



“Anthropogenic activities and effects on the living environment and human health.”

Sustainable development and life cycle design

Andrea D’Anna

anddanna@unina.it

3477603055

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Mission 4 “Education and Research” - Component 2: “From research to business” - Investment
3.1: “Fund for the realisation of an integrated system of research and innovation infrastructures”



What you will gain

- ✓ explore the intricate relationship between science, policy, and sustainability
- ✓ gain understanding of air quality and climate change and related policies
- ✓ be equipped to engage effectively in sustainable decision-making processes

Environmental Sustainability

Growing populations and affluence, around the globe, have put increasing pressure on **air** and **water**, **arable land**, and **raw materials**

The capacity of the earth's natural systems and human cultural systems to **survive**, **flourish**, and **adapt** to changing environmental conditions into the **very long-term future** is part of the concept of sustainability

Requires:

A transition in human **attitudes** toward the environment, and a **shift in behavior**, can lead to a much better future for the planet in the future

Sustainable Development

Our Common Future (WCED, 1987 p. 41)

Sustainable development is development that **meets the needs of the present without compromising the ability of future generations to meet their own needs**. It contains within it two key concepts:

- 1) the concept of “needs”, in particular the essential needs of the world's poor, to which overriding priority should be given;
- 2) the idea of limitations imposed by the state of technology and social organization on the environment's ability to meet present and future needs.

Sustainable Design

Sustainable design is the way of doing things or making things such that the result of the design meets the **three pillars of sustainability**

- 1) it should **NOT** cause irreversible change to the environment – locally and globally
- 2) should be functional, practical, and economically viable
- 3) should benefit society.

Sustainable design uses a holistic approach that optimizes the **overall system performance**, not just the product or service itself.

Design for Sustainability

The basic design for sustainability techniques for products and processes include

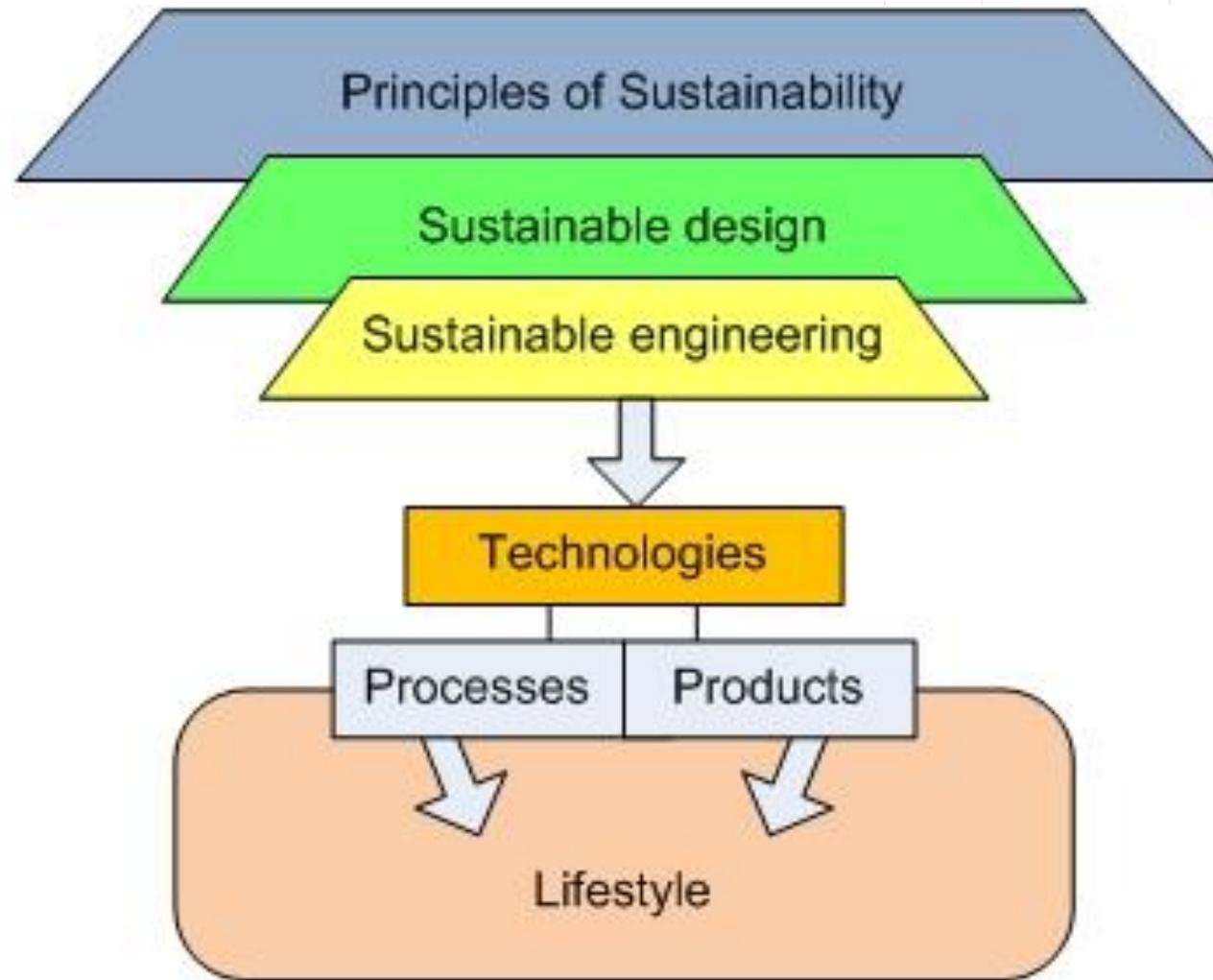
- ✓ increasing energy efficiency,
- ✓ using recycled materials,
- ✓ designing for recyclability,
- ✓ reducing toxic materials,
- ✓ extending product life
- ✓ providing services in new ways

Life cycle analysis and **supply chain management** are more precise tools for evaluating material flows and environmental impacts in a product's life cycle and can help designers identify additional improvements

Product Life Cycle

- ❖ Holistic approach to environmental, social, and economic issues
- ❖ Minimize environmental impacts (pollution, waste, disruption, etc.)
- ❖ Use renewable energy and resources efficiently
- ❖ Design for reuse, recycling, and emotionally and functionally durability

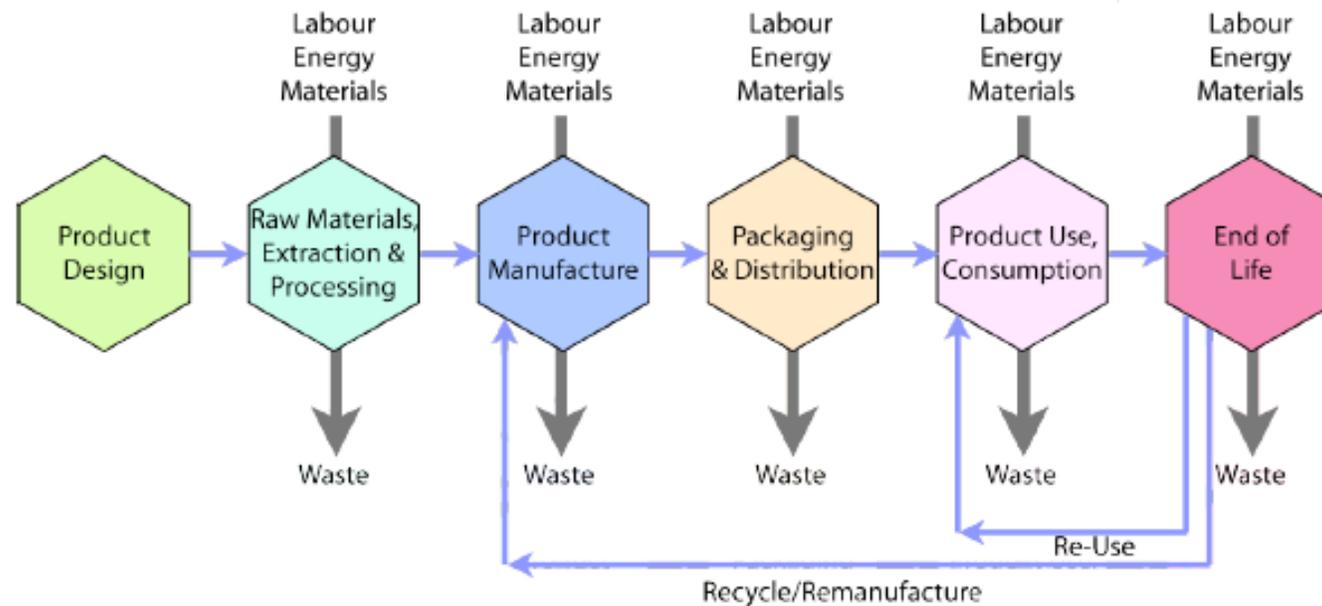
Sustainability Hierarchy



Principles of Sustainability Design

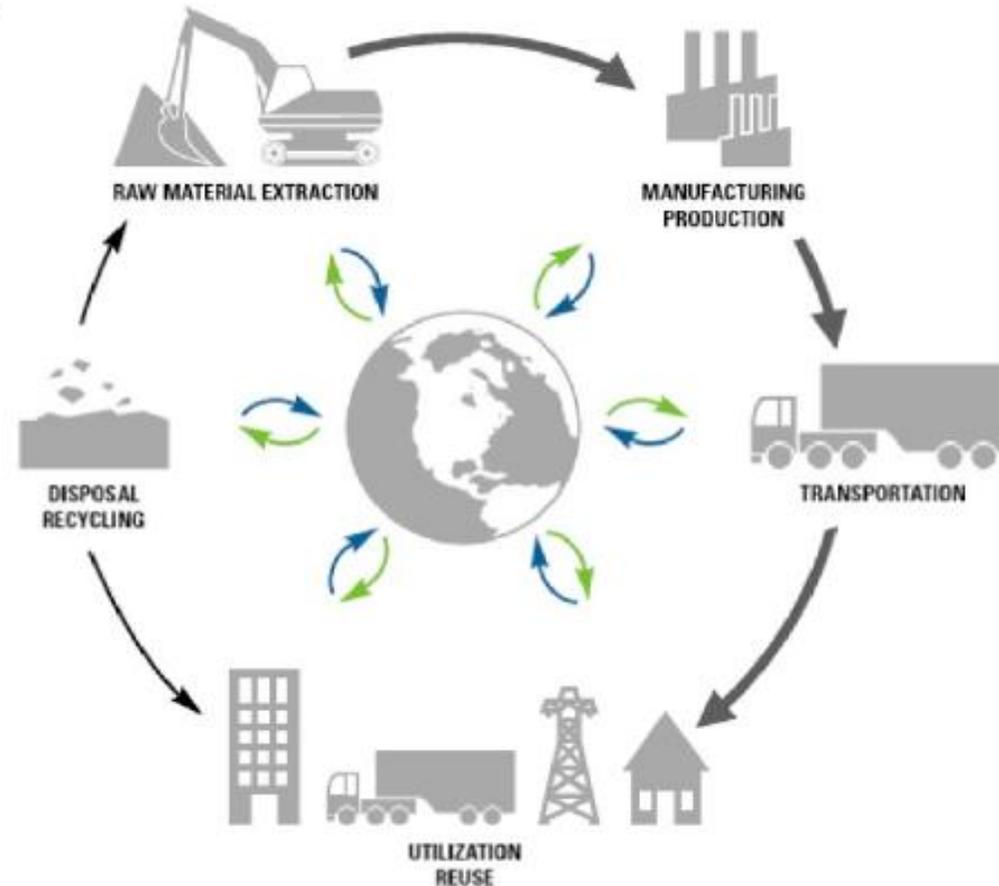
The life-cycle of a “product” from its conception and design, to manufacture, to service and finally to disposal, is depicted below.

At each stage there are labor, energy and material inputs, and waste outputs that create environmental and social impacts.



Sustainable Product Life Cycle

In a more ideal product life cycle: resources and waste are managed in a closed-loop cycle, with products being reused, recycled and remanufactured.



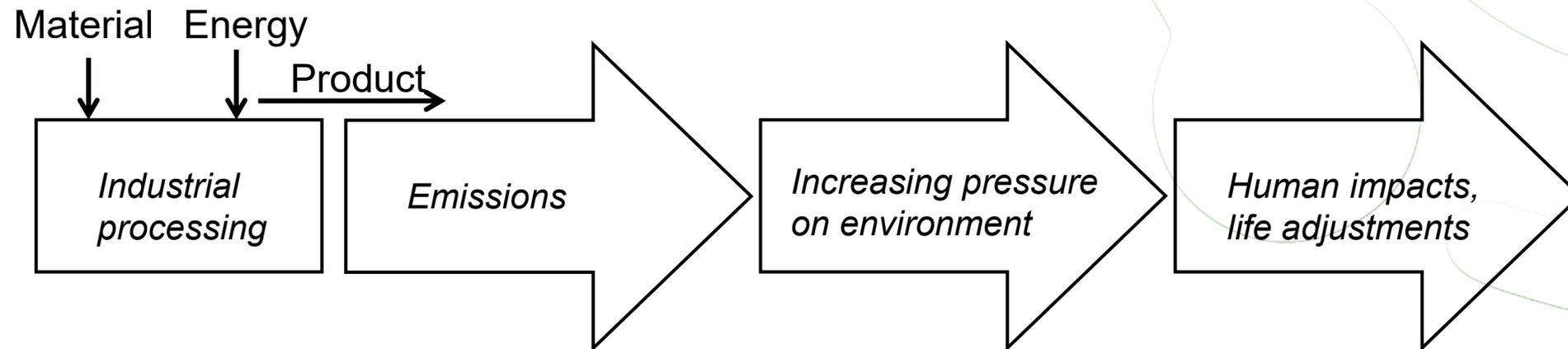
Global Product's Lifecycle

- ❖ Life Cycle Design, is an activity whereby the designer recognizes and takes into account the various phases of a product's life cycle, during the design of that product.
- ❖ If all phases of a product's life are recognized and considered during the design phase, the final product is likely to 'integrate better' into our environment, and be produced, used and disposed of in a more sustainable manner.
- ❖ In other words, we should strive to consider life-cycle-based criteria during our concept generation and design selection activities. For example, for design selection, we can assign appropriate weighting to life-cycle based criteria for decision making purposes.

Life Cycle Assessment (LCA)

- ❖ A “Life Cycle Assessment” (LCA) is the investigation and evaluation of the environmental impacts of a given product or service caused or necessitated by its existence
- ❖ The purpose of LCA is to assess the full range of environmental and social impacts assignable to products or services, to be able to choose the one with the most beneficial outcome, or least impact
- ❖ LCA can be a great tool for making decisions based on quantifiable information
- ❖ LCA can be controversial depending on its use. Since the scores assigned and the ‘scope’ of assignment can vary, some factors may be difficult to quantify and to interpret

Cause-and-Effect Chain



Energy

- ❖ Energy is required for all economic activity
- ❖ Inexpensive energy makes possible a high standard of living and many of the conveniences enjoyed in modern societies:
 - ✓ Heating
 - ✓ Lighting
 - ✓ Electronic devices
 - ✓ Travel
 - ✓ All forms of communications
- ❖ Understanding of global energy supplies, and the environmental impacts associated with energy production and use, is important in understanding our ability to sustain current standards of living

Energy

- ❖ Renewable and nonrenewable
- ❖ Renewable energy sources include:
 - Solar radiation
 - Wind
 - Biomass
- ❖ Nonrenewable energy sources include fossil fuels:
 - Crude oil
 - Coal
 - Natural gas

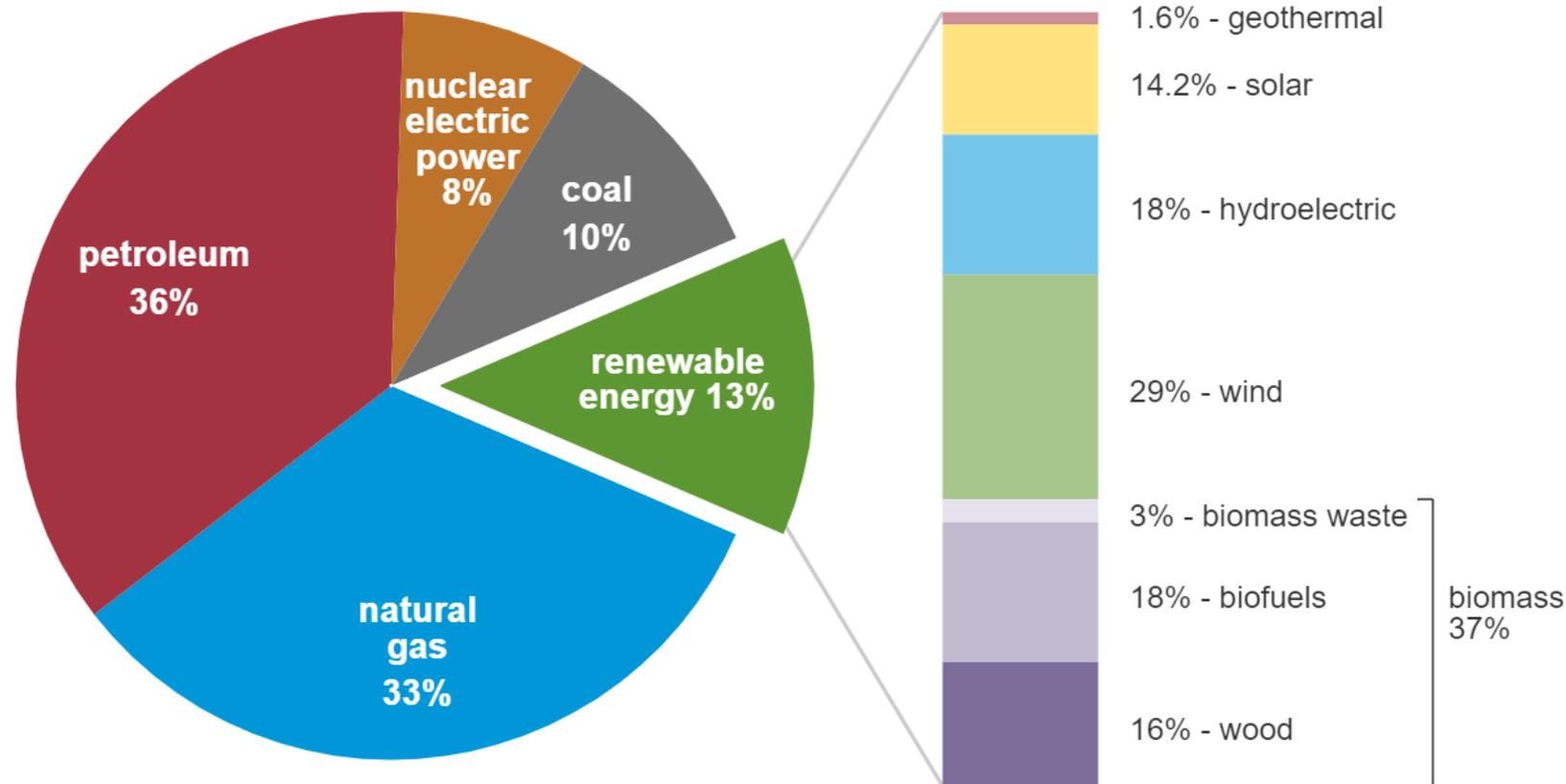
they are nonrenewable energy sources because of the long periods necessary for regeneration, which can be on the order of millions of years

- ❖ **Fossil fuels** (petroleum, coal, and natural gas) make up **84%** of world's energy consumption
- ❖ **Renewable sources** such as biomass (including animal waste), hydroelectric, solar, and wind power account for about **10%** of the energy supply.
- ❖ **Nuclear** energy provides roughly **6%** of world energy demand

U.S. primary energy consumption by energy source, 2022

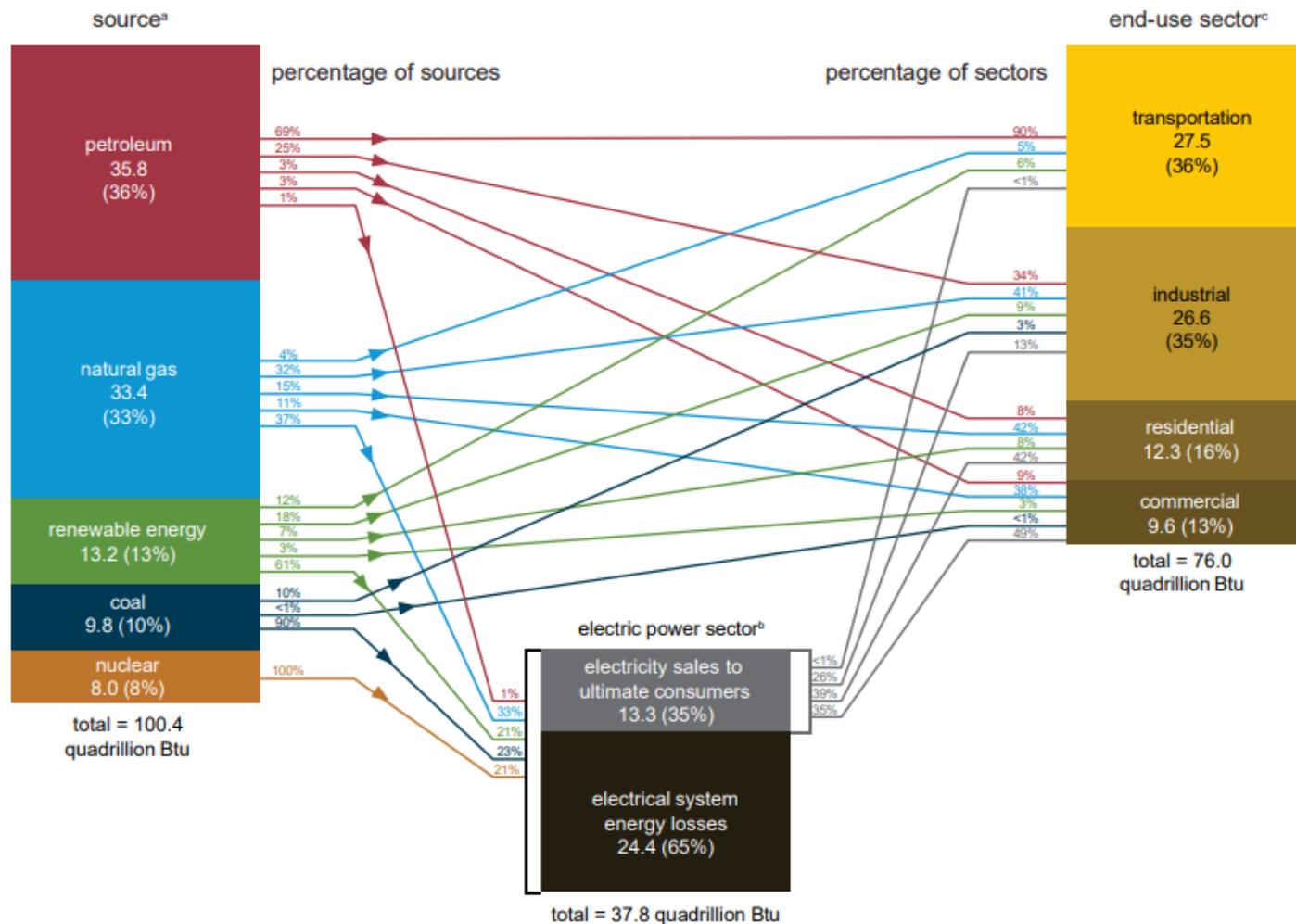
total = 100.41 quadrillion
British thermal units (Btu)

total = 13.18 quadrillion Btu



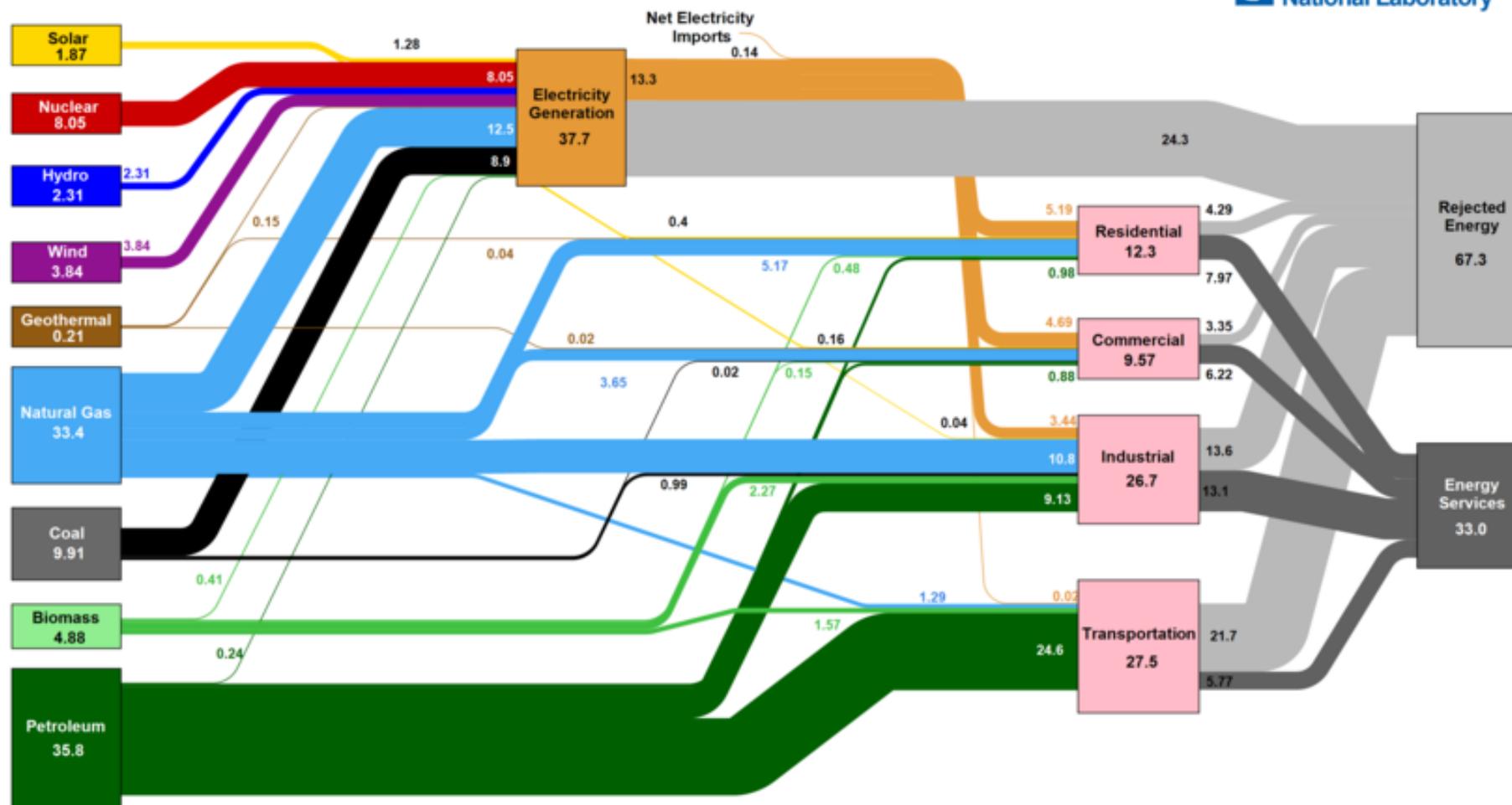
U.S. energy consumption by source and sector, 2022

quadrillion British thermal units (Btu)



- ❖ About 40% of the energy is used to generate electricity.
- ❖ The remaining nonelectrical uses are transportation, non-electricity-generating industrial uses, and residential and commercial (largely building) energy use.

Estimated U.S. Energy Consumption in 2022: 100.3 Quads



Source: LLNL July, 2023. Data is based on DOE/EIA SEDS (2021). If this information or a reproduction of it is used, credit must be given to the Lawrence Livermore National Laboratory and the Department of Energy, under whose auspices the work was performed. Distributed electricity represents only retail electricity sales and does not include self-generation. EIA reports consumption of renewable resources (i.e., hydro, wind, geothermal and solar) for electricity in BTU-equivalent values by assuming a typical fossil fuel plant heat rate. The efficiency of electricity production is calculated as the total retail electricity delivered divided by the primary energy input into electricity generation. End use efficiency is estimated as 0.63% for the residential sector, 0.45% for the commercial sector, 0.49% for the industrial sector, and 0.21% for the transportation sector. Totals may not equal sum of components due to independent rounding. LLNL-WI-410527

From energy sources to energy uses more than 50% of the energy flow is transformed in **rejected energy**.

These energy losses come about for a variety of reasons:

The loss is in part a result of the laws of thermodynamics. Generating electrical power generally involves converting heat into mechanical work.

This “waste” heat is not lost: energy is conserved. It is simply available at too low a temperature to be of significant economic value, so it is released into the environment as hot water or hot gases.

Improving energy efficiency can reduce costs and conserve natural resources; it can also reduce environmental impacts.

Renewable energies are not totally environmentally benign:

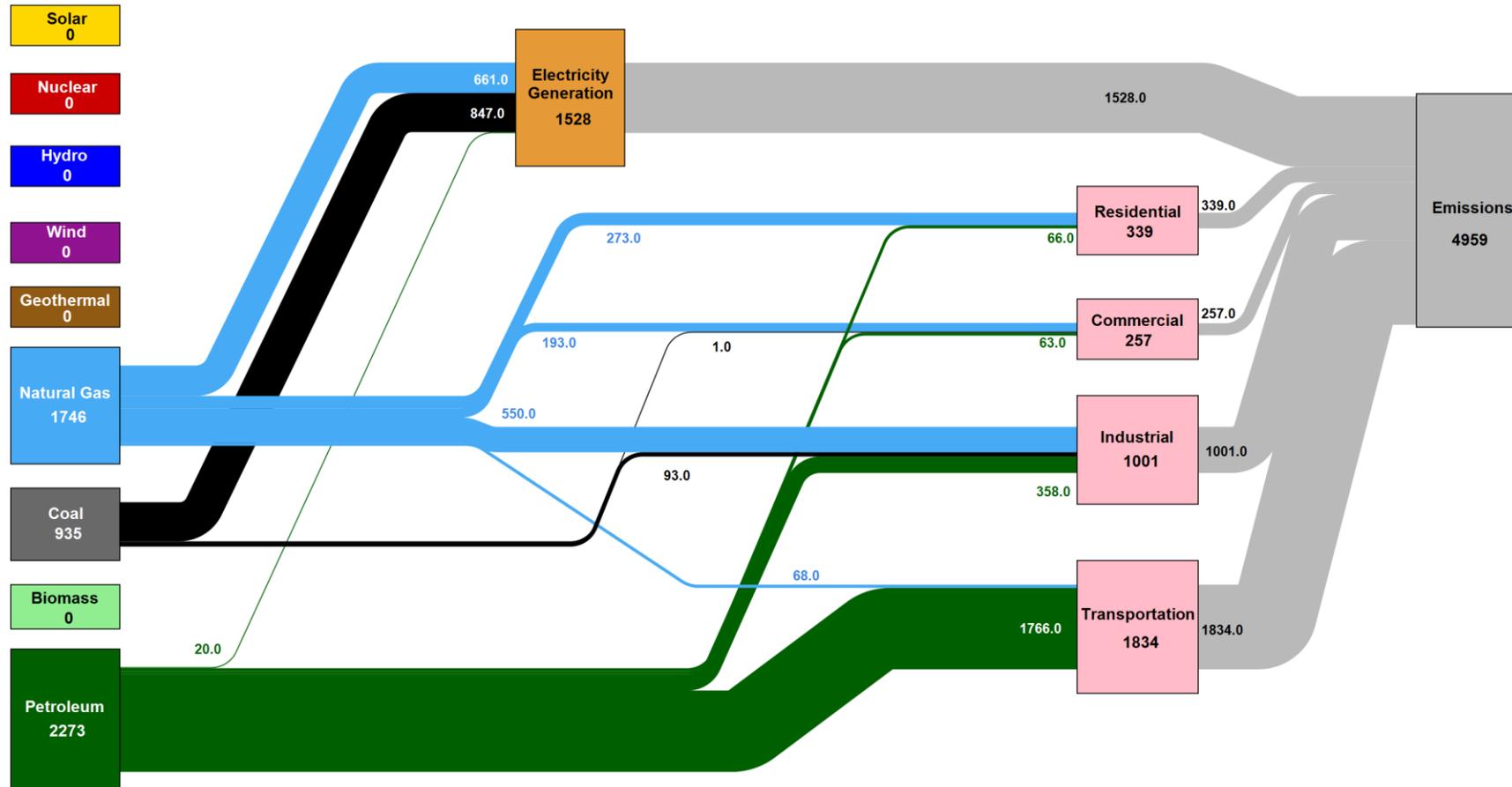
Hydropower energy generation causes land inundation, habit destruction, and alteration in surface and groundwater flows

Nuclear power has environmental problems linked to uranium mining and spent nuclear fuel disposal

Solar power panels require energy-intensive use of heavy metals and creation of metal wastes

Renewable fuels (biofuels) generate toxic-combustion by-products and strong pollution events

U.S. Energy-related Carbon Dioxide Emissions in 2022: 4959 million metric tons



Source: LLNL July, 2023. Data is based on DOE/EIA Energy-Related CO2 Emissions (2022). If this information or a reproduction of it is used, credit must be given to the Lawrence Livermore National Laboratory and the Department of Energy, under whose auspices the work was performed. Carbon dioxide emissions are attributed to their physical source, and emissions from electricity production are not allocated to end use for electricity consumption in the residential, commercial, industrial, and transportation sectors. Petroleum consumption in the electric power sector includes the non-renewable portion of municipal solid waste. Combustion of biologically derived fuels is assumed to have zero net carbon emissions and The lifecycle emissions associated with producing biofuels are included in the commercial and industrial sectors. Totals may not equal sum of components due to independent Rounding. LLNL-MI-410527

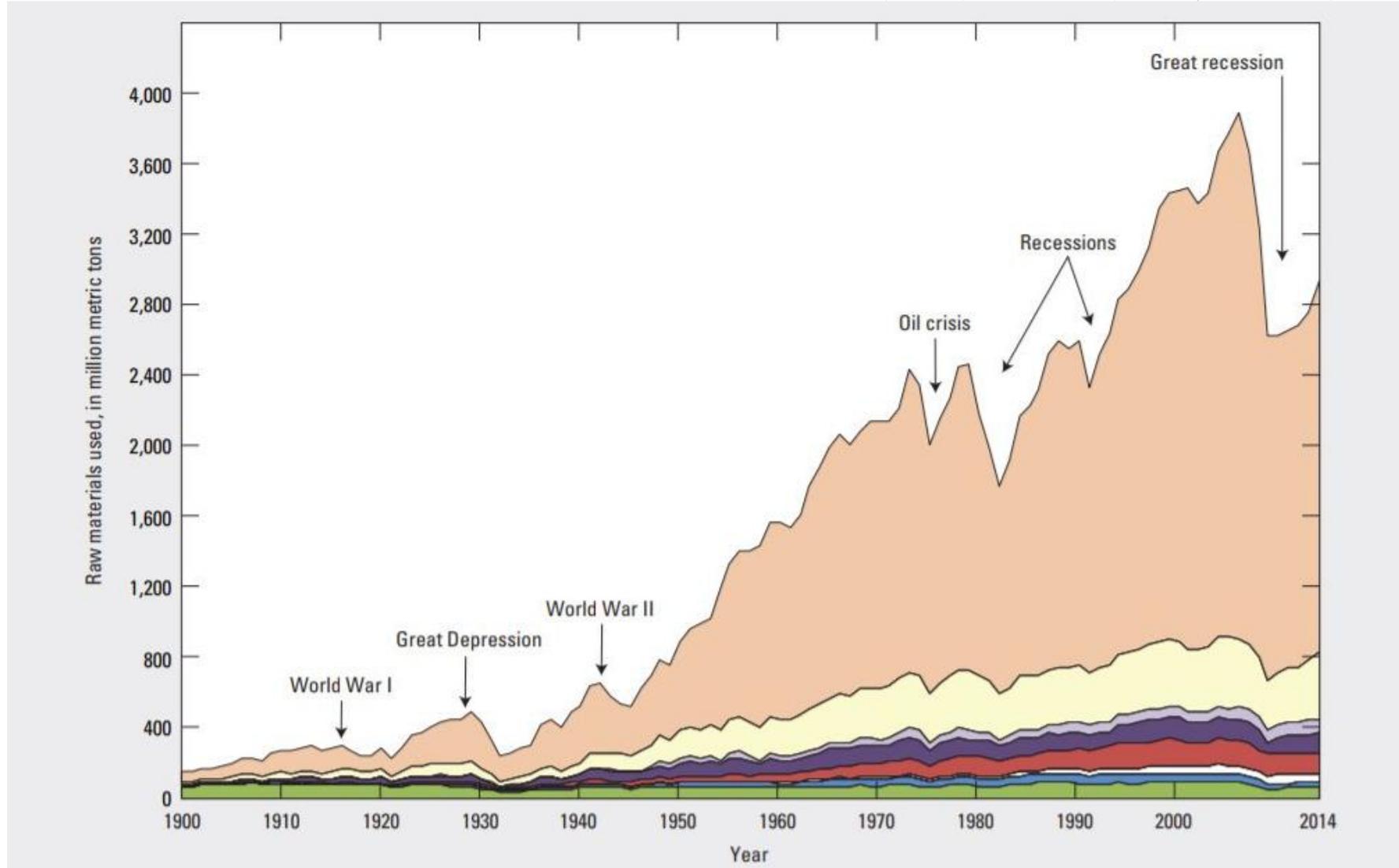
Materials Use

Materials use is a required basis of economic activity

Many of the materials are limited natural sources

Increasing scarcity of materials and concerns about releasing waste materials into the environment drive engineers to design systems that reuse and recycle materials.

Materials Use



Water

Water is essential to life, and water use exceeds the use of any other substances.

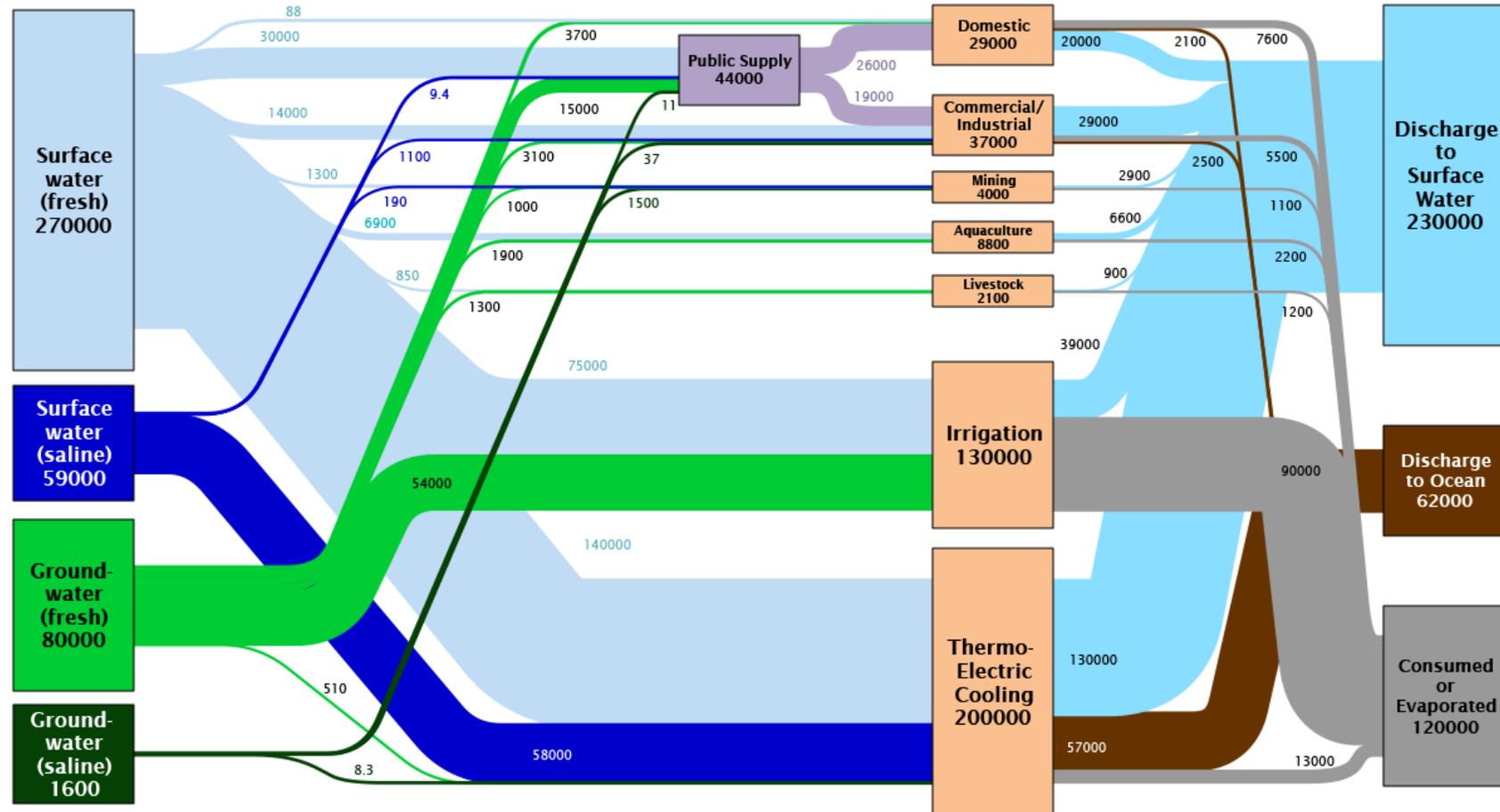
The sources include surface waters, such as lakes and rivers, and groundwater.

Surface water is renewed on relatively short timescales

Groundwater is a resource that has accumulated over long periods of time and may or may not be replaced at the same rate at which it is withdrawn

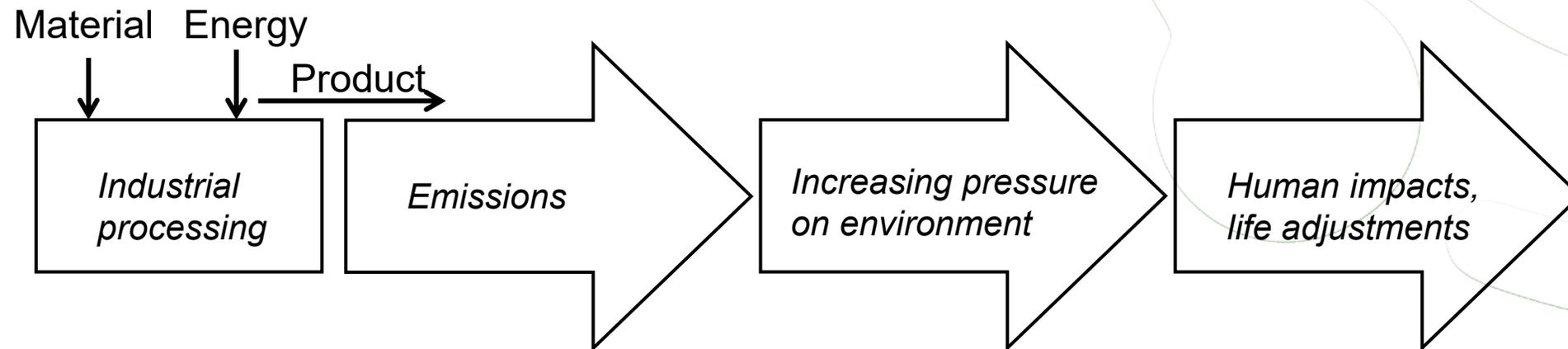
The largest uses of water are for agriculture, thermoelectric power, and public supplies

Estimated United State Water Flow in 2005: 410000 Million Gallons/Day



Source: LLNL 2011. Data is based on USGS Circular 1344, October 2009. If this information or a reproduction of it is used, credit must be given to the Lawrence Livermore National Laboratory and the Department of Energy, under whose auspices the work was performed. All quantities are rounded to 2 significant digits and annual flows of less than 0.05 MGal/day are not included. Totals may not equal sum of flows due to independent rounding. Further detail on how all flows are calculated can be found at <http://flowcharts.llnl.gov>. LLNL-TR-475772

Cause-and-Effect Chain



Our goals are

- ❖ Analyze the mechanisms of pollutant formation
- ❖ Study pollutant characteristics
- ❖ Analyze the pressure on the environment
- ❖ Reduce human impacts through life adjustments

Biggest Environmental Problems

- ❖ Climate change mitigation and adaptation
- ❖ Pollution problems and their effect on health
- ❖ The energy transition and renewables
- ❖ Sustainable urban development and mobility
- ❖ Extreme meteorological phenomena
- ❖ Overpopulation and waste management

Climate change mitigation and adaptation

Global warming due to CO₂ emissions - which according to the UN have increased by almost 50% since 1990 - is accelerating climate change and threatens the survival of millions of people, plants, and animals by causing meteorological events like droughts, fires, and floods, which are becoming increasingly frequent and more extreme.

This means we must take actions to reduce its impact and adjust to its effects. Even if we limit global warming to 2°C as stipulated by the Paris Agreement, its effects will persist for centuries.

Pollution problems and their effect on health

The data from the World Health Organization (WHO) indicates that nearly the entire global population (99%) is exposed to air that exceeds WHO guideline limits, containing high levels of pollutants. Low- and middle-income countries are particularly affected.

WHO estimates that the combined impact of both ambient air pollution and household air pollution is linked to 7 million premature deaths annually.

The energy transition and renewables

While energy accounts for 60% of global greenhouse gas (GHG) emissions, the UN calculates that 13% of the world's population lacks access to electricity and that 3 billion people depend on fossil fuels for cooking.

This situation necessitates an energy transition towards a cleaner, more accessible, and efficient model based on the use of renewable energy sources.

The goal is to build communities that are more sustainable, inclusive, and resilient to environmental problems like climate change.

Sustainable urban development and mobility

The growth of cities will be one of the major environmental challenges of the next decade, as they will need to accommodate around 5 billion people by 2030.

The cities of the future will need to be compact, safe, inclusive, ecological, and energy efficient.

This will involve having more green spaces, environmentally friendly buildings, and sustainable methods of transportation that prioritize the needs of pedestrians over those of traffic.

Extreme meteorological phenomena

Global warming is causing more frequent, intense, and devastating droughts, hurricanes, and heatwaves.

Stabilizing temperatures, as has been emphasized in high-level negotiations, and enhancing our ability to respond to climate emergencies are crucial for reducing the occurrence of these disasters, adapting to them, and protecting ourselves from them.

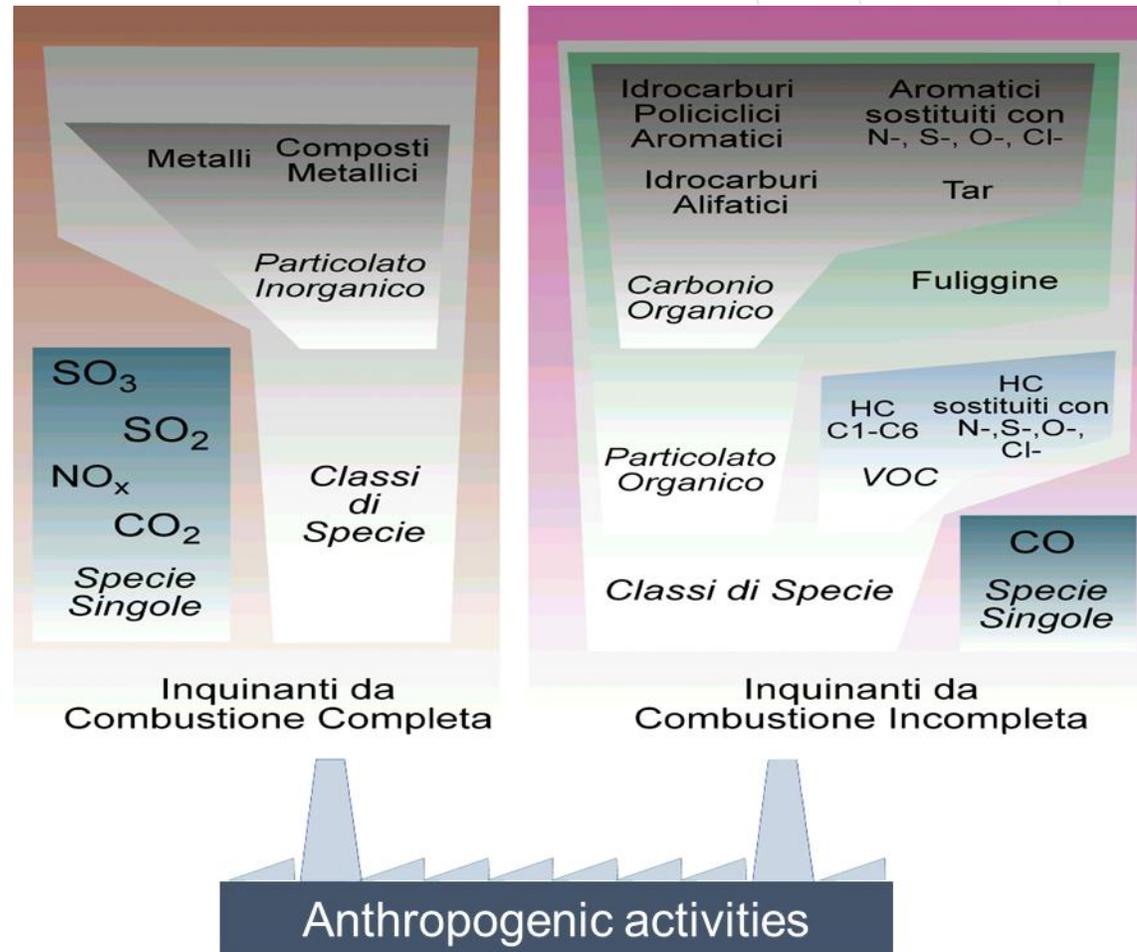
Overpopulation and waste management

The United Nations anticipates that the global population will surpass 8.5 billion by 2030.

This will require us to significantly decrease the quantity of waste we produce by focusing on prevention, reduction, reusing, and recycling as part of the circular economy.

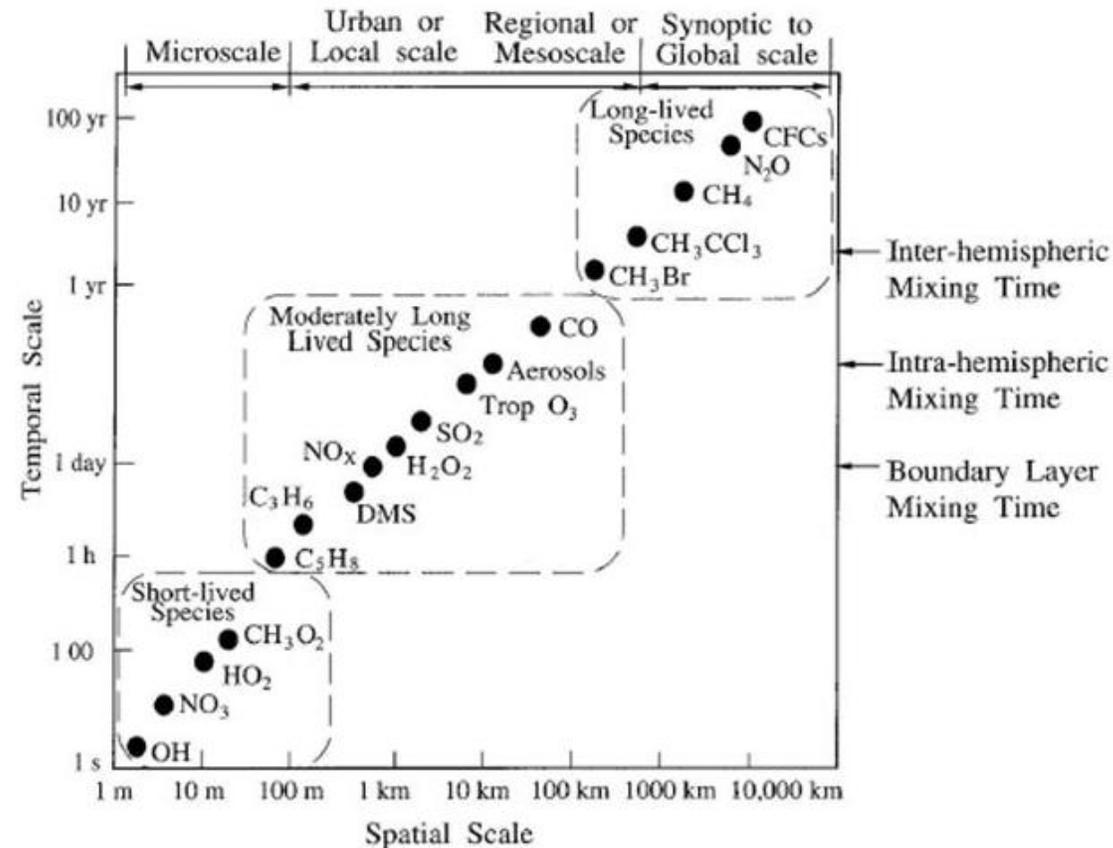
The goal is to minimize the impact on both health and the environment.

Environmental Emissions



Environmental Emissions

Environmental emissions and their impacts have global, regional, and local scope, acting over timescales ranging from hours to decades.



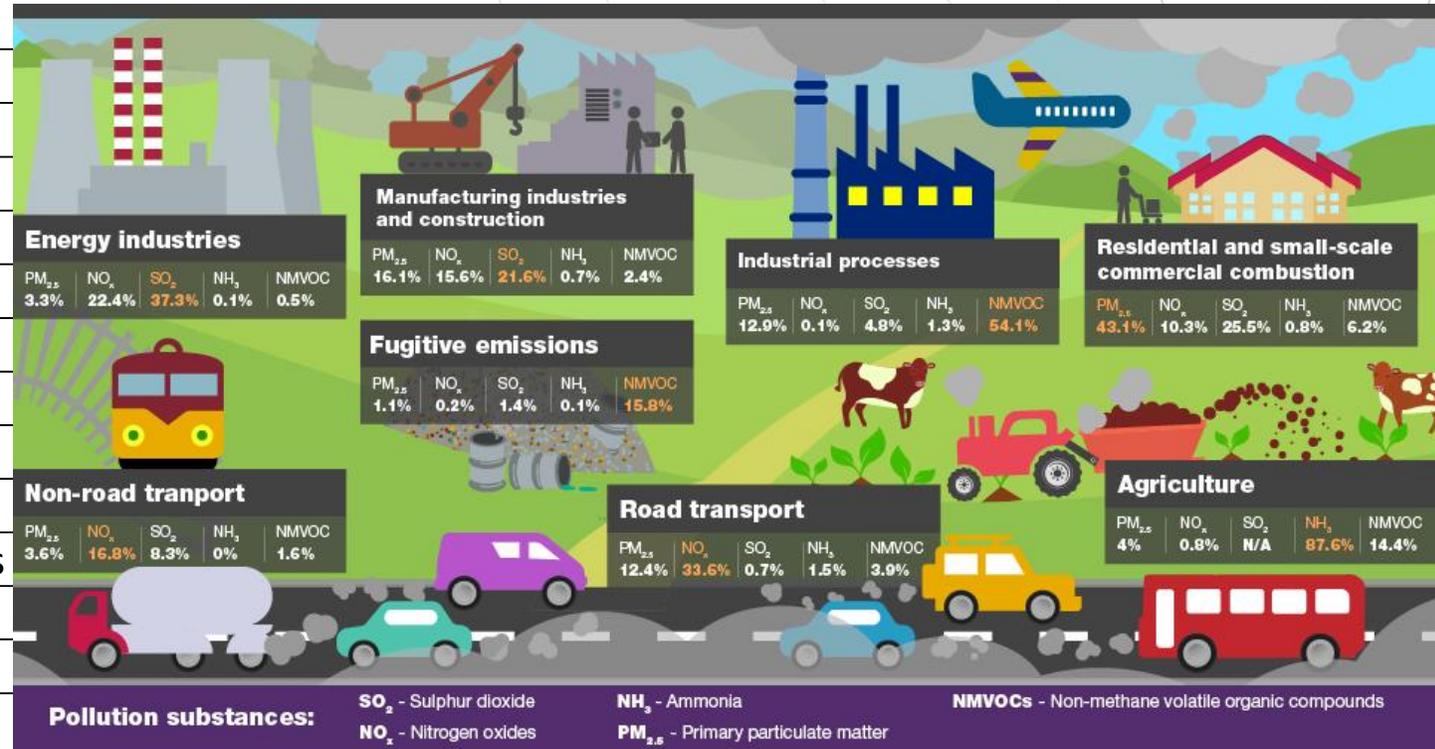
Air composition

Many pollutants are part of the normal air composition

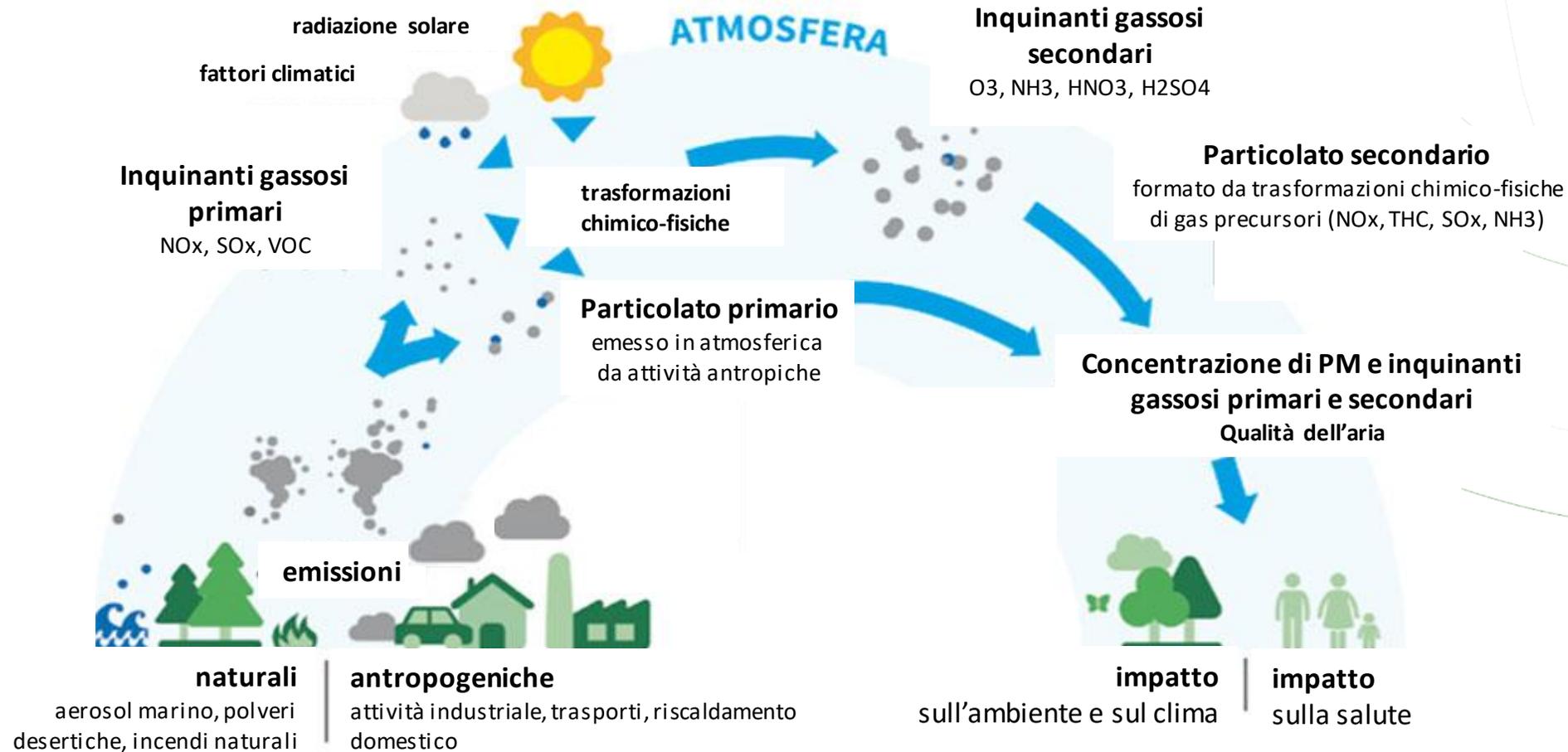
<i>species</i>	<i>concentration</i>	<i>atmospheric cycle</i>	
Ar	9340	no cycles	accumulated during Earth life
Ne	18		
Kr	1.1		
Xe	0.09		
N ₂	780,840.00	biologic cycle	
O ₂	209,460.00		
CH ₄	1.72	biogenic & anthropogenic	
CO ₂	355		
CO	0.18		
H ₂	0.58	biogenic & chemical	steady-state composition
N ₂ O	0.311	biogenic & chemical	
SO ₂	10 ⁻⁵ – 10 ⁻⁴	anthropogenic, biogenic & chemical	
NH ₃	10 ⁻⁴ – 10 ⁻³	biogenic & chemical	
NO	10 ⁻⁶ – 10 ⁻²	anthropogenic, biogenic & chemical	
NO ₂			
O ₃	10 ⁻² – 10 ⁻¹	chemical	
H ₂ O	variable		
He	5.2		

Primary pollutants and their source

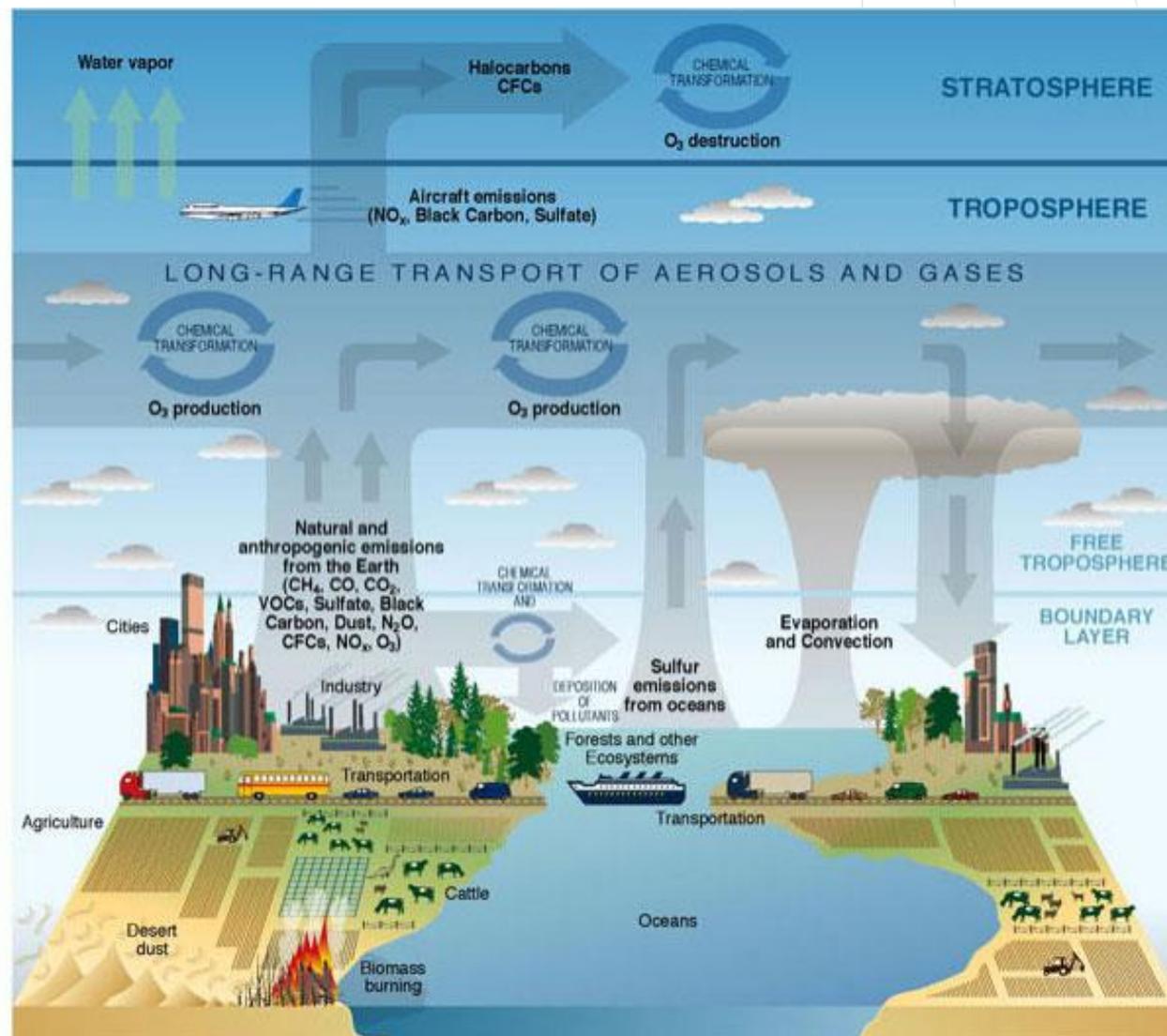
CH ₄	Methane
CO ₂	Carbon dioxide
CO	Carbon monoxide
SO _x	Sulphur oxides
NO _x	Nitrogen oxides
PM	Particulate Matter
VOC	Volatile Organic Carbon
NMHC	Non-Methane HydroCarbons
SVOC	Semi-Volatile Organic Carbon
HAPs	Hazardous Atmospheric Pollutants
Dioxins	
Metals	Ni, Cr, Co, Fe, Pb, etc.



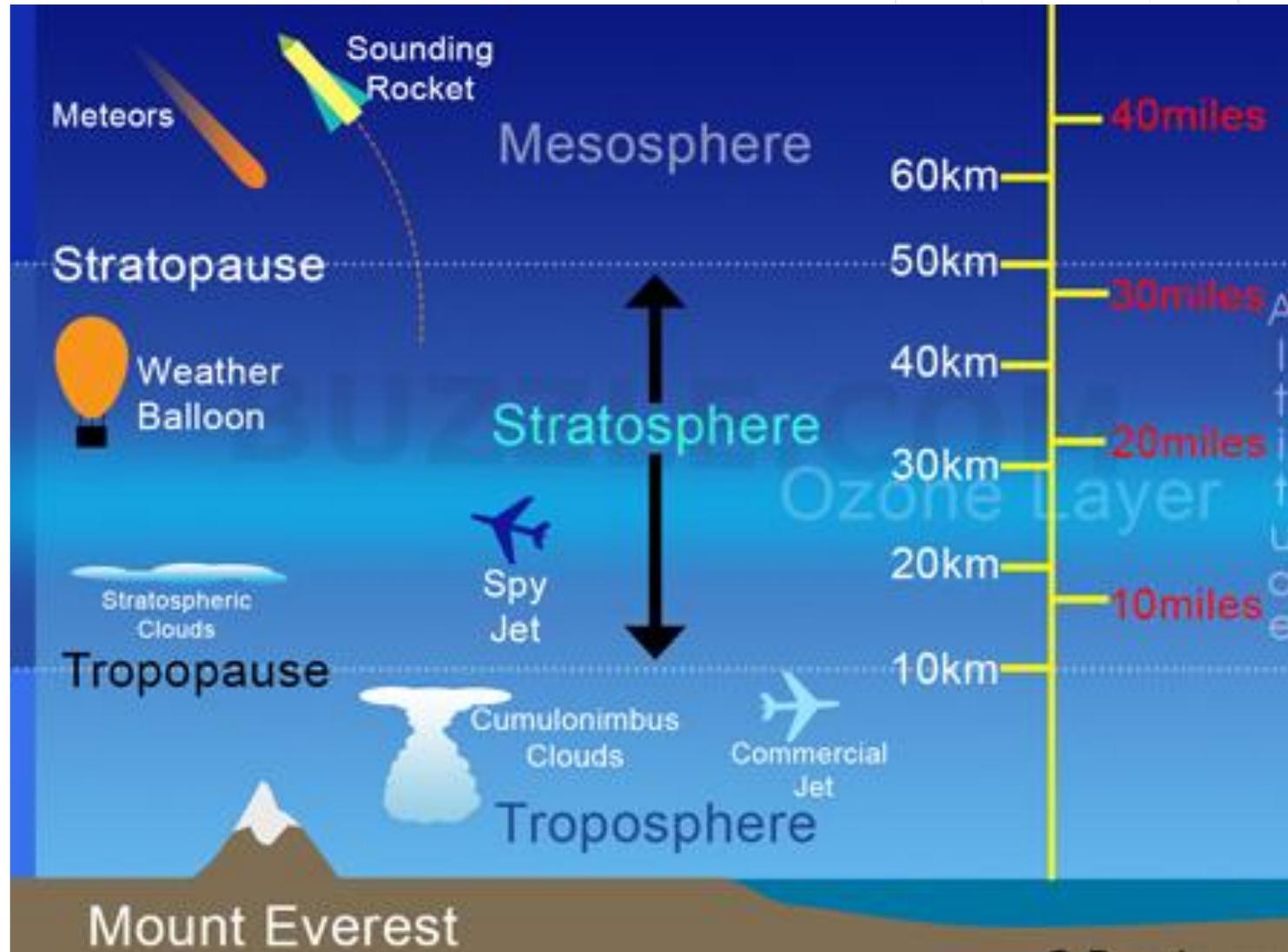
Pollutants in the Atmosphere



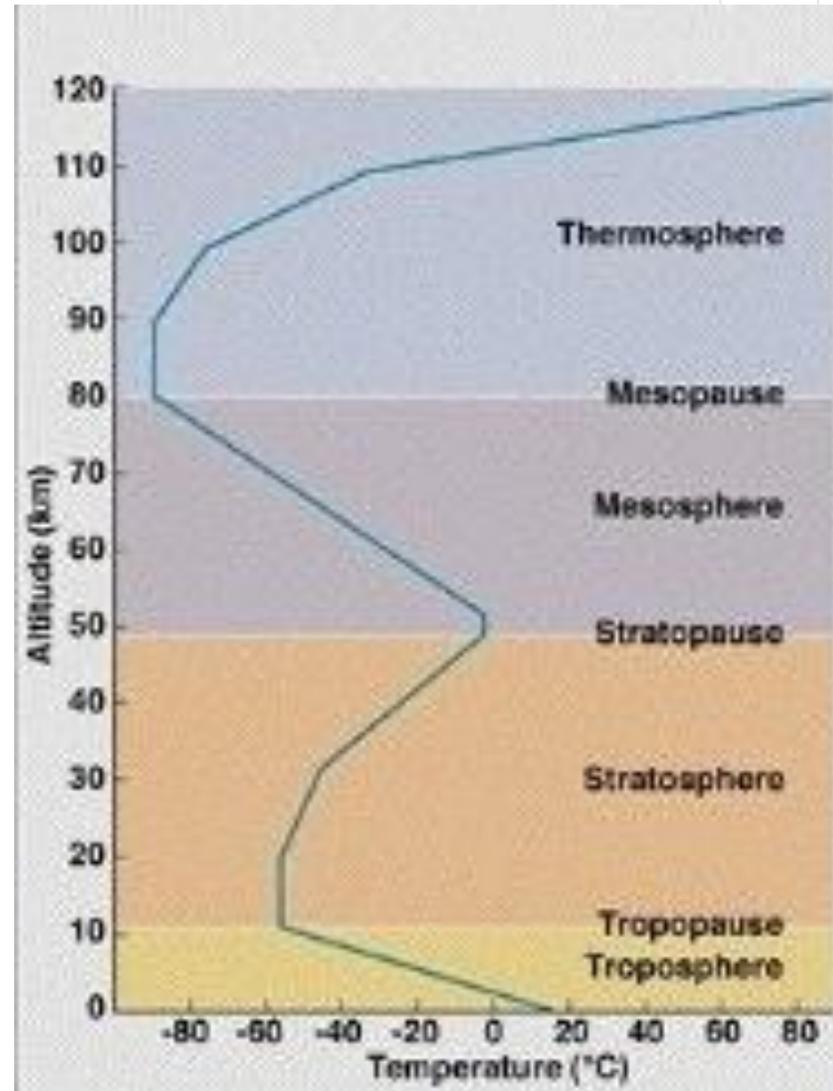
Pollutants in the Atmosphere



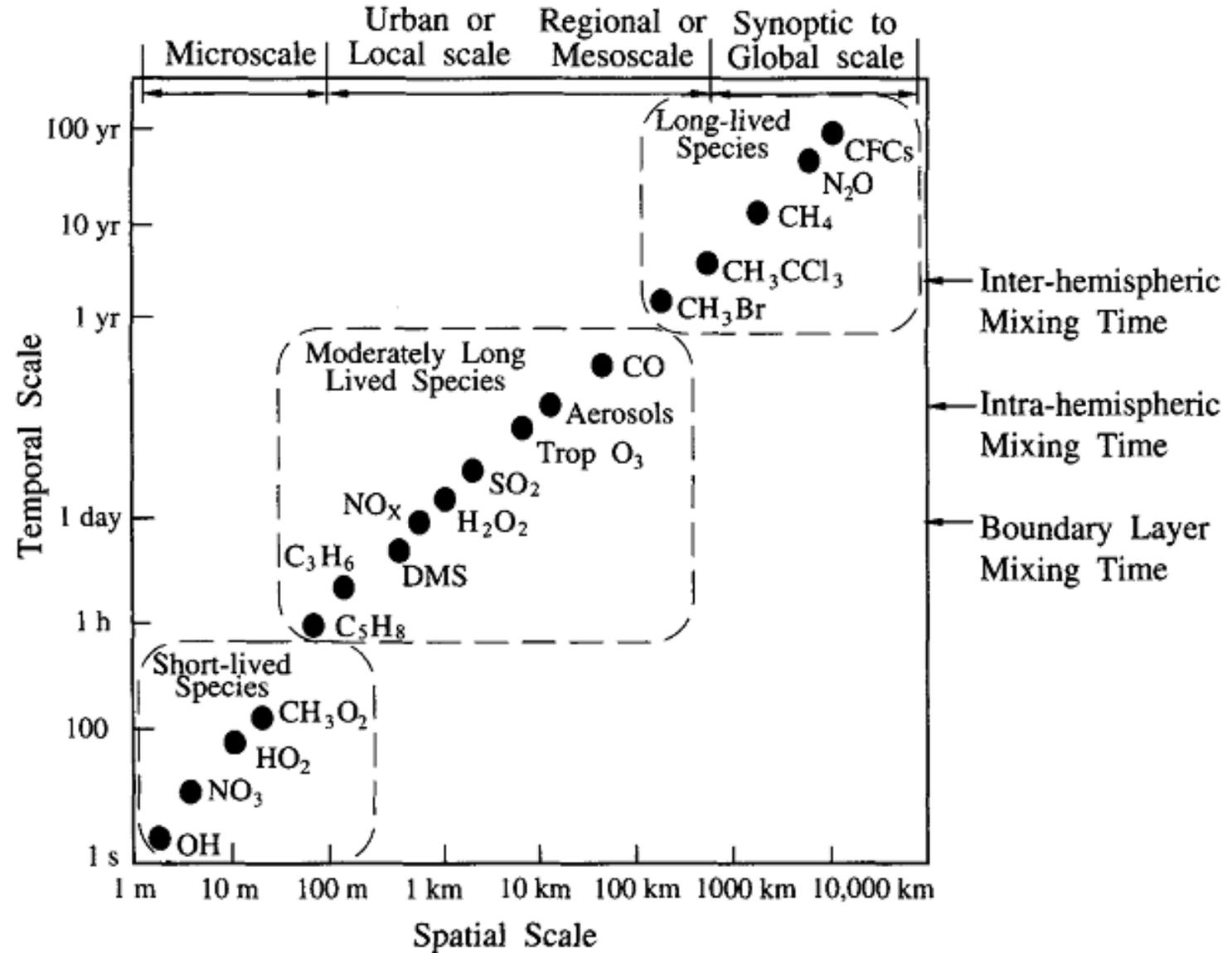
Earth Atmosphere



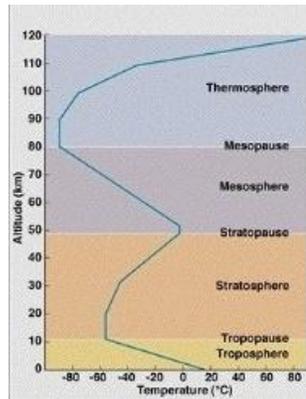
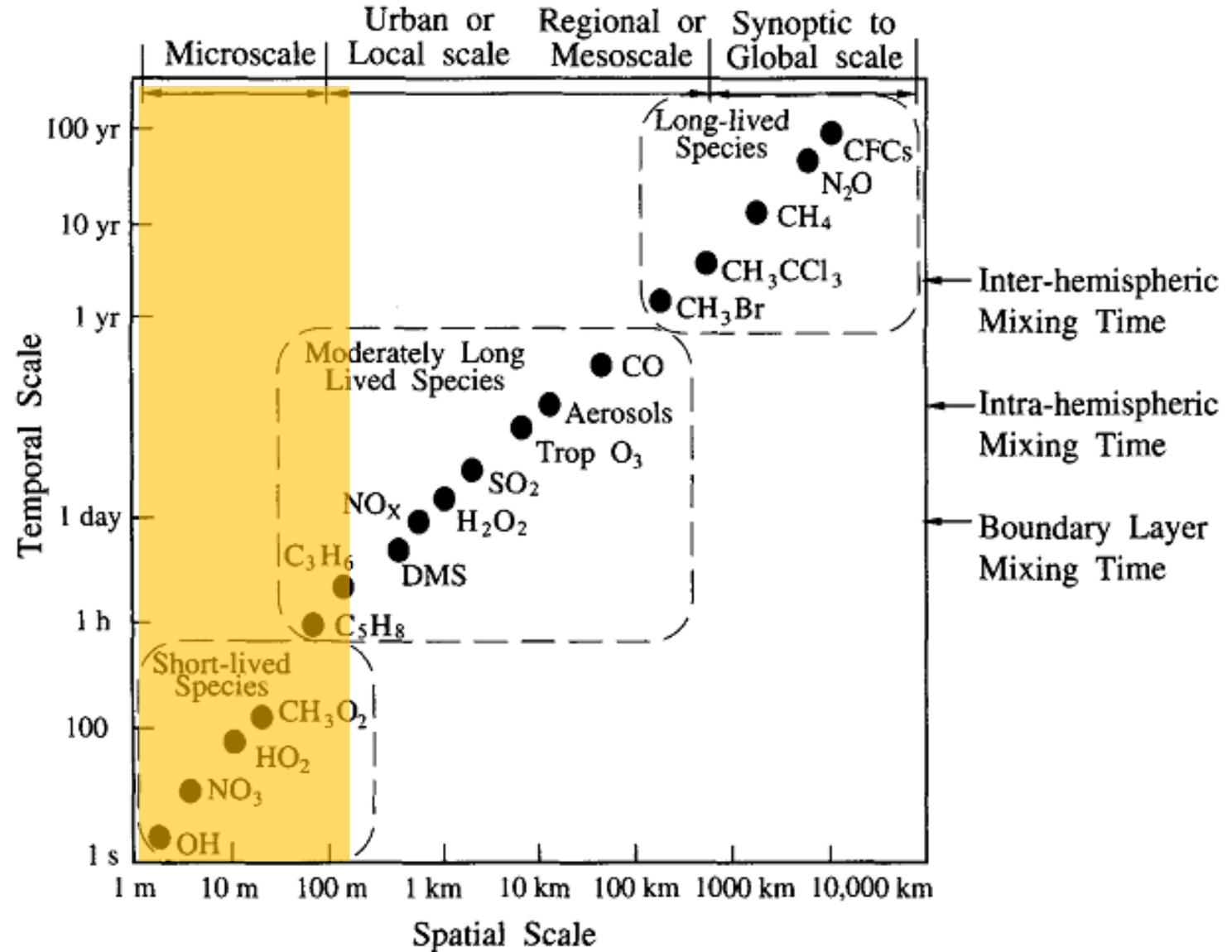
Earth Atmosphere



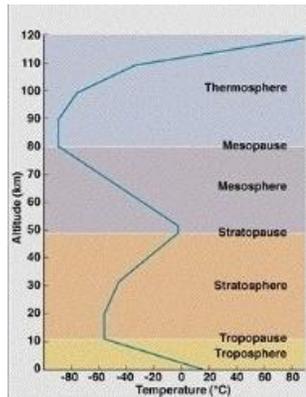
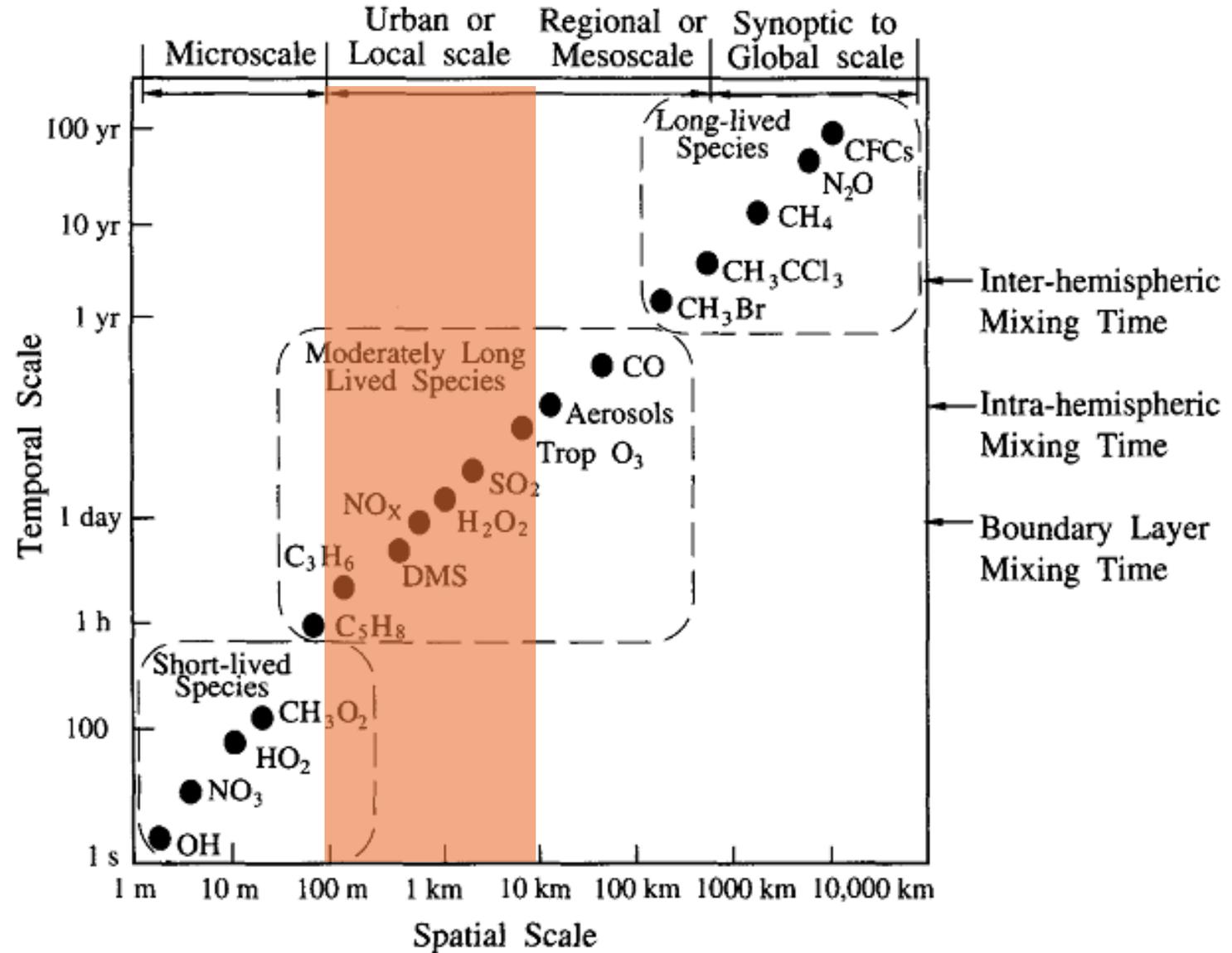
Earth Atmosphere



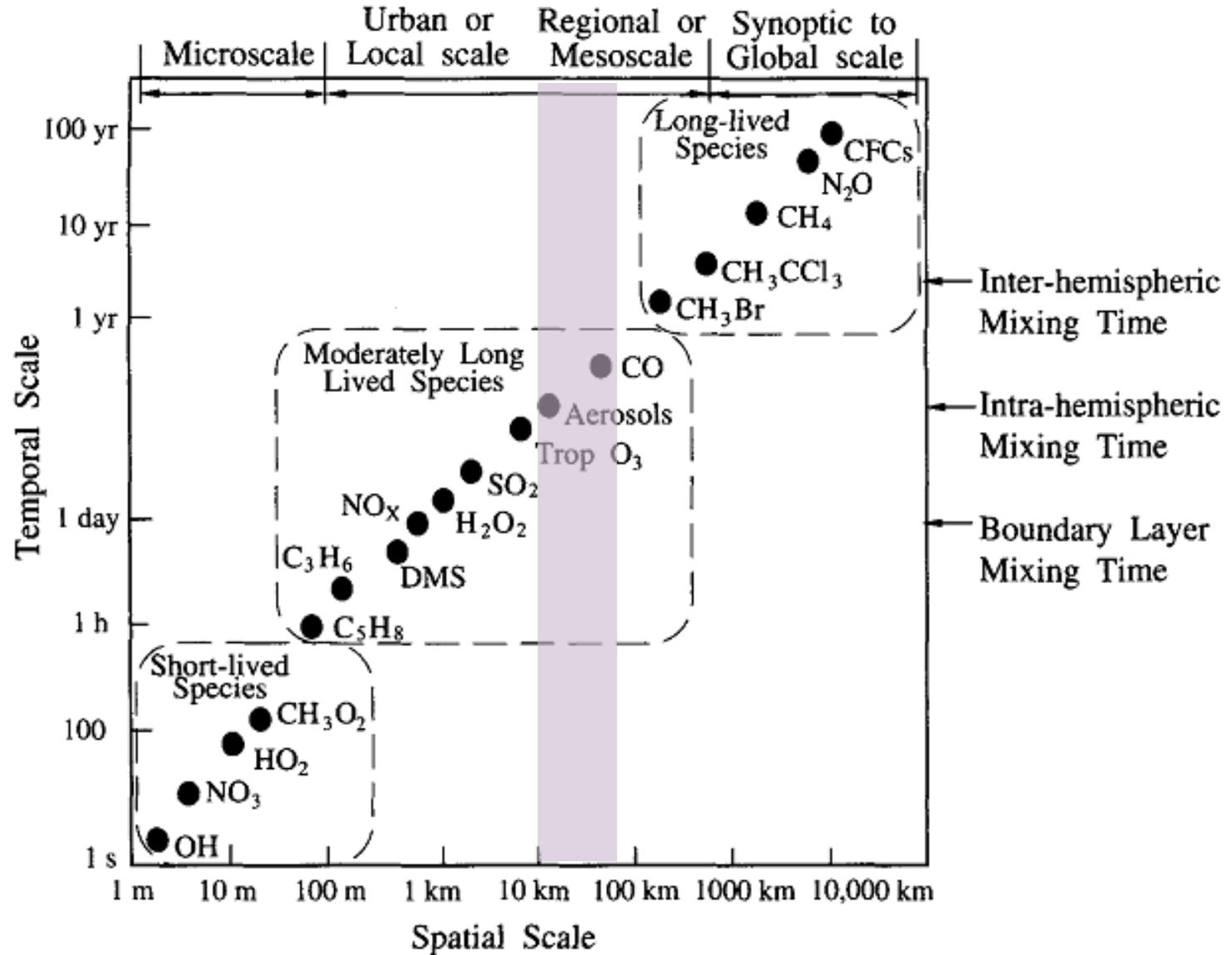
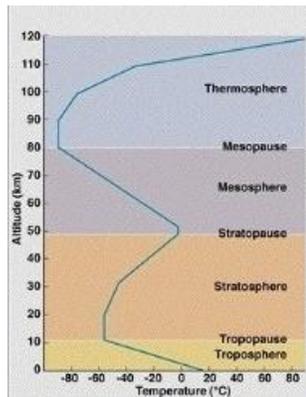
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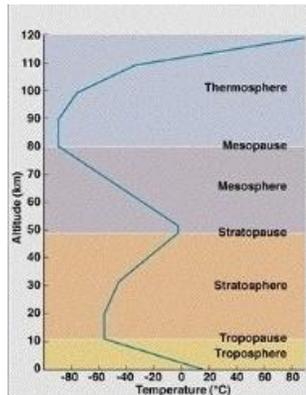
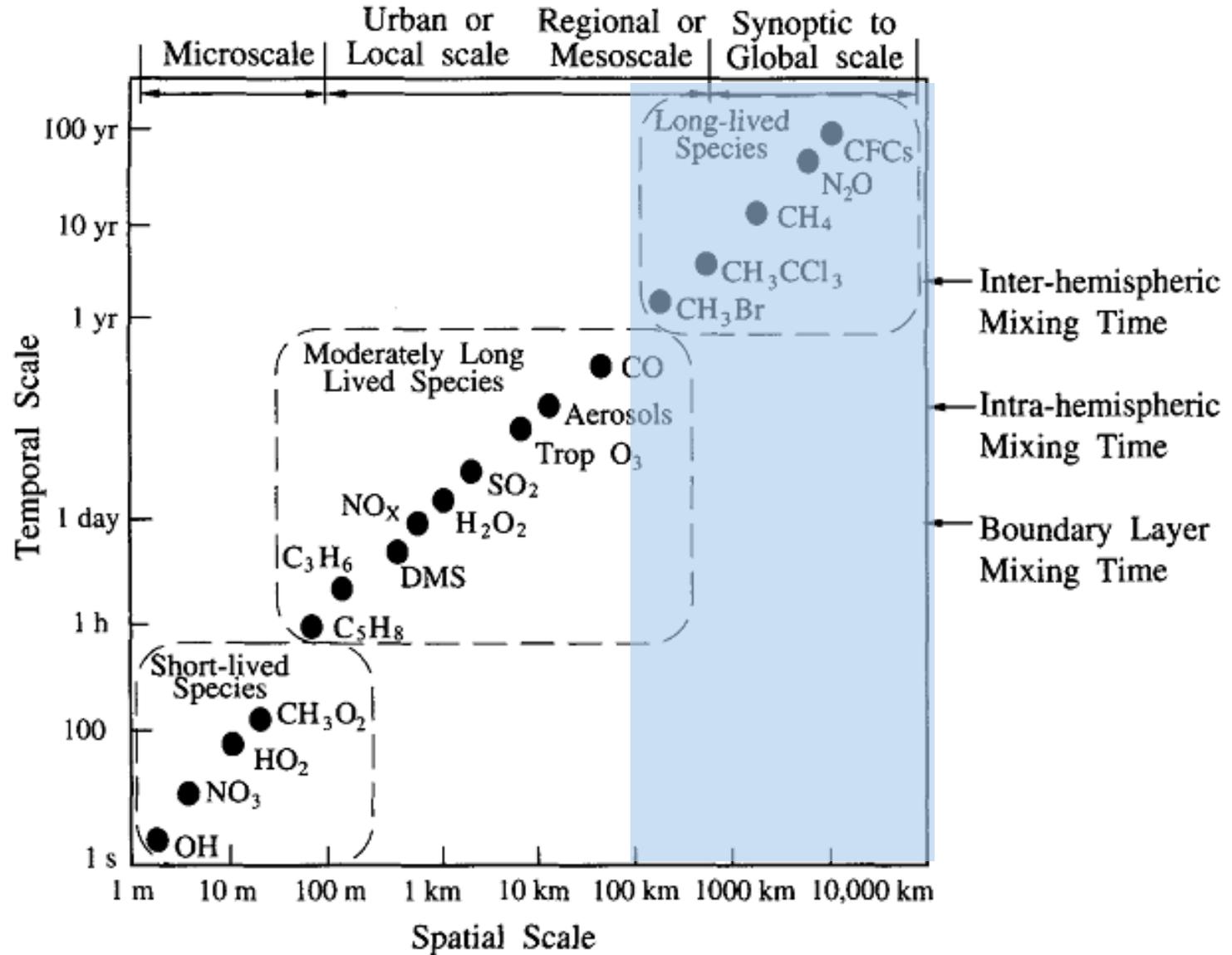
Earth Atmosphere



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