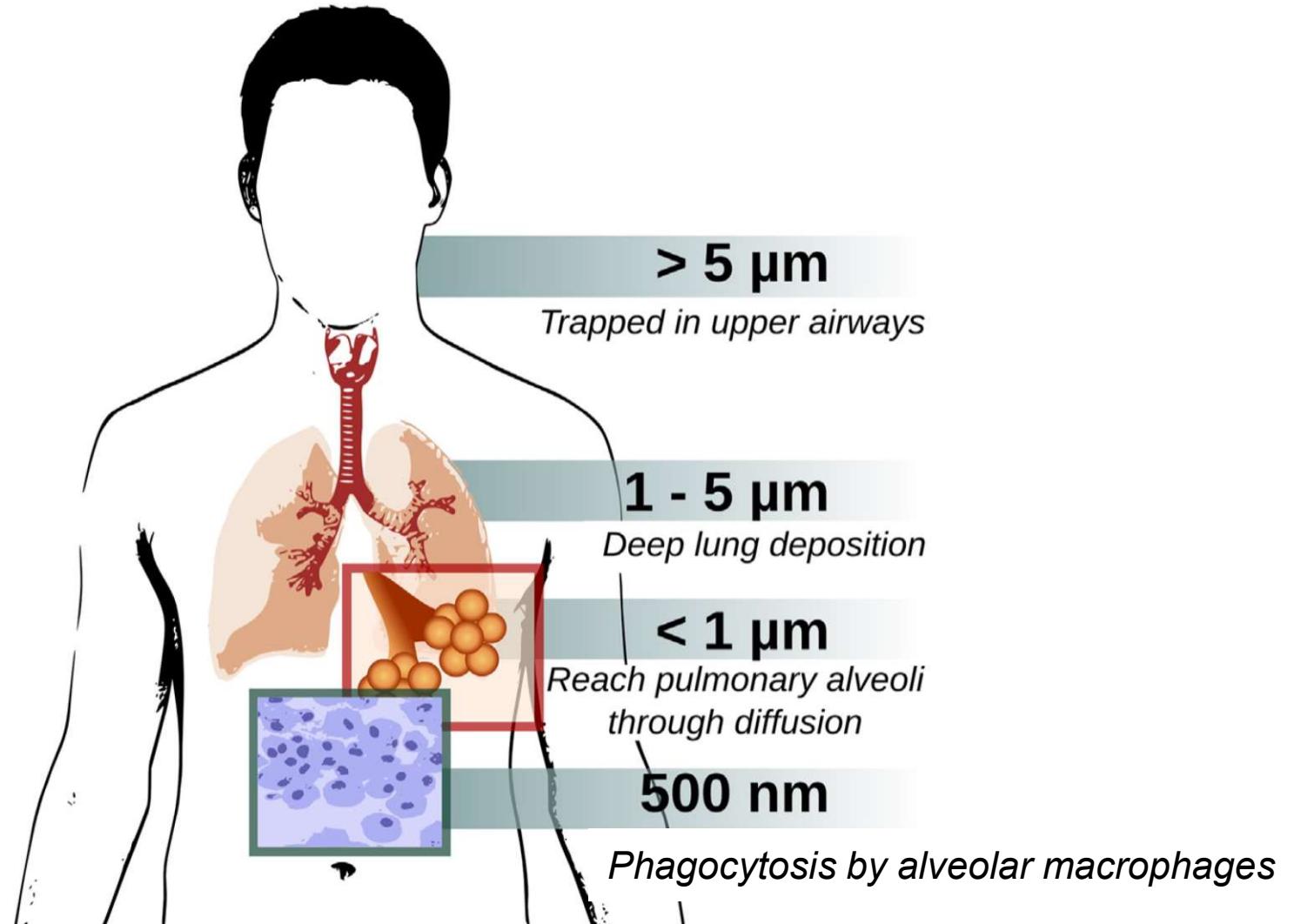
Particulate Matter (PM)

- **Description:** Variety of particles and droplets (aerosols) small and light enough to remain suspended in the atmosphere for short periods (large particles) to long periods (small particles); cause smoke, dust and haze.
- **Major human sources:** Burning coal in power and industrial plants (40%), burning diesel and other fuels in vehicles (17%), agriculture (plowing, burning off fields), unpaved roads, construction.
- **Health effects:** Nose and throat irritation, lung damage, and bronchitis; aggravates bronchitis and asthma; shortens life; toxic particulates (such as lead, cadmium and dioxins) can cause mutations, reproductive problems, cancer.
- **Environmental effects:** Reduces visibility; acid deposition of H_2SO_4 droplets can damage trees, soils, and aquatic life in water bodies.
- **Property damage:** Corrodes metal; soils and discolors buildings, clothes, fabrics and paints.

- The degree of damage of PM depends on the size of PM, number of particles inhaled, and the general health of the person who inhaled.



- Larger particles may be trapped in the nose or eliminated through coughing and sneezing. Fine particles can penetrate deep into the lungs, and ultrafine particles may even enter the blood stream. These particles can carry toxic chemicals which are linked to cancer.





Ground Level Ozone

- **Description:** Highly reactive, irritating gas with an unpleasant odor that forms in the troposphere as a major component of photochemical smog.
- **Major human sources:** Chemical reaction with volatile organic compounds (VOCs, emitted mostly by cars and industries) and nitrogen oxides to form photochemical smog.
- **Health effects:** Breathing problems; coughing; eye, nose, and throat irritation; aggravates chronic diseases such as asthma, bronchitis, emphysema, and heart disease; reduces resistance to colds and pneumonia; may speed up lung tissue aging.
- **Environmental effects:** Ozone can cause more damage to plants than any other pollutants; smog can reduce visibility.
- **Property damage:** Damages rubber, fabrics, and paints.

Lead (Pb)

- **Description:** Solid toxic metal and its compounds, emitted into the atmosphere to particulate matter.
- **Major human sources:** Paint (old houses), smelters (metal refineries), lead manufacture, storage batteries, leaded gasoline (being phased out in developed countries).
- **Health effects:** Accumulates in the body; brain and other nervous system damage and mental retardation (especially in children); digestive and other health problems; some lead-containing chemicals can cause cancer.
- **Environmental effects:** Can harm wildlife.



Air Quality Index

- The air quality index (AQI) is an index for reporting air quality on a daily basis.
- It is a measure of how air pollution affects one's health within a short time period.
- The AQI is based on measurement of PM_{2.5} and PM₁₀, O₃, NO₂, SO₂ and CO emissions.
- Every day, monitors record concentrations of the major pollutants. These raw measurements are converted into a separate AQI value for each pollutant PM_{2.5} and PM₁₀, O₃, NO₂, SO₂ and CO) using standard formulae developed by the US EPA.
- The purpose of the AQI is to help people know how the local air quality impacts their health. It quickly disseminates air quality information in real-time.
- The higher the AQI value, the greater the level of air pollution and the greater the health concerns.

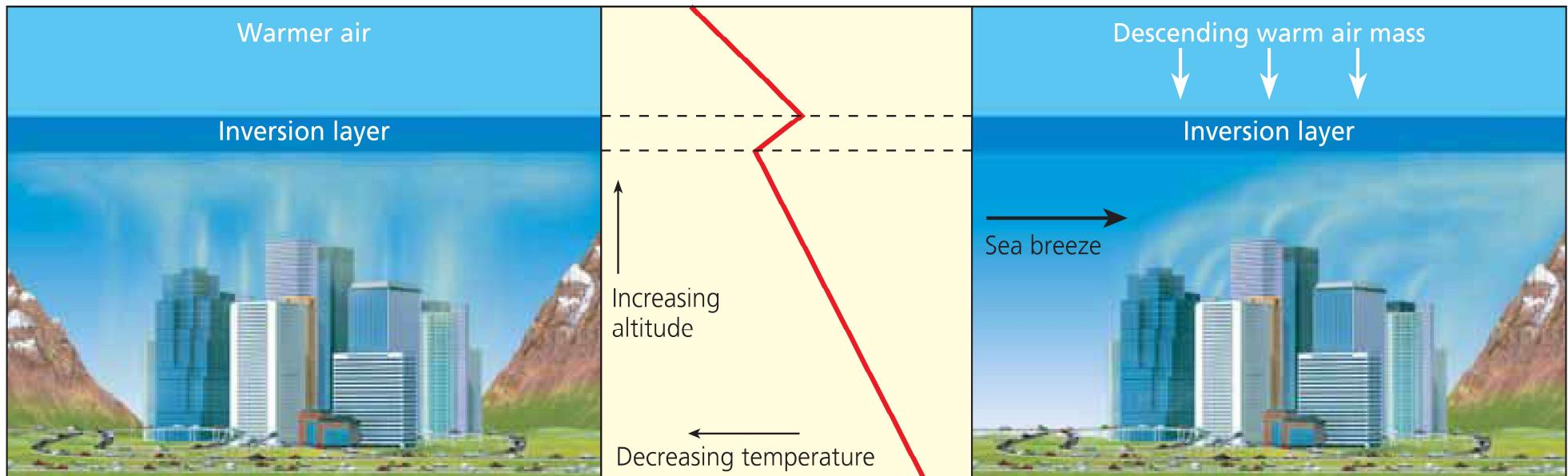




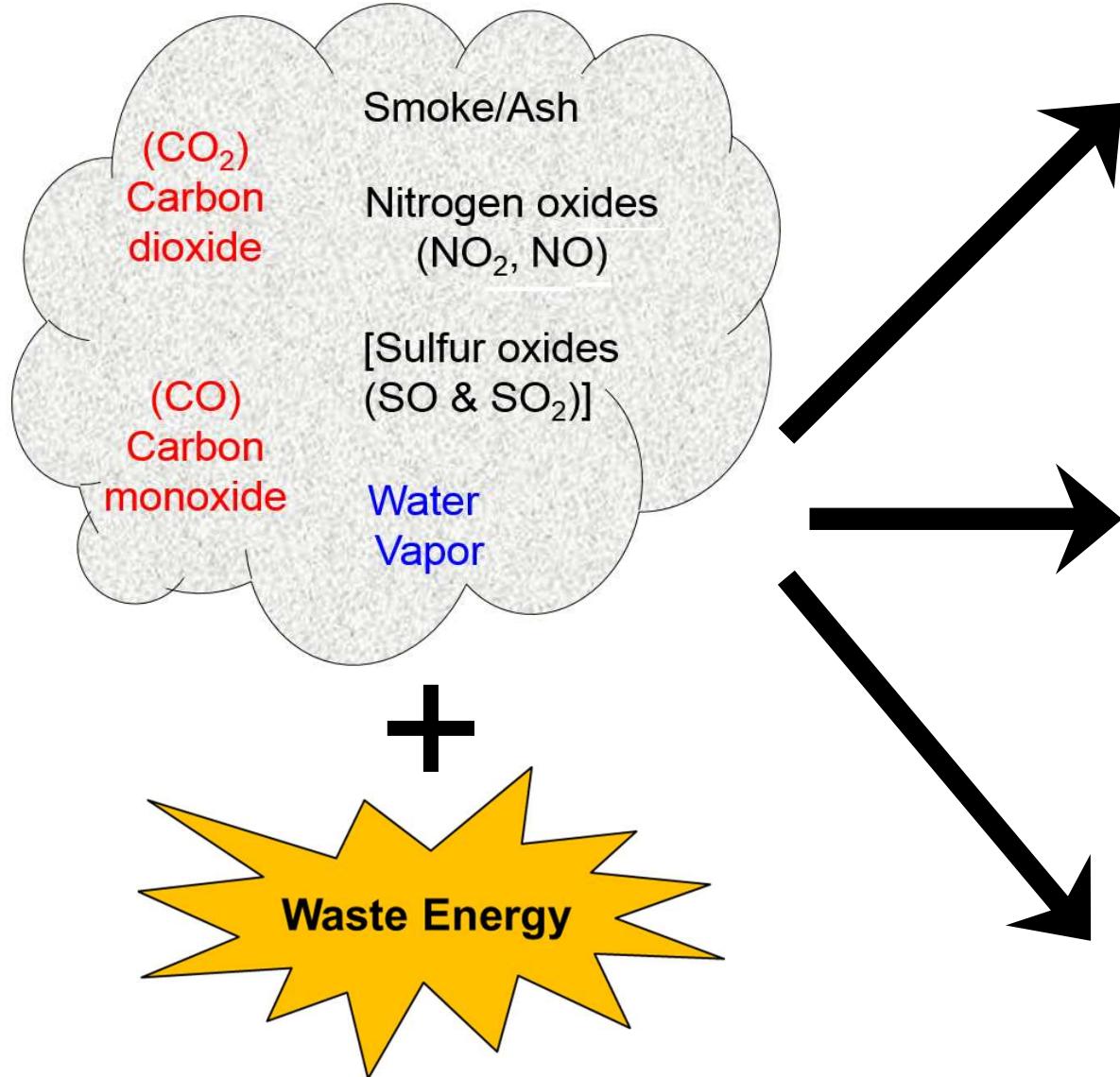
Numerical Value	Color	Air Quality Index Levels of Health Concern	Meaning
0 - 50	Green	Good	Air quality is considered satisfactory, and air pollution poses little or no risk.
51 - 100	Yellow	Moderate	Air quality is acceptable; however, for some pollutants there may be a moderate health concern for a very small number of people who are unusually sensitive to air pollution.
101 - 150	Orange	Unhealthy for sensitive groups	Members of sensitive groups may experience health effects. The general public is not likely to be affected.
151 - 200	Red	Unhealthy	Everyone may begin to experience health effects; members of sensitive groups may experience more serious health effects.
201 -300	Purple	Very unhealthy	Health alert: everyone may experience more serious health effects.
301 - 500	Maroon	Hazardous	Health warnings of emergency conditions. The entire population is more likely to be affected.

Temperature Inversions

- A **temperature inversion**, in which a warm air layer sits atop a cooler air layer, can take place in either of two sets of topography and weather conditions.
- Air pollutants can build to harmful levels during an inversion, which can occur during cold, cloudy weather in a valley surrounded by mountains (left).
- Frequent and prolonged temperature inversions can also occur in an area with a sunny climate, light winds, mountains on three sides, and the ocean on the other (right). A layer of descending warm air from a high-pressure system prevents ocean-cooled air near the ground from ascending enough to disperse and dilute pollutants.



Environmental Impacts

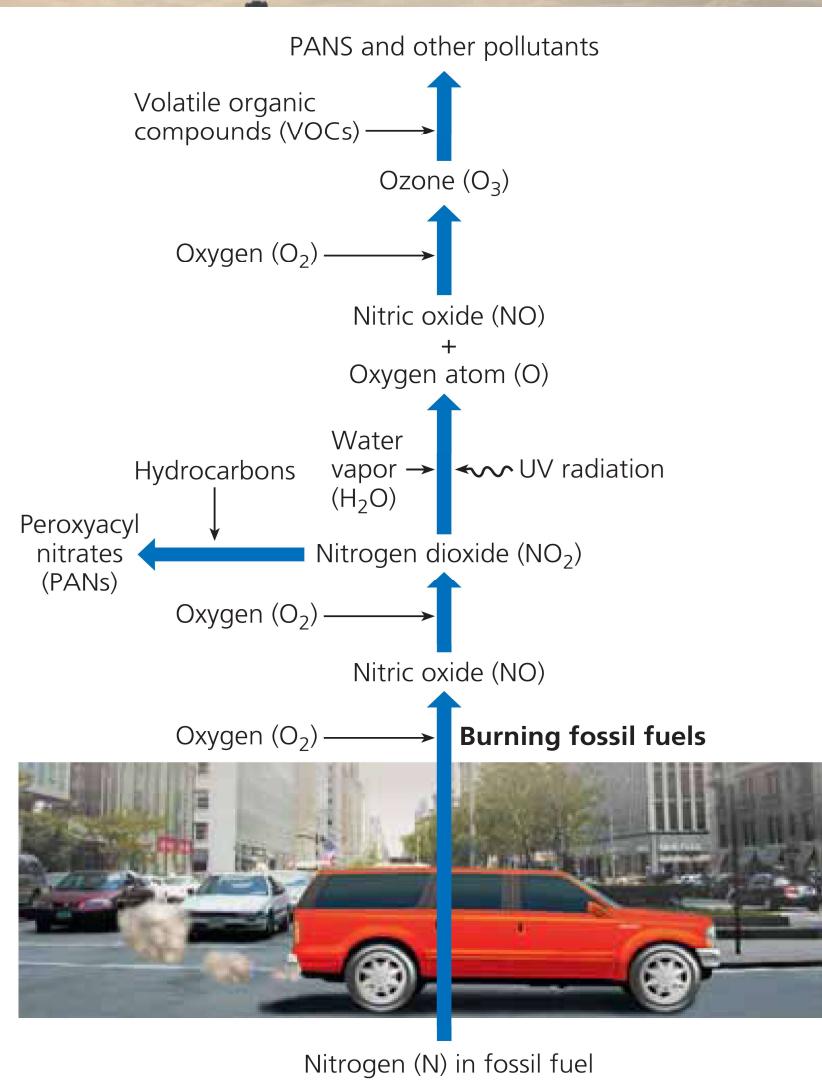




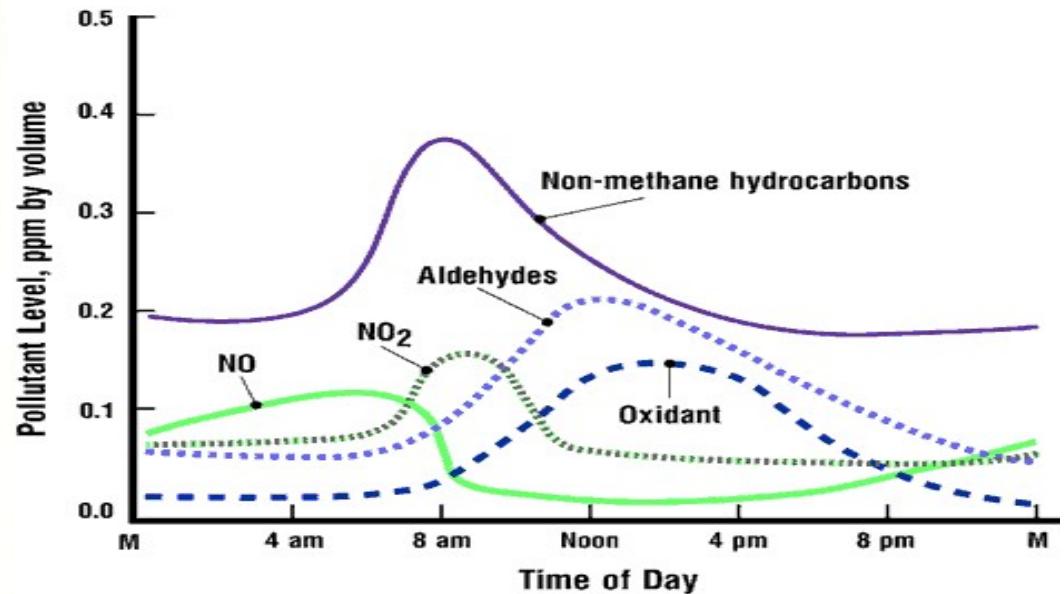
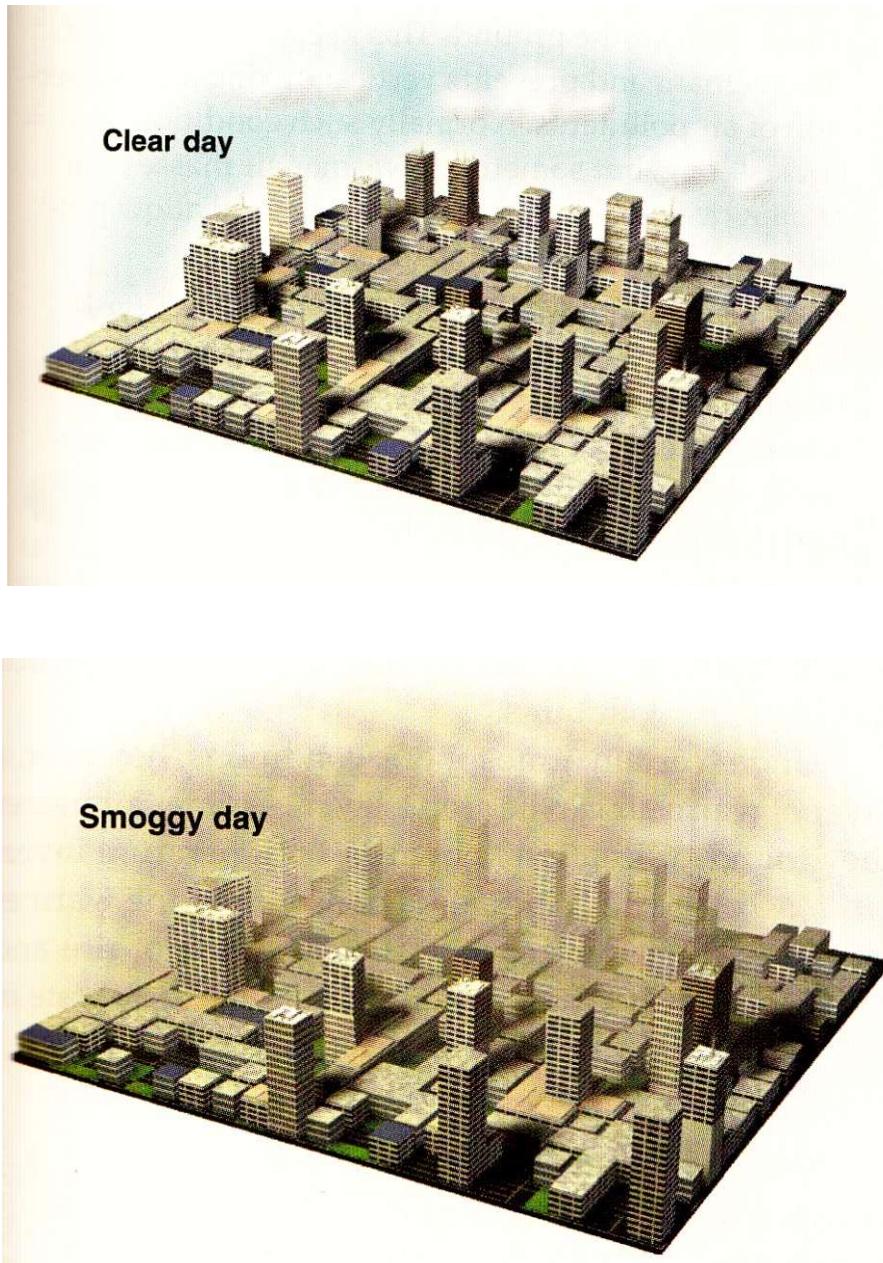
Photochemical Smog (Local Impact)

Bad Ozone Makes Photochemical Smog

- Noxious mixture of pollutants (mostly ozone, aldehydes, and peroxyacetyl nitrate) formed when NO_x , VOCs, and hydrocarbons, mainly from motor vehicle and industrial emissions, react in presence of sunlight, creating a reddish brown haze above cities.



Bad Ozone Makes Photochemical Smog



Effect of Photochemical Smog on Plants



- Ground level ozone causes more damage to plants than all other air pollutants combined.
- Ozone enters leaves through stomata during normal gas exchange. As a strong oxidant, ozone causes several types of symptoms including chlorosis and necrosis.
- High concentrations of ozone cause plants to close their stomata, slowing down photosynthesis.
- Prolonged ozone exposure reduces health and productivity of crops.
- High ozone concentrations can also affect soil fertility. Plants that are exposed to high ozone concentrations metabolize less carbon dioxide, so less carbon is available in the soil, and fewer soil microbes grow and thrive.



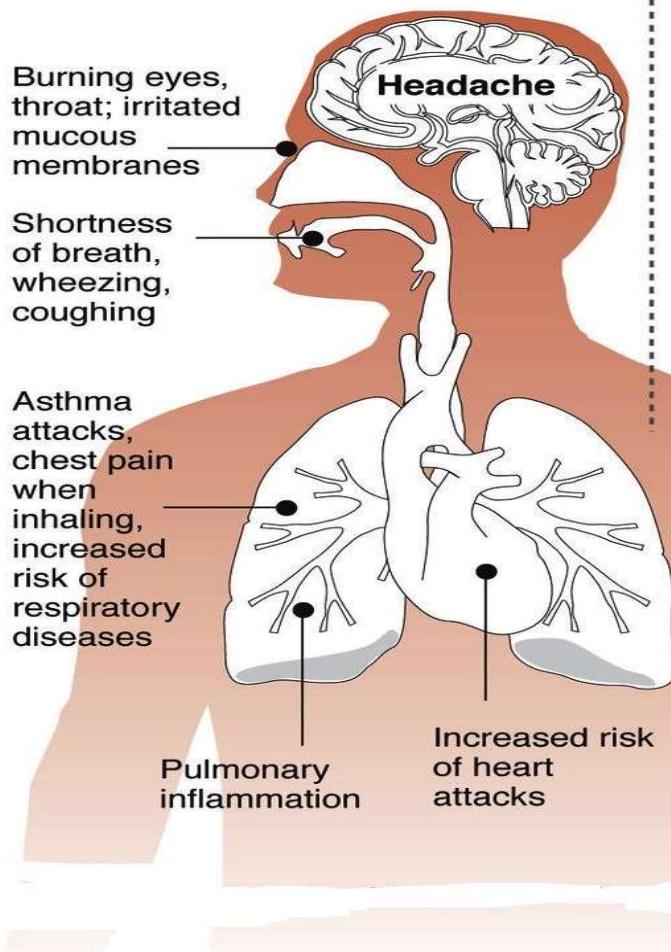
Effect of Photochemical Smog on Humans

- Ozone air pollution causes over 150 thousand premature deaths every year, and millions more chronic diseases, particularly in children and the elderly.

Why smog is harmful

Ozone, the main ingredient in smog, is one of the most widespread air pollutants and among the most dangerous.

Effects on health



How ozone forms

1 Oxygen in the atmosphere



2 Nitric oxide, byproduct of combustion



3 Sunlight breaks up nitric oxide



4 Ozone formed by three oxygen atoms



U.S. ozone limits

In parts per billion

• 1997-2008	84
• 2008-present	75
• New EPA proposal	60-70

Preventing Photochemical Smog

Solutions

Motor Vehicle Air Pollution

Prevention

Use mass transit



Walk or bike

Use less polluting fuels

Improve fuel efficiency

Get older, polluting cars off the road

Give large tax write-offs or rebates for buying low-polluting, energy efficient vehicles

Cleanup

Require emission control devices

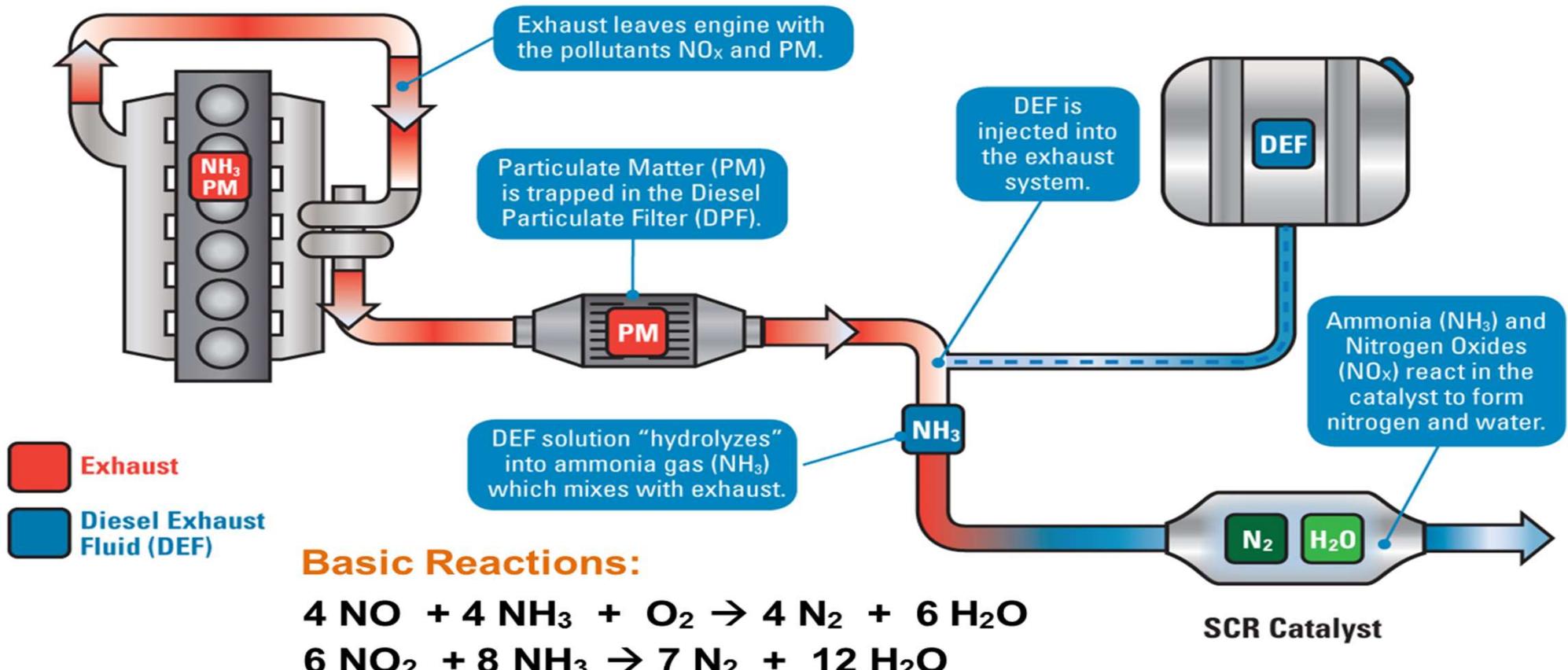
Inspect car exhaust systems twice a year



Set strict emission standards

NO_x Control: Selective Catalytic Reduction

- **Selective catalytic reduction (SCR)** is an advanced NO_x emissions control technology that injects a liquid-reductant agent through a special catalyst into the exhaust stream of a diesel engine. The reductant source is usually automotive-grade urea, otherwise known as diesel exhaust fluid (DEF). The DEF sets off a chemical reaction that converts NO_x into nitrogen and water, which is then expelled through the vehicle tailpipe.



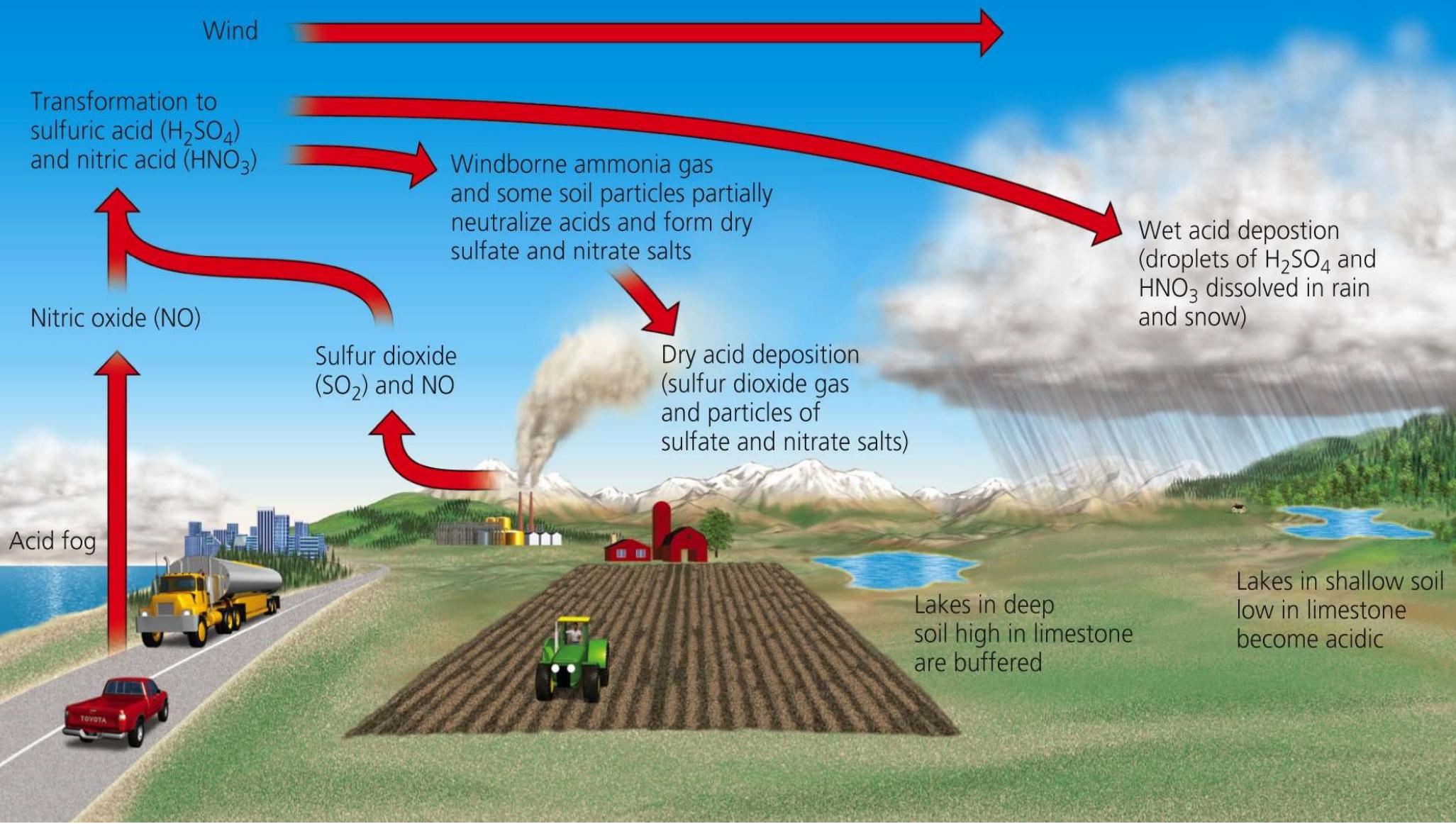


Acid Deposition

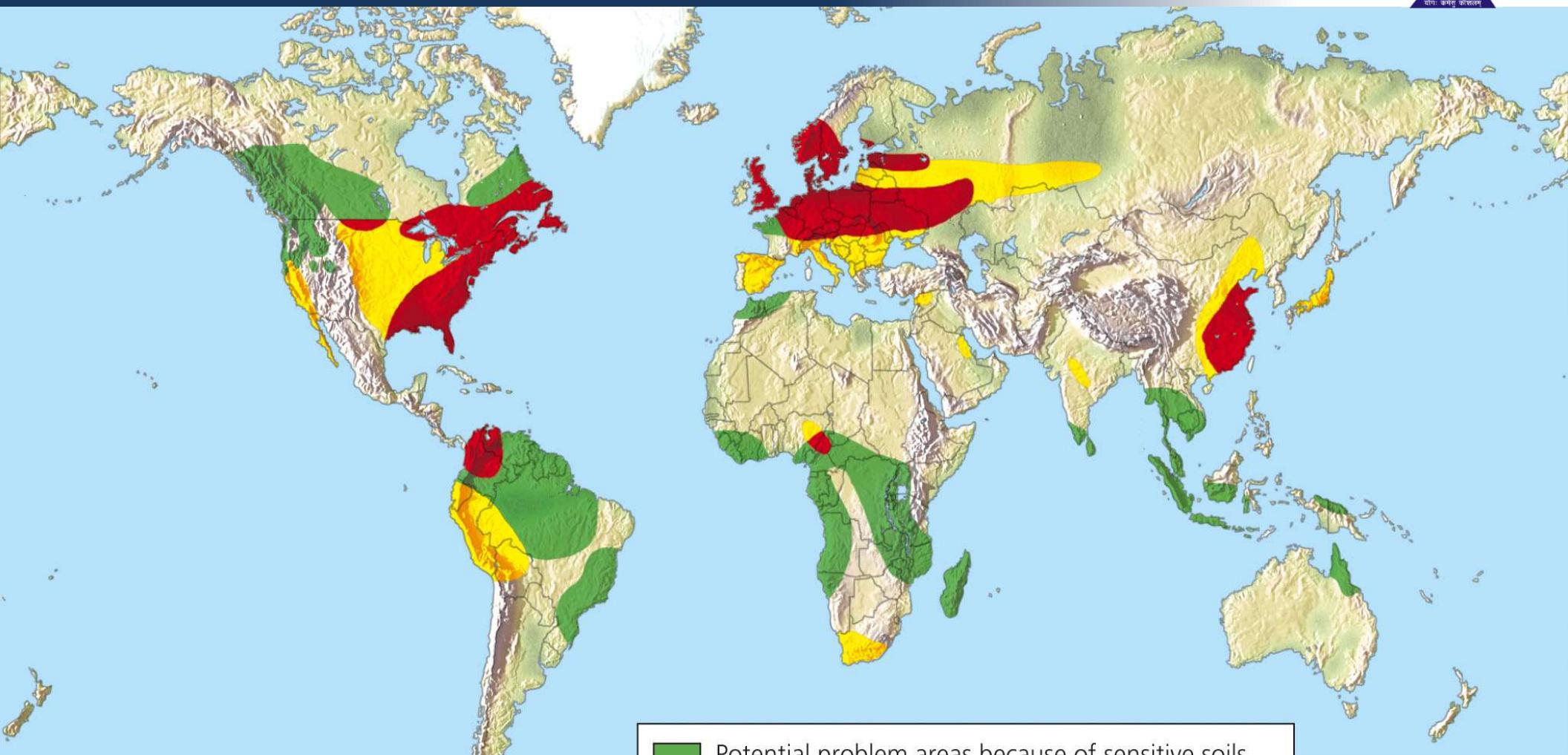
(Regional Impact)

Acid Deposition (Acid Rain)

- The accumulation of acids or acidic compounds on land, in water, or in the tissues of vegetation, as a result of acid precipitation or of the settling or absorption of such compounds directly from the atmosphere.



Acid Deposition is a Regional Problem



- █ Potential problem areas because of sensitive soils
- █ Potential problem areas because of air pollution: emissions leading to acid deposition
- █ Current problem areas (including lakes and rivers)

Effect of Acid Rain on Terrestrial Ecosystems

- Acid rain causes demineralization of soil. Base cations like Ca^{2+} , Mg^{2+} , Na^+ , and K^+ are leached away and replaced by acid cations such as H^+ , Al^{3+} ions.
- Nitrogen fixation ability of nitrifying bacteria diminishes rapidly below pH 6.
- Acidification of soil adversely affects soil fauna and lead to reduced forest productivity.
- Acid rain also retards the growth of vegetables, such as pea, beans, radish, spinach, etc.

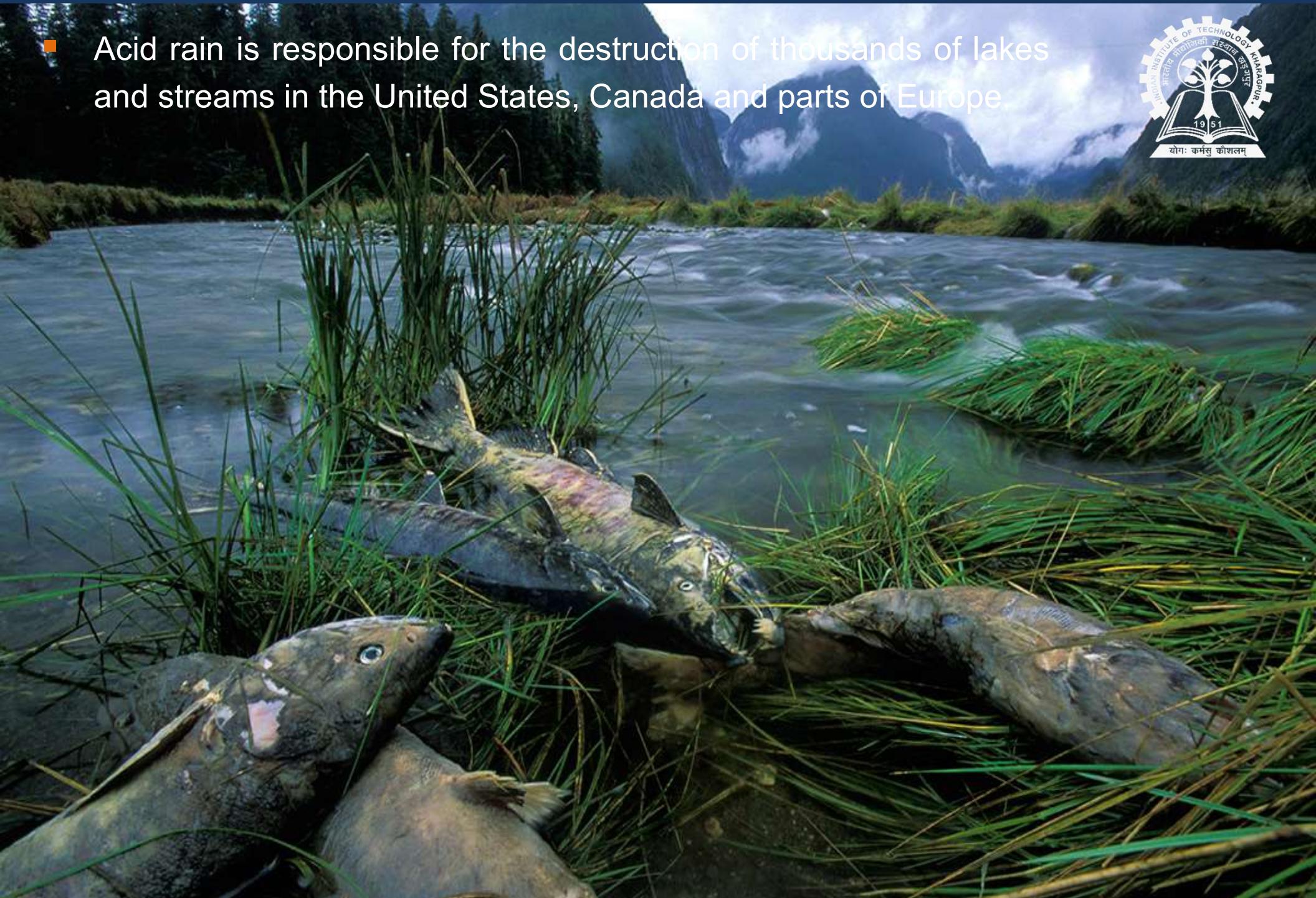


Effect of Acid Rain on Aquatic Ecosystems

- Many bacteria and blue green algae are killed due to acidification, disrupting the whole ecological balance.
- Acidic water can also leach aluminium from the soil. This runoff carry dissolved aluminium to lakes, rivers and streams causing massive fish death by clogging their gills and thus depriving them of oxygen.
- Fresh water lakes are fairly alkaline with Ca^{2+} and Mg^{2+} and HCO_3^- as the dominant ions. Phytoplankton and zooplankton are affected by acidity of water.
- Snails, clams, oysters etc. having their shells of calcium carbonate are among the first animals to die in acidic lakes.

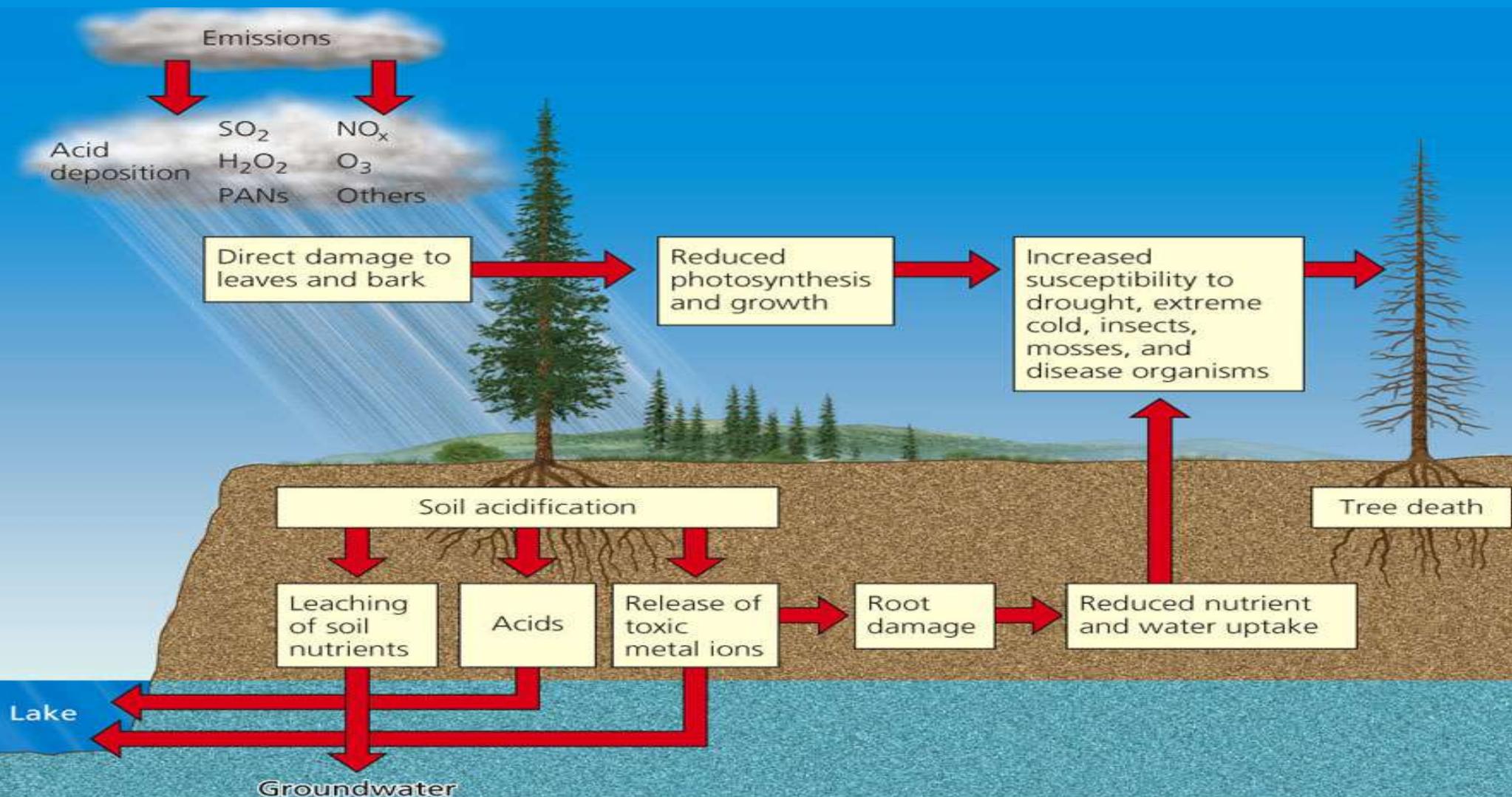


- Acid rain is responsible for the destruction of thousands of lakes and streams in the United States, Canada and parts of Europe.

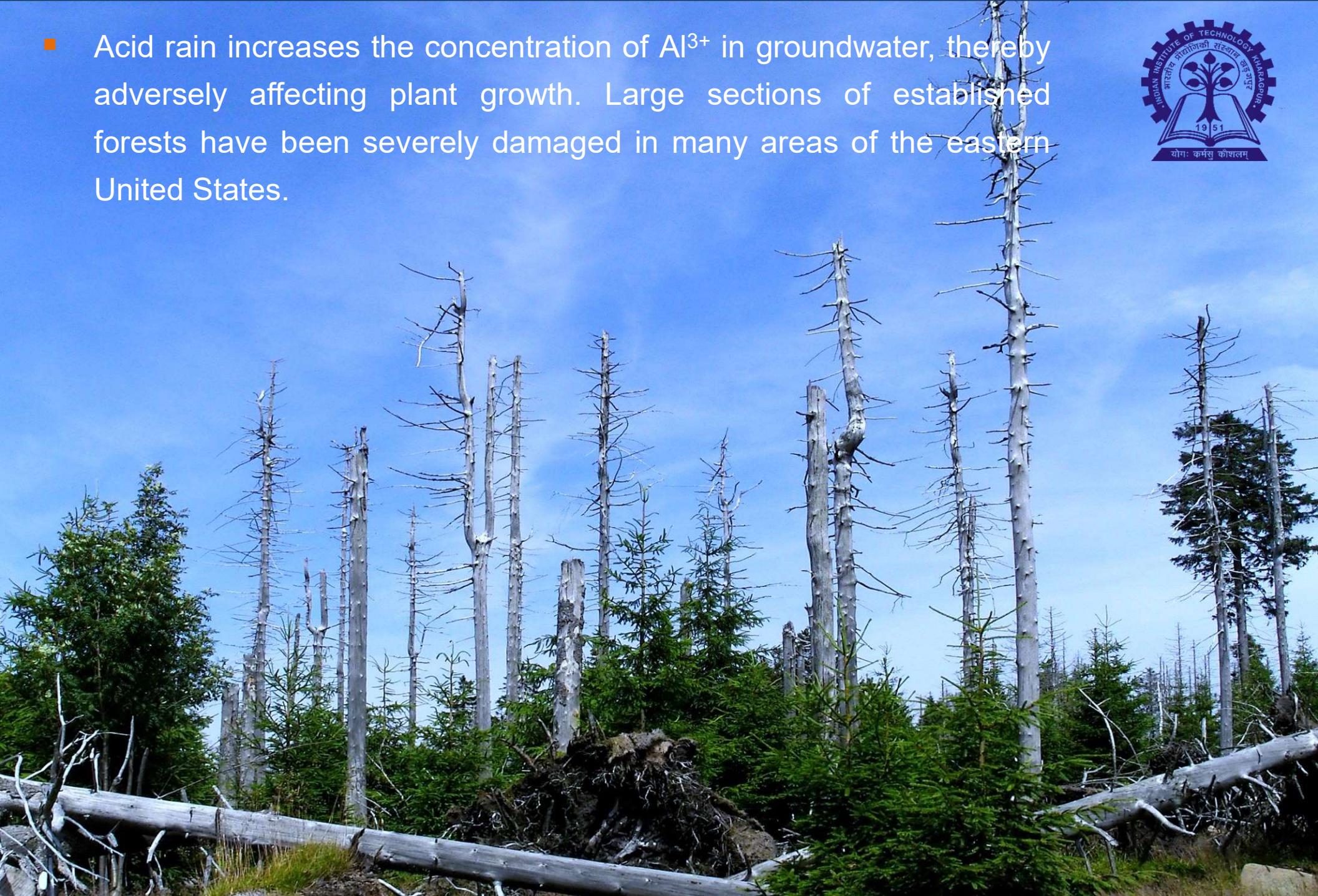


Effect of Acid Rain on Vegetation

- Acid rain does not kill trees directly. Instead, it weaken trees by damaging their leaves, limiting the nutrients available to them, or exposing them to toxic substances slowly released from the soil. Quite often, injury or death of trees is a result of these effects of acid rain in combination with one or more additional threats.



- Acid rain increases the concentration of Al^{3+} in groundwater, thereby adversely affecting plant growth. Large sections of established forests have been severely damaged in many areas of the eastern United States.

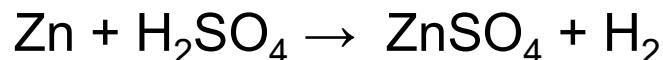
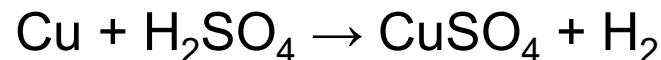


Effect of Acid Rain on Architecture

- Acid rain causes extensive damage to monuments and stone sculptures of marble, limestone, slate etc. The damage caused to rocks and marble by acid rain is called as **marble-leprosy or stone-leprosy**.



- Acid rain corrodes houses, buildings, bridges, fences and railing that require huge cost for maintenance every year.



- Acid precipitation causes damage to steel, oil based paints and automobile coatings. It also disintegrates textile, paper etc.



Preventing Acid Deposition

Solutions

Acid Deposition

Prevention

- Reduce coal use
- Burn low-sulfur coal
- Increase natural gas use
- Increase use of renewable energy resources
- Remove SO₂ particulates and NO_x from smokestack gases
- Remove NO_x from motor vehicular exhaust
- Tax emissions of SO₂
- Reduce air pollution by improving energy efficiency



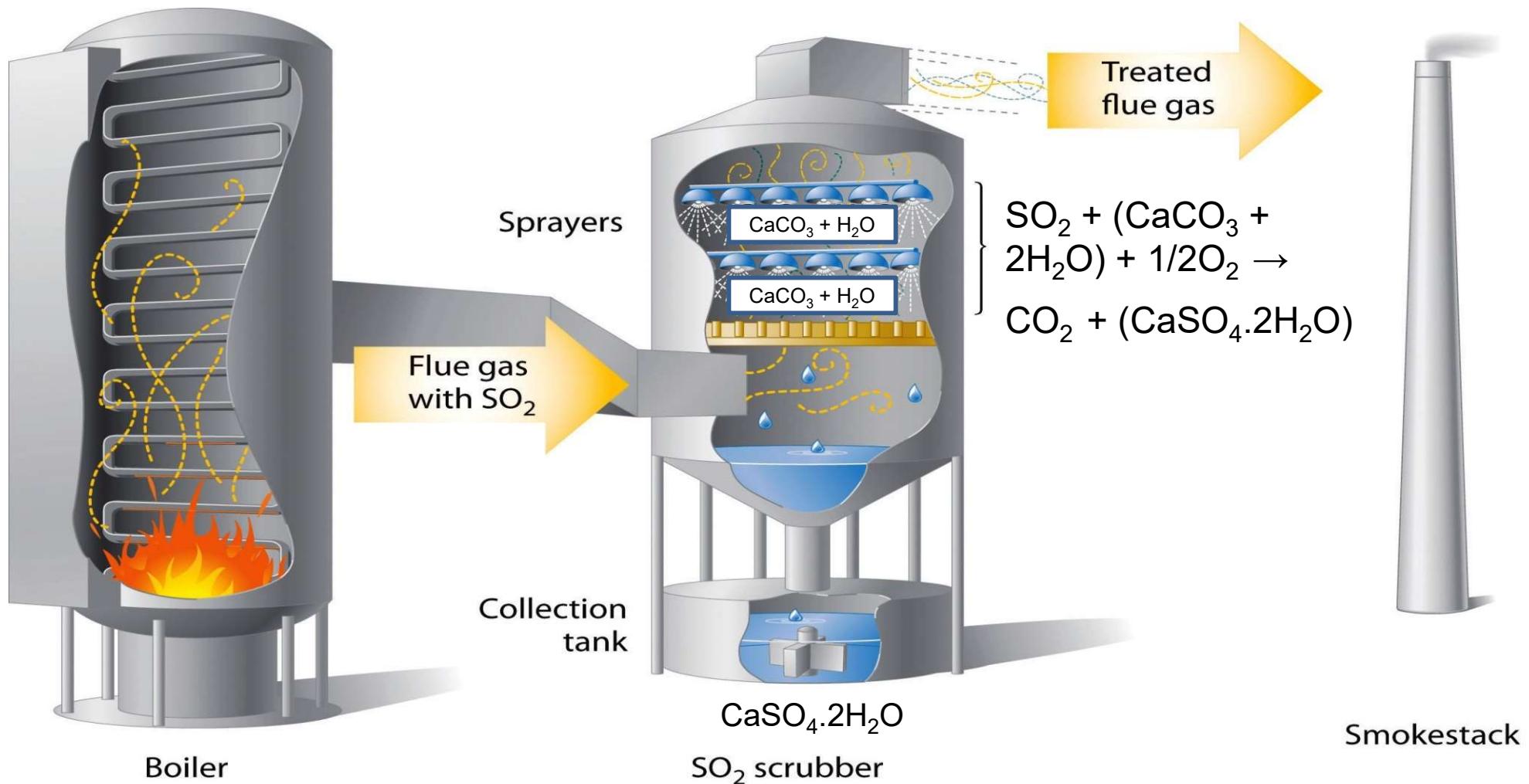
Cleanup

- Add lime to neutralize acidified lakes
- Add phosphate fertilizer to neutralize acidified lakes



SO₂ Control: Flue Gas Desulfurization

- Flue gas desulfurization (FGD) technology employs a slurry of pulverized limestone mixed with water to remove SO₂ from the combustion exhaust gas of power plants via chemical reactions that take place in a vessel commonly known as scrubber.



Preventing Outdoor Air Pollution

Solutions

Stationary Source Air Pollution

Prevention

Burn low-sulfur coal



Remove sulfur from coal

Convert coal to a liquid or gaseous fuel

Shift to less polluting energy sources

Dispersion or Cleanup

Disperse emissions above thermal inversion layer with tall smokestacks

Remove pollutants after combustion



Tax each unit of pollution produced



Ozone Depletion (Global Impact)

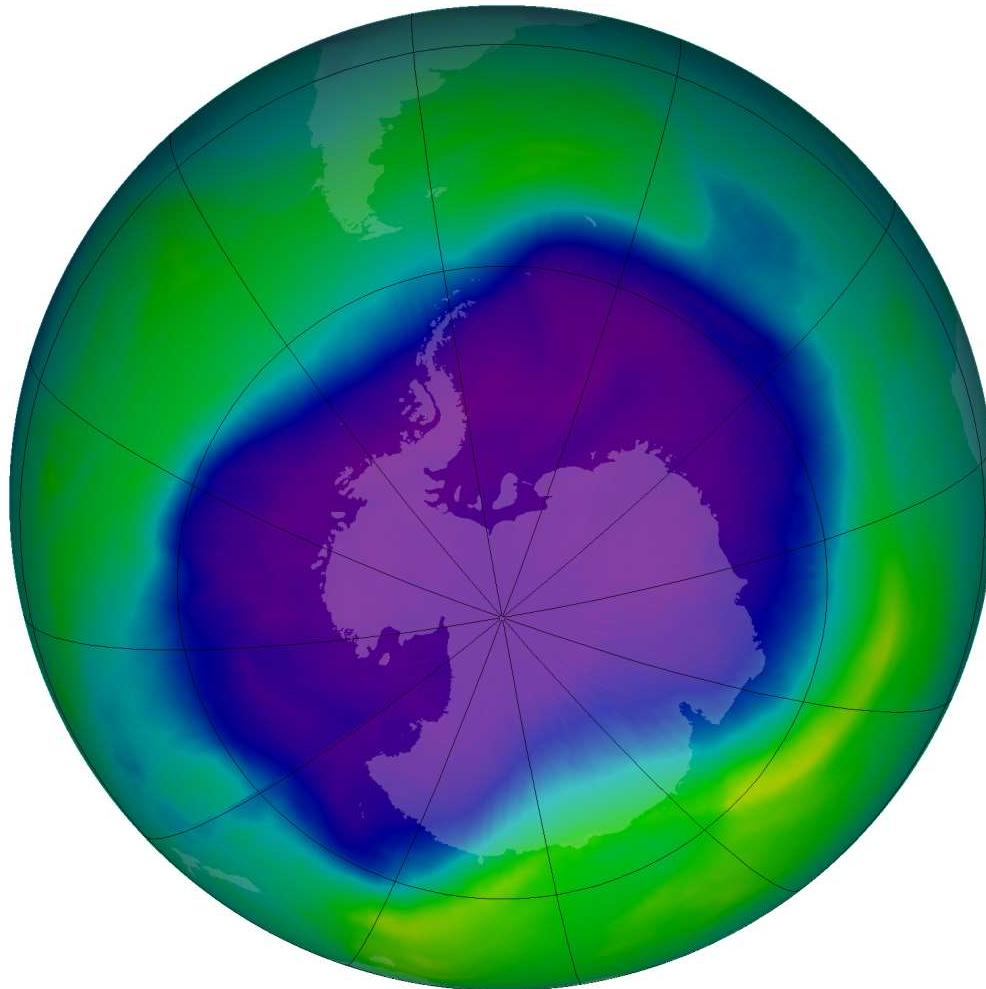
Ozone Depletion

- Gradual **thinning** of Earth's ozone layer caused by the release of certain chemical compounds from industry and other human activity that contain gaseous chlorine.
- **Chlorofluorocarbons (CFCs)** and other halogenated ozone depleting substances (ODS) such as hydrochlorofluorcarbons (HCFCs), halons, methyl chloroform and carbon tetrachloride are mainly responsible for man-made chemical ozone depletion.
- Dramatic loss of ozone in the lower stratosphere was first noticed in the early 1970s. The thinning was most pronounced in the polar regions, especially over Antarctica and has been called **ozone hole**.
- Ozone depletion is a major environmental problem because it increases the amount of ultraviolet (UV) radiation that reaches Earth's surface, increasing the rate of skin cancer, eye cataracts, and genetic and immune system damage.



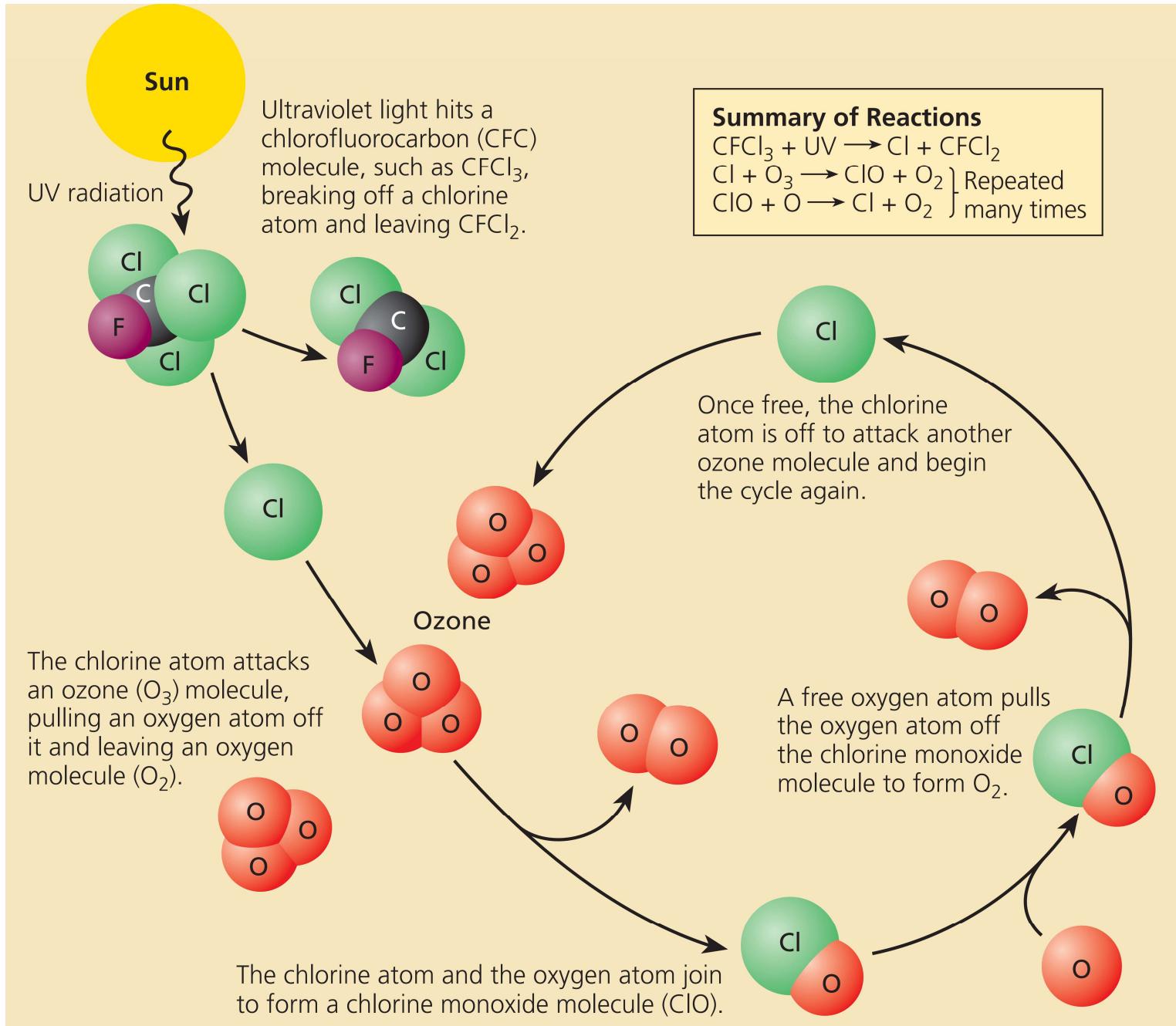
Ozone Depletion

- Satellites observed the largest ozone hole over Antarctica in September, 2006. The center of this image shows a large area where the concentration of ozone decreased by 50% or more.



24 September 2006

Stratospheric Ozone Depletion





Ozone Hole is a Springtime Phenomenon

- The ozone hole is not technically a “hole” where no ozone is present, but is actually a region of exceptionally depleted ozone in the stratosphere over the Antarctic that happens at the beginning of **Southern Hemisphere spring** (August–October).
- The hole forms in the Antarctic because cold air is trapped as a result of the **polar vortex** — strong, circulating winds.
- The cold temperatures allow the formation of **polar stratospheric clouds (PSCs)**, or ice clouds.
- These PSCs are conducive to the breakdown of chlorine-containing compounds, which are there because of our production of CFCs. This makes the area especially susceptible to ozone depletion.
- When the sun hits the PSCs in early spring, large amounts of chlorine are from CFCs and ODS.
- Fortunately, by early summer, ozone from other areas comes in to help fill this hole. However, due to continued CFC production, the hole returns next year.

Environmental Effects of Ozone Depletion

Effects of Ozone Depletion

Human Health

- Worse sunburns
- More eye cataracts
- More skin cancers
- Immune system suppression

Food and Forests

- Reduced yields for some crops
- Reduced seafood supplies from reduced phytoplankton
- Decreased forest productivity for UV-sensitive tree species

Wildlife

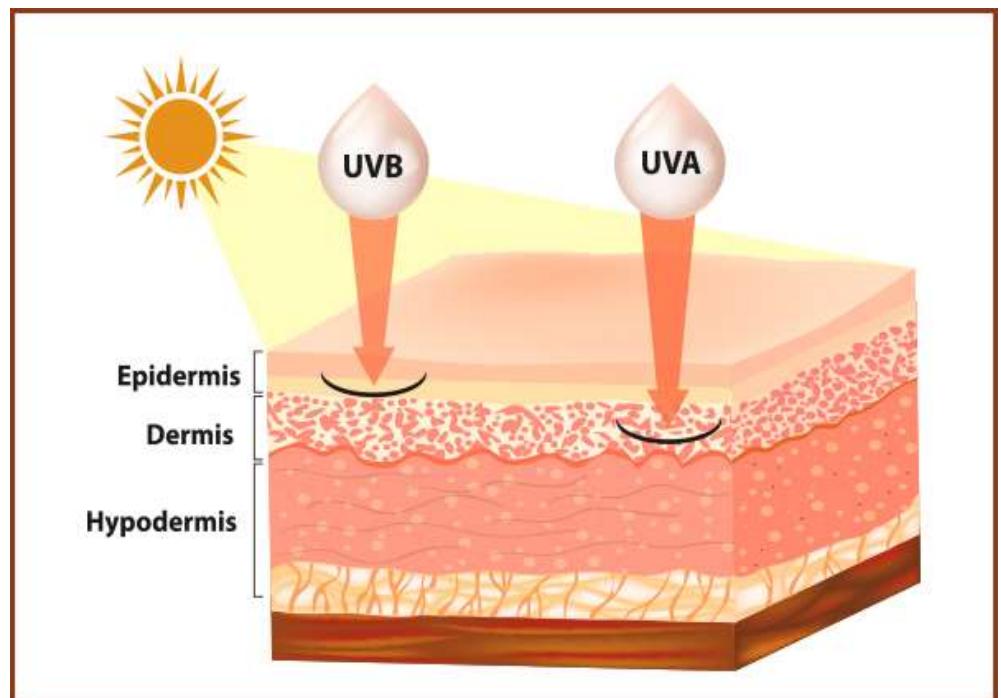
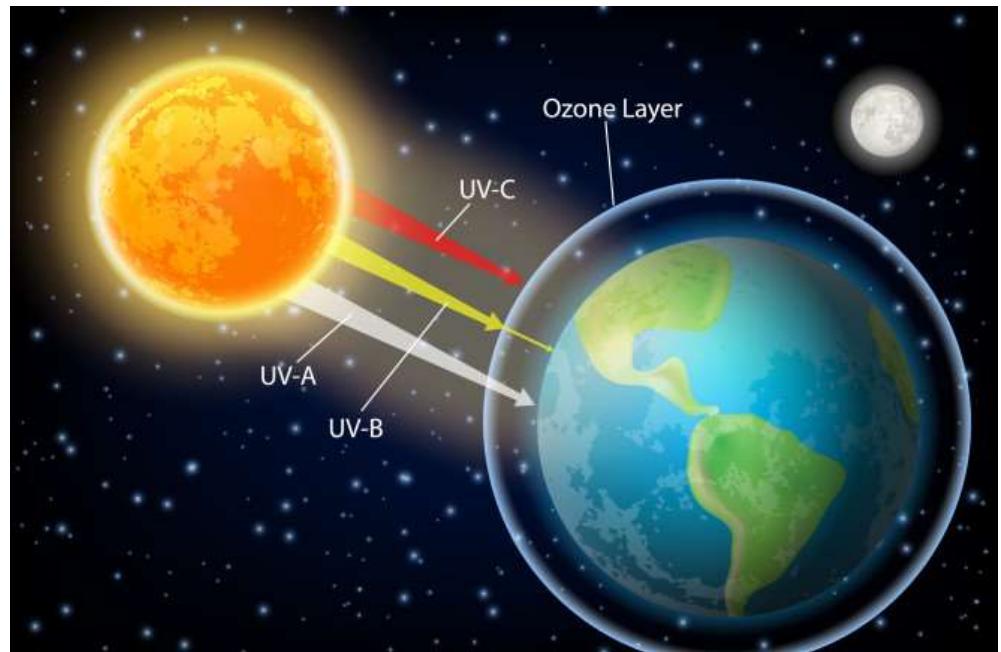
- Increased eye cataracts in some species
- Decreased populations of aquatic species sensitive to UV radiation
- Reduced populations of surface phytoplankton
- Disrupted aquatic food webs from reduced phytoplankton

Air Pollution and Materials

- Increased acid deposition
- Increased photochemical smog
- Degradation of outdoor paints and plastics

Global Warming

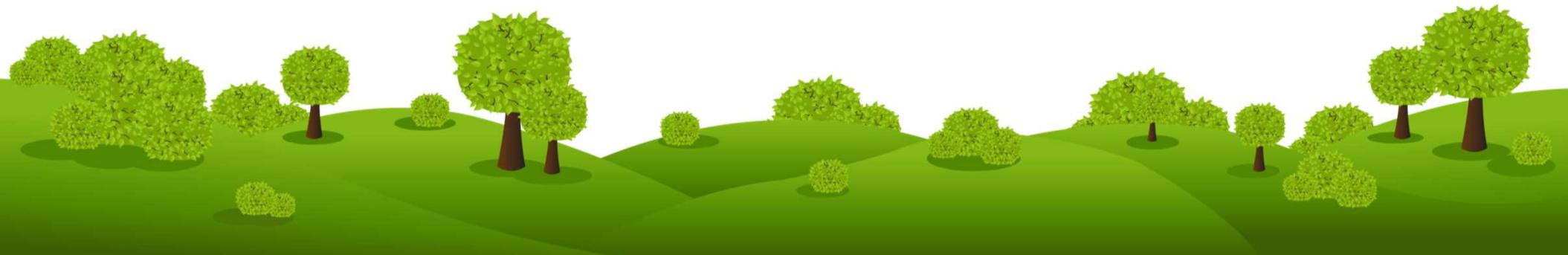
- While in troposphere, CFCs act as greenhouse gases





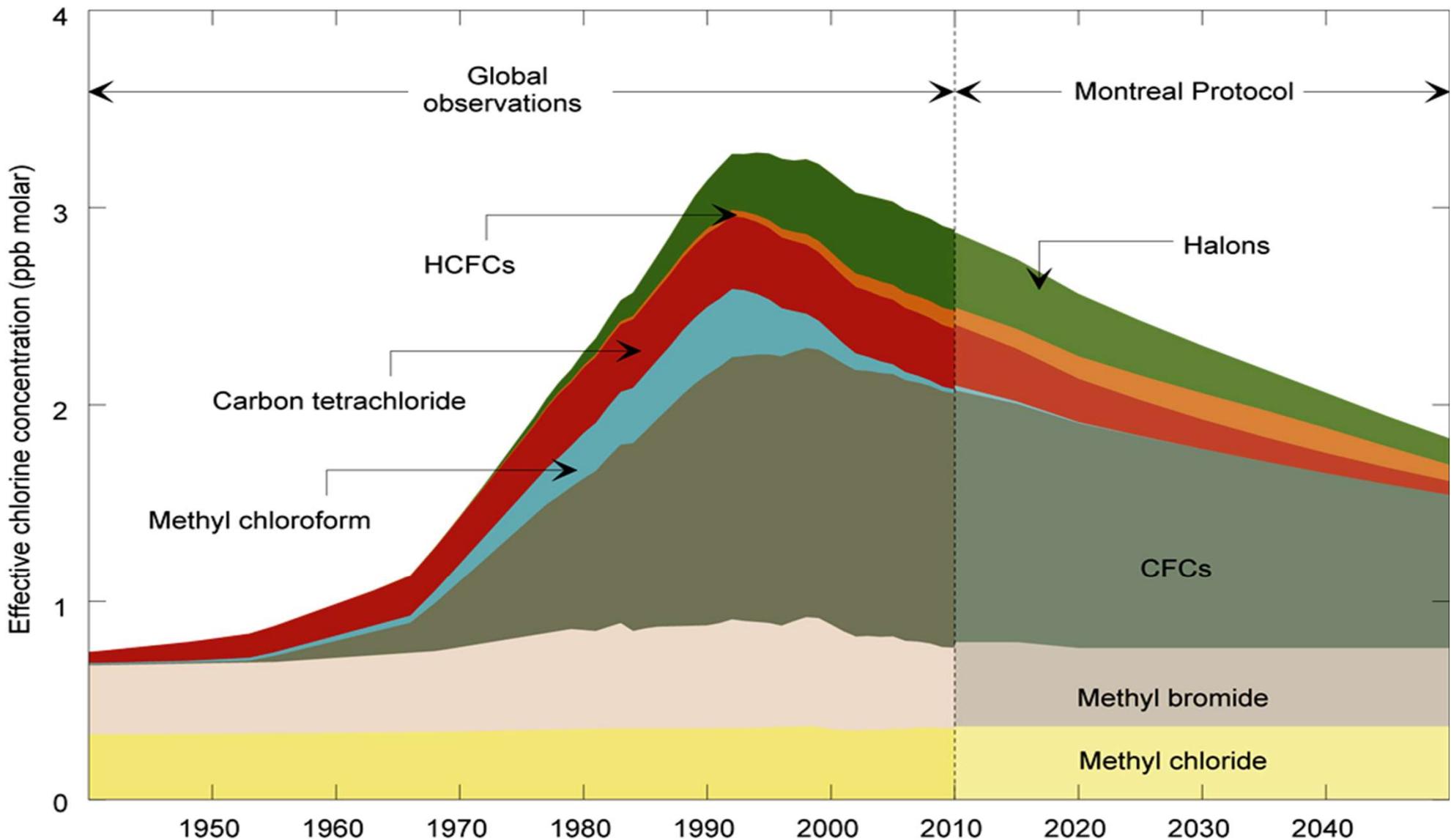
Reversing Ozone Depletion

- The **Montreal Protocol** on ‘Substances that deplete the ozone layer’ is a landmark international agreement designed to protect the stratospheric ozone layer.
- The treaty was originally signed in 1987 and substantially amended in 1990 and 1992.
- The Montreal Protocol stipulates that the production and consumption of compounds that deplete ozone in the stratosphere are to be phased out by 2000.
- The Montreal Protocol has, contributed to a significant drop in total global production and consumption of ozone depleting substances used in agricultural, consumer and industrial sectors around the world.
- It has also generated climate benefits as some of these substances are greenhouse gases, too.

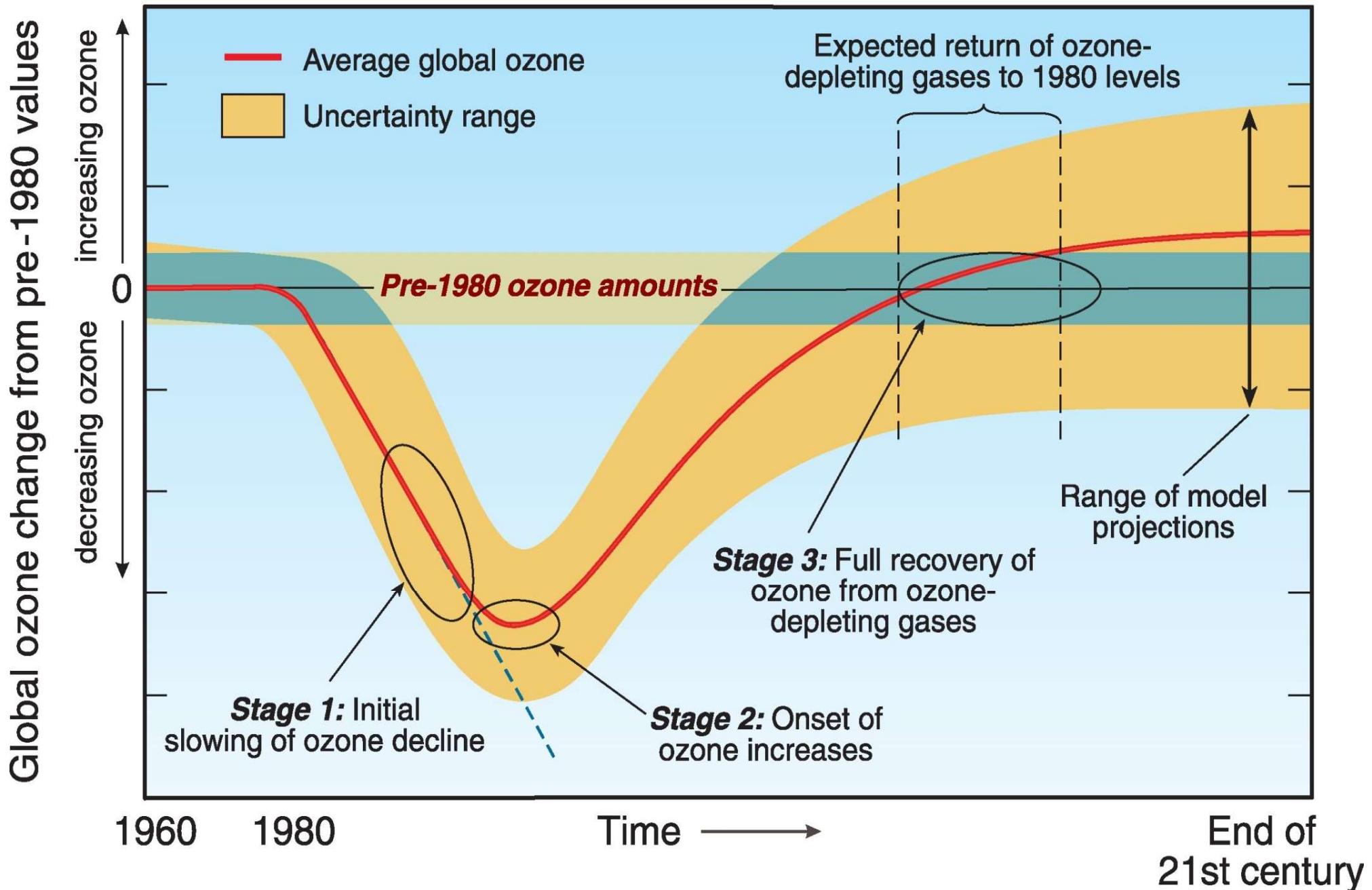


Reversing Ozone Depletion

- The Montreal Protocol has been keeping our planet cool for years by phasing out ozone-depleting substances that are also potent global-warming gases.



Recovery Stages of Global Ozone





Indoor Air Pollution



Indoor Air Pollution

- Indoor air contains higher concentrations of pollutants than outdoor air.
- Indoor air pollution usually is a greater threat to human health than outdoor air pollution.
- Developed countries – chemicals used in building materials and products.
- According to the US Environmental Protection Agency (EPA), four most dangerous indoor air pollutants in developed countries include tobacco smoke, formaldehyde, radioactive radon-222 gas and very small (ultrafine) particles.
- Less-developed countries – indoor burning of wood, charcoal, dung, crop residues, coal, and other fuels in open fires.



Important Indoor Air Pollutants

Chloroform

Source: Chlorine-treated water in hot showers
Possible threat: Cancer

1,1,1-Trichloroethane

Source: Aerosol sprays
Threat: Dizziness, irregular breathing

Nitrogen oxides

Source: Unvented gas stoves and kerosene heaters, woodstoves
Threat: Irritated lungs, children's colds, headaches

Particulates

Source: Pollen, pet dander, dust mites, cooking smoke particles
Threat: Irritated lungs, asthma attacks, itchy eyes, runny nose, lung disease

Asbestos

Source: Pipe insulation, vinyl ceiling and floor tiles
Threat: Lung disease, lung cancer

Para-dichlorobenzene

Source: Air fresheners, mothball crystals
Threat: Cancer

Tetrachloroethylene

Source: Dry-cleaning fluid fumes on clothes
Threat: Nerve disorders, damage to liver and kidneys, possible cancer

Carbon monoxide

Source: Faulty furnaces, unvented gas stoves and kerosene heaters, woodstoves
Threat: Headaches, drowsiness, irregular heartbeat, death

Formaldehyde

Source: Furniture stuffing, paneling, particleboard, foam insulation
Threat: Irritation of eyes, throat, skin, and lungs; nausea; dizziness

Styrene

Source: Carpets, plastic products
Threat: Kidney and liver damage

Benzo- α -pyrene

Source: Tobacco smoke, woodstoves
Threat: Lung cancer

Radon-222

Source: Radioactive soil and rock surrounding foundation, water supply
Threat: Lung cancer

Tobacco smoke

Source: Cigarettes
Threat: Lung cancer, respiratory ailments, heart disease

Methylene chloride

Source: Paint strippers and thinners
Threat: Nerve disorders, diabetes

Preventing Indoor Air Pollution

Solutions

Indoor Air Pollution

Prevention

Clean ceiling tiles and line AC ducts to prevent release of mineral fibers

Ban smoking or limit it to well-ventilated areas

Set stricter formaldehyde emissions standards for carpet, furniture, and building materials

Prevent radon infiltration

Use office machines in well-ventilated areas

Use less polluting substitutes for harmful cleaning agents, paints, and other products



Cleanup or Dilution

Use adjustable fresh air vents for work spaces

Increase intake of outside air

Change air more frequently

Circulate a building's air through rooftop greenhouses

Use efficient venting systems for wood-burning stoves

Use exhaust hoods for stoves and appliances burning natural gas

What Can You Do?

Indoor Air Pollution

- Test for radon and formaldehyde inside your home and take corrective measures as needed
- Do not buy furniture and other products containing formaldehyde
- Remove your shoes before entering your house to reduce inputs of dust, lead, and pesticides
- Test your house or workplace for asbestos fiber levels, and check for any crumbling asbestos materials if it was built before 1980
- Do not store gasoline, solvents, or other volatile hazardous chemicals inside a home or attached garage
- If you smoke, do it outside or in a closed room vented to the outside
- Make sure that wood-burning stoves, fireplaces, and kerosene and gas-burning heaters are properly installed, vented, and maintained
- Install carbon monoxide detectors in all sleeping areas

