GREEN HOUSE GASSES

Group: 10 - Class: CC02

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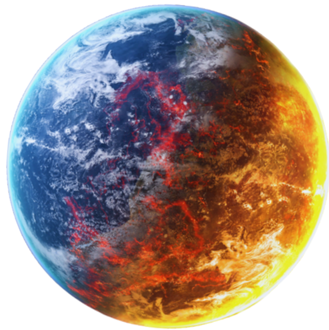
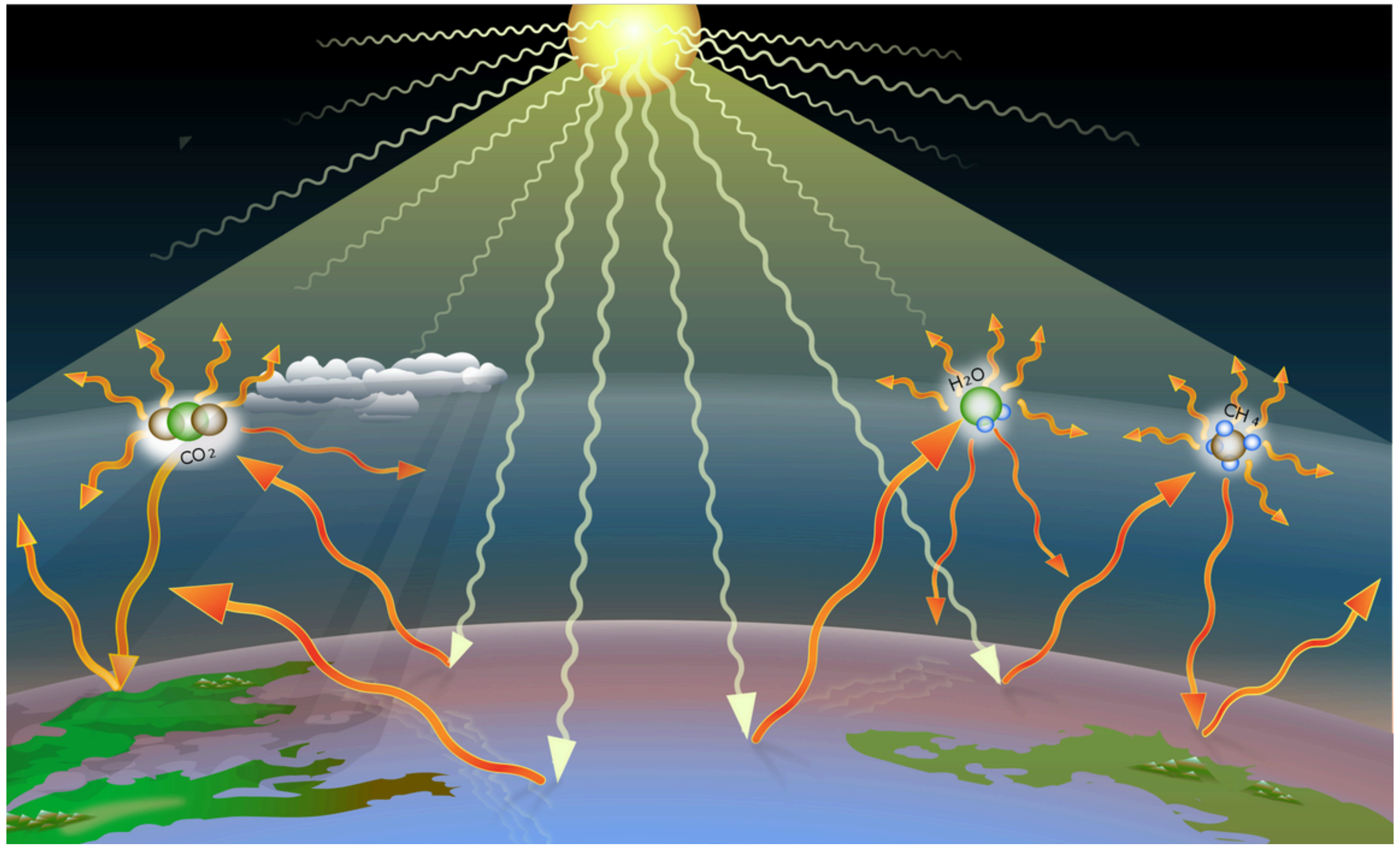


01 SOURCE

WHAT IS GREEN HOUSE GAS?



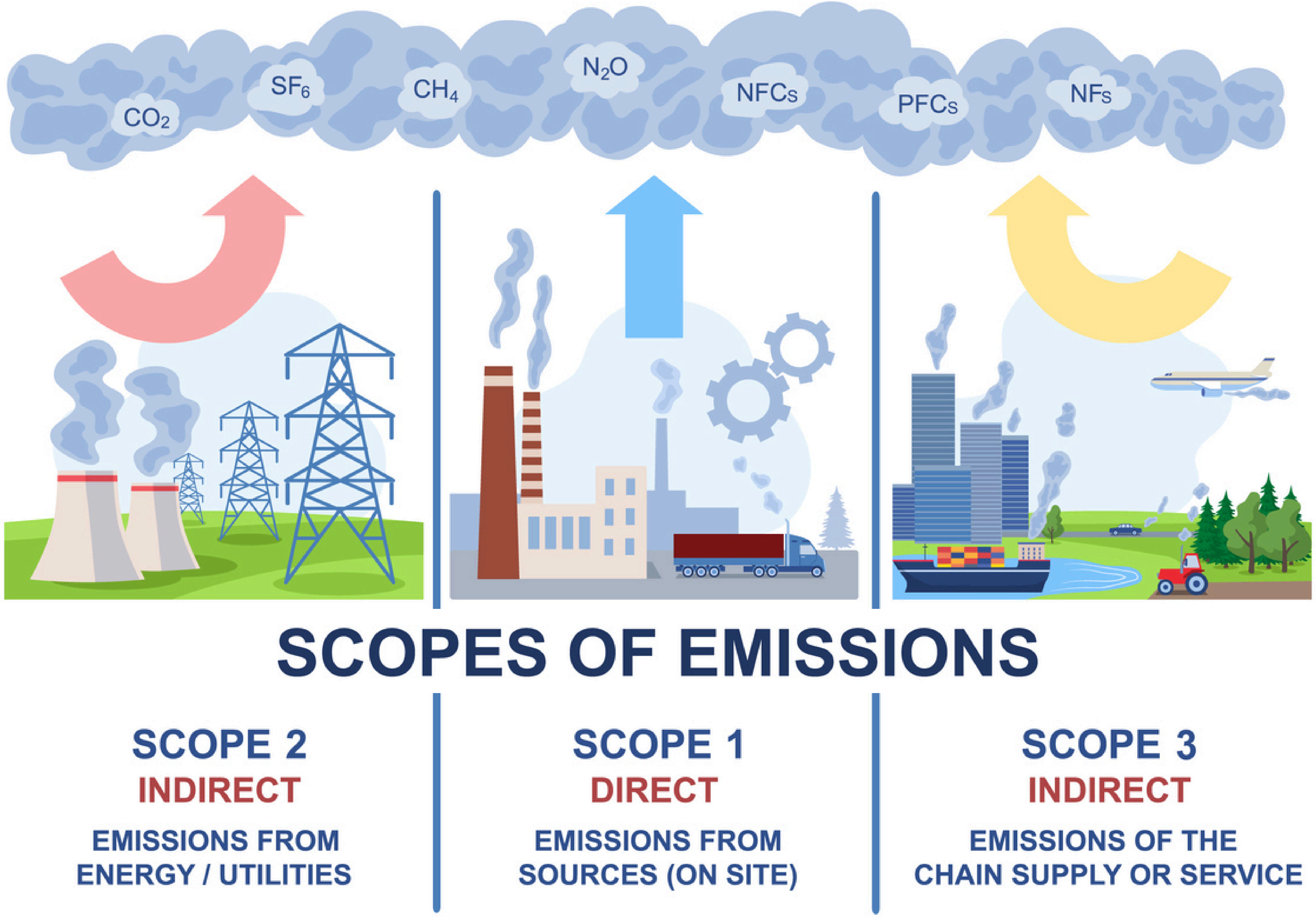
Radiated heat energy from the earth's surface is captured in the atmosphere by the radiatively active gases .

The gases capable of capturing heat energy from the earth's surface are called greenhouse gases.

- Carbon dioxide (CO2)
- Methane (CH4)
- Nitrous oxide (N2O)
- Hydrofluorocarbons (HFCs)
- Perfluorocarbons (PFCs)
- Sulfur hexafluoride (SF6), etc.

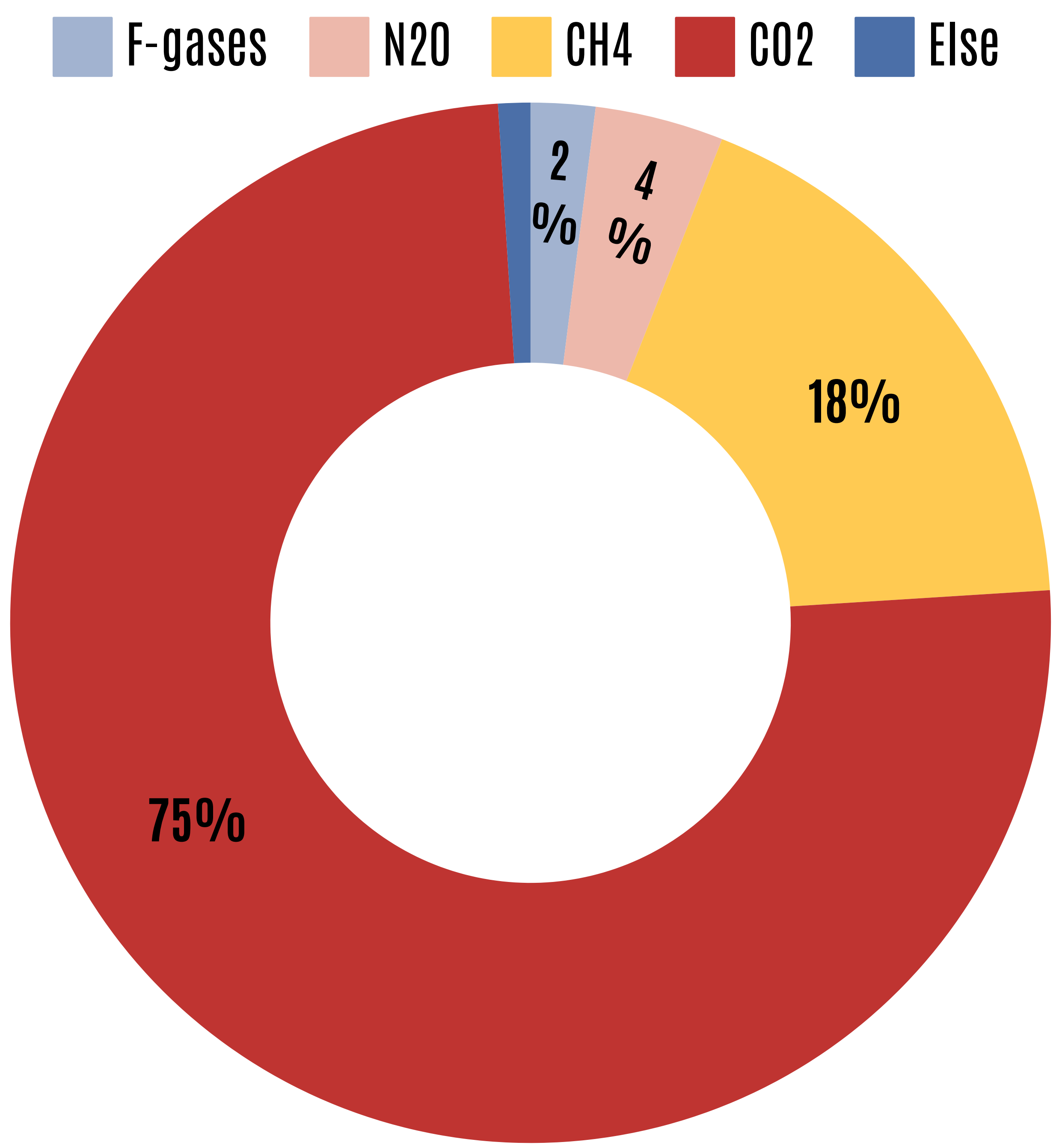
[11] Sonwani, S., & Saxena, P. (Eds.). (2022). Greenhouse gases: sources, sinks and mitigation. Singapore:: Springer, page 15.

MAJOR GHGS IN THE ATMOSPHERE



[11] Sonwani, S., & Saxena, P. (Eds.). (2022). Greenhouse gases: sources, sinks and mitigation. Singapore:: Springer, page 15.

MAJOR GAS IN THE GHGS



Graph 1.2 The percentage of each GHGs in 2019

CO_2 (75%):

From burning of fossil fuels in thermal power plant and transportation sector

CH_4 (18%):

Emission from the agricultural sector and waste

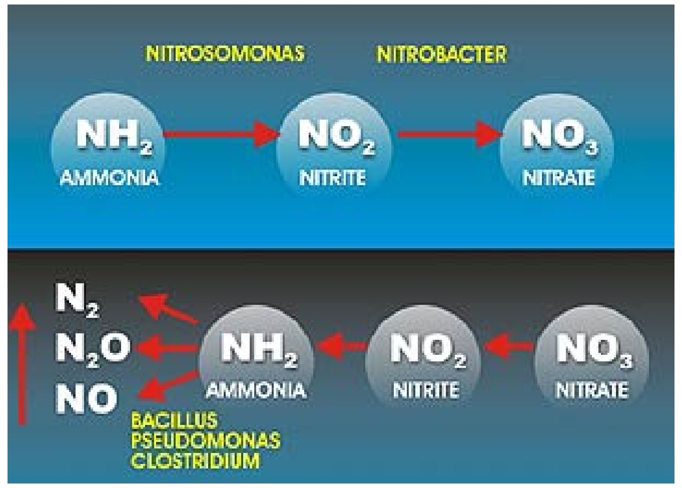
NO_2 (4%):

Microbial denitrification, nitrification processes in the oceans and tropical soils.

Fluorinated gases (2%):

Applications of HFCs and PFCs include coolant in refrigerators

Applications of SF6 include electrical uses,...



[11] Sonwani, S., & Saxena, P. (Eds.). (2022). Greenhouse gases: sources, sinks and mitigation. Singapore:: Springer, page 15.

ENERGY

The combustion of fossil fuels in industries, transportation, and other activities, including fugitive emissions during fuel handling, are major sources of greenhouse gases in the energy sector.

CO_2, CH_4, N_2O, NO_x, CO, NMVOC, and SO_2

[11] Sonwani, S., & Saxena, P. (Eds.). (2022). Greenhouse gases: sources, sinks and mitigation. Singapore:: Springer, page 24-30.

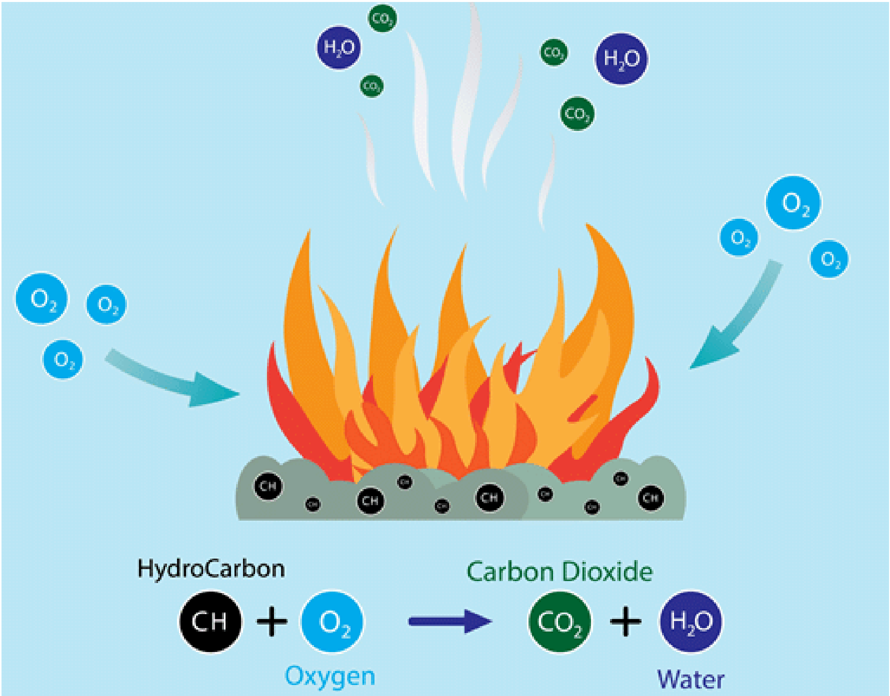
ENERGY

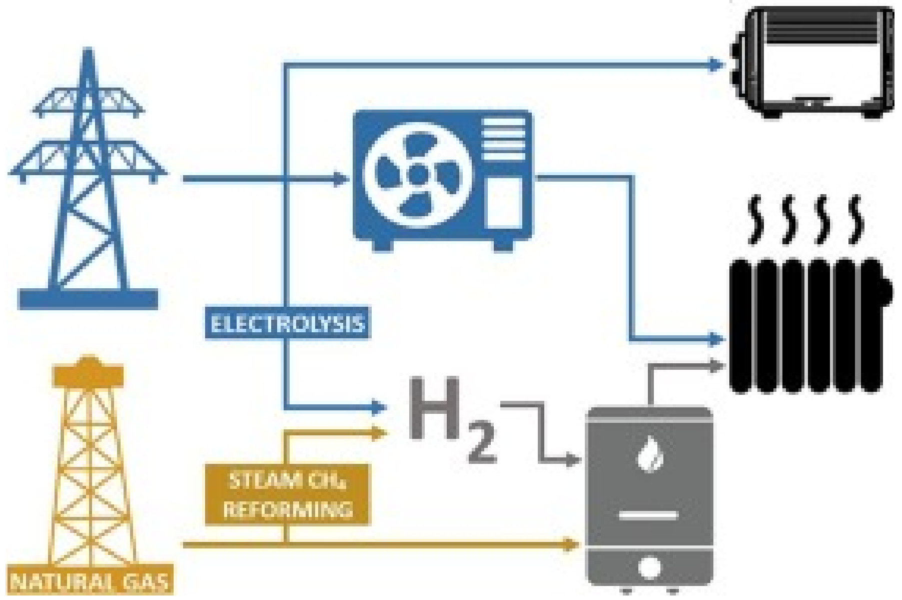
Fuel combustion activities

1. Emission from energy industries, viz. electricity production, CHP, ...

2. Emission from the burning of fuels in manufacturing and construction industries, viz. metal industries,...
Emissions from the combustion and evaporative emissions of fuel from all transport activity, ...

3. Combustion for electricity and heat from residential, commercial,

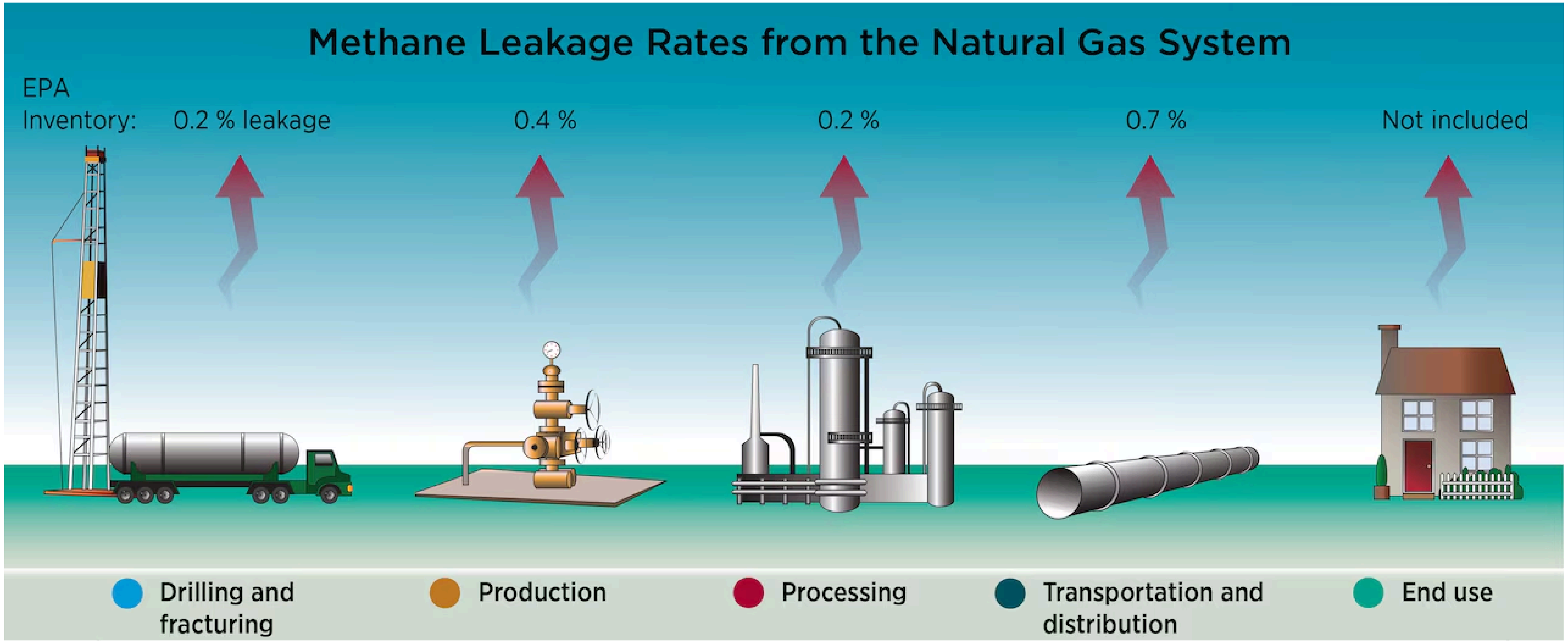




[11] Sonwani, S., & Saxena, P. (Eds.). (2022). Greenhouse gases: sources, sinks and mitigation. Singapore:: Springer, page 24-30.

ENERGY

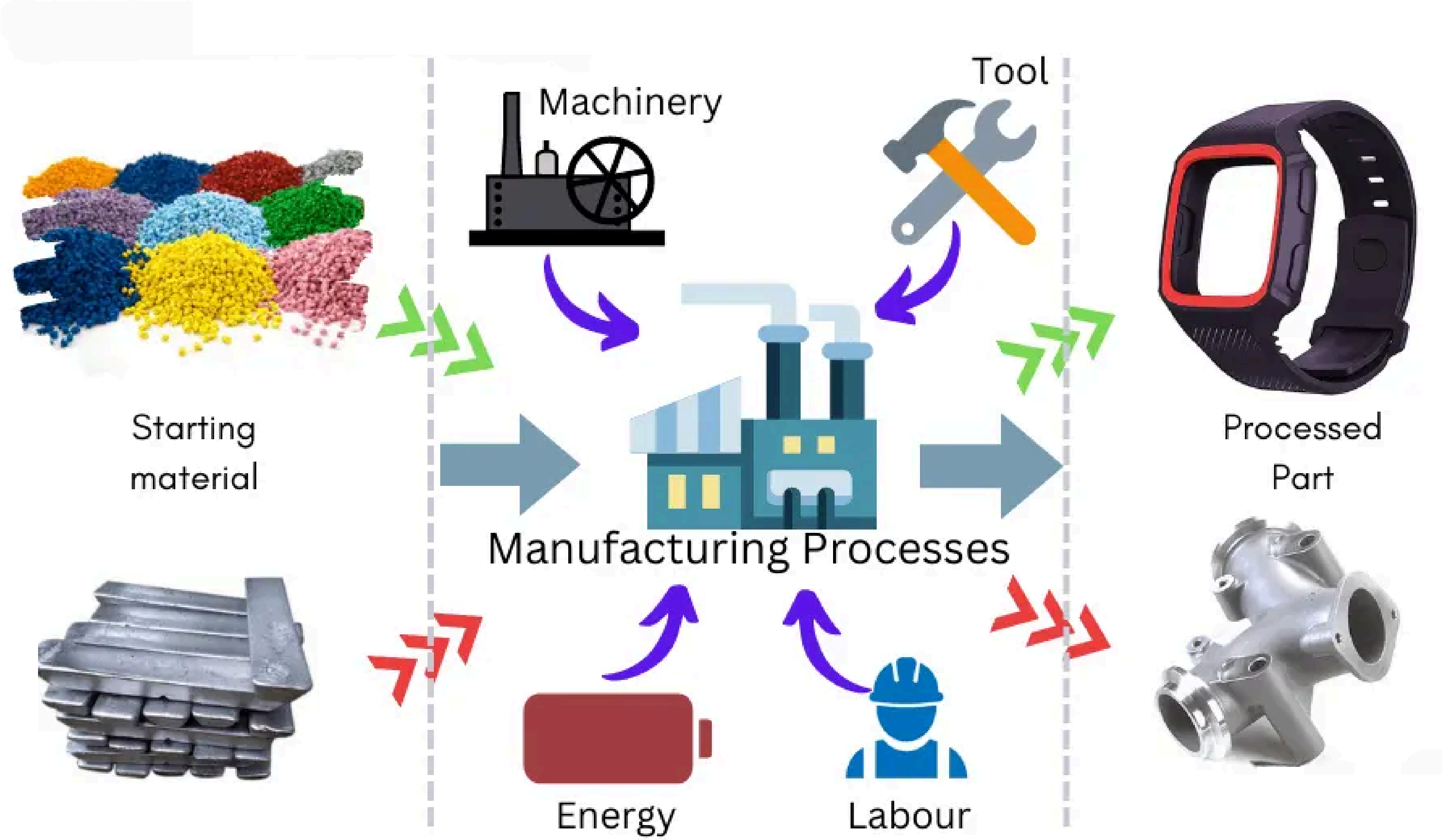
Fugitive emissions from fuels



- Fugitive emissions include activities such as mining, exploration, processing, storage, transportation, and accidental combustion of fossil fuels.
- It contributes minimally compared to fuel combustion but significantly in oil-producing countries.

[11] Sonwani, S., & Saxena, P. (Eds.). (2022). Greenhouse gases: sources, sinks and mitigation. Singapore:: Springer, page 24-30.

INDUSTRIAL PROCESSES AND PRODUCTS



- Metal production
- Chemicals used
- Electronics industry
- Mineral products
- Chemical industry

The main greenhouse gases from the industrial sector are: CO_2, CH_4, N_2O, HFCs, PFCs, SF_6,...

Depending on products and processes of transformations various GHGs are released

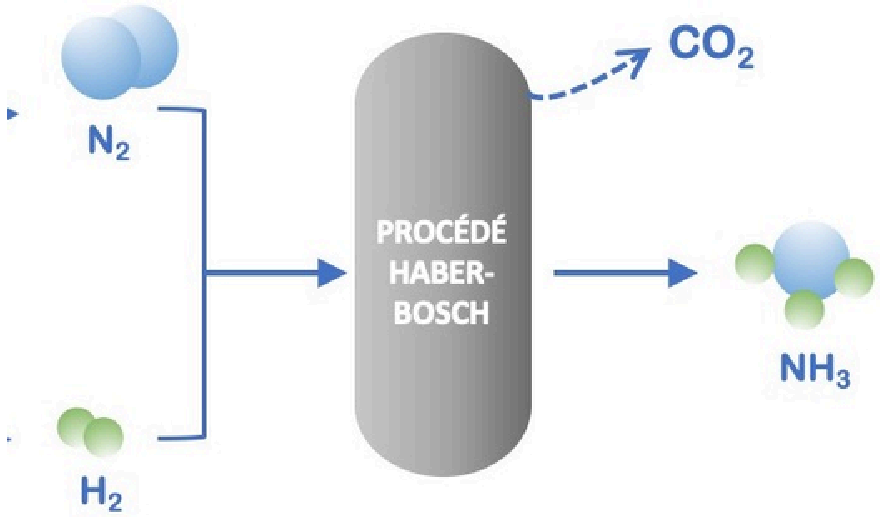
[11] Sonwani, S., & Saxena, P. (Eds.). (2022). Greenhouse gases: sources, sinks and mitigation. Singapore:: Springer, page 24-30

INDUSTRIAL PROCESSES AND PRODUCTS

Mineral products

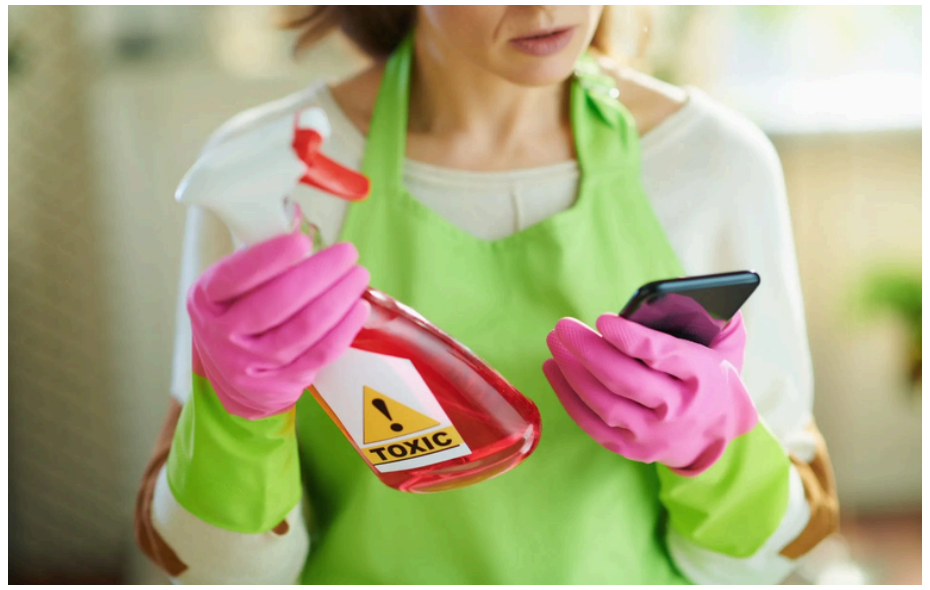
- Cement production
- Lime production
- Limestone and dolomite
- Soda ash production and use,etc

Chemical industry



- Ammonia production
- Nitric acid production
- Adipic acid production
- Fluorochemical production, etc.

Chemicals used



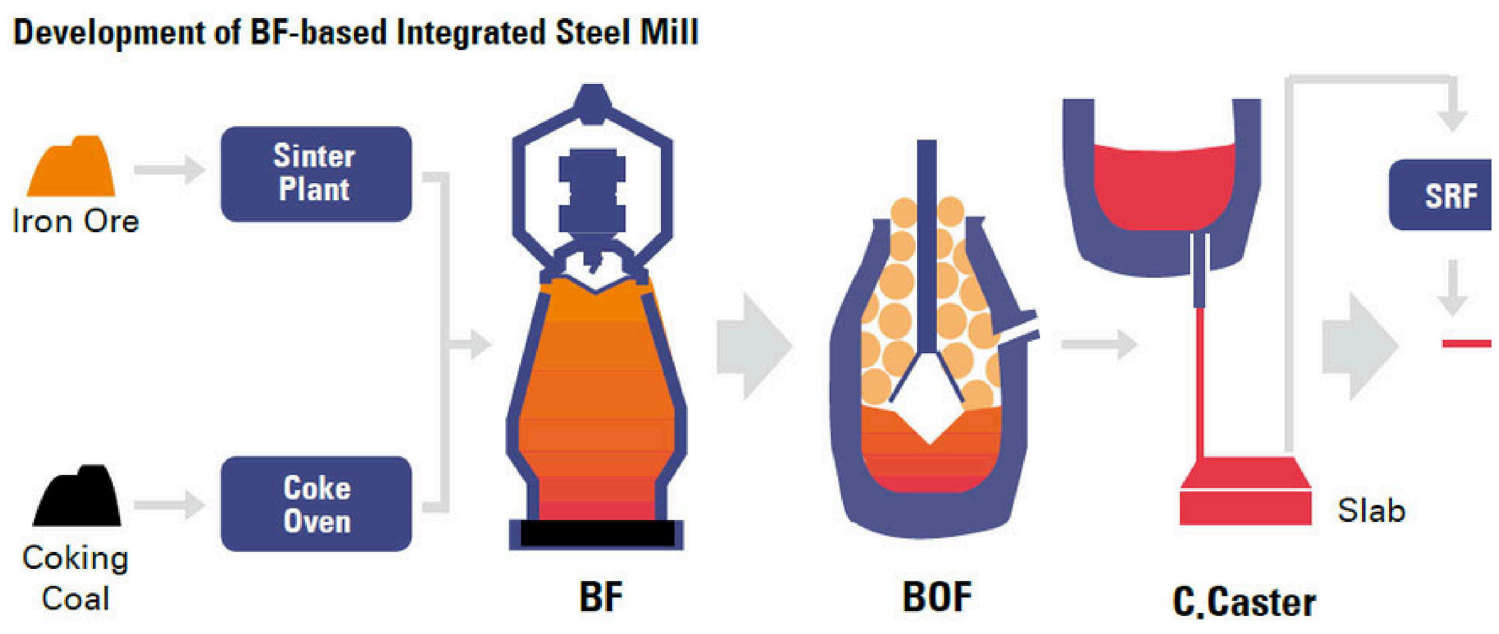
- Iron and steel production
- Ferroalloys production
- Aluminum production
- Lead production, zinc production, etc

[11] Sonwani, S., & Saxena, P. (Eds.). (2022). Greenhouse gases: sources, sinks and mitigation. Singapore:: Springer, page 24-30.

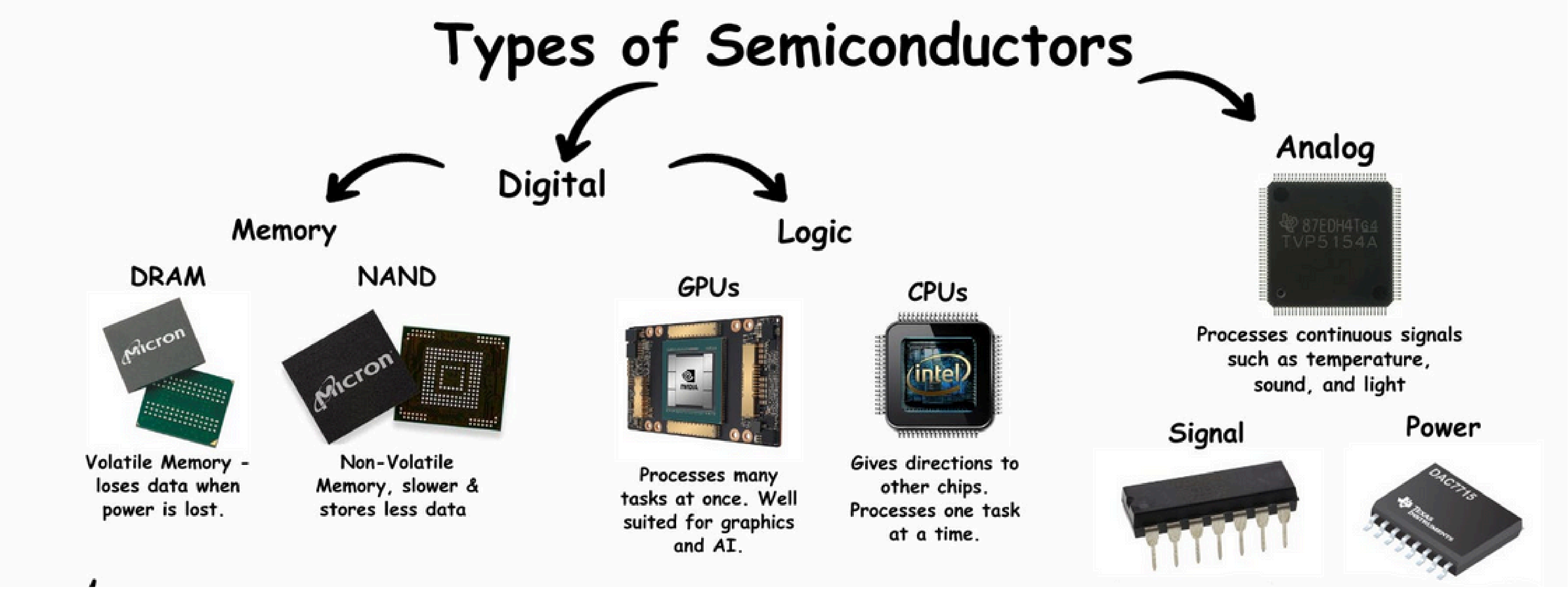
INDUSTRIAL PROCESSES AND PRODUCTS

- Iron and steel production
- Ferroalloys production
- Aluminum production
- Lead production, zinc production, magnesium production, etc

- TFT flat panel display
- Photovoltaics
- Heat transfer fluid, other
- Integrated circuit or semiconductor



Metal production



Electronics industry

[11] Sonwani, S., & Saxena, P. (Eds.). (2022). Greenhouse gases: sources, sinks and mitigation. Singapore:: Springer, page 24-30.

AGRICULTURE, FORESTRY & OTHER LAND USE

Livestock

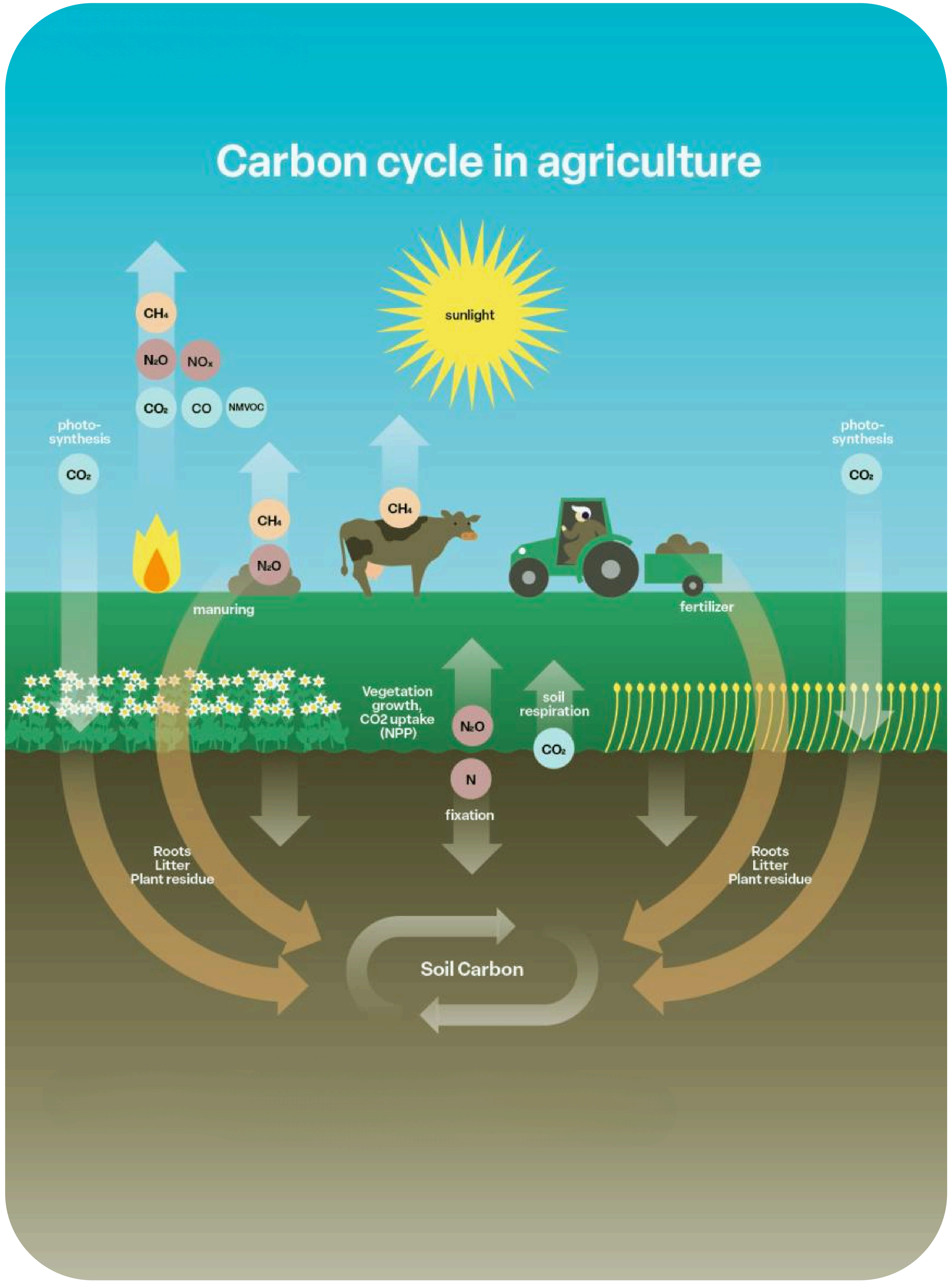
CH4 from enteric fermentation of livestock population and CH4 and from manure management

Land

Greenhouse gases from this sector include CO2, CH4, N2O, NOx, CO, NMVOC, and SO2.

Biomass burning

Forest fire and agriculture residue burning produce N2O, CH4, CO2 emissions.



[11] Sonwani, S., & Saxena, P. (Eds.). (2022). Greenhouse gases: sources, sinks and mitigation. Singapore:: Springer, page 24-30.

AGRICULTURE, FORESTRY & OTHER LAND USE

Rice cultivation

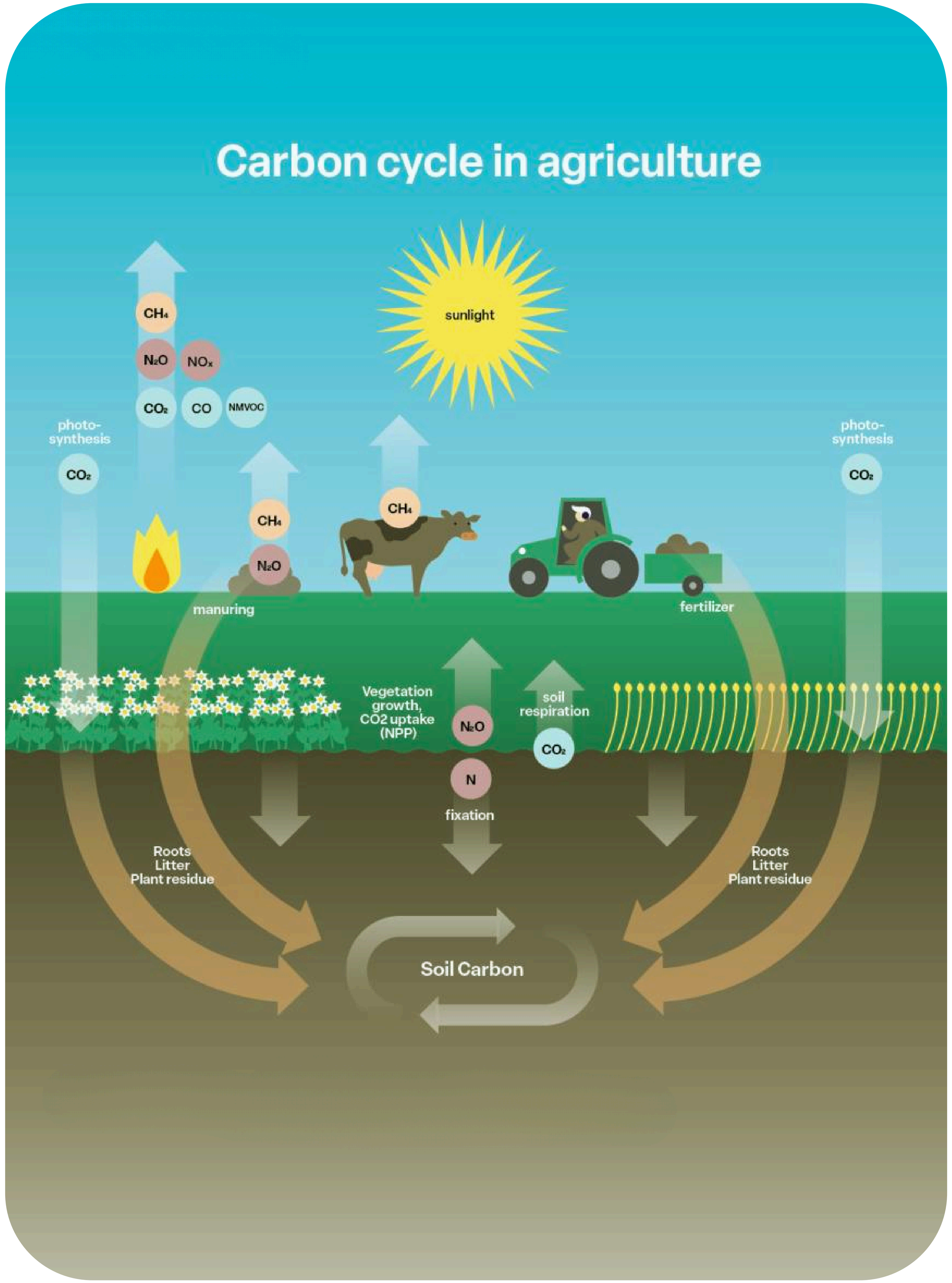
CH4 emissions from rice cultivation are another major source of GHG emissions.

Liming

Liming is done to maintain the soil pH. Lime releases CO2 from the agricultural field.

Urea application

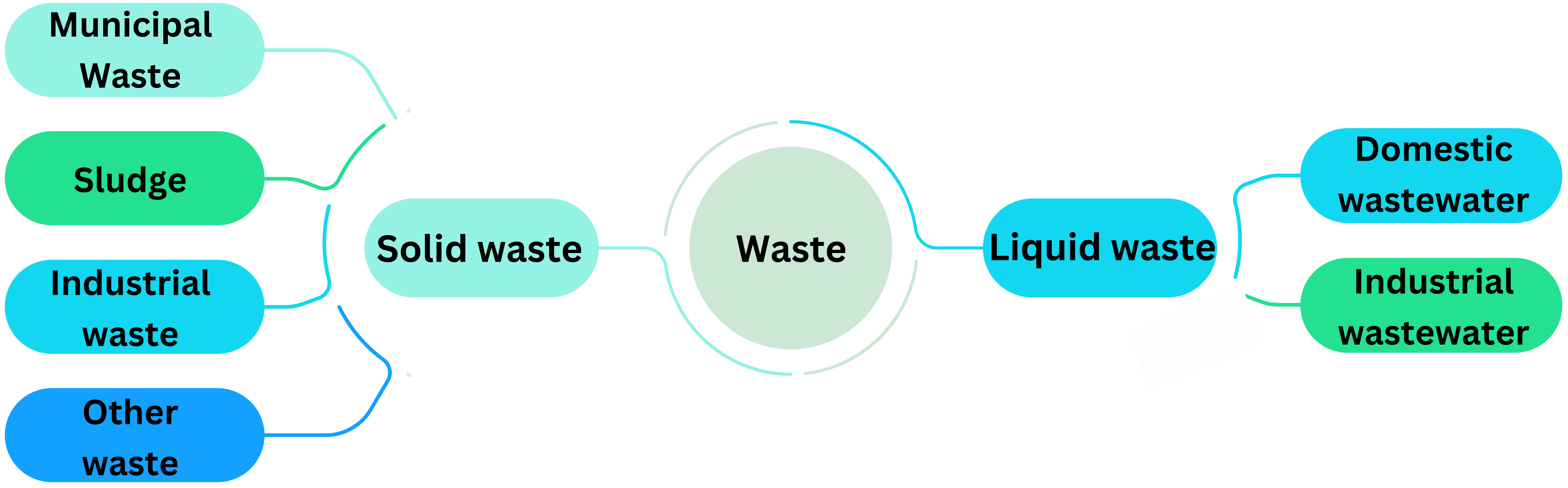
Urea which is used for increasing the fertility of soil releases CO2.



[11] Sonwani, S., & Saxena, P. (Eds.). (2022). Greenhouse gases: sources, sinks and mitigation. Singapore:: Springer, page 24-30.

WASTE

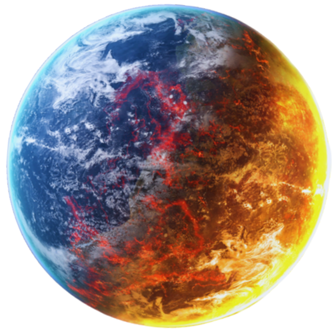
Waste generation rate from any society are governed by socio-economic position, and degree of industrialization



Solid waste disposal sites are the primary source of CH_4 emissions, accounting for 5-20% of global human-induced CH_4 emissions.

Biological waste and wastewater treatment releases CO_2, CH_4, N_2O, NO_x, CO, NMVOC, and small amounts of NH_3.

[11] Sonwani, S., & Saxena, P. (Eds.). (2022). Greenhouse gases: sources, sinks and mitigation. Singapore:: Springer, page 24-30.

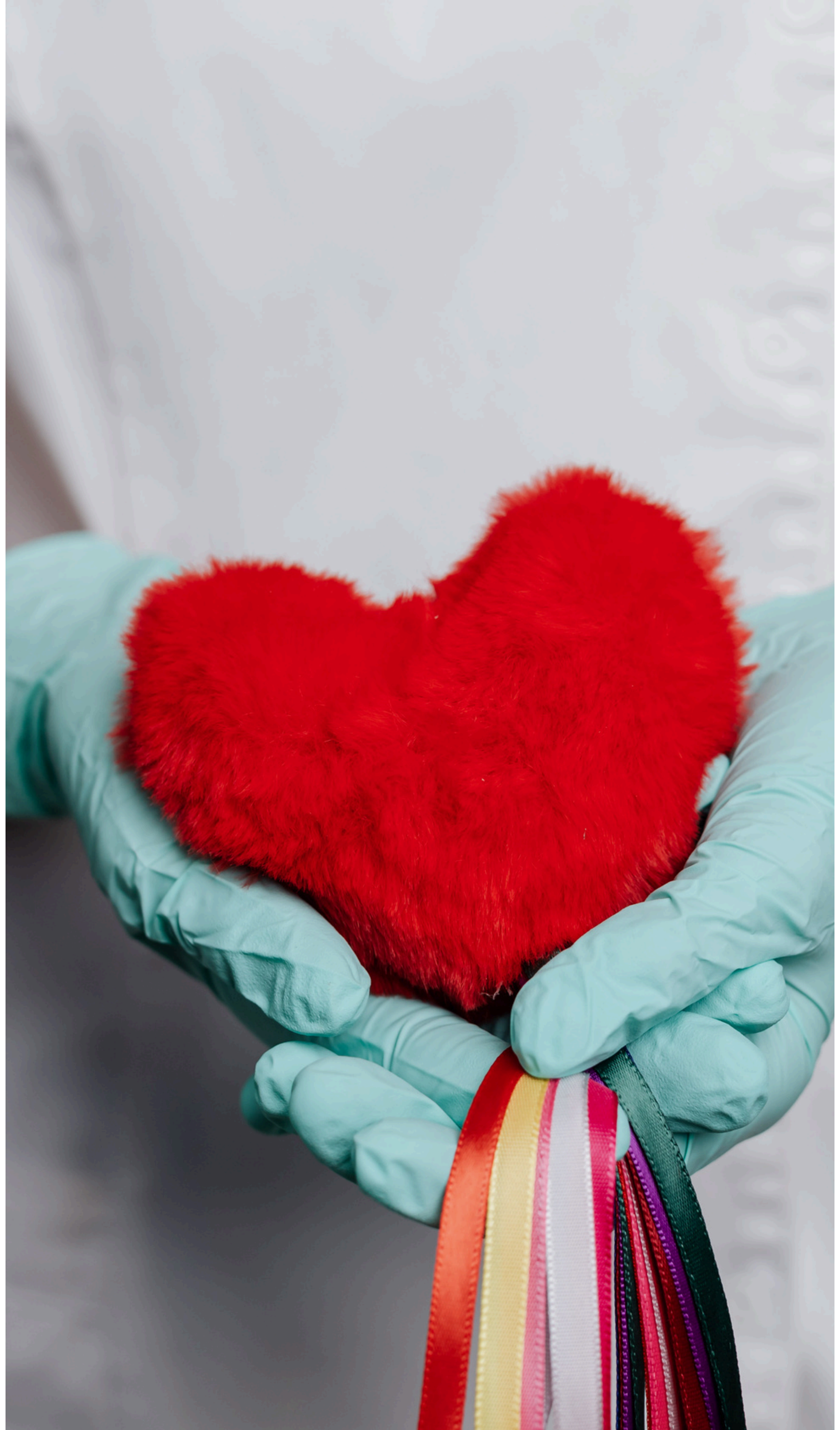


02 IMPACT

CLIMATE CHANGE

&

HUMAN HEALTH



CLIMATE CHANGE

The increasing concentration of greenhouse gases in the atmosphere is causing a range of significant impacts, including:

- **Rising global temperatures**
- **Extreme weather events**
- **Sea-Level rise**
- **Ocean acidification**
- **Disruption of ecosystems**

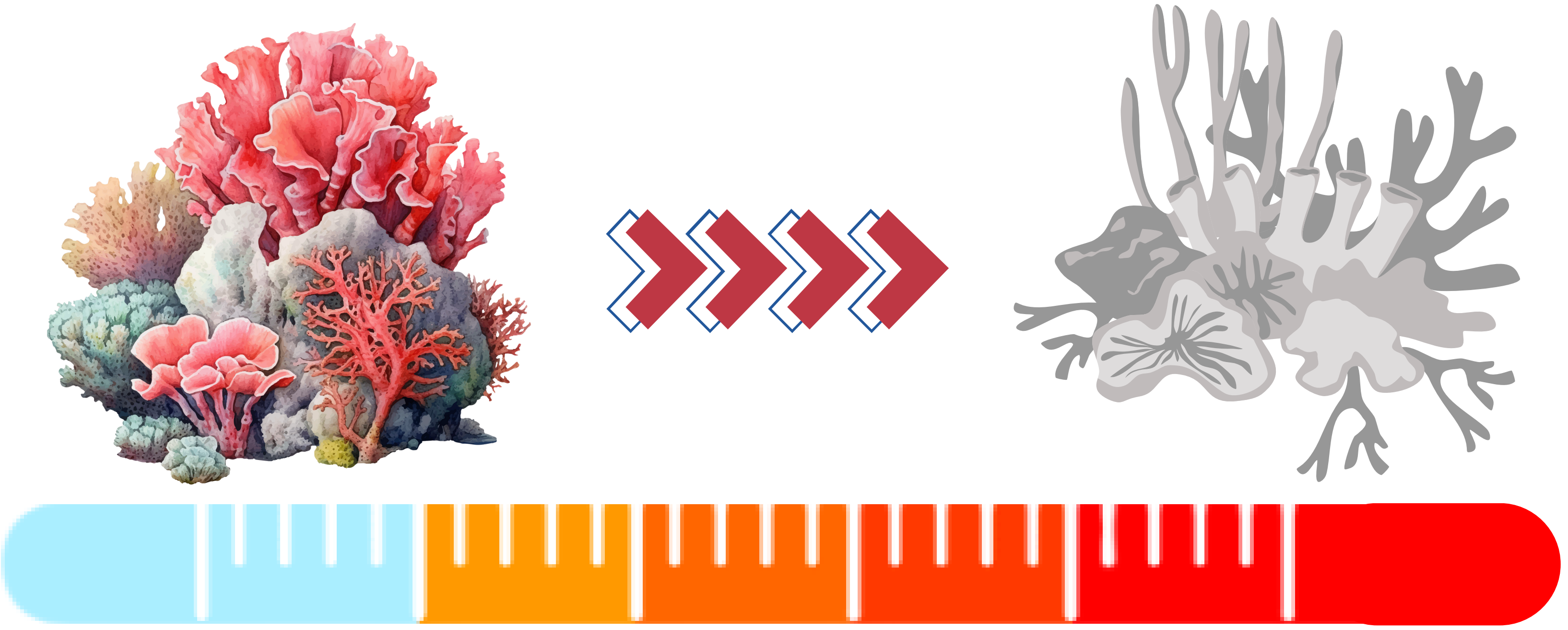
RISING GLOBAL TEMPERATURES

Heatwaves:

Heat and hot weather that lasted for several days can significantly impact society leading to heat-related illnesses and deaths. Heatwaves can also strain resources, and disrupt food and livelihood security. [1].

Warming Ocean:

As the planet's greatest carbon sink, the ocean absorbs excess heat from rising GHG emissions trapped in the Earth's system, disrupting marine ecosystems and leading to coral bleaching [2].



[1] World Health Organization. (n.d.). Heatwaves. World Health Organization. Retrieved November 2, 2024, from https://www.who.int/health-topics/heatwaves#tab=tab_1

[2] United Nations. (2023, October 26). How is climate change impacting the world's ocean [United Nations Framework Convention on Climate Change]. Retrieved November 3, 2024, from https://www.un.org/en/climatechange/science/climate-issues/ocean-impacts

EXTREME WEATHER EVENTS

More Intense Storms:

Hurricanes, typhoons, and other storms can become stronger and more destructive. As more water vapor is evaporated into the atmosphere it becomes fuel for more powerful storms to develop [3].

Flooding and Droughts:

Changes in precipitation patterns can lead to severe floods and droughts. This claims lives, destroys homes and infrastructure, and puts a huge economic burden on our societies [4].

[3] U.S. Geological Survey. (n.d.). How Can Climate Change Affect Natural Disasters? [USGS.gov]. Retrieved November 3, 2024, from https://www.usgs.gov/faqs/how-can-climate-change-affect-natural-disasters

[4] European Commission (EC). (2023, August 3). How climate change is disrupting rainfall patterns and putting our health at risk. [Climate Action - European Commission]. Retrieved November 3, 2024, from https://climate.ec.europa.eu/news-your-voice/news/how-climate-change-disrupting-rainfall-patterns-and-putting-our-health-risk-2023-08-03_en

SEA-LEVEL RISING

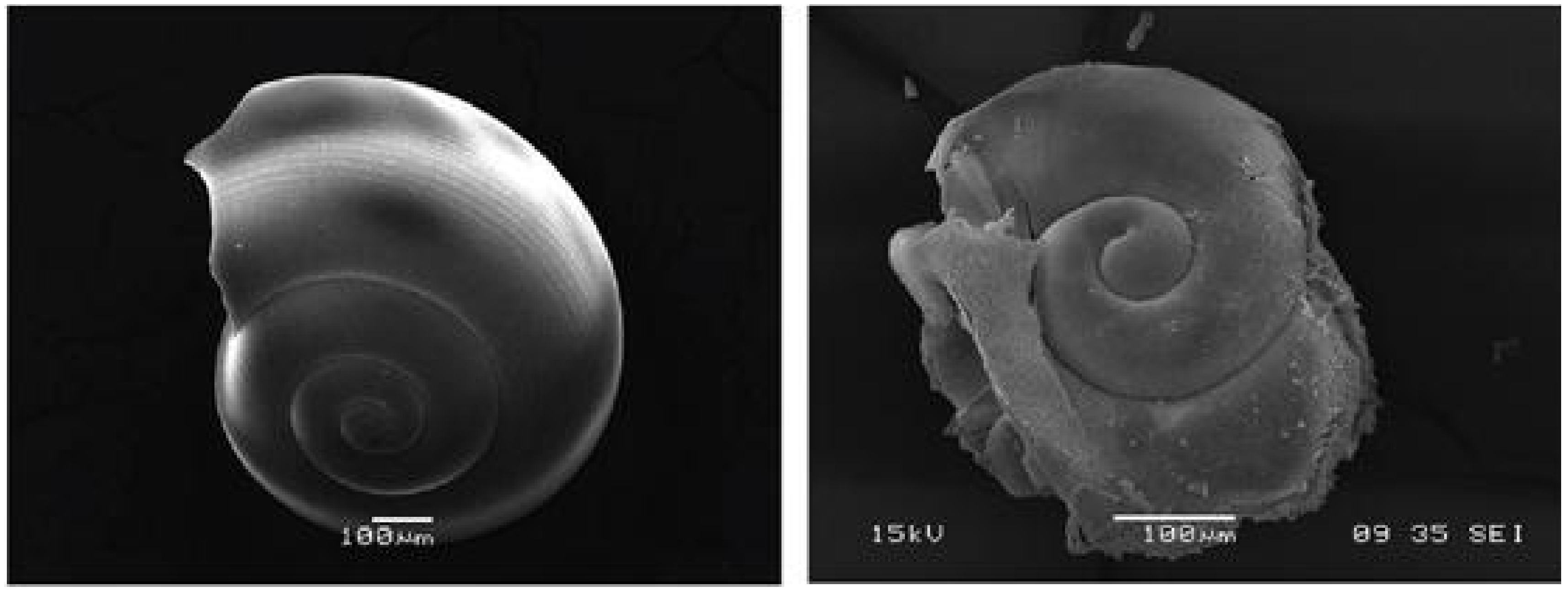
Coastal Erosion and Flooding:
Rising sea levels threaten coastal cities and communities by which local sea level rise, strong wave action, and coastal flooding wear down or carry away rocks, soils, and/or sands along the coast [5].

Salination of Water Sources:
Saltwater intrusion can contaminate freshwater sources such as wells, freshwater aquifers, and septic systems [6].

[5] C40 Cities. (n.d.). The Future We Don't Want: Sea Level Rise. [Scaling Up Climate Action]. Retrieved November 3, 2024, from https://www.c40.org/what-we-do/scaling-up-climate-action/adaptation-water/the-future-we-dont-want/sea-level-rise/
[6] Environmental Finance Center Network. (n.d.). Saltwater Intrusion: Should Your Utility Be Concerned? Retrieved November 3, 2024, from https://efcnetwork.org/saltwater-intrusion-should-your-utility-be-concerned/

OCEAN ACIDIFICATION

Threatening marine ecosystems and biodiversity: CO_2 is absorbed from the atmosphere and will increase the ocean's acidity.



Shell Dissolve in Acidified Ocean Water [7]

$$CO_2 + H_2O + CO_3^{2-} \rightarrow 2HCO_3^-$$

Increased acidity in the ocean can harm marine organisms, particularly those with calcium carbonate ($CaCO_3$) shells, if the pH gets too low, shells can begin to dissolve [8].

[7] Sailors for the Sea. (2019). Oceans Acid. [Sailors for the Sea]. Retrieved November 3, 2024, from https://sailorsforthesea.org/ocean-watch-essays/oceans-acid/
[8]National Oceanic and Atmospheric Administration (NOAA). (n.d.). Ocean Acidification. [National Oceanic and Atmospheric Administration]. Retrieved November 3, 2024, from https://www.noaa.gov/education/resource-collections/ocean-coasts/ocean-acidification

DISRUPTION OF ECOSYSTEMS

Loss of Biodiversity: Climate change can alter habitats and disrupt ecosystems, leading to species loss [9].

Shifting of Species Ranges: As temperatures change, species may migrate to new areas, impacting local ecosystems [10].

[9] United Nations. (2023, September 15). Biodiversity - our strongest natural defense against climate change. [United Nations Framework Convention on Climate Change]. Retrieved November 3, 2024, from [7] National Oceanic and Atmospheric Administration (NOAA). (n.d.). Ocean Acidification. [National Oceanic and Atmospheric Administration]. Retrieved November 3, 2024, from https://www.noaa.gov/education/resource-collections/ocean-coasts/ocean-acidification

[10] North Carolina State University. (2023, July 12). Species Range Shifts Are Not As Simple As You Think. Southeast Climate Adaptation Science Center. Retrieved November 3, 2024, from https://secasc.ncsu.edu/2023/07/12/species-range-shifts-are-not-as-simple-as-you-think/

HUMAN HEALTH

Impact of components in Greenhouse Gases on human health

- CO_2
- CH_4
- CFCs
- N_2O

CO_2

Carbon dioxide (CO_2) exposure affects human health in various ways, depending on the concentration and duration of exposure [11].

Short-Term Effects

Headaches

Anxiety

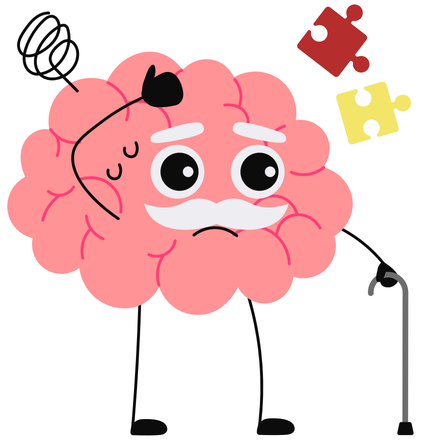
Unconsciousness

Difficulty breathing

Difficulty concentrating

Ringing in ear (Tinnitus)

Long-Term Effects



Memory loss

Chronic Respiratory Acidosis

Sleep disturbances

Inflammation

[11] Sonwani, S., & Saxena, P. (Eds.). (2022). Greenhouse gases: sources, sinks and mitigation. Singapore:: Springer.

CH_4

Methane can pose health risks when inhaled in high concentrations. It's not directly toxic but it’s displacing oxygen, leading to various health problems [11].

Asphyxiation	Oxygen Deprivation Symptoms

Methane displaces oxygen in the lungs

→ Difficulty breathing

Dizziness

Nausea & vomiting

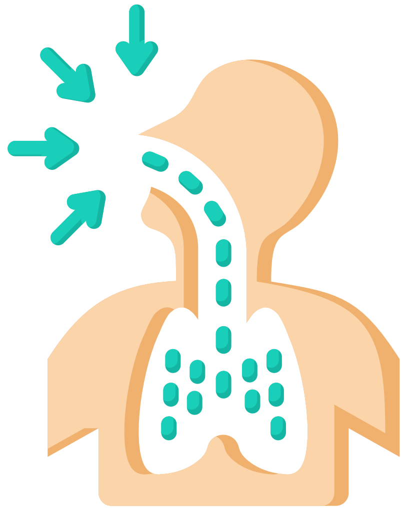
Blurred vision

[11] Sonwani, S., & Saxena, P. (Eds.). (2022). Greenhouse gases: sources, sinks and mitigation. Singapore:: Springer.

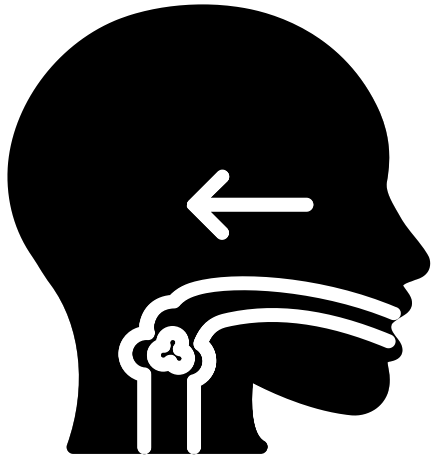
CFC

Exposure Routes

Most absorbed CFCs are eliminated within a day



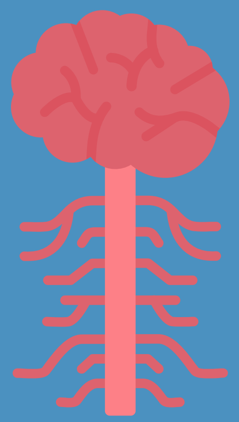
Inhalation



Ingestion

Skin contact

Health Effects



Central Nervous System (CNS)

Lightheadedness

Tremors

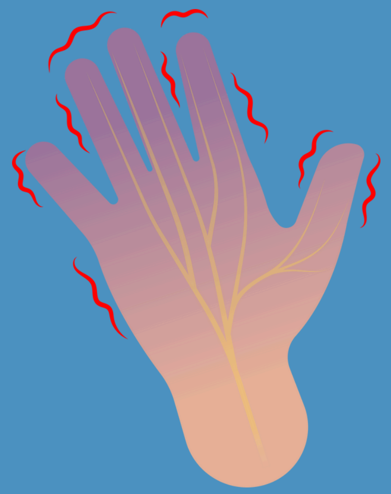
Convulsions

[11] Sonwani, S., & Saxena, P. (Eds.). (2022). Greenhouse gases: sources, sinks and mitigation. Singapore:: Springer.

CFC

Skin Contact

Irritation



frostbite

Ingestion

Nausea
& vomiting

Diarrhea

Digestive
upset

[11] Sonwani, S., & Saxena, P. (Eds.). (2022). Greenhouse gases: sources, sinks and mitigation. Singapore:: Springer.

N_2O

Neurological Effects

Cognitive Impairment: N2O can impair cognitive function, including memory, attention, and problem-solving abilities.

Neurotoxicity: Prolonged exposure can lead to neurotoxicity, damaging the nervous system.

Peripheral Neuropathy: This condition can cause numbness, tingling, and weakness in the extremities [11].

Hematological Effects

Megaloblastic Anemia: N2O inhibits the production of red blood cells, leading to anemia.

Increased Homocysteine Levels: Elevated homocysteine levels are linked to cardiovascular disease [11].

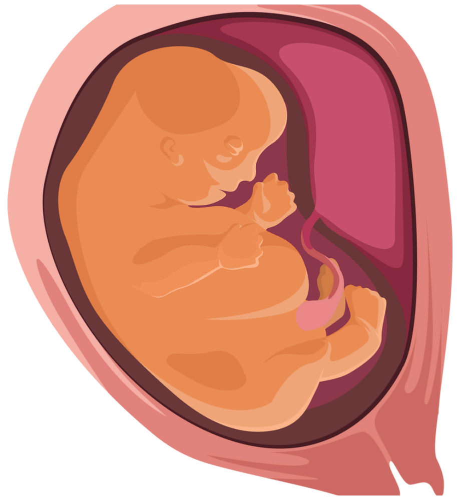
[11] Sonwani, S., & Saxena, P. (Eds.). (2022). Greenhouse gases: sources, sinks and mitigation. Singapore:: Springer.

N_2O

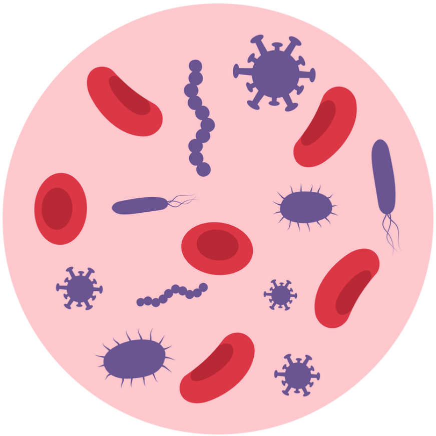
Reproductive Effects

Teratogenicity: Exposure during pregnancy can increase the risk of birth defects [11].

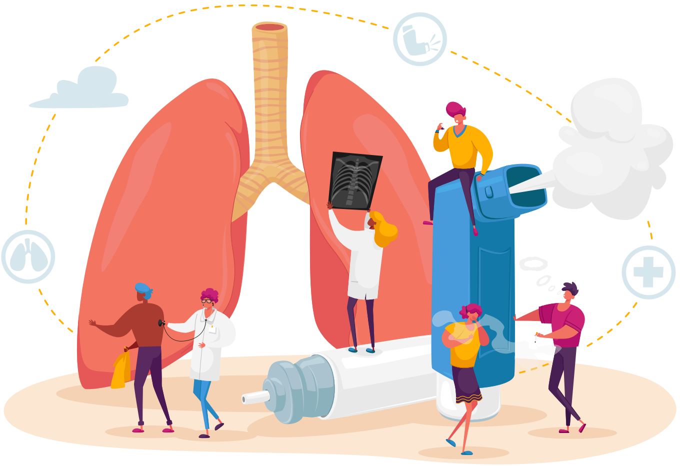
Reduced Fertility: N2O can impair fertility in both men and women.



Other Effects



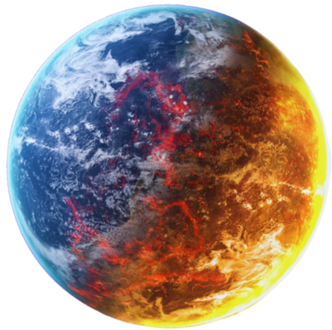
Immune System Suppression



Respiratory Effects

Cardiovascular Effects

[11] Sonwani, S., & Saxena, P. (Eds.). (2022). Greenhouse gases: sources, sinks and mitigation. Singapore:: Springer.



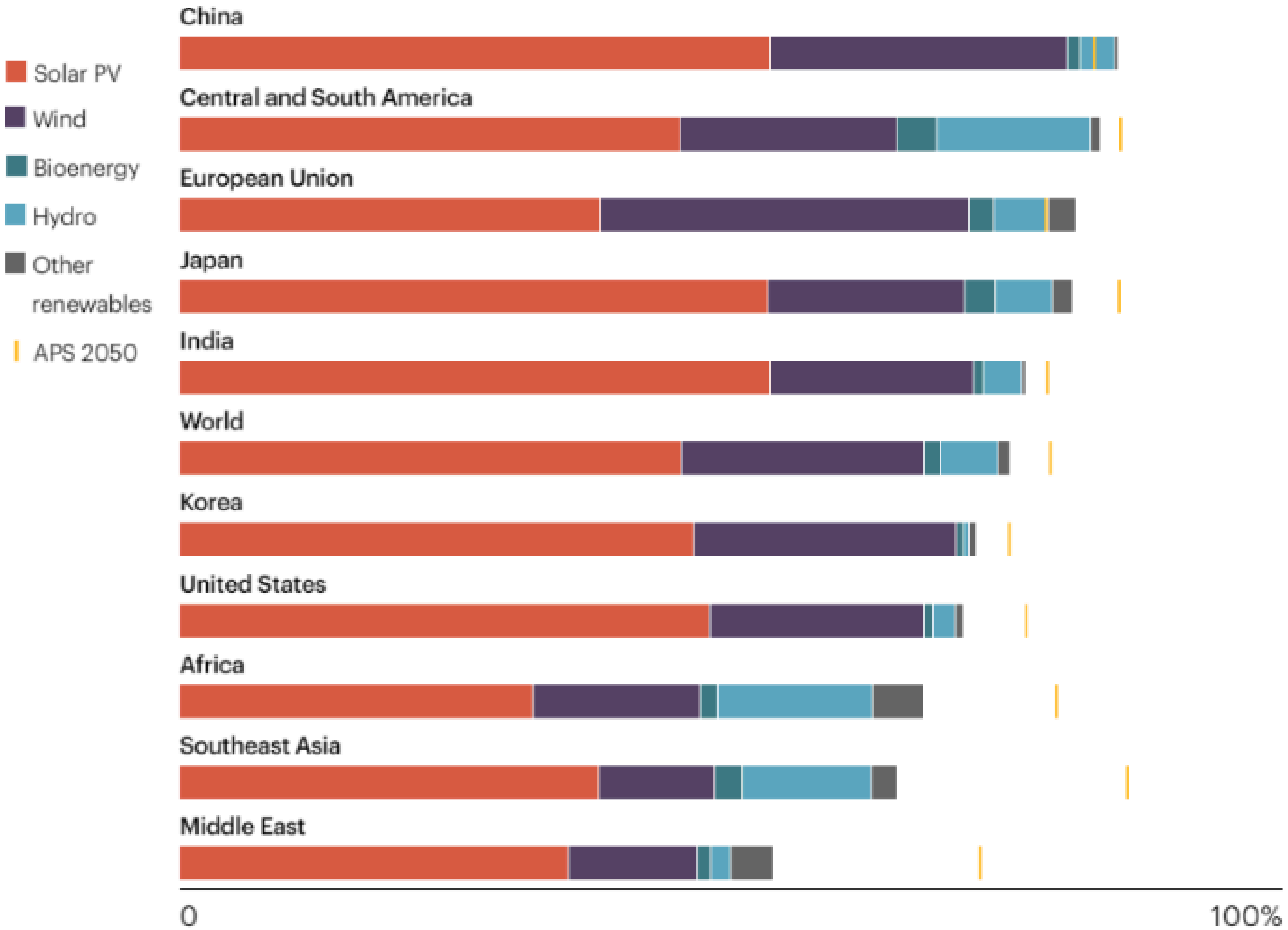
03 SOLUTION

12 SOLUTIONS *corresponding to* PRINCIPLES OF GREEN CHEMISTRY

1. Prevention
2. Atom Economy
3. Less Hazardous Chemical Syntheses
4. Design Safer Chemicals
5. Reduce Derivatives
6. Use of Renewable Feedstocks
7. Design for Energy Efficiency
8. Safer Solvents Auxiliaries
9. Catalysis
10. Design for Degradation
11. Real-time analysis for Pollution Prevention
12. Inherently Safer Chemistry for Accident Prevention

PREVENTION

Renewable energy sources: like solar and wind power are being widely adopted to prevent CO_2 emissions from fossil fuels. [1]



Graph 3.1 Solar PV and wind are set to dominate global capacity additions by 2050 [2]

The adoption of renewable energy sources has significantly increased.

Various countries around the world have made substantial investments in renewable energy infrastructure, leading to a notable reduction in CO_2 emissions.

[1] Nunez, Christina. “Renewable Energy, Facts and Information.” Environment, National Geographic, 30 Jan. 2019, www.nationalgeographic.com/environment/article/renewable-energy.
[2] “KPT.” Kptgroup.com.vn, 2022, vi.kptgroup.com.vn/news/non-ipsa.

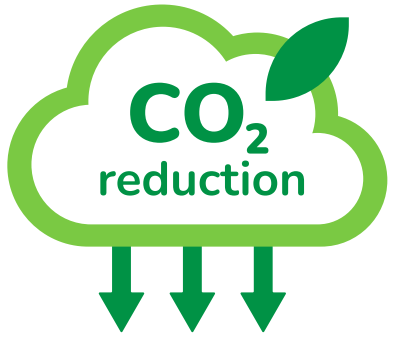
RENEWABLE ENERGY PROJECTS

(from 2014)

Power Plant Name	Technology	Country	Year	Installed Capacity (MW)
Bhadla Solar Park	Photovoltaics	India	2018	2245
Huanghe Hydropower Hainan Solar Park	Photovoltaics	China	2020	2200
Longyangxia Dam Solar Park	Photovoltaics & Hydro electric Power	China	2015	2130
Muppandal wind farm	On - Shore Wind Farm	India	2023	1500
Ouarzazate Solar Power Station	Parabolic trough and solar power tower (CSP)	Morocco	2016	580
Ivanpah Solar Power Facility	Solar power tower (CSP)	United States	2014	377
Mojave Solar Project	Parabolic trough (CSP)	United States	2014	280

[3] Sayed, E.T.; Olabi, A.G.; Alami, A.H.; Radwan, A.; Mdallal, A.; Rezk, A.; Abdelkareem, M.A. Renewable Energy and Energy Storage Systems. Energies 2023, 16, 1415. https://doi.org/10.3390/ en16031415

SOLUTIONS EFFICIENCY



Reduction in Greenhouse Gas: Operating with little or no emissions of greenhouse gases, which mean that do not contribute to climate change and global warming. [4]

Year	CO_2 Emissions (Gt)	Reduction due to Renewable (Gt)	Reduction percentage (%)
2000	24.5	0.5	2.0
2005	27.0	1.0	3.7
2010	30.0	1.5	5.0
2015	32.5	2.5	7.7
2020	34.0	3.5	10.3
2022	36.3	4.0	11.0

Table 3.1 Reduction in Greenhouse Gas Emissions Due to Renewable Energy [5]

[4] Pawar, Mr Vikas, and Safia Farooqui. "THE EFFECTIVENESS of RENEWABLE ENERGY TECHNOLOGIES in REDUCING GREENHOUSE GAS EMISSIONS." INTERNATIONAL CONFERENCE on INDUSTRY 5.0: SUSTAINABILITY & INNOVATIONS in BUSINESS, 29 Aug. 2023, www.researchgate.net/publication/373453524.

[5] Ritchie, Hannah, et al. "Renewable Energy." Our World in Data, Our World in Data, Jan. 2024, ourworldindata.org/renewable-energy.

ATOM ECONOMY

Catalytic converters: typically precious metals like platinum, palladium, and rhodium, to facilitate chemical reactions.[6]

Vehicles and industrial processes improve atom economy by maximizing the conversion of reactants to useful products, reducing waste, emissions of harmful gases.

They are now standard in many countries, contributing to cleaner air and reduced greenhouse gas emissions

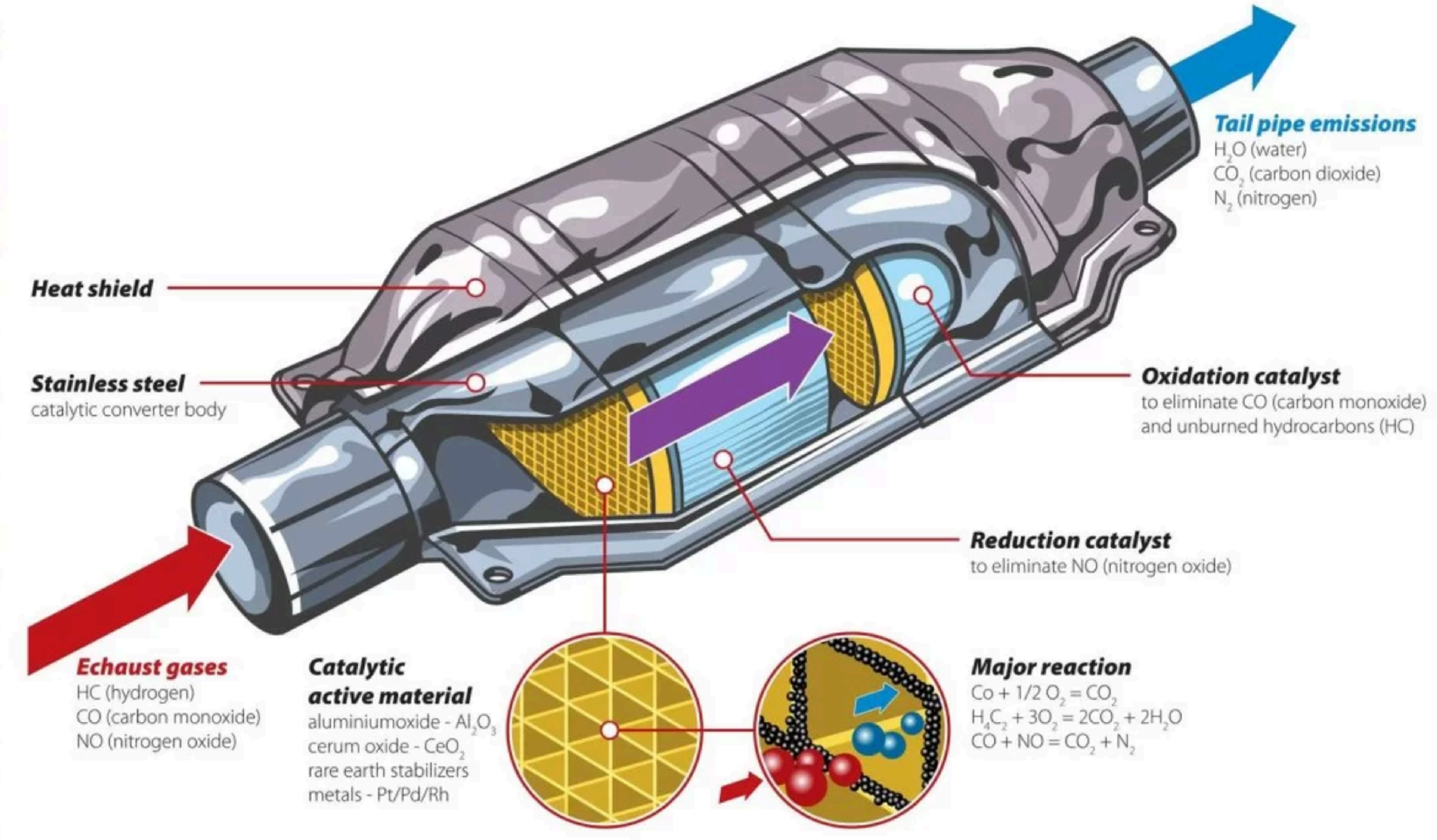


Figure 3.1 Inside a car catalytic converter [7]

[6] Centi, Gabriele, and Siglinda Perathoner. “Catalytic Technologies for the Conversion and Reuse of CO2.” Springer EBooks, 1 Jan. 2021, pp. 1–50, https://doi.org/10.1007/978-1-4614-6431-0_119-1
[7] Lynn, Jo. “Why Is Catalytic Converter Theft on the Rise?” DeBroux Automotive, 29 Oct. 2021, debrouxautomotive.com/why-is-catalytic-converter-theft-on-the-rise/.

SOLUTIONS EFFICIENCY

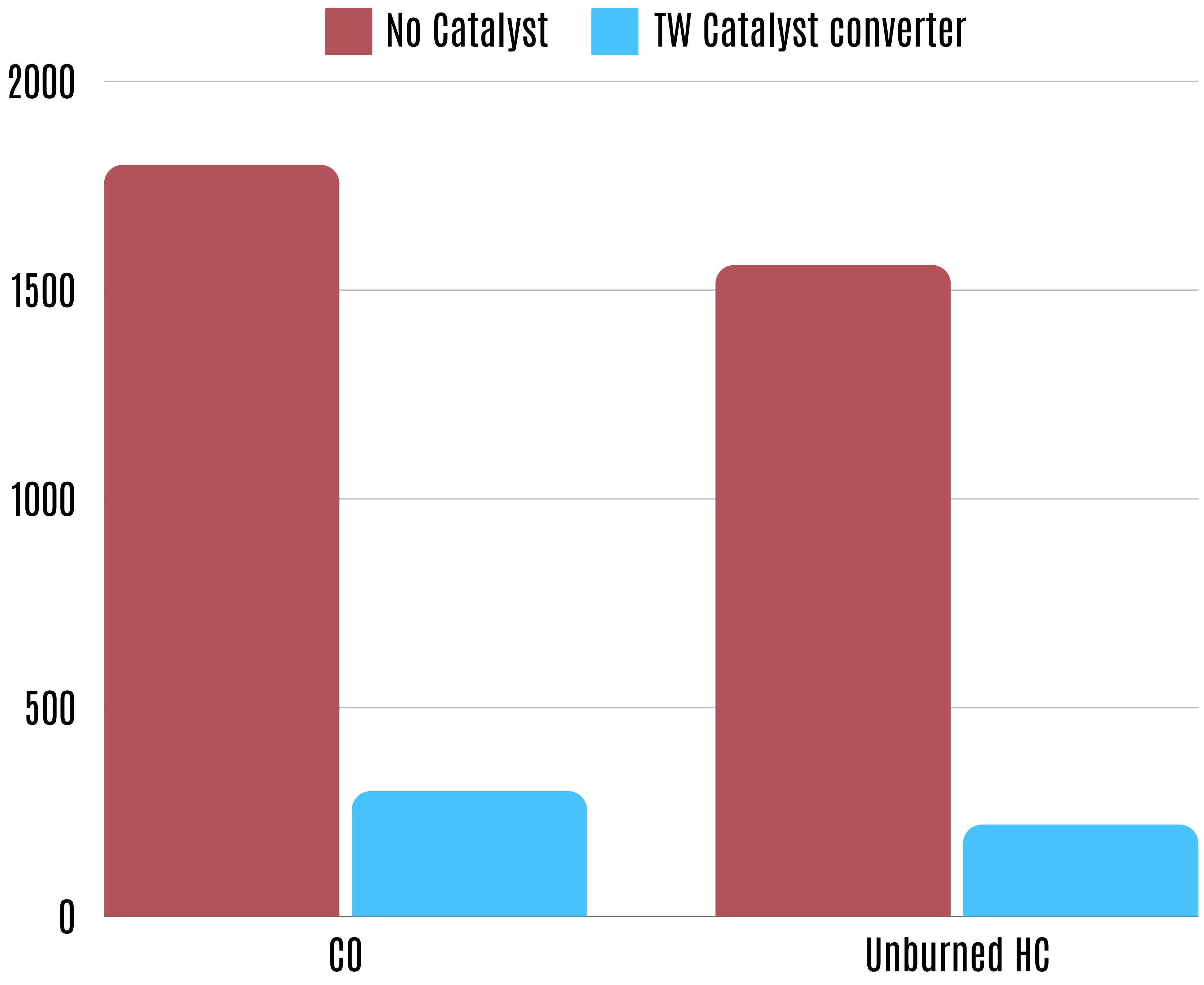
Reduction of Non-CO_2 GHGs:

Catalytic converters help reduce emissions of non-CO_2 greenhouse gases such as methane (CH_4) and nitrous oxide (N_2O) by converting them into less harmful substances. [8]

$$CH_4 + O_2 \rightarrow CO_2 + 2H_2O$$

$$CO + O_2 \rightarrow CO_2$$

$$2NO_X \rightarrow xO_2 + N_2$$



Graph 3.2 The emissions (mg/km) of CO and Unburned HC in a gasoline exhaust from vehicles without catalysts and a TWC [9]

[8] Centi, Gabriele, and Siglinda Perathoner. "Reduction of Non-CO2 Greenhouse Gas Emissions by Catalytic Processes." Springer EBooks, 1 Jan. 2024, pp. 1–43, https://doi.org/10.1007/978-1-4614-6431-0_49-4.

[9] Kritsanaviparkporn, E.; Baena-Moreno, F.M.; Reina, T.R. Catalytic Converters for Vehicle Exhaust: Fundamental Aspects and Technology Overview for Newcomers to the Field. Chemistry 2021, 3, 630–646. https://doi.org/10.3390/ chemistry3020044

LESS HAZARDOUS CHEMICAL SYNTHESES

Supercritical CO_2: using as a solvent in chemical processes reduces the need for hazardous organic solvents. [10]

Figure 3.2 Supercritical CO_2 in reduce greenhouse gases [12]

- Supercritical CO_2 significantly reduces greenhouse gases, especially when integrated into various industrial processes.
- The International Energy Agency (IEA) estimates it could contribute to 14% of emissions reductions needed by 2050 to meet climate goals.[11]

[10] Wu, T., Han, B. (2019). Supercritical Carbon Dioxide (CO2) as Green Solvent. In: Han, B., Wu, T. (eds) Green Chemistry and Chemical Engineering. Encyclopedia of Sustainability Science and Technology Series. Springer, New York, NY. https://doi.org/10.1007/978-1-4939-9060-3_391

[11]“Read “Negative Emissions Technologies and Reliable Sequestration: A Research Agenda” at NAP.edu.” Nap.nationalacademies.org, nap.nationalacademies.org/read/25259/chapter/9.

[12] “Siêu Tới Han CO2 Nhà Máy Phục Hồi - Hypro.” Hypro Engineers, 9 Dec. 2020, hypro.co.in/vi/products/co2-recovery/supercritical-co2-recovery-system/.

SOLUTIONS EFFICIENCY

Non-Flammability and Non-Toxicity: supercritical CO_2 is non-flammable and non-toxic, making it safer to handle and use in various industrial processes. [13]

Industrial Process	Application of supercritical CO_2	Efficiency/Impact Data
Pharmaceuticals	Drug synthesis, purification	Supercritical CO_2 can improve drug purity and yield by 20-40%
Food Industry	Food processing, flavor extraction	Supercritical CO_2 reduces the need for chemical solvents by 80%
Materials Processing	Polymer synthesis, nanomaterial production	Efficiency gains of up to 30% in processing times
Biofuel Production	Biofuel synthesis	Increases yield by 15-25% compared to traditional methods
Environmental Remediation	Soil and water remediation	Enhances removal efficiency by 20-30% over conventional methods
Extraction	Decaffeination, essential oil extraction	Supercritical CO_2 extraction can reduce solvent use by up to 90%

Table 3.2 The use of supercritical CO_2 in various industrial processes [14]

[13] Markets, Research and. “Global Bioplastics Market Surges with an 11.4% CAGR, Driven by Eco-Friendliness and Expanding Applications across Industries.” Www.prnewswire.com, www.prnewswire.com/news-releases/global-bioplastics-market-surges-with-an-11-4-cagr-driven-by-eco-friendliness-and-expanding-applications-across-industries-301920642.html.

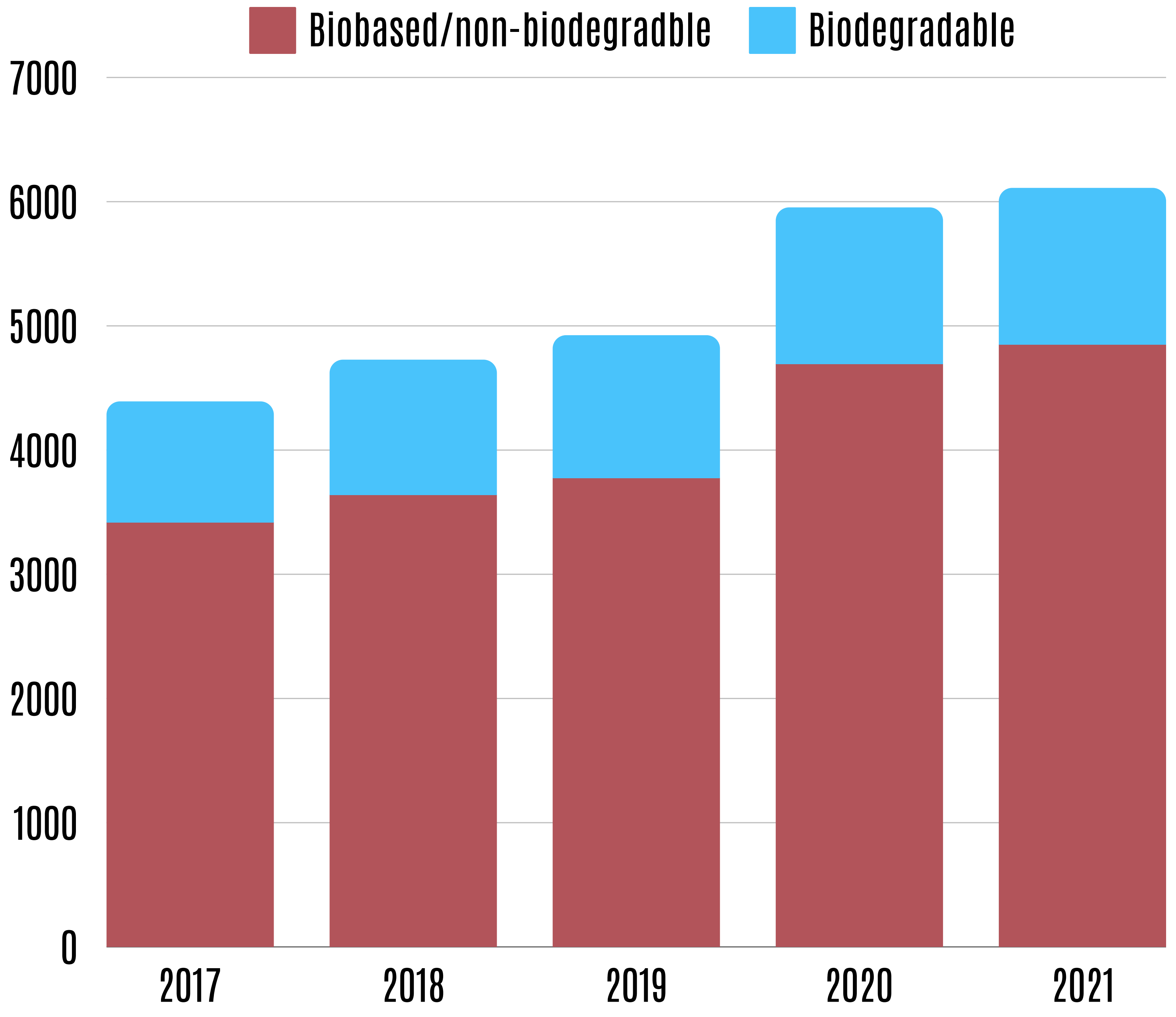
[14 Varma, A.K., Ghosh, S. (2020). Supercritical Carbon Dioxide: A Glimpse from the Modern Era of Green Chemistry. In: Inamuddin, Asiri, A. (eds) Advanced Nanotechnology and Application of Supercritical Fluids. Nanotechnology in the Life Sciences. Springer, Cham. https://doi.org/10.1007/978-3-030-44984-1_5

DESIGN SAFER CHEMICALS

Biodegradable plastics and safer refrigerants:

Development of biodegradable plastics and safer refrigerants that have lower global warming potential. [15]

- These materials reduce plastic pollution and greenhouse gas emissions from traditional plastics.
- The Kigali Amendment to the Montreal Protocol targets over 80% reduction in HFC production and consumption in the next 30 years. [16]



Graph 3.3 Market breakdown of global production capacities for biobased verses biodegradable plastics (1000 tonnes). [17]

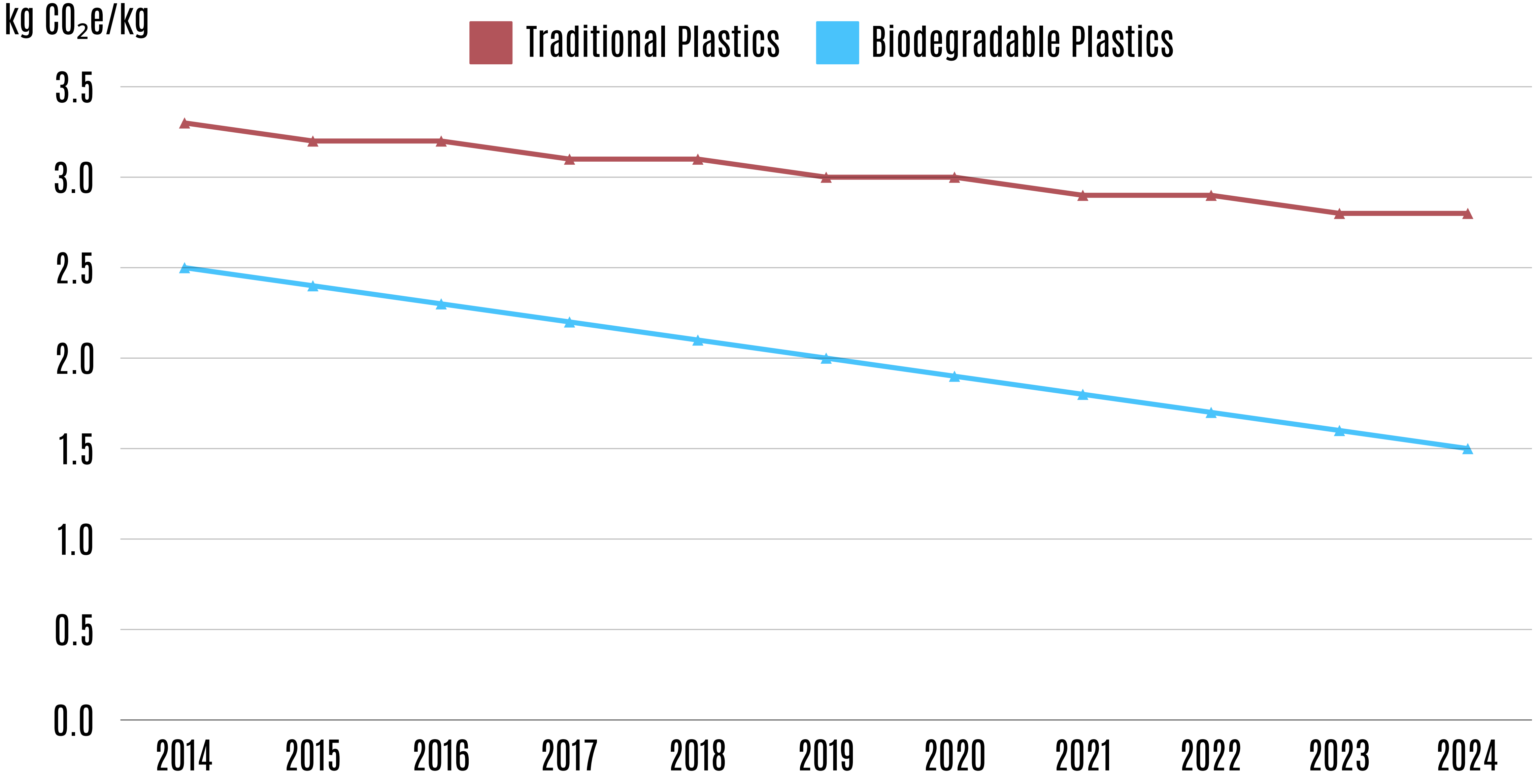
[15] Morais, A.M.M.B., Morais, R.M.S.C., Lackner, M. (2024). Biodegradable Bio-Based Plastics Toward Climate Change Mitigation. In: Lackner, M., Sajjadi, B., Chen, WY. (eds) Handbook of Climate Change Mitigation and Adaptation. Springer, New York, NY. https://doi.org/10.1007/978-1-4614-6431-0_91-3

[16] “Kigali Amendment.” UNDP, www.undp.org/chemicals-waste/montreal-protocol/kigali-amendment.

[17] Dilkes-Hoffman, L.S., et al. “The Role of Biodegradable Plastic in Solving Plastic Solid Waste Accumulation.” Plastics to Energy, 2019, pp. 469–505, www.sciencedirect.com/science/article/pii/B9780128131404000194, https://doi.org/10.1016/b978-0-12-813140-4.00019-4.

SOLUTIONS EFFICIENCY

Reduced Carbon Footprint: Biodegradable plastics can reduce carbon dioxide emissions by over 30% and lower carbon footprints by 42%. Bioplastics production also consumes 65% less energy compared to traditional petroleum-based plastics.[19]



Graph 3.4 Reduction in Carbon Footprint by Using Biodegradable Plastics (2014-2024) [20]

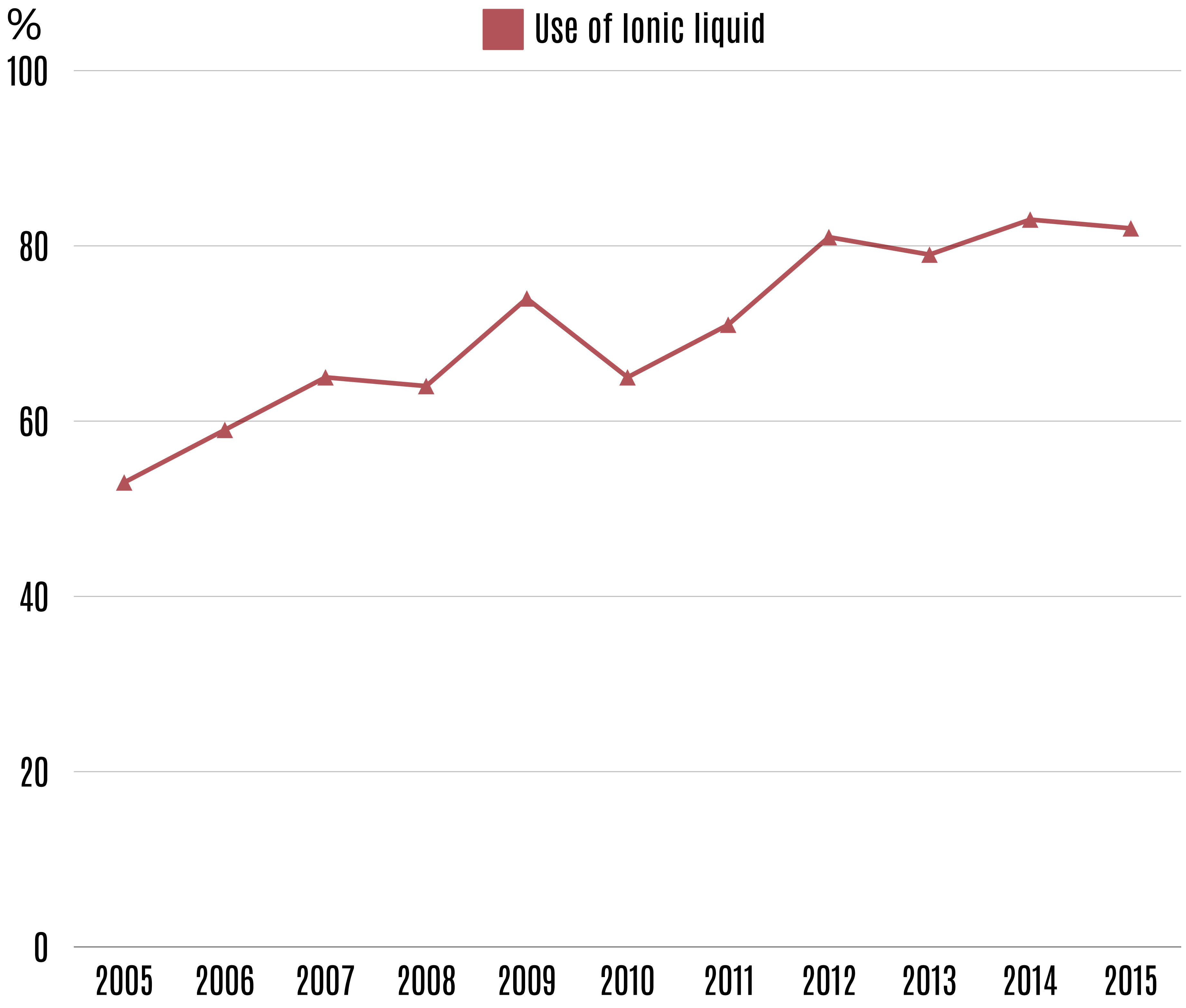
[19] Markets, Research and. "Global Bioplastics Market Surges with an 11.4% CAGR, Driven by Eco-Friendliness and Expanding Applications across Industries." Www.prnewswire.com, www.prnewswire.com/news-releases/global-bioplastics-market-surges-with-an-11-4-cagr-driven-by-eco-friendliness-and-expanding-applications-across-industries-301920642.html.

[20] Osman, A.I., Farghali, M., Dong, Y. et al. Reducing the carbon footprint of buildings using biochar-based bricks and insulating materials: a review. Environ Chem Lett 22, 71–104 (2024). https://doi.org/10.1007/s10311-023-01662-7

SAFER SOLVENTS AUXILIARIES

Water and ionic liquids: are being used as safer solvents in various chemical processes. [21]

- Many industries: pharmaceuticals, cosmetics, and food processing, are using safer solvents to minimize environmental and health risks while enhancing or maintaining process efficiency. [22]



Graph 3.5 Chart showing the percentage of the using of ionic liquid [23]

[21] Wagare, D.S., Shirsath, S.E., Shaikh, M. et al. Sustainable solvents in chemical synthesis: a review. Environ Chem Lett 19, 3263–3282 (2021). https://doi.org/10.1007/s10311-020-01176-6

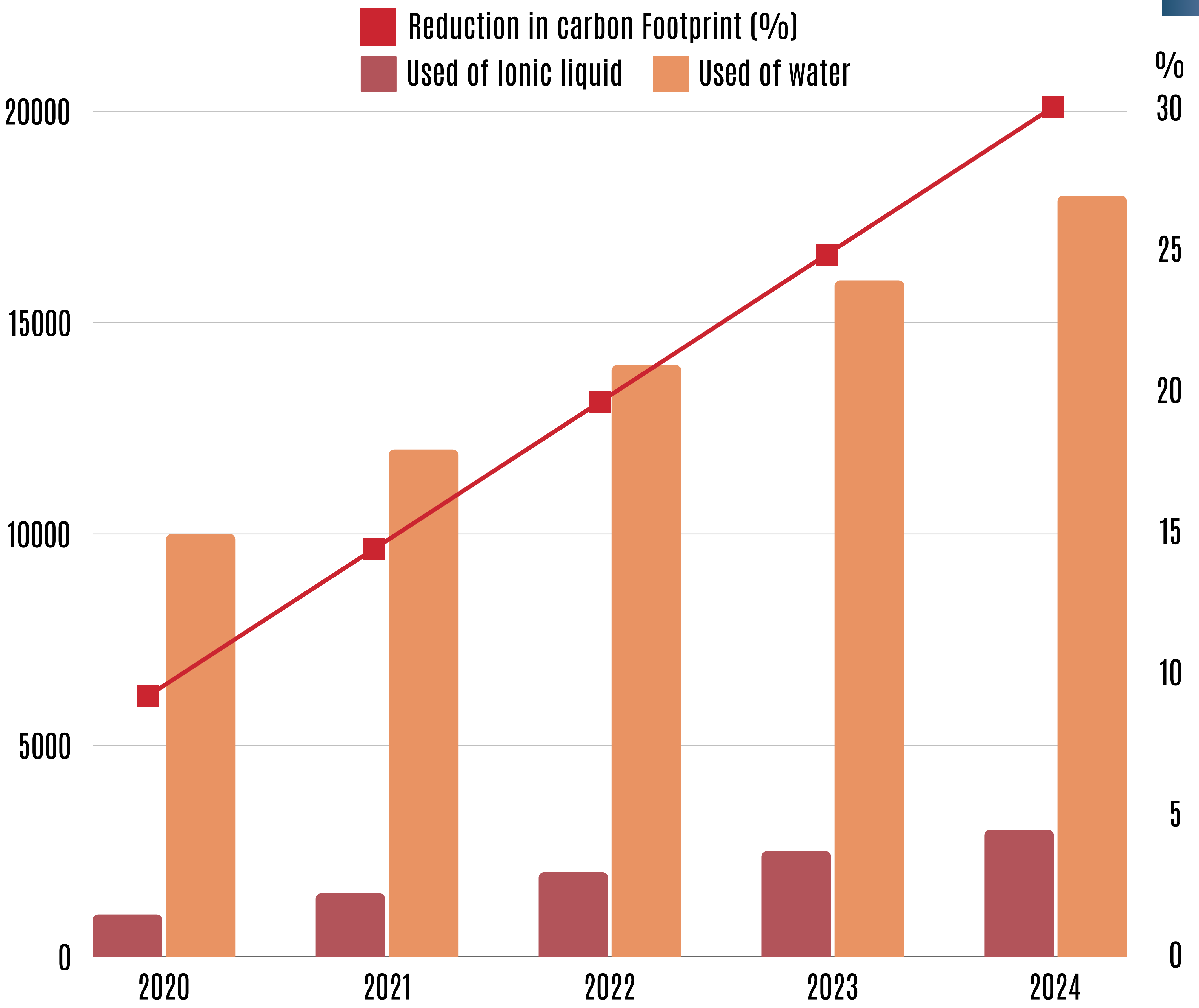
[22] Agata Wawoczny, and Danuta Gillner. "The Most Potent Natural Pharmaceuticals, Cosmetics, and Food Ingredients Isolated from Plants with Deep Eutectic Solvents." Journal of Agricultural and Food Chemistry, vol. 71, no. 29, 11 July 2023, pp. 10877–10900, https://doi.org/10.1021/acs.jafc.3c01656.

[23] M.D. Morton, C.K. Hamer, Ionic liquids – the beginning of the end or the end of the beginning?- A look at the life of ionic liquids through patent claims, Separation and Purification Technology (2017), doi: https://doi.org/10.1016/j.seppur.2017.11.023

SOLUTIONS EFFICIENCY

Recyclability

- Ionic liquids and water can often be recycled and reused multiple times while maintaining their performance.
- This reduces the need for constant production of new solvents, thereby lowering the carbon footprint.[24]



Graph 3.6 The relationship between ionic liquids, water, and carbon footprint over the years from 2020 [25]

[24] Unfccc.int, 2024, unfccc.int/news/new-un-climate-change-report-shows-national-climate-plans-fall-miles-short-of-what-s-needed.
[25] Shukla, Shashi Kant, et al. "Ionic Liquids: Potential Materials for Carbon Dioxide Capture and Utilization." Frontiers in Materials, vol. 6, 22 Mar. 2019, https://doi.org/10.3389/fmats.2019.00042.

DESIGN FOR ENERGY EFFICIENCY

Energy-efficient technologies: like LED lighting and smart thermostats reduce energy consumption and greenhouse gas emissions. [26]

- The world is increasingly applying energy-efficient technologies to reduce greenhouse gas emissions across various sectors. [27]
- The International Energy Agency (IEA) estimates that energy efficiency could deliver over 40% of the emissions reductions.

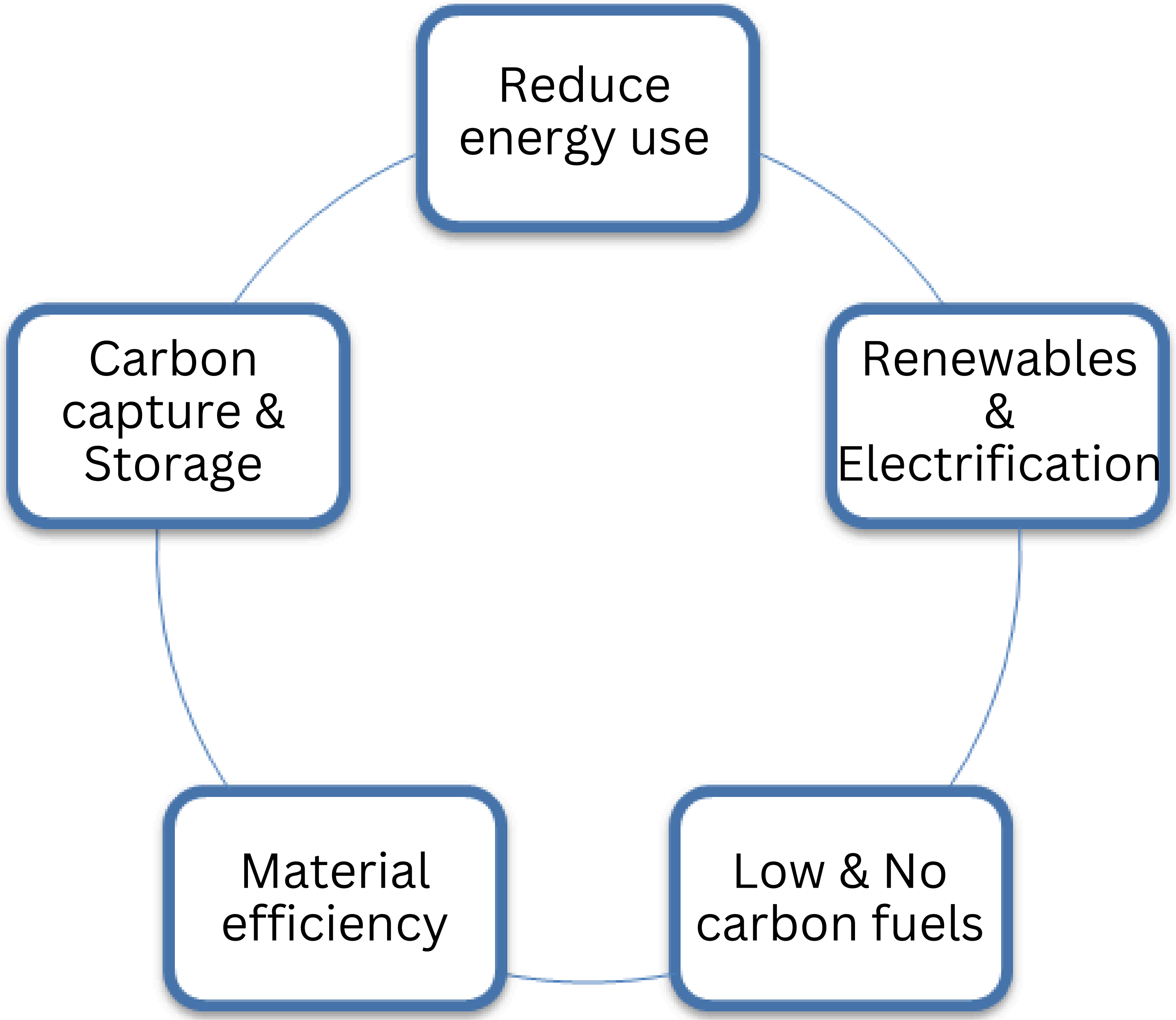


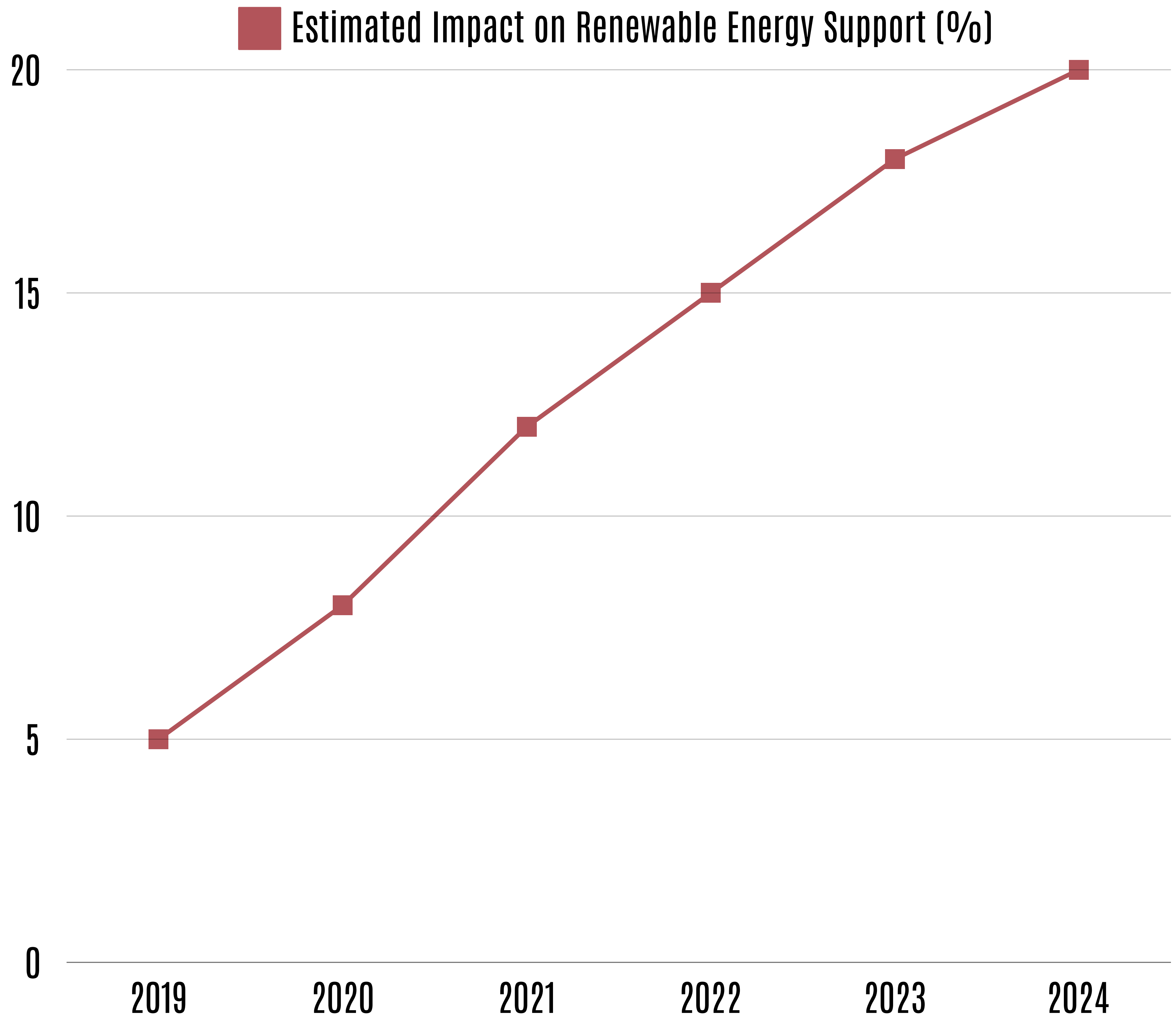
Figure 3.3 Energy efficiency is the foundation for other decarbonization strategies [28]

[26] “SML1-Understanding Smart Lighting - IEEE Smart Lighting.” Smartlighting.ieee.org, smartlighting.ieee.org/topics-ai/sml1-understanding-smart-lighting.
[27]Fischer, Alyssa. “How Energy Efficiency Will Power Net-Zero Climate Goals – Analysis.” IEA, 29 Mar. 2021, www.iea.org/commentaries/how-energy-efficiency-will-power-net-zero-climate-goals.
[28] “Energy Efficiency Reduces Industrial Carbon Emissions.” Www.energystar.gov, www.energystar.gov/industrial_plants/decarbonizing_industry/energy_efficiency_reduces_industrial_carbon_emissions.

SOLUTIONS EFFICIENCY

Support for Renewable Energy:
These technologies enhance renewable energy systems by lower the total energy load, making it easier to meet energy needs with sustainable sources. [29]

Environmental Protection:
Less energy use means fewer pollutants in the atmosphere, leading to improved air quality and a healthier environment.



Graph 3.7 The estimated percentage impact of energy-efficient technologies on supporting renewable energy from 2019 to 2024 [30]

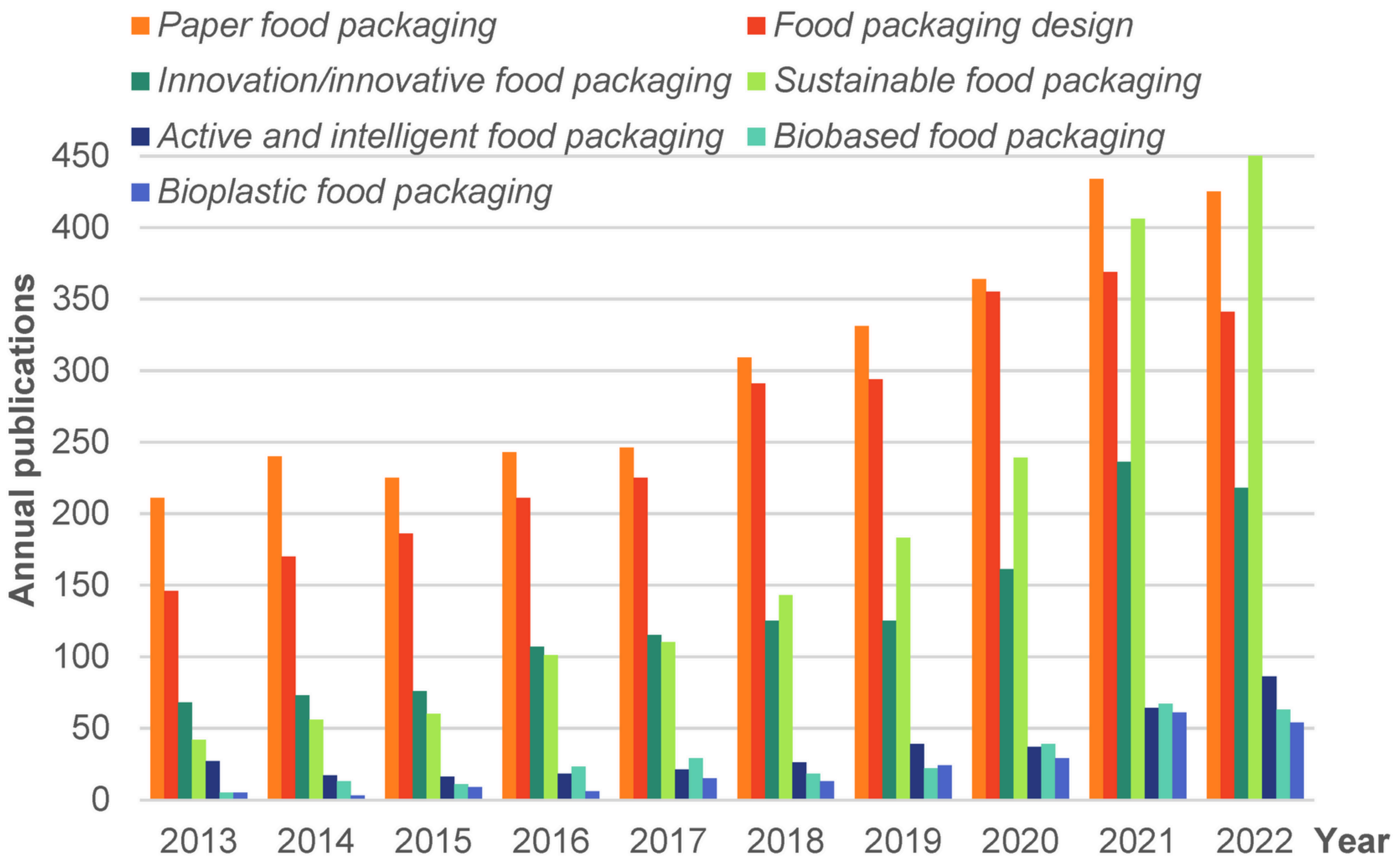
[29] “Introduction to System Integration of Renewables – Analysis.” IEA, www.iea.org/reports/introduction-to-system-integration-of-renewables?mode=overview.
[30] Nations, United. “The Impact of Renewable Energy Technologies on Global Energy Efficiency.” United Nations, Dec. 2015, www.un.org/en/chronicle/article/impact-renewable-energy-technologies-global-energy-efficiency.

USE OF RENEWABLE FEEDSTOCKS

Bio-based materials:

Materials from biological sources, like bioplastics made from corn or sugarcane, are replacing petroleum-based products. [31]

- The use of bio-based materials is increasing.
- These materials help reduce dependence on fossil fuels and lower greenhouse gas emissions. [32]



Graph 3.8 Total number of publications reported in literature in the last ten years on food packaging for specific keywords [33]

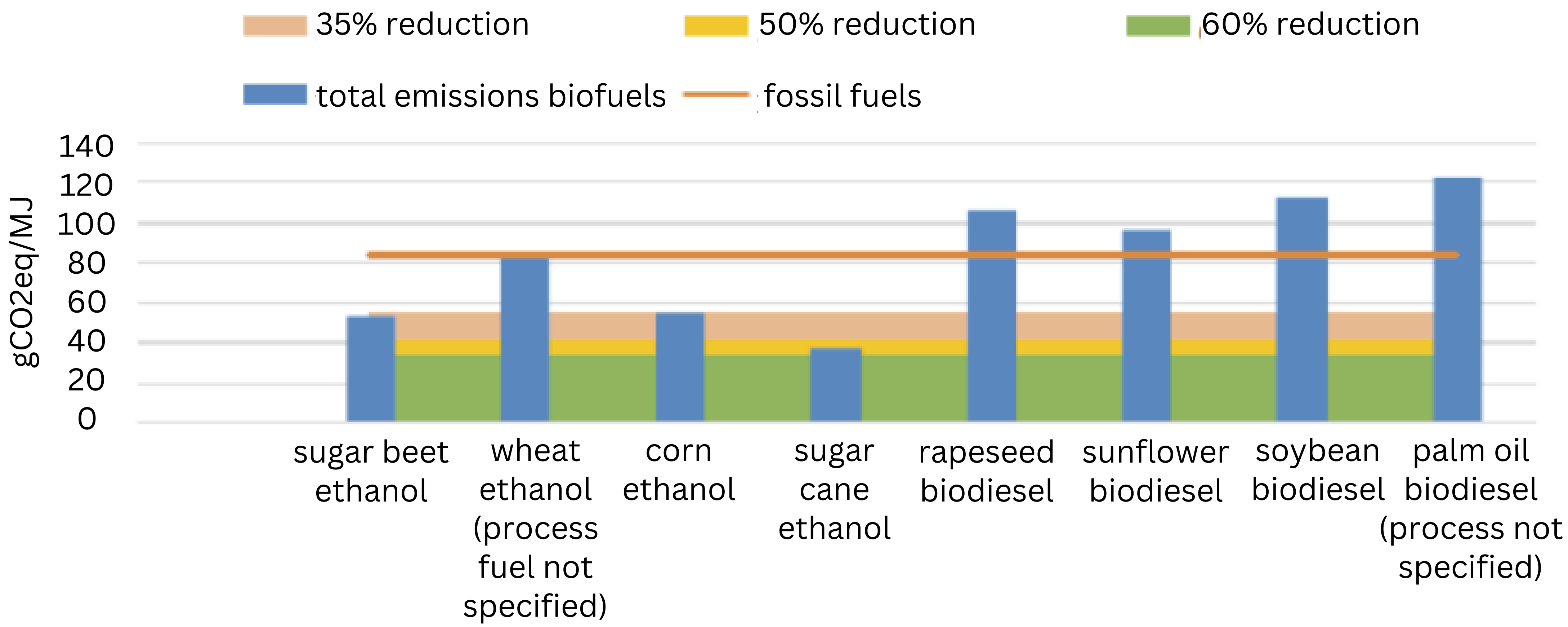
[31] Morais, A.M.M.B., Morais, R.M.S.C., Lackner, M. (2024). Biodegradable Bio-Based Plastics Toward Climate Change Mitigation. In: Lackner, M., Sajjadi, B., Chen, WY. (eds) Handbook of Climate Change Mitigation and Adaptation. Springer, New York, NY. https://doi.org/10.1007/978-1-4614-6431-0_91-3

[32]Singh, P., Verma, R. (2020). Bioplastics: A Green Approach Toward Sustainable Environment. In: Singh, A., Srivastava, S., Rathore, D., Pant, D. (eds) Environmental Microbiology and Biotechnology. Springer, Singapore. https://doi.org/10.1007/978-981-15-6021-7_3

[33] Versino, Florencia, et al. "Sustainable and Bio-Based Food Packaging: A Review on Past and Current Design Innovations." Foods, vol. 12, no. 5, 1 Jan. 2023, p. 1057. Mdpi, www.mdpi.com/2304-8158/12/5/1057, https://doi.org/10.3390/foods12051057.

SOLUTIONS EFFICIENCY

Decreased Dependence on Fossil Fuels: By using biomass instead of petroleum-based raw materials, we can reduce our reliance on fossil fuels and associated greenhouse gas emissions. [34]



Graph 3.9 Biofuel policy-estimated emissions versus fossil fuel emissions [35]

Energy Efficiency: Some bio-based materials require less energy to produce, further reducing their overall greenhouse gas footprint.

[34] U.S. Energy Information Administration. "Biomass and the Environment." Eia.gov, 7 Nov. 2022, www.eia.gov/energyexplained/biomass/biomass-and-the-environment.php.
[35] Bentivoglio, Deborah, and Michele Rasetti. "Biofuel Sustainability: Review of Implications for Land Use and Food Price." Italian Review of Agricultural Economics, vol. 70, no. 1, 25 Sept. 2015, pp. 7–31, oajournals.fupress.net/index.php/rea/article/view/9819, https://doi.org/10.13128/REA-16975.

REDUCE DERIVATIVES

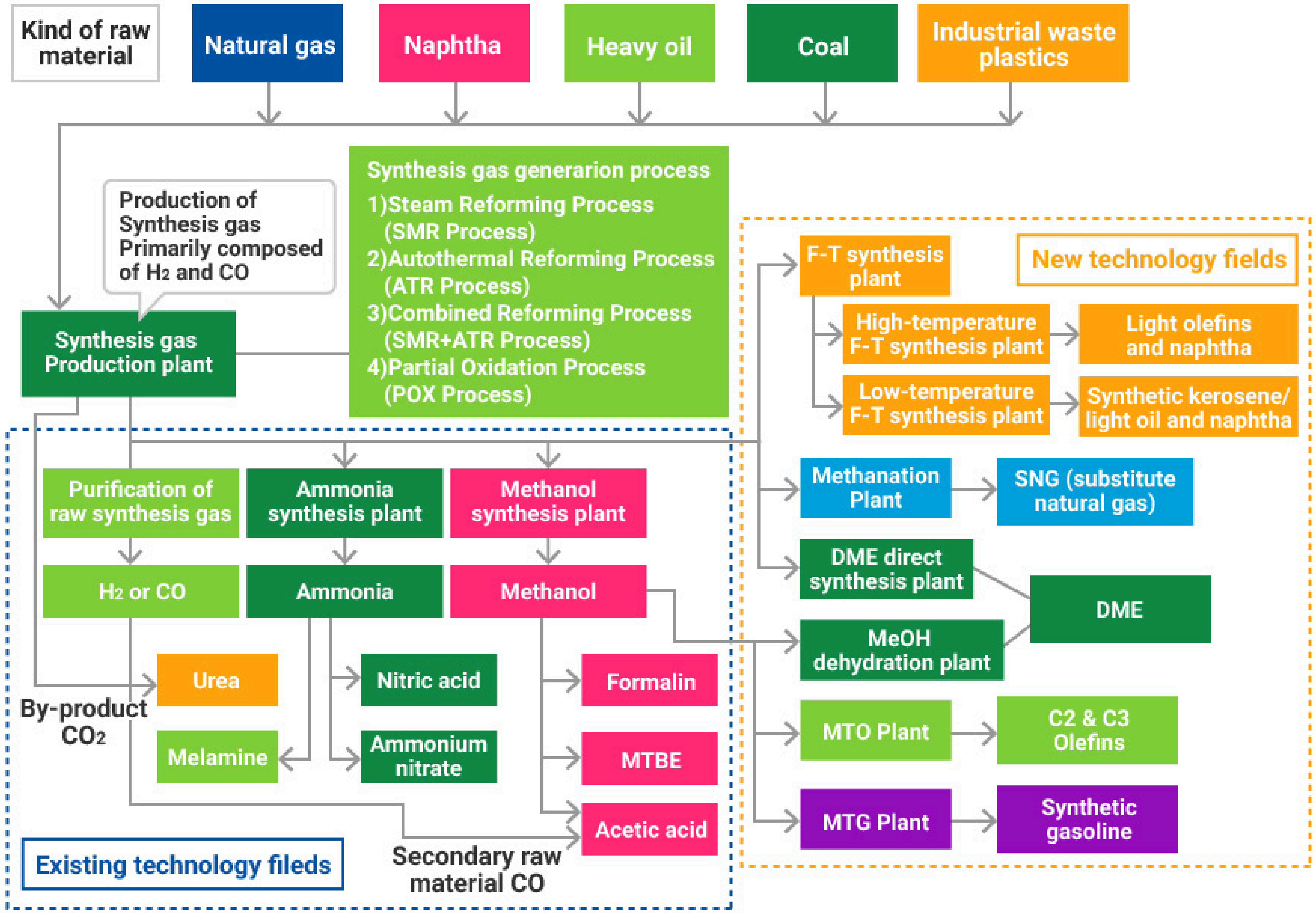


Figure 3.4 Process of using Direct synthesis methods to produce Syngas from Greenhouse Gases [38]

Direct synthesis methods:

Direct methods in pharmaceuticals and other industries minimize unnecessary steps and reagents, reducing waste and improving efficiency. [36]

- Adoption of these methods is growing across various sectors, including pharmaceuticals, chemicals, and energy, as industries seek to reduce their environmental impact and meet stricter regulations.
- The adoption of direct synthesis methods have significantly reductions in waste and cost. [37]

[36] Barker, Graeme, and Simona Rapposelli. "New Synthetic Methodology for Drug-like Molecules." Molecules, vol. 28, no. 15, 26 July 2023, p. 5632, www.ncbi.nlm.nih.gov/pmc/articles/PMC10419429/, https://doi.org/10.3390/molecules28155632.
[37] Ahmad, Sageer, et al. "Recent Advances in Green Chemistry Approaches for Pharmaceutical Synthesis." Sustainable Chemistry One World, Oct. 2024, p. 100029, https://doi.org/10.1016/j.scowo.2024.100029.
[38] "Synthesis Gas and Derivatives | CHIYODA CORPORATION." CHIYODA CORPORATION, www.chiyodacorp.com/en/service/gtl/.

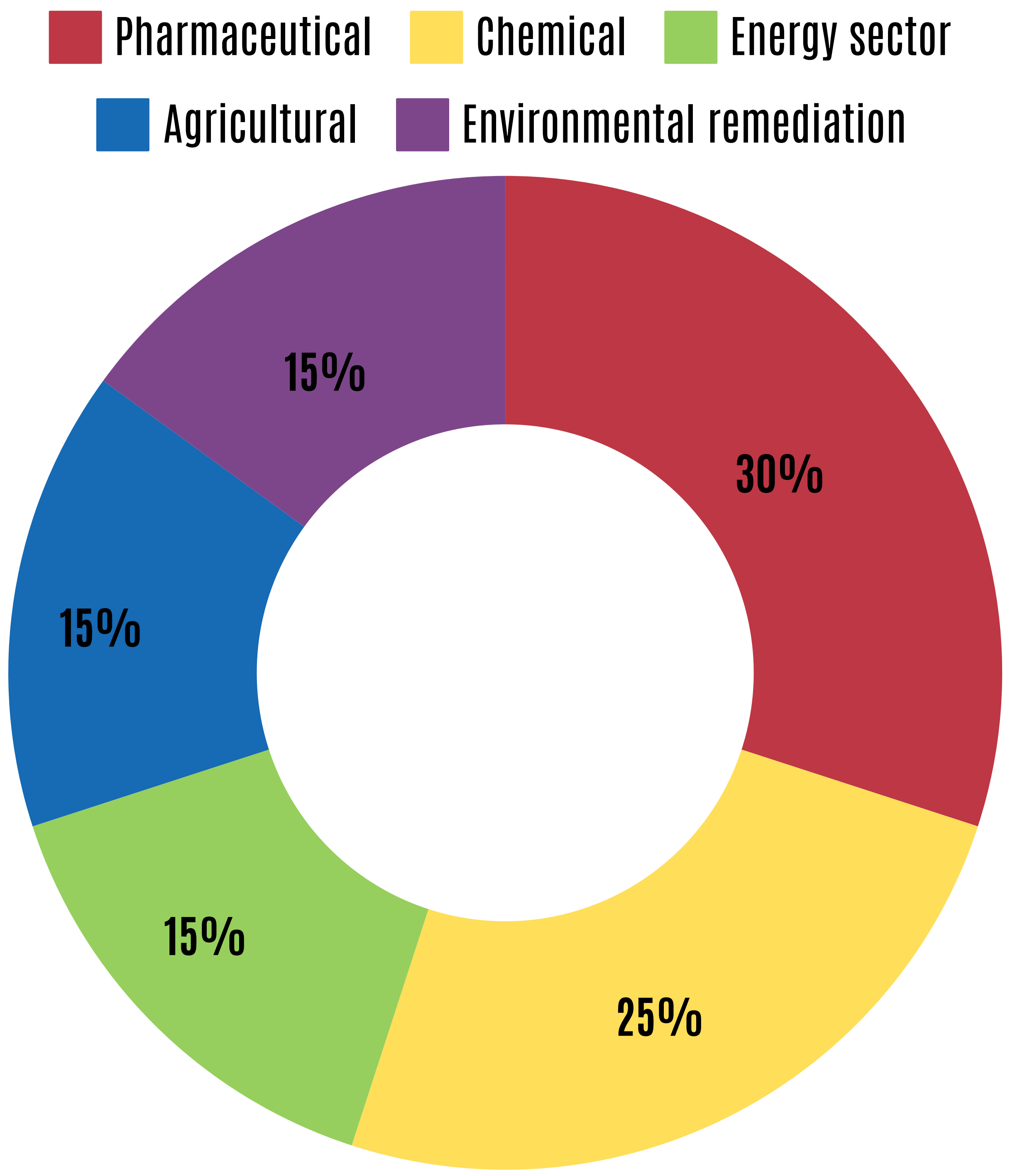
SOLUTIONS EFFICIENCY

Waste Reduction

Direct synthesis reduces the generation of waste byproducts, contributing to a cleaner environment. [39]

Energy Efficiency

These methods often require less energy for production, resulting in reduced energy consumption and lower emissions. [39]



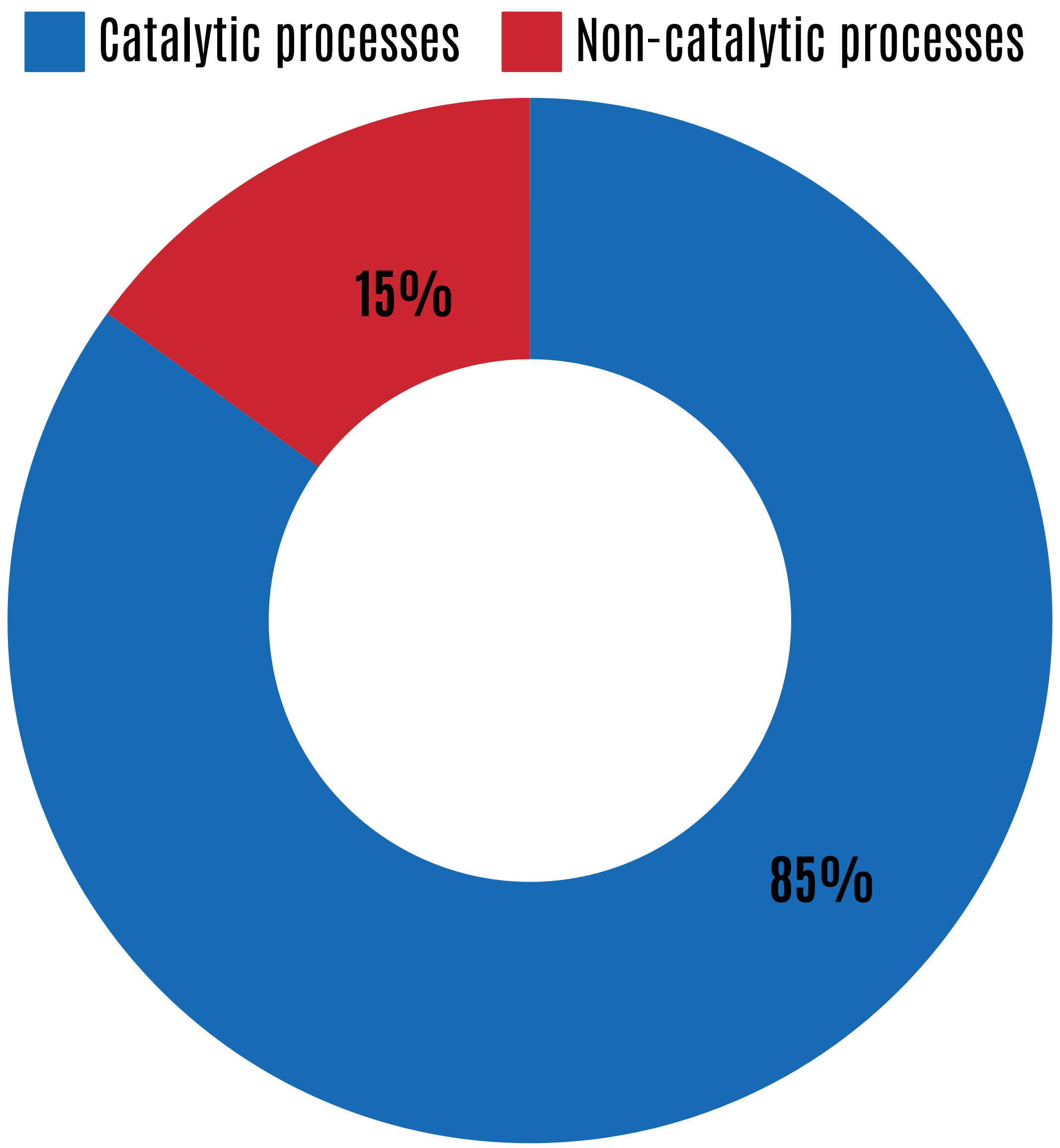
Graph 3.10 The waste reduction in various industries [40]

[39] Marlin, Dana S., et al. “Process Advantages of Direct CO2 to Methanol Synthesis.” Frontiers in Chemistry, vol. 6, 27 Sept. 2018, www.frontiersin.org/articles/10.3389/fchem.2018.00446/full, https://doi.org/10.3389/fchem.2018.00446.

[40] Yimer, Ali Mohammed, et al. “Direct Synthesis of Multiple Heteroatoms Functionalized Mesoporous Silica Adsorbents from Phosphate Industry Mining Byproducts. Decontaminating Water from Pb(Ii) Ions as an Application Case.” Journal of Materials Chemistry A, vol. 12, no. 43, 2024, pp. 29669–29683, https://doi.org/10.1039/d4ta05281a.

CATALYSIS

Catalytic processes: are used to convert CO_2 into useful chemicals, such as methanol, which can be used as fuel or a chemical feedstock. [41]



Graph 3.11 The contribution of catalytic processes to the chemical industry [43]

- Catalysis is widely used in in the production of chemicals, fuels, and pharmaceuticals.
- Catalytic processes are highly effective in reducing energy consumption and waste. [42]

[41] Zhang, Xinbao, et al. “Catalytic Conversion of Carbon Dioxide to Methanol: Current Status and Future Perspective.” Frontiers in Energy Research, vol. 8, 9 Feb. 2021, https://doi.org/10.3389/fenrg.2020.621119.
[42] Li, Kailing, et al. “Forecasting Greenhouse Gas Emissions with the New Information Priority Generalized Accumulative Grey Model.” Science of the Total Environment, vol. 807, 10 Feb. 2022, p. 150859, www.sciencedirect.com/science/article/pii/S0048969721059374, https://doi.org/10.1016/j.scitotenv.2021.150859.
[43] Wacławek, Stanisław, et al. “Major Advances and Challenges in Heterogeneous Catalysis for Environmental Applications: A Review.” Ecological Chemistry and Engineering S, vol. 25, no. 1, 1 Mar. 2018, pp. 9–34, https://doi.org/10.1515/eces-2018-0001.

SOLUTIONS EFFICIENCY

Reduction of Harmful Emissions: Catalytic technologies can effectively reduce emissions of non-CO_2 greenhouse gases, such as methane (CH_4) and nitrous oxide (N_2O), by converting them into less harmful substances.[44]

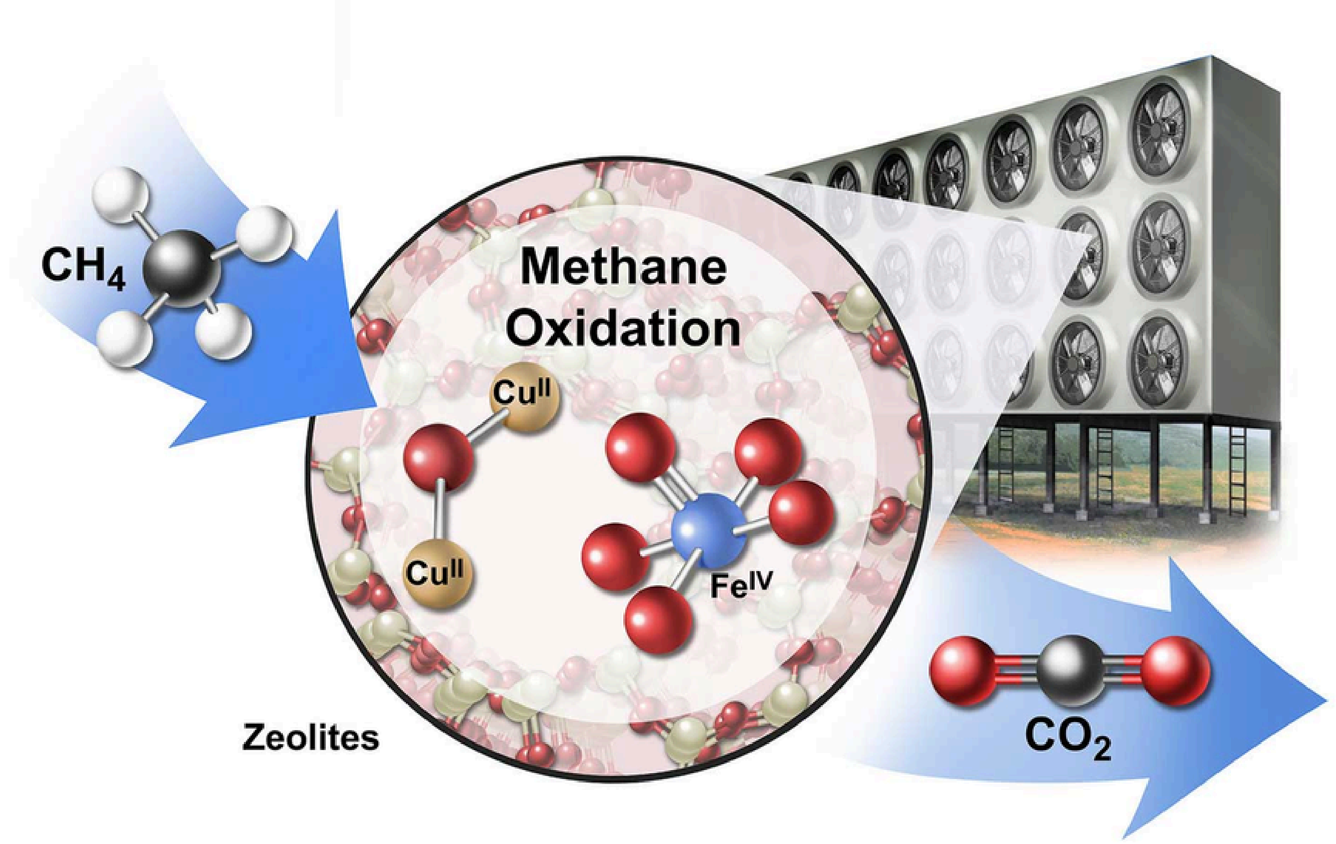


Figure 3.5 Process of converting CH_4 to CO_2

Greenhouse Gas	Catalytic Process	Reduction Mechanism	Reduction percentage (%)
Methane (CH_4)	Catalytic Combustion	Converts CH_4 to CO_2	80-90%
Nitrous Oxide (N_2O)	Catalytic Decomposition	Converts N_2O to N_2	70-85%
Fluorocarbons (F-gases)	Catalytic Conversion	Converts F-gases to less harmful chemicals	60-75%

Table 3.3 The reduction of harmful emissions by using catalytic processes [45]

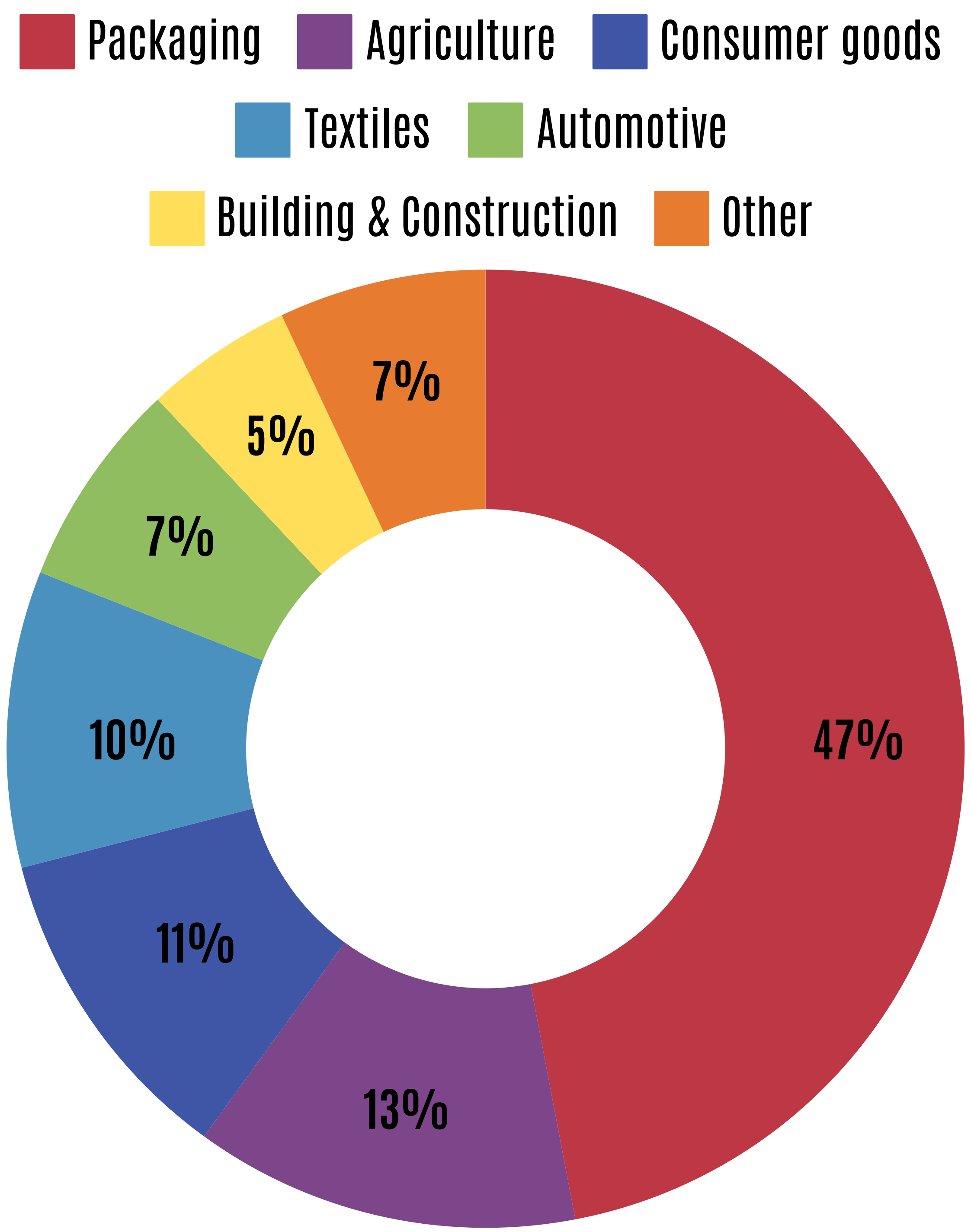
[44] Centi, G., Perathoner, S. (2024). Reduction of Non-CO2 Greenhouse Gas Emissions by Catalytic Processes. In: Lackner, M., Sajjadi, B., Chen, WY. (eds) Handbook of Climate Change Mitigation and Adaptation. Springer, New York, NY. https://doi.org/10.1007/978-1-4614-6431-0_49-4
[45] Centi, G., Perathoner, S. (2017). Reduction of Greenhouse Gas Emissions by Catalytic Processes. In: Chen, WY., Suzuki, T., Lackner, M. (eds) Handbook of Climate Change Mitigation and Adaptation. Springer, Cham. https://doi.org/10.1007/978-3-319-14409-2_49

DESIGN FOR DEGRADATION

Biodegradable materials:

Products like biodegradable packaging materials are designed to break down into non-toxic components after use. [46]

- Industries such as packaging and consumer goods are increasingly.
- Biodegradable plastics and other materials have been effective in reducing plastic pollution.

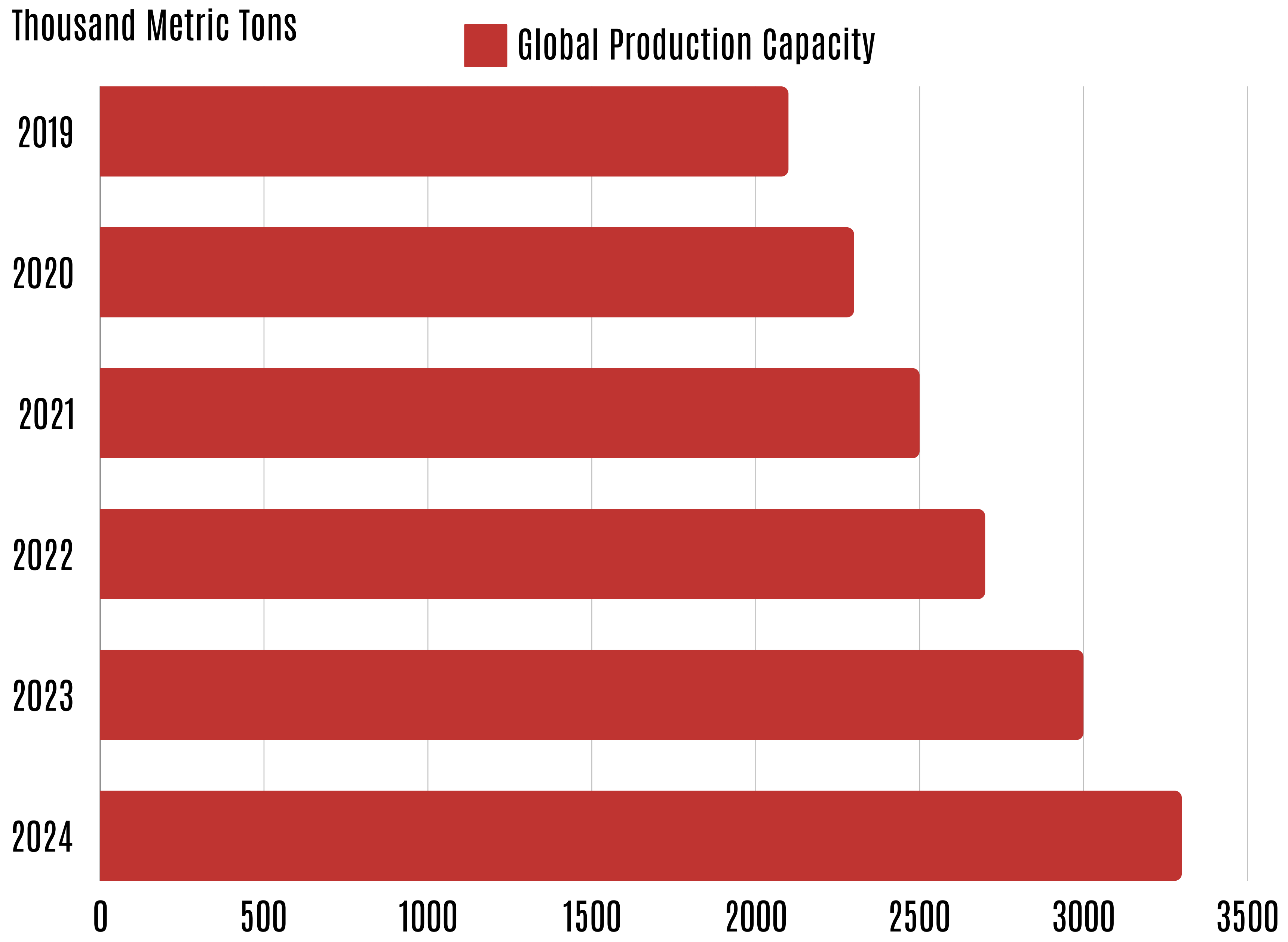


Graph 3.12 The use of biodegradable materials in various industries in 2020 [47]

[46] Ali, G.A.M., Thalji, M.R., Makhlouf, A.S.H. (2022). Biodegradable Materials: Fundamentals, Importance, and Impacts. In: Ali, G.A.M., Makhlouf, A.S.H. (eds) Handbook of Biodegradable Materials. Springer, Cham. https://doi.org/10.1007/978-3-030-83783-9_74-1

[47] Younis, Heba, et al. "An Overview of Biodegradable Polymers and Types of Bioplastics: Properties and Applications." Intechopen.com, 12 Nov. 2024, www.intechopen.com/online-first/1201338, https://doi.org/10.5772/intechopen.1007621.

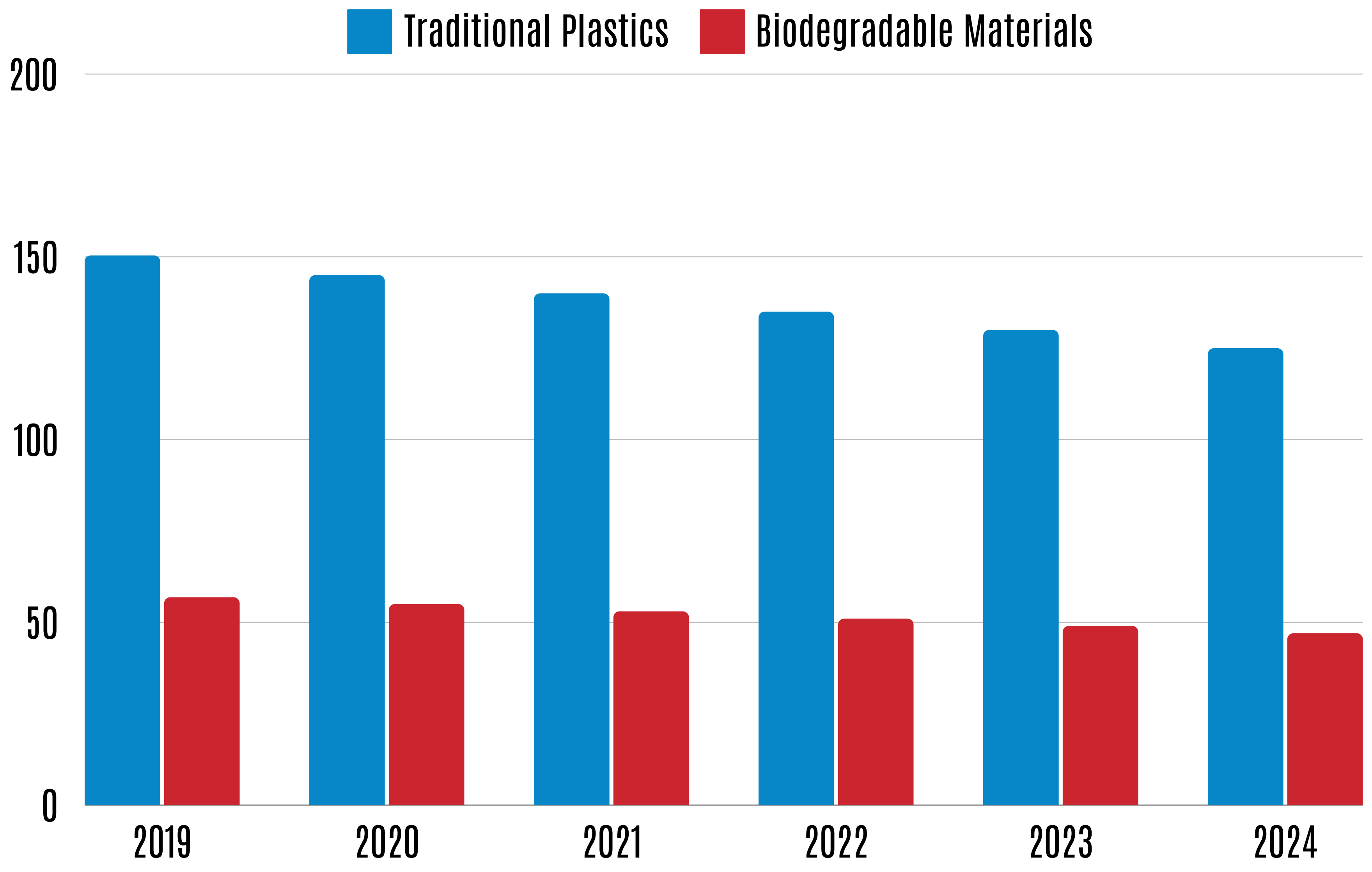
SOLUTIONS EFFICIENCY



Graph 3.13 The global production capacity of biodegradable materials from 2019 to 2024

The global production capacity for biodegradable plastics has been rising, with significant growth expected in the coming years.

Lower Emissions:
The production of biodegradable materials typically generates fewer greenhouse gases compared to conventional plastics made from fossil fuels.[49]



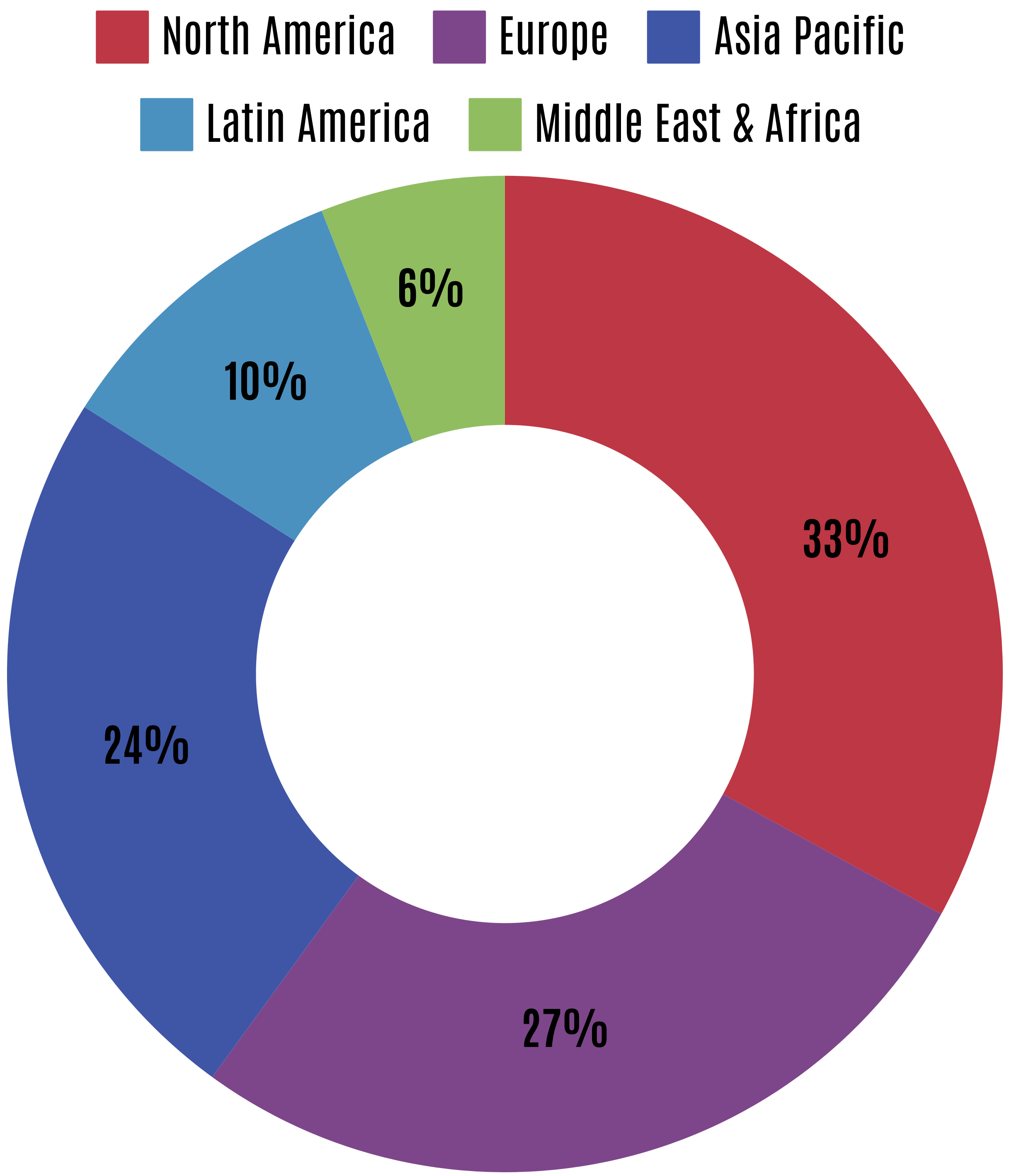
Graph 3.14 Comparing the greenhouse gas emissions of traditional plastics and biodegradable materials over the years [50]

[48] "Topic: Bioplastics Industry Worldwide." Statista, www.statista.com/topics/8744/bioplastics-industry-worldwide/.
[49] Coppola, G., Gaudio, M.T., Lopresto, C.G. et al. Bioplastic from Renewable Biomass: A Facile Solution for a Greener Environment. Earth Syst Environ 5, 231–251 (2021). https://doi.org/10.1007/s41748-021-00208-7
[50] Engineering. "Study: Replacing Plastics with Biodegradable Alternatives Would Lead to Significant Carbon Emissions Reduction." Phys.org, phys.org/news/2024-02-plastics-biodegradable-alternatives-significant-carbon.html.

REAL TIME ANALYSIS FOR POLLUTION PREVENTION

Advanced monitoring systems: in industrial plants help detect and reduce emissions in real-time. [51]

- These systems become more sophisticated and widely used, improving overall environmental performance.
- The World Meteorological Organization (WMO) aims to provide precise, actionable data on global GHG net fluxes using enhanced observational networks and data integration to help countries track progress and make informed decisions in their climate actions. [52]



Graph 3.15 Emission monitoring systems market share, by region in 2023 (%) [53]

[51] Vavra, Chris. "Improve Plant Uptime with Advanced Sensing Systems." Plant Engineering, 9 Apr. 2020, www.plantengineering.com/articles/improve-plant-uptime-with-advanced-sensing-systems/.
[52]"Global Greenhouse Gas Watch (G3W)." World Meteorological Organization, 22 Aug. 2024, g3w.wmo.int/site/global-greenhouse-gas-watch-g3w.
[53] "Search Reports - Precedence Research." Precedenceresearch.com, 2024, www.precedenceresearch.com/emission-monitoring-system-market.

SOLUTIONS EFFICIENCY

Real-Time Monitoring: Advanced technologies enable real-time monitoring, allowing for immediate detection and response to emission spikes. [54]

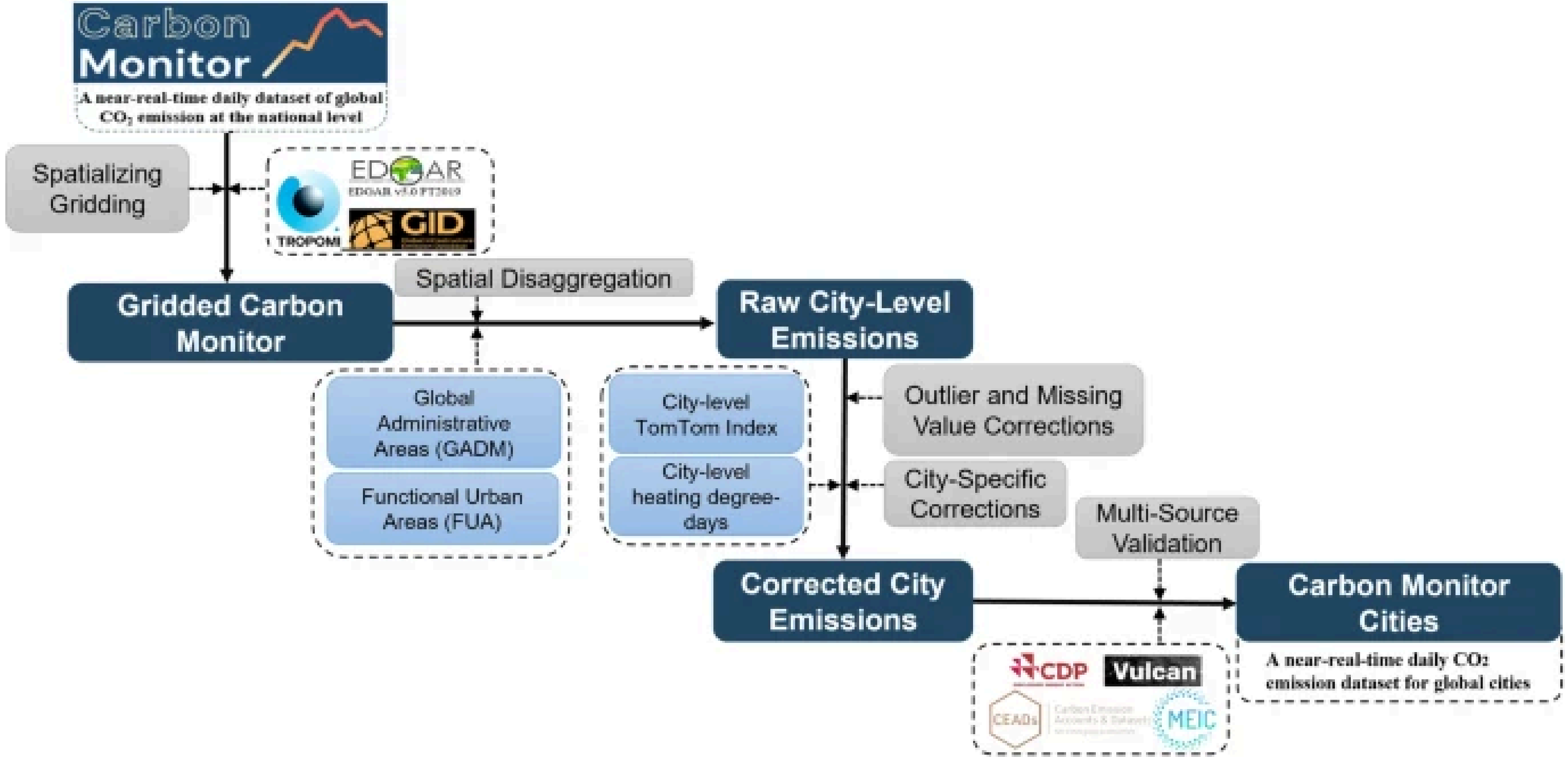


Figure 3.6 The main workflow othe Carbon Monitor [55]

Public Awareness: Transparent monitoring systems increase public awareness and accountability, driving collective action towards emission reduction.[56]

[54] Greenhouse Gas Monitoring Technologies.https://archive.epa.gov/nrmrl/archive-etv/web/pdf/p1005ku4.pdf

[55] Huo, D., Huang, X., Dou, X. et al. Carbon Monitor Cities near-real-time daily estimates of CO2 emissions from 1500 cities worldwide. Sci Data 9, 533 (2022). https://doi.org/10.1038/s41597-022-01657-z

[56] Sun, Y., Yin, H., Wang, W., Shan, C., Notholt, J., Palm, M., Liu, K., Chen, Z., and Liu, C.: Monitoring greenhouse gases (GHGs) in China: status and perspective, Atmos. Meas. Tech., 15, 4819–4834, https://doi.org/10.5194/amt-15-4819-2022, 2022.

INHERENTLY SAFER CHEMISTRY FOR ACCIDENT PREVENTION

The use of less volatile and less toxic chemicals: reduces the risk of accidents, using less hazardous chemicals and designing processes that operate under safer conditions. [57]

- Leading to a reduction in industrial accidents and improved safety in chemical manufacturing.
- Replacing traditional solvents with less volatile alternatives can reduce volatile organic compound (VOC) emissions by up to 90%. [58]

Figure 3.7 Eco-friendly cleaning products do not release VOCs [59]

[57] Wagare, D.S., Shirsath, S.E., Shaikh, M. et al. Sustainable solvents in chemical synthesis: a review. Environ Chem Lett 19, 3263–3282 (2021). https://doi.org/10.1007/s10311-020-01176-6
[58] Crawford, S.E., Hartung, T., Hollert, H. et al. Green Toxicology: a strategy for sustainable chemical and material development. Environ Sci Eur 29, 16 (2017). https://doi.org/10.1186/s12302-017-0115-z
[59] Carlos, Eco-Friendly Cleaning: Combat Climate Change, March 2 2024, https://zerohourclimate.org/use-natural-cleaning-products-climate-change/

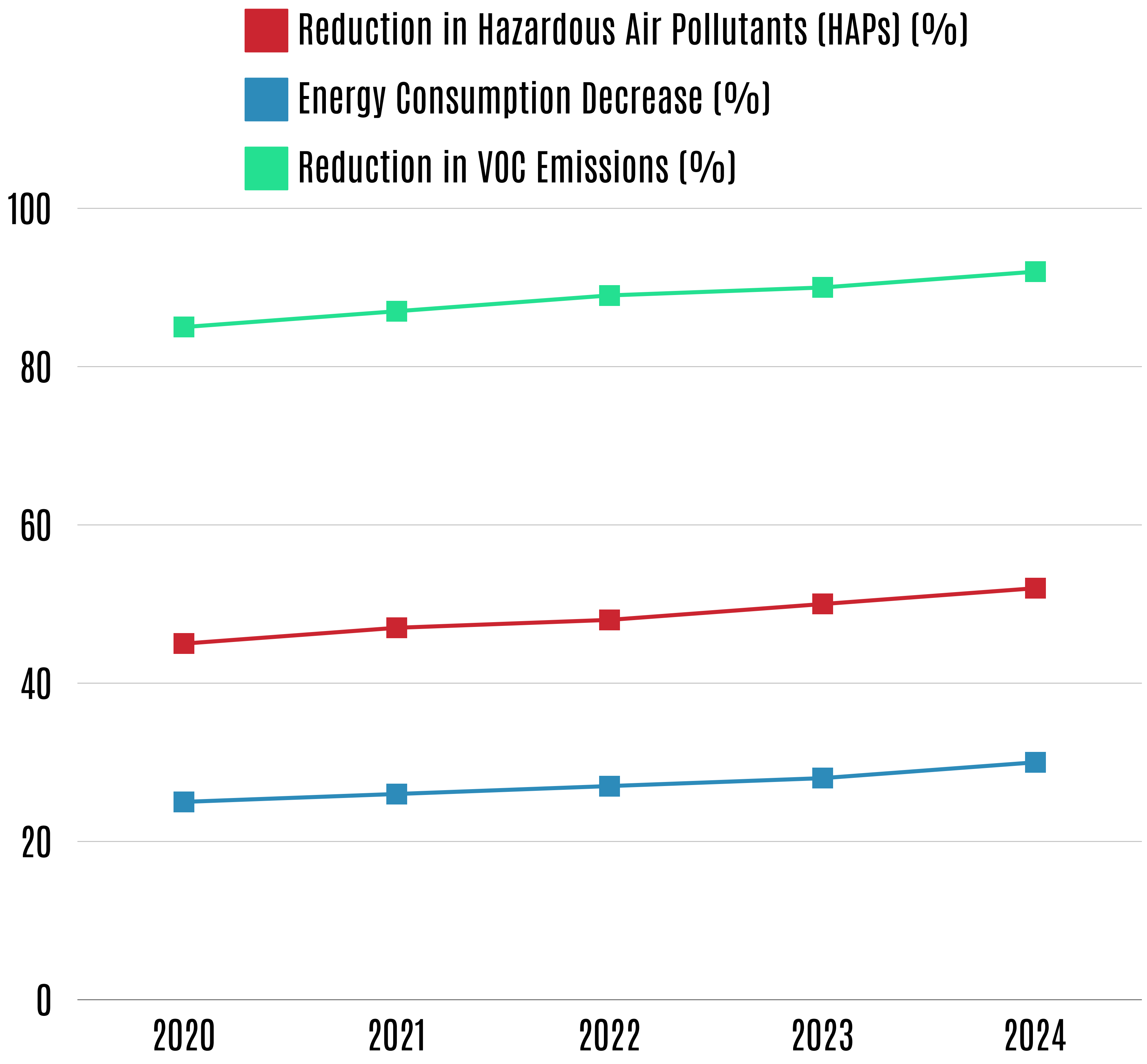
SOLUTIONS EFFICIENCY

Improved Air Quality:

By minimizing the release of harmful substances, air quality improves, benefiting both the environment and public health. [60]

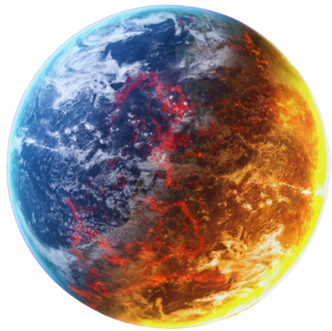
Energy Efficiency:

Green solvents often require less energy for production and use, resulting in a 20-30% decrease in energy consumption. [61]



Graph 3.16 The impact of less volatile and less toxic chemicals on air quality improvement [62]

[60] Crawford, S.E., Hartung, T., Hollert, H. et al. Green Toxicology: a strategy for sustainable chemical and material development. Environ Sci Eur 29, 16 (2017). https://doi.org/10.1186/s12302-017-0115-z
[61] Shah, P., Parikh, S., Shah, M. et al. A holistic review on application of green solvents and replacement study for conventional solvents. Biomass Conv. Bioref. 12, 1985–1999 (2022). https://doi.org/10.1007/s13399-021-01465-2
[62] Quarmby, Sarah, et al. "Air Quality Strategies and Technologies: A Rapid Review of the International Evidence." Sustainability, vol. 11, no. 10, 14 May 2024, p. 2757, https://doi.org/10.3390/su11102757.



04 STATUS

Remarkable Event

- Global GHG emissions hit a record of 52.9 billion metric tons ($GtCO_2e$) in 2023, a 1.9% increase from 2022.
- Fossil CO_2 emissions, the main contributors to GHG emissions, have also reached a record high, rising despite climate agreements.
- CO_2 levels are currently 50% higher than pre-industrial levels, along with rising methane and nitrous oxide concentrations.

GLOBAL STATUS

[1] Crippa, M., Guizzardi, D., Pagani, F., Banja, M., Muntean, M., Schaaf, E., Monforti-Ferrario, F., Becker, W.E., Quadrelli, R., Risquez Martin, A., Taghavi-Moharamli, P., Köykkä, J., Grassi, G., Rossi, S., Melo, J., Oom, D., Branco, A., San-Miguel, J., Manca, G., Pisoni, E., Vignati, E. and Pekar, F., GHG emissions of all world countries, Publications Office of the European Union, Luxembourg, 2024, doi:10.2760/4002897, JRC138862

[2] Greenhouse Gas concentrations hit record high. Again. (2023, November 16). World Meteorological Organization. https://wmo.int/news/media-centre/greenhouse-gas-concentrations-hit-record-high-again

[8] Statista. (2024, September 26). Global greenhouse gas emissions 1970-2023. https://www.statista.com/statistics/1285502/annual-global-greenhouse-gas-emissions/

GLOBAL STATUS

Minimizing greenhouse gas (GHG) emissions such as carbon dioxide and methane is essential for addressing climate change. However, despite numerous climate commitments, global GHG emissions have continued to increase.

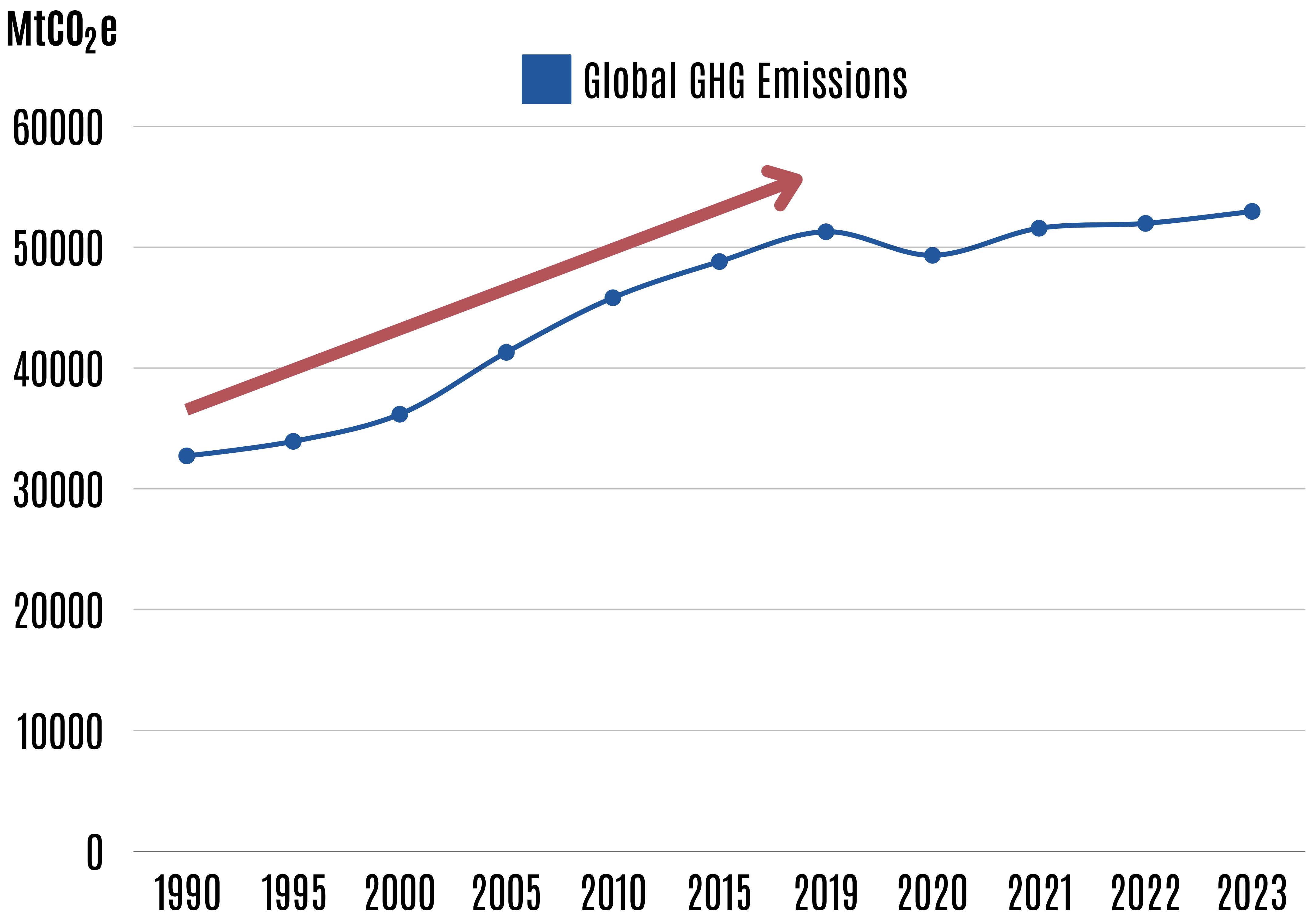
Global Temperatures

- In 2023, the global surface temperature was 1.19°C above the 20th-century average, the highest ever recorded.
- This rise reflects a long-term warming trend due to the increasing greenhouse gas levels, especially CO_2.

Biggest Contributors

- In 2023, China, the U.S., India, the EU27, Russia, and Brazil were the largest GHG emitters.
- China, India, Russia, and Brazil continue to increase their emissions.
- All EU27 nations, except Croatia and Cyprus, successfully reduced their emissions.

[1] Crippa, M., Guizzardi, D., Pagani, F., Banja, M., Muntean, M., Schaaf, E., Monforti-Ferrario, F., Becker, W.E., Quadrelli, R., Risquez Martin, A., Taghavi-Moharamli, P., Köykkä, J., Grassi, G., Rossi, S., Melo, J., Oom, D., Branco, A., San-Miguel, J., Manca, G., Pisoni, E., Vignati, E. and Pekar, F., GHG emissions of all world countries, Publications Office of the European Union, Luxembourg, 2024, doi:10.2760/4002897, JRC138862
[2] Greenhouse Gas concentrations hit record high. Again. (2023, November 16). World Meteorological Organization. https://wmo.int/news/media-centre/greenhouse-gas-concentrations-hit-record-high-again
[8] Statista. (2024, September 26). Global greenhouse gas emissions 1970-2023. https://www.statista.com/statistics/1285502/annual-global-greenhouse-gas-emissions/



Graph 4.1 Global GHG emissions from 1990 - 2023

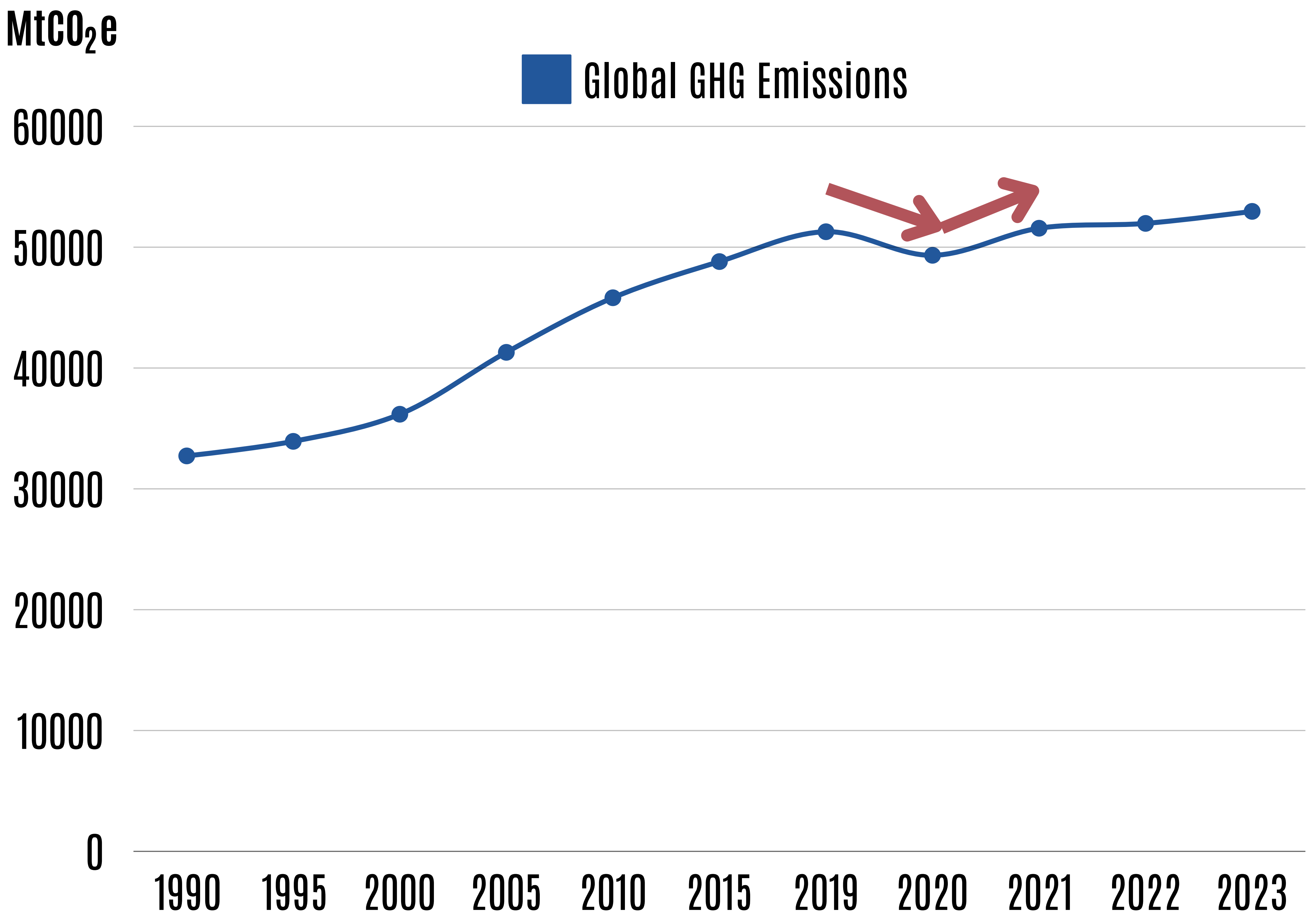
STATUS

In the world (1990 - 2019)

Since the beginning of the 21st century until 2019, global greenhouse gas (GHG) emissions have been gradually rising, by approximately 36%, mainly due to higher emissions rates from developing countries.

Therefore, the levels of greenhouse gases in the atmosphere have substantially increased, making the natural greenhouse effect stronger, which could lead to a negative impact on life on Earth.

[3] Crippa, M., Guizzardi, D., Pagani, F., Banja, M., Muntean, M., Schaaf E., Becker, W., Monforti-Ferrario, F., Quadrelli, R., Risquez Martin, A., Taghavi-Moharamli, P., Köykkä, J., Grassi, G., Rossi, S., Brandao De Melo, J., Oom, D., Branco, A., San-Miguel, J., Vignati, E., GHG emissions of all world countries, Publications Office of the European Union, Luxembourg, 2023, doi:10.2760/953322, JRC134504.



Graph 4.1 Global GHG emissions from 1990 - 2023

STATUS

In the world (2019-2021)

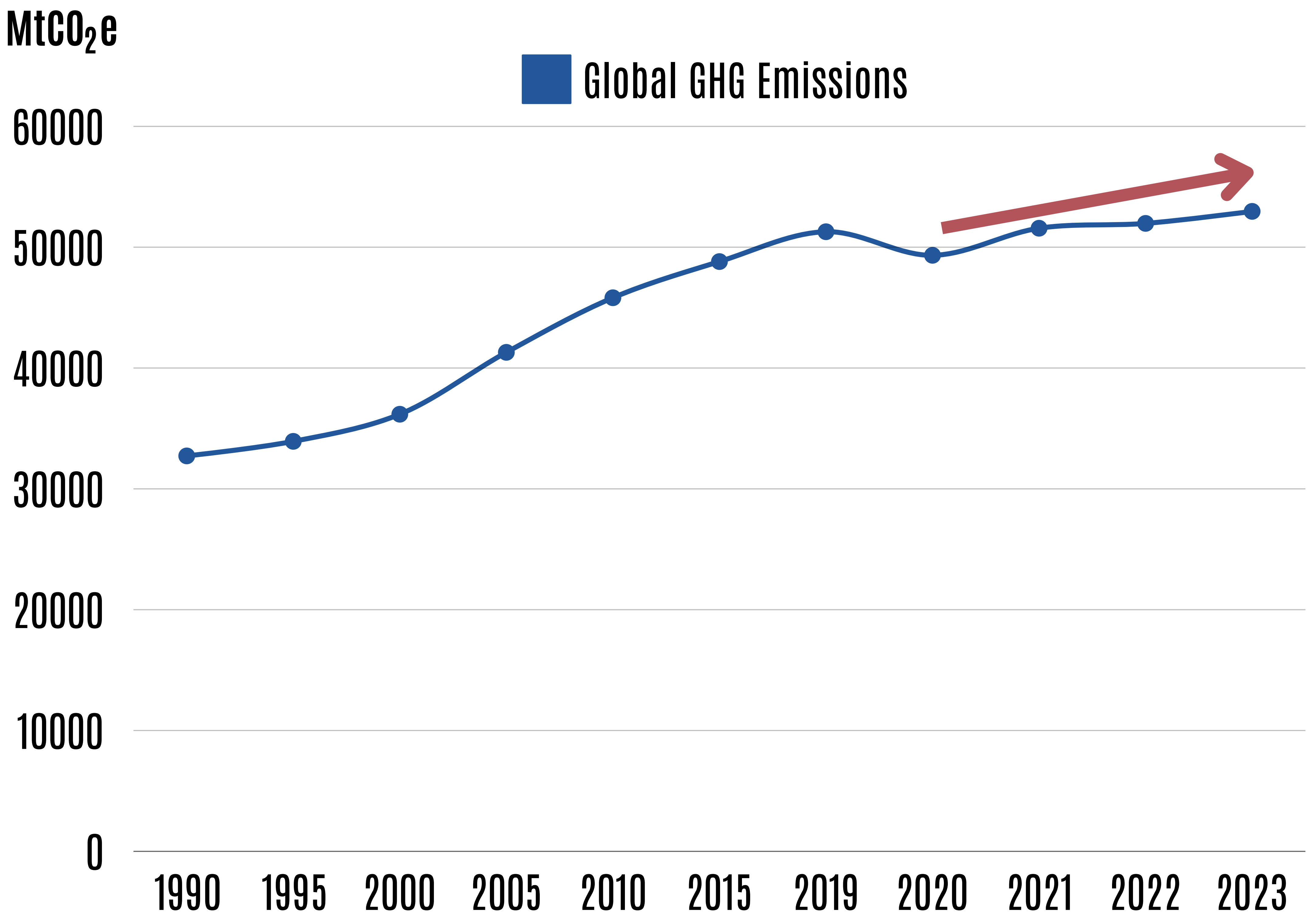
Because of the COVID-19 pandemic, global GHG emissions have decreased by 3.7% in 2020 compared to 2019. This marks a stop in a continuously increasing trend of more than ten years.

However, global GHG emissions started to grow again just after the pandemic's peak and in 2022 reaching the level of 51.9 Gt CO2eq, which is 1.3% higher than in 2019 and 0.78% higher than in 2021.

[3] Crippa, M., Guizzardi, D., Pagani, F., Banja, M., Muntean, M., Schaaf E., Becker, W., Monforti-Ferrario, F., Quadrelli, R., Risquez Martin, A., Taghavi-Moharamli, P., Köykkä, J., Grassi, G., Rossi, S., Brandao De Melo, J., Oom, D., Branco, A., San-Miguel, J., Vignati, E., GHG emissions of all world countries, Publications Office of the European Union, Luxembourg, 2023, doi:10.2760/953322, JRC134504.

STATUS

In the world (2021-2023)



Graph 4.1 Global GHG emissions from 1990 - 2023

Regardless of the slowing down of global emissions in 2020 caused by the global COVID-19 pandemic, climate change remains an issue.

Global GHG emissions in 2023 reached 52.9 Gt CO2eq, representing the highest level recorded and experienced an increase of 1.9% or about 994 Mt CO2eq compared to the emission levels in 2022.

[1] Crippa, M., Guizzardi, D., Pagani, F., Banja, M., Muntean, M., Schaaf, E., Monforti-Ferrario, F., Becker, W.E., Quadrelli, R., Risquez Martin, A., Taghavi-Moharamli, P., Köykkä, J., Grassi, G., Rossi, S., Melo, J., Oom, D., Branco, A., San-Miguel, J., Manca, G., Pisoni, E., Vignati, E. and Pekar, F., GHG emissions of all world countries, Publications Office of the European Union, Luxembourg, 2024, doi:10.2760/4002897, JRC138862

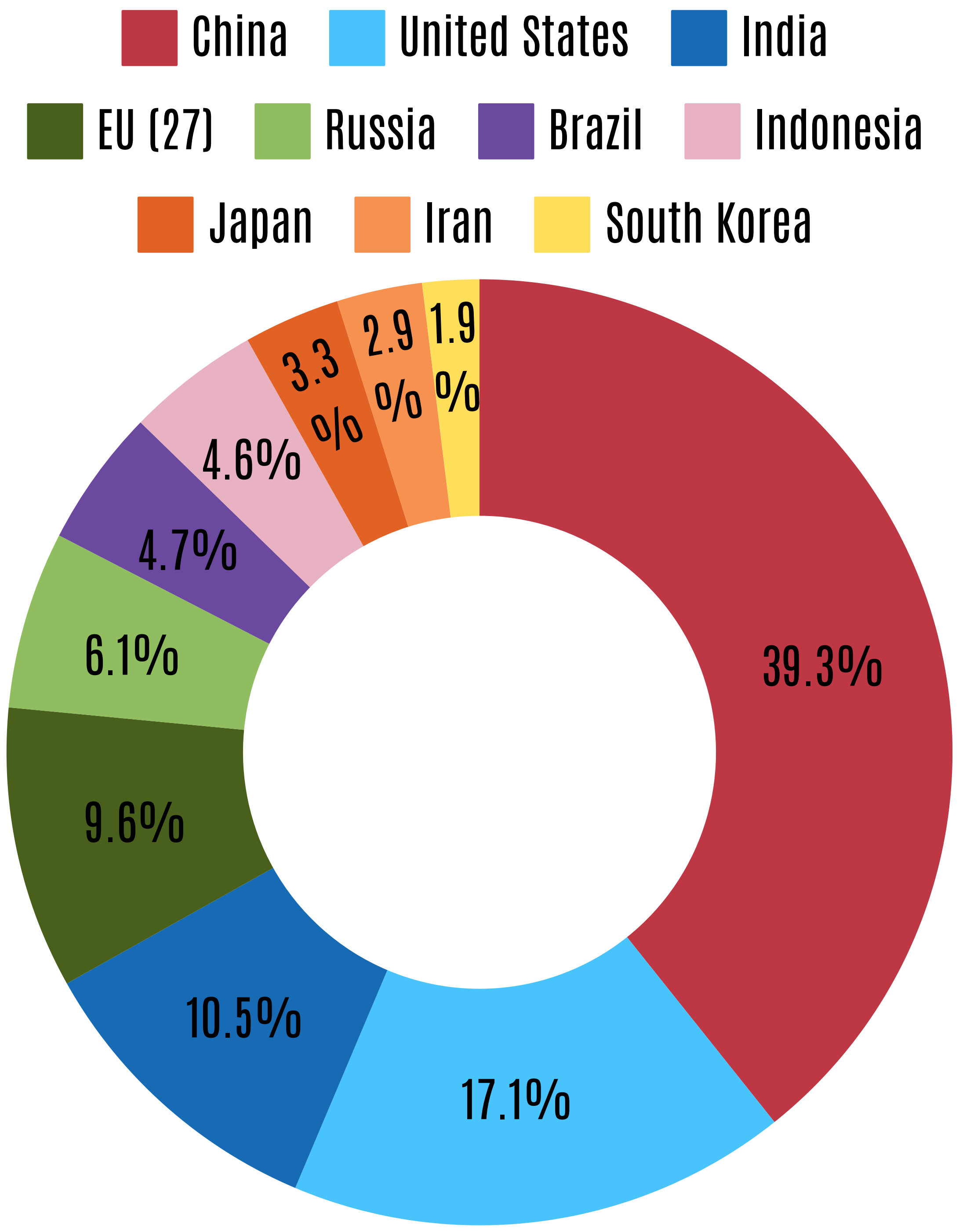
STATUS

Global Top 10 (2021)

The leading three greenhouse gas (GHG) emitters are:

- China
- The United States
- India

These countries collectively contribute more than 60% (over two-thirds) of worldwide GHG emissions, whereas the bottom 100 nations only represent 2.9%.



Graph 4.2 Global Top 10 GHG emissions in 2021

The world **cannot** successfully fight climate change without significant action from the top 10 emitters.

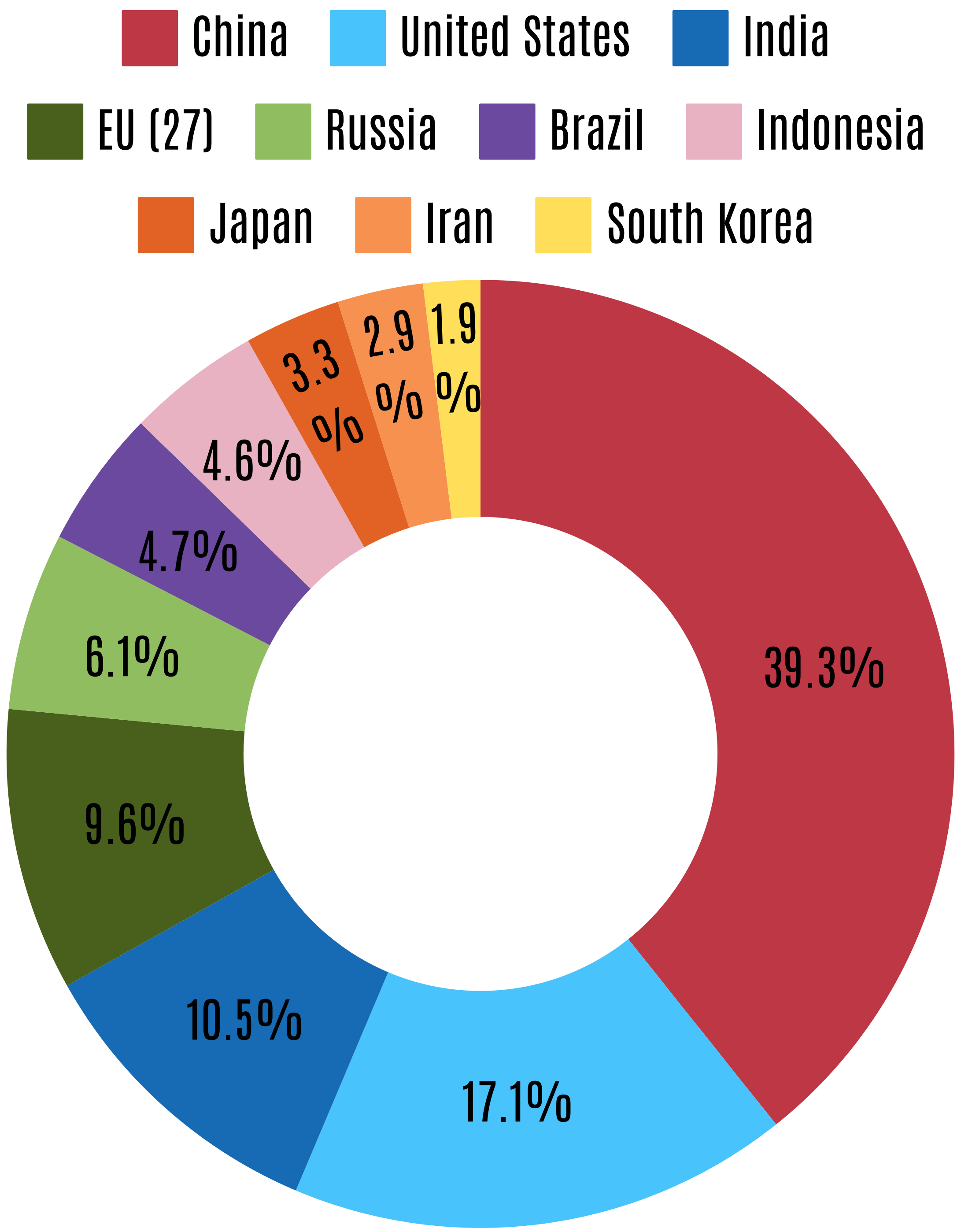
[4] Climate Watch Historical GHG Emissions. 2022. Washington, DC: World Resources Institute. Available online at: https://www.climatewatchdata.org/ghg-emissions

[5] Friedrich, J. (n.d.). This interactive chart shows changes in the world's top 10 emitters. World Resources Institute. https://www.wri.org/insights/interactive-chart-shows-changes-worlds-top-10-emitters

STATUS

Global Top 10 (2021)

In 2019, India surpassed the European Union in total annual greenhouse gas (GHG) emissions, making it the third-largest emitter globally, following China and the United States until now.



Graph 4.2 Global Top 10 GHG emissions in 2021

However, with a population nearly three times larger than that of the EU, India's per capita emissions falls significantly behind the other top ten emitters.

[4] Climate Watch Historical GHG Emissions. 2022. Washington, DC: World Resources Institute. Available online at: https://www.climatewatchdata.org/ghg-emissions
[6] Vigna, L. (n.d.). 9 Charts explain per capita greenhouse gas emissions by country. World Resources Institute. https://www.wri.org/insights/charts-explain-per-capita-greenhouse-gas-emissions

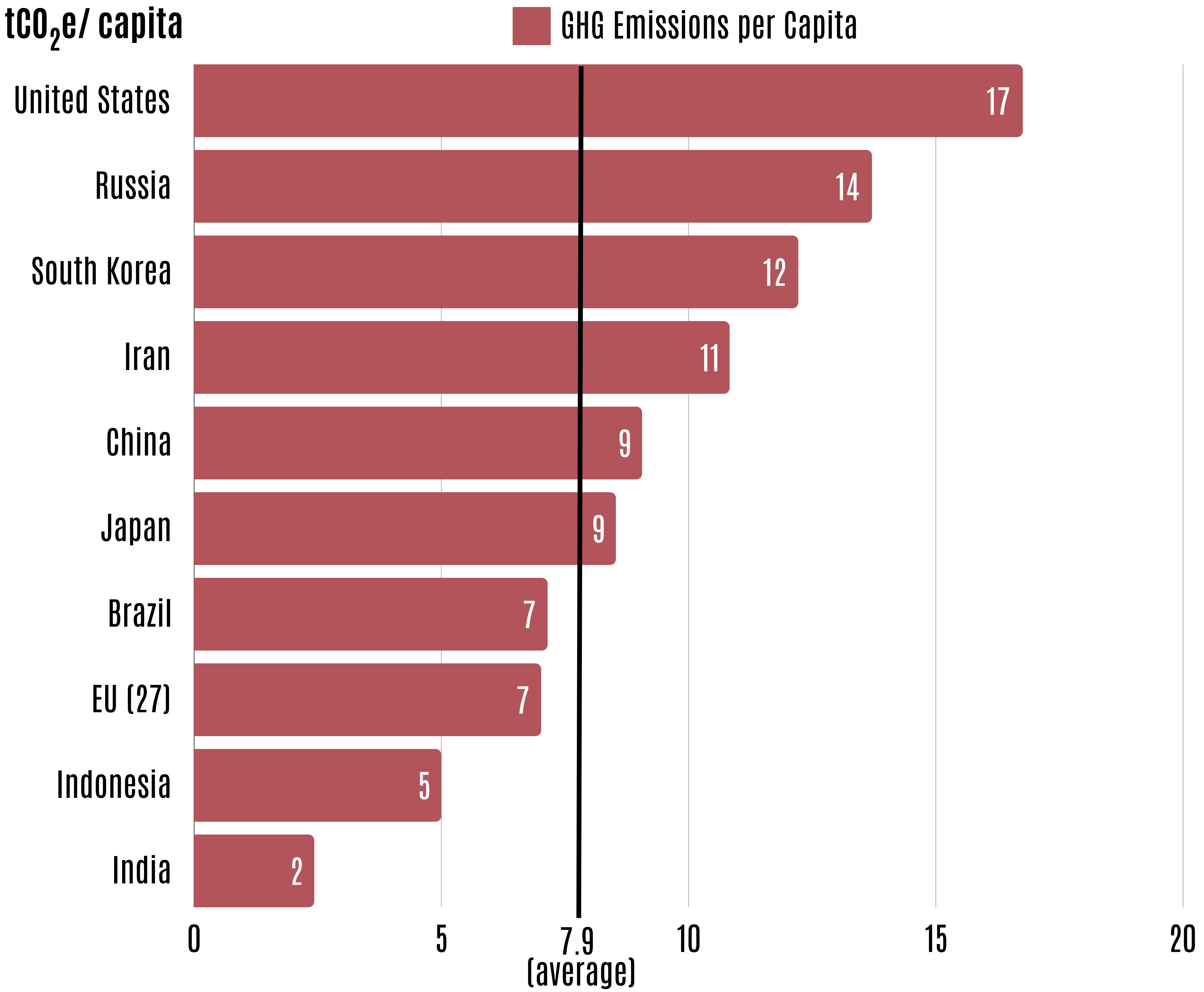
STATUS

Global Top 10 (2021)

Among the top 10 highest emitters, the U.S. and Russia lead in per capita emissions:

- The United States: 17 (tCO_2e/ capita)
- Russia: 14 (tCO_2e/ capita)

In contrast, India's per capita emissions are the lowest, at only 2 (tCO_2e/ capita)

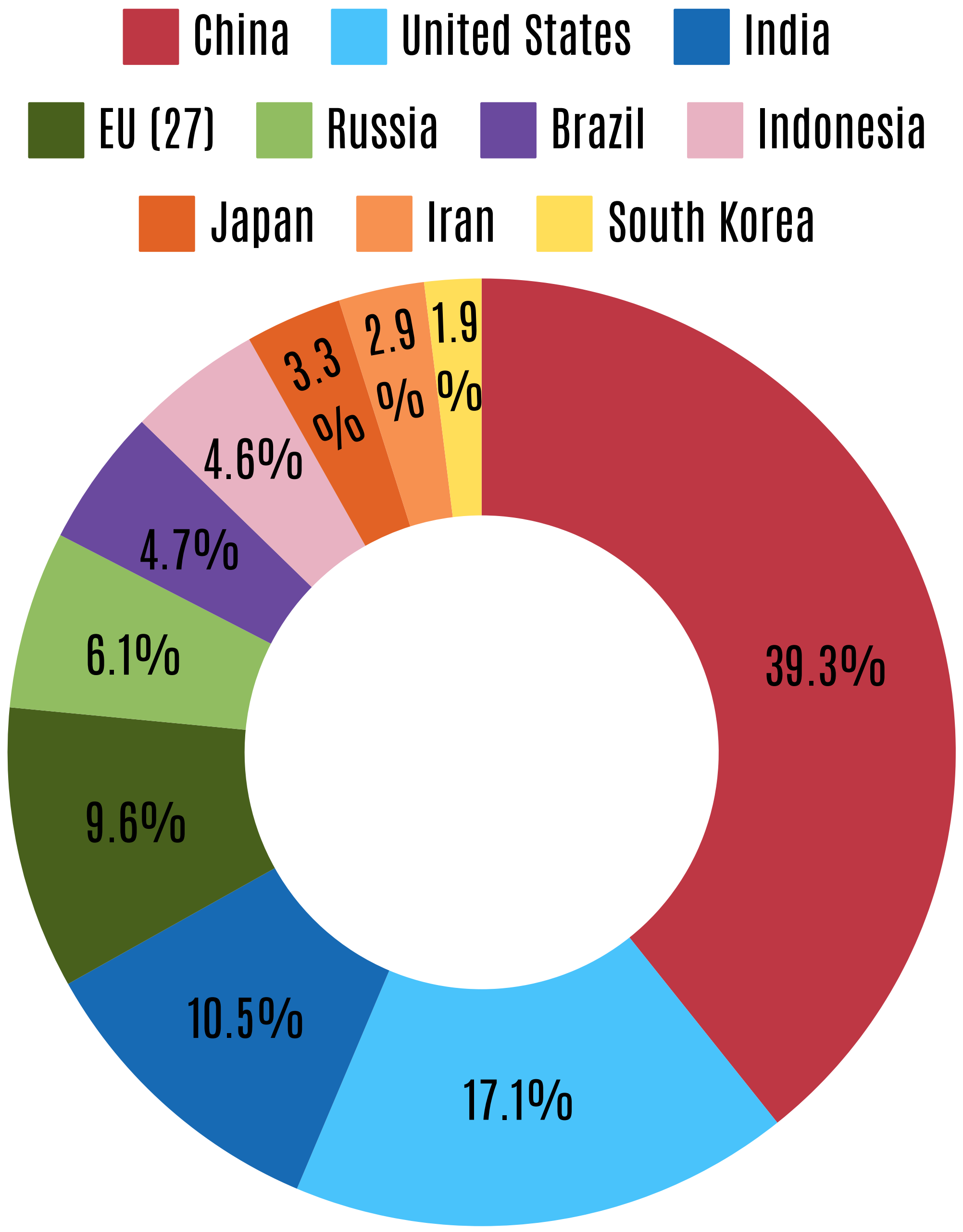


Graph 4.3 Global Top 10 GHG emissions per Capita in 2021

[4] Climate Watch Historical GHG Emissions. 2022. Washington, DC: World Resources Institute. Available online at: https://www.climatewatchdata.org/ghg-emissions
[6] Vigna, L. (n.d.). *9 Charts explain per capita greenhouse gas emissions by country*. World Resources Institute. https://www.wri.org/insights/charts-explain-per-capita-greenhouse-gas-emissions

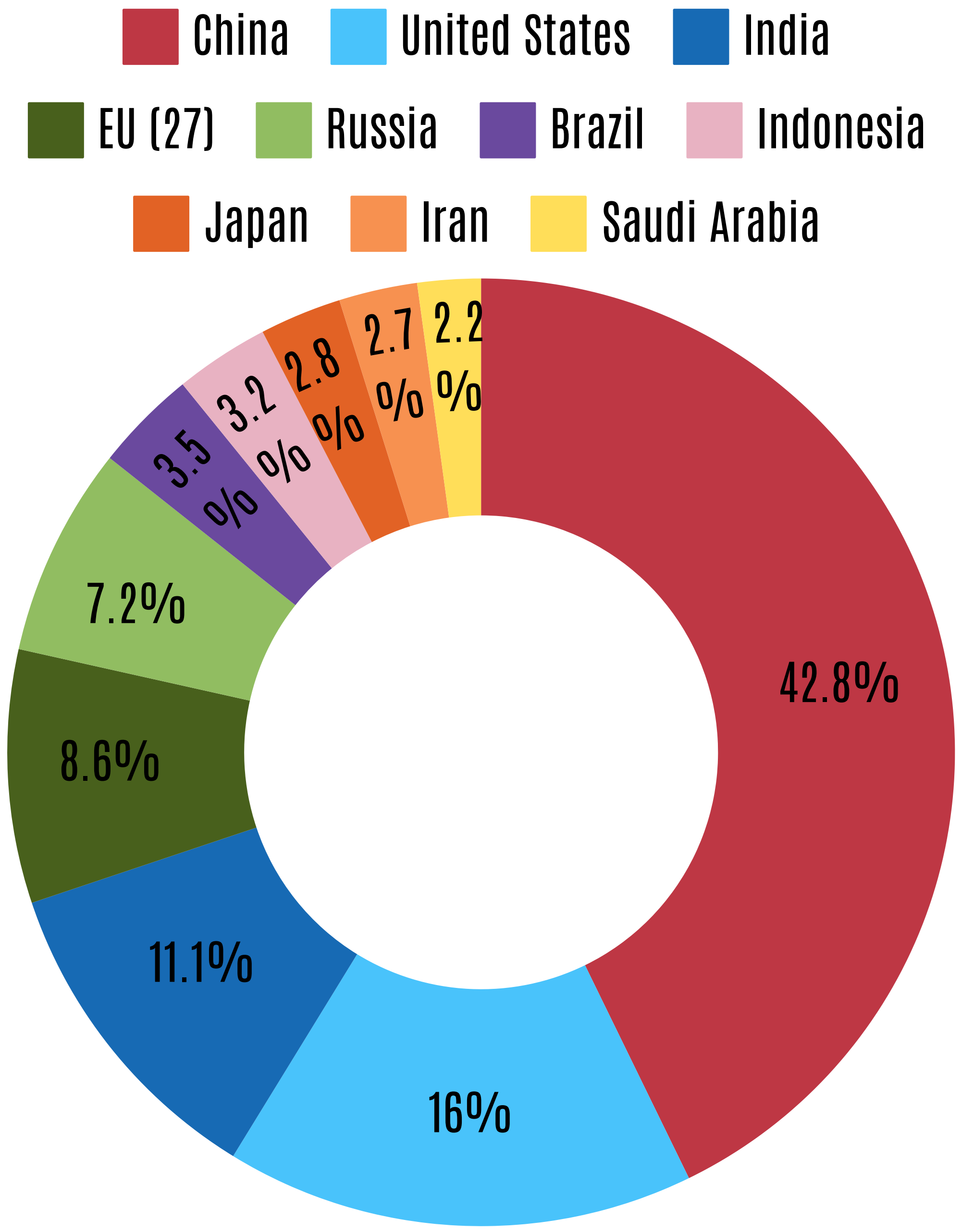
STATUS

Global Top 10 (2021-2023)



Graph 4.2 Global Top 10 GHG emissions in 2021

- China, India, Russia, and Brazil continue to increase their emissions, with India and China having the largest rises.
- All EU27 nations, with the exception of Croatia and Cyprus, successfully reduced their emissions.
- The 10th emitter see a minor shift, with Saudi Arabia surpassing South Korea in the rankings.



Graph 4.4 Global Top 10 GHG emissions in 2023

[1] Crippa, M., Guizzardi, D., Pagani, F., Banja, M., Muntean, M., Schaaf, E., Monforti-Ferrario, F., Becker, W.E., Quadrelli, R., Risquez Martin, A., Taghavi-Moharamli, P., Köykkä, J., Grassi, G., Rossi, S., Melo, J., Oom, D., Branco, A., San-Miguel, J., Manca, G., Pisoni, E., Vignati, E. and Pekar, F., GHG emissions of all world countries, Publications Office of the European Union, Luxembourg, 2024, doi:10.2760/4002897, JRC138862

VIETNAM STATUS

Climate Change

Temperature:

- In 2018, Vietnam's average annual temperature rose by 0.89°C (equivalent to 0.15°C/decade).
- Projected temperature increases in Vietnam are similar to the global average and may range between 1.0°C and 3.4°C by 2080–2099.

Precipitation:

- The annual average precipitation of the whole country increased by 2.1%, with the most increase in the south Central Coast, while the northern and southern Central Highlands experienced a decrease.

Extreme weather events:

- The frequency of intense typhoons has been on the rise, accompanied by an increase in extreme rainfall.
- Additionally, average sea levels at monitoring stations have risen by 2.74 mm/year and 3.0 mm/year between 1993 and 2018.

[9] Impacts of climate change in Vietnam. (n.d.). https://pilot.dcc.gov.vn/en/Impacts-of-climate-change-in-Vietnam
[10] World Bank. (2021). Vietnam Country Profile. Retrieved from World Bank Climate Change Knowledge Portal.

VIETNAM STATUS

Sea Level Rise

- Vietnam's coastal and river delta regions are highly vulnerable to rising sea levels.
- Depending on emissions pathway, the population affected by fluvial flooding is projected to be 3 – 9 million people by 2035–2044.
- If the sea level rises by 100cm, the risks of permanent flooding of areas are: (% of areas)

47.3% in the Mekong River Delta
17.2% in Ho Chi Minh City
13.2% in the Red River Delta
Smaller percentages in:
Quang Ninh
Central coastal provinces
Ba Ria - Vung Tau.

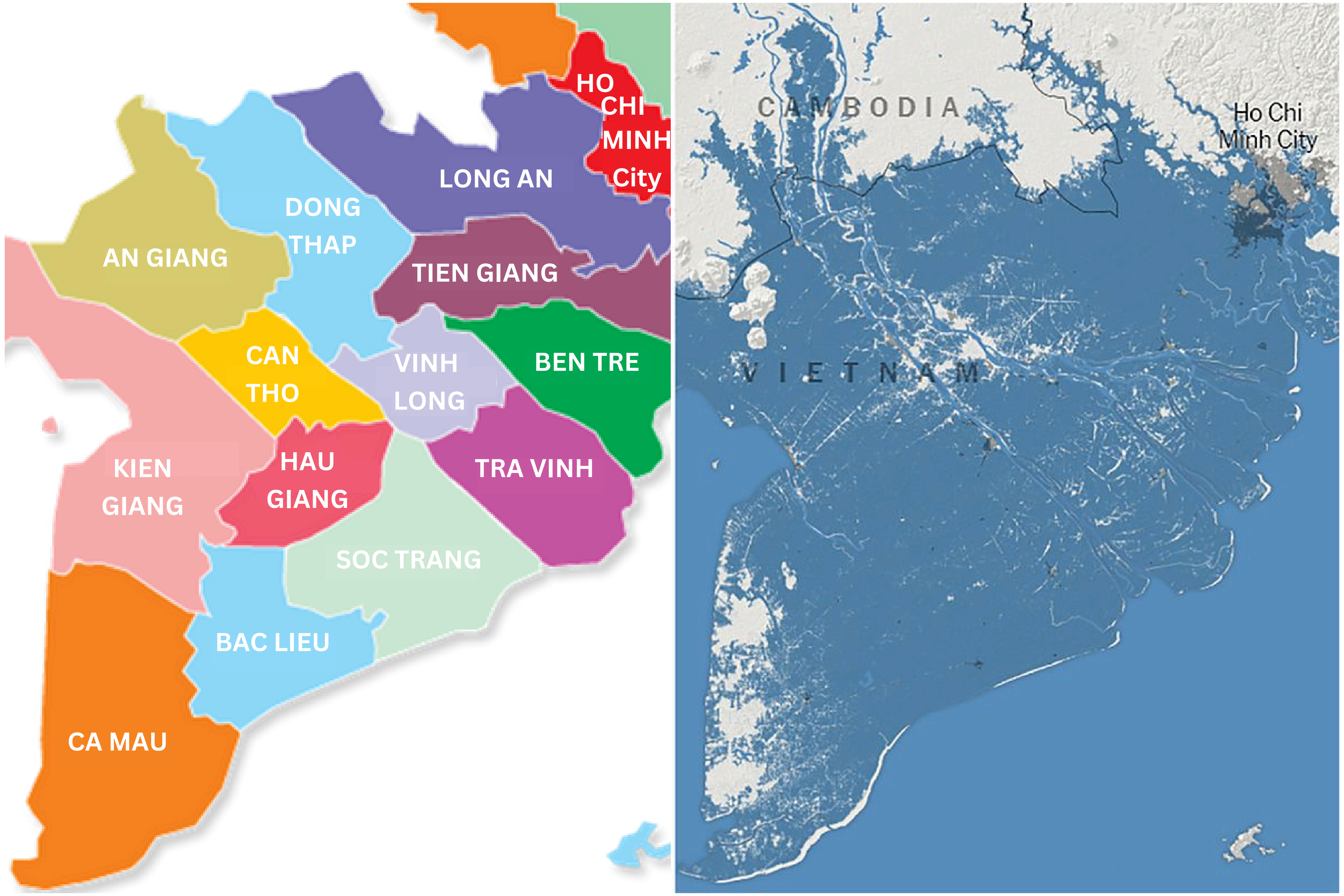
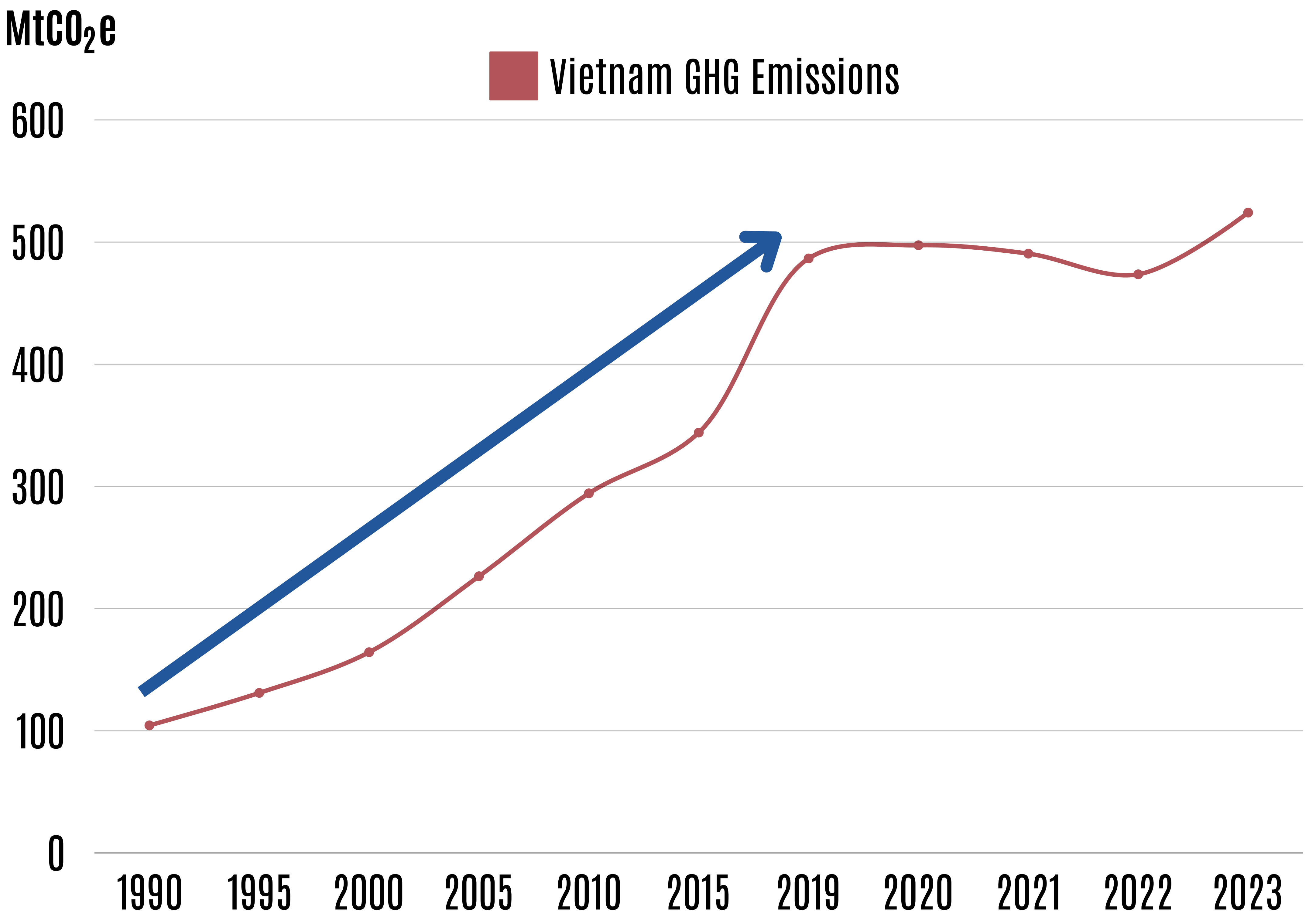


Figure 4.1 Projections for Flooded Land at High Tide in 2050 in Mekong Region

[9] Impacts of climate change in Vietnam. (n.d.). https://pilot.dcc.gov.vn/en/Impacts-of-climate-change-in-Vietnam
[10] World Bank. (2021). Vietnam Country Profile. Retrieved from World Bank Climate Change Knowledge Portal.



Graph 4.5 Vietnam GHG emissions from 1990 - 2023

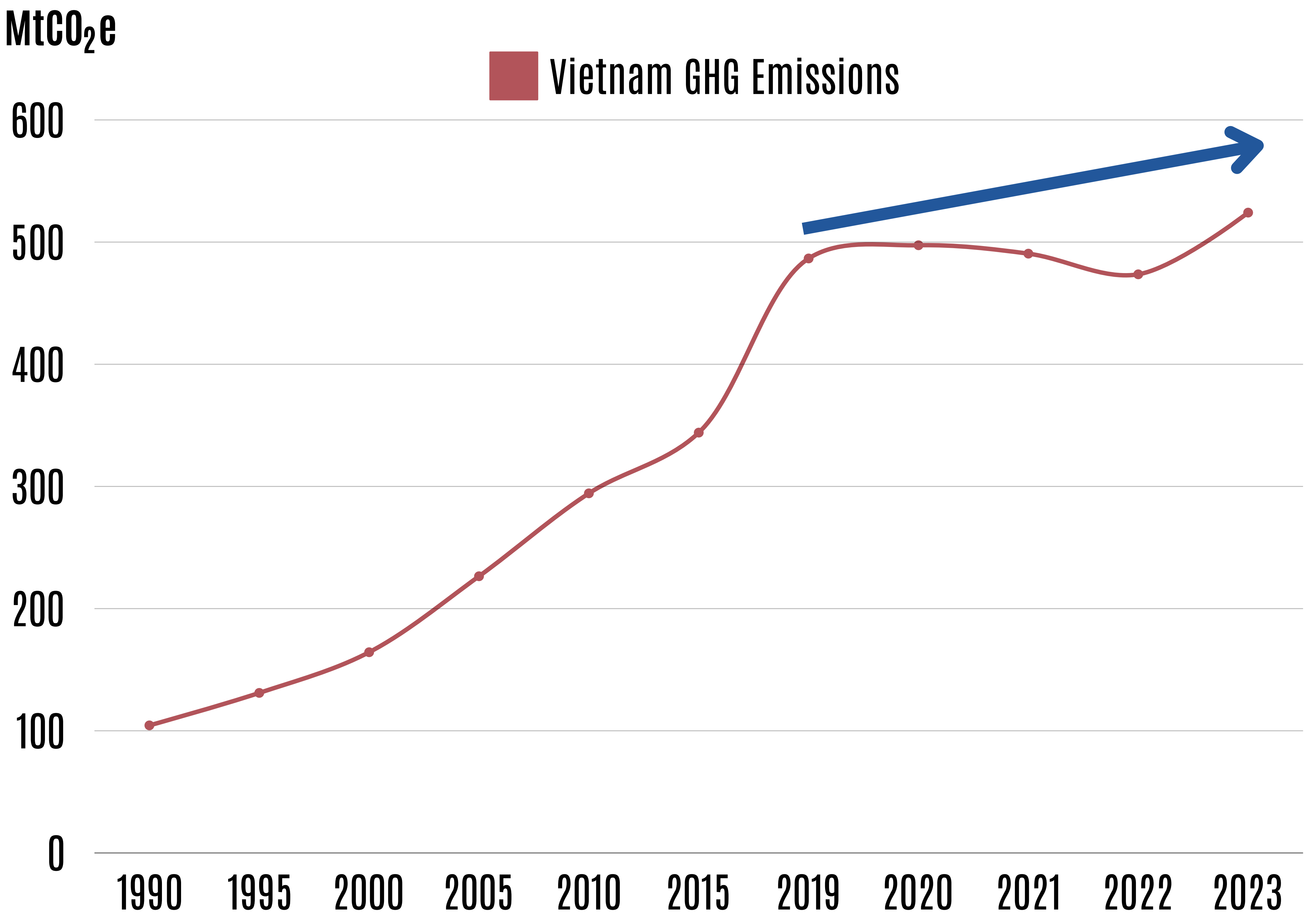
STATUS

Viet Nam (1990 - 2019)

Since the start of the 21st century up until 2019, greenhouse gas (GHG) emissions in Vietnam have risen dramatically, increasing by about 78.6%.

This rate is **double** that of the global increase rate during the same period.

[2] Crippa, M., Guizzardi, D., Pagani, F., Banja, M., Muntean, M., Schaaf, E., Monforti-Ferrario, F., Becker, W.E., Quadrelli, R., Risquez Martin, A., Taghavi-Moharamli, P., Köykkä, J., Grassi, G., Rossi, S., Melo, J., Oom, D., Branco, A., San-Miguel, J., Manca, G., Pisoni, E., Vignati, E. and Pekar, F., GHG emissions of all world countries, Publications Office of the European Union, Luxembourg, 2024, doi:10.2760/4002897, JRC138862



Graph 4.5 Vietnam GHG emissions from 1990 - 2023

STATUS

Viet Nam (2019 - 2023)

Vietnam’s COVID-19 response has not focused on a green recovery.

In 2020, Vietnam's carbon emissions ranged from 0.5 to 122 (g C/m².yr), that is higher than in 2019.

For instance, Hanoi's emissions increased, reflecting the national average trend.

[2] Crippa, M., Guizzardi, D., Pagani, F., Banja, M., Muntean, M., Schaaf, E., Monforti-Ferrario, F., Becker, W.E., Quadrelli, R., Risquez Martin, A., Taghavi-Moharamli, P., Köykkä, J., Grassi, G., Rossi, S., Melo, J., Oom, D., Branco, A., San-Miguel, J., Manca, G., Pisoni, E., Vignati, E. and Pekar, F., GHG emissions of all world countries, Publications Office of the European Union, Luxembourg, 2024, doi:10.2760/4002897, JRC138862
[12] Ray, R. L., Singh, V. P., Singh, S. K., Acharya, B. S., & He, Y. (2022). What is the impact of COVID-19 pandemic on global carbon emissions?. Science of The Total Environment, 816, 151503.

VIETNAM’S SITUATION

Reasons

- Vietnam's susceptibility to climate change arises from the buildup of GHG in the atmosphere and the slow reaction of major polluters to cut their GHG emissions.
- This issue is further worsened by poor planning and unsustainable management of natural resources within the country.

Consequences

- As the climate changes, Vietnam's economy is affected and projected to lost $10 billion in 2020, or 3.2% of its GDP.
- The WHO estimates air pollution in urban centers leads to 60,000 deaths yearly, causing significant economic costs due to health and productivity losses.
- A case in point for poor management is the Mekong Delta where continued sand mining compounds the effect of sea level rise on erosion of the coastline and riverbanks.

[11] World Bank. (2022). Vietnam country climate and development report.

MITIGATION PLAN

Decarbonizing Pathway

- The mitigation measures to lower greenhouse gas emissions are not only support our national goals but also help reduce harmful air pollution in bustling urban areas.
- Moreover, international companies and consumers in Vietnam's main export markets are shifting toward a greener, low-carbon economy.

Vietnam's climate strategies require a balance between adaptation and mitigation.

- While current strategies focus on mitigation, the country, being highly vulnerable to climate change, must invest in resilience to counteract its severe impacts on growth.
- Some progress has been made in developing carbon pricing instruments, but are not yet implemented at scale. The current Environmental Protection Tax (EPT) are lower than most countries and too low to incentivize large-scale decarbonization:

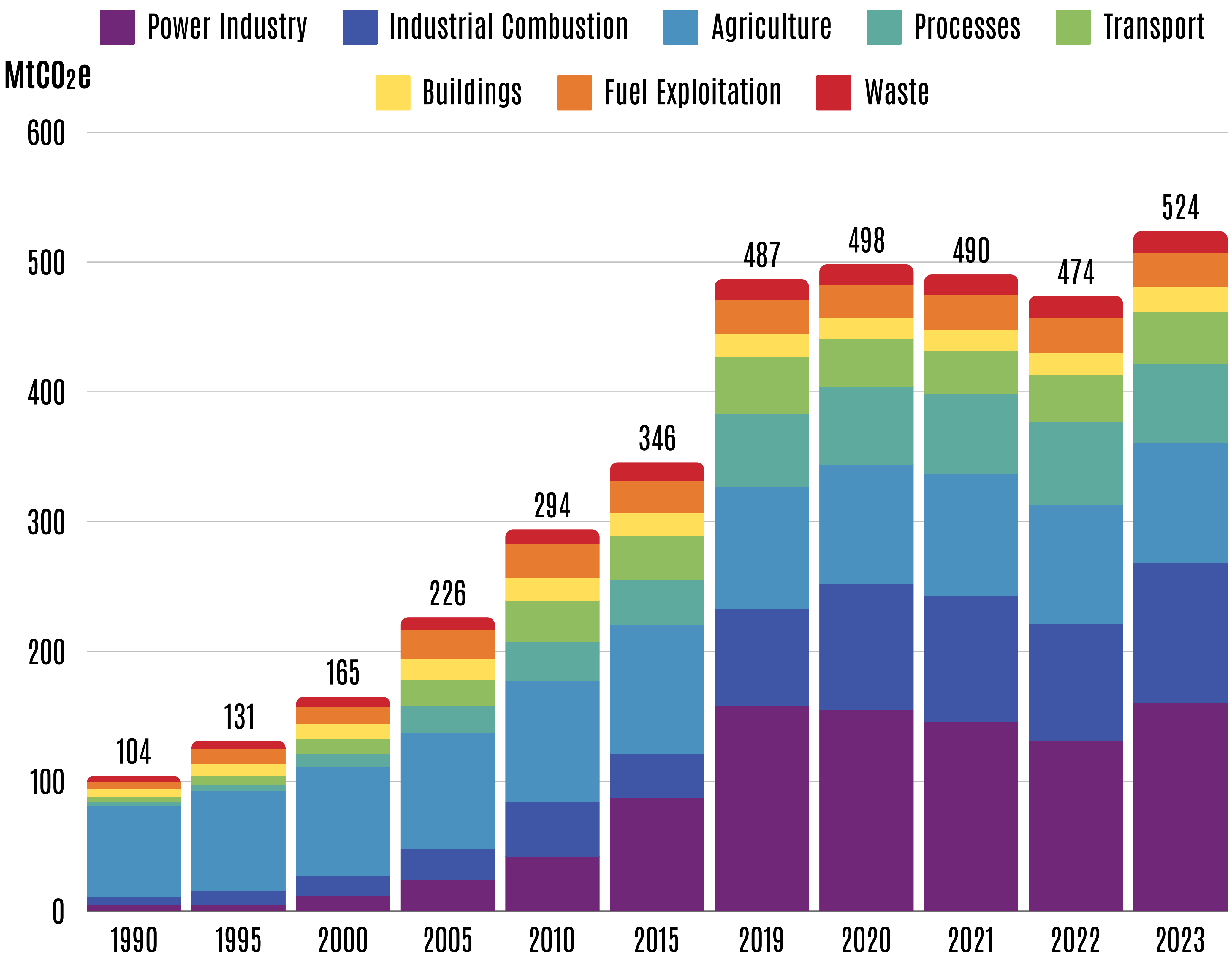
  \$0.50/tCO2e on coal \$77.60/tCO2e on gasoline \$32.90/tCO2e on diesel
- Moreover, Vietnam's strategies must be updated to include recent commitments from COP26, such as the net-zero carbon emission target, which is not yet reflected in national or sectoral strategies.

[11] World Bank. (2022). Vietnam country climate and development report.

EMISSION SECTOR

Power Sector

- The installed capacity of coal power plants in Vietnam increased 4-times over the past decade, rising from 5 GW in 2010 to 20 GW in 2020. This has made the power sector the country's **largest contributor** to GHG emissions.
- In 2020, the power sector accounted for 70% of the 88 million tons of coal consumed in Vietnam (about 1 percent of global consumption).



Graph 4.6 Vietnam GHG emissions by sectors from 1990 - 2023

[11] World Bank. (2022). Vietnam country climate and development report.

MITIGATION PLAN

At COP26, Vietnam committed to phase out coal power by the 2040s to achieve net zero emissions by 2050. This requires adjustments in the Eighth Power Development Plan (PDP8):

Increasing the renewable energy capacity from 17 GW to 36 GW.

Reducing coal power capacity to 38 GW by 2030, just nearly-double the installed capacity in 2020 (20 GW).

Vietnam needs an inclusive transition away from coal and gas towards renewable energy sources.

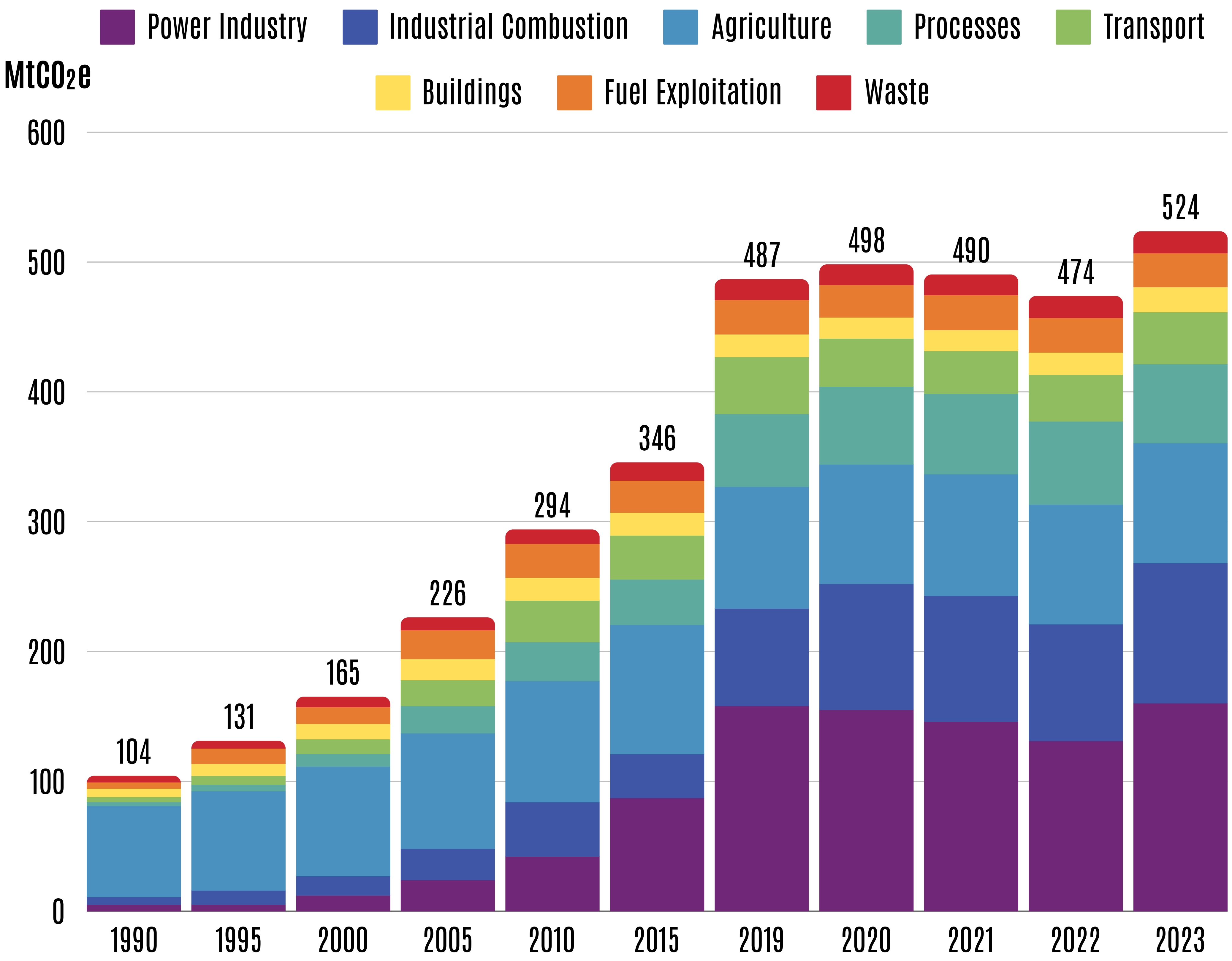
- The draft PDP8 increases investments in both renewable sources and fossil fuels and Vietnam has announced a plan to incentivize solar development which is promising, though it lacks a clear budget allocation.
- While coal and gas continue to play a significant role in power development planning for baseload energy, Vietnam is emerging as a regional leader in solar energy.

[11] World Bank. (2022). Vietnam country climate and development report.
[12] Aleksandra. (2021b, November 4). CP2020 Vietnam. Climate Transparency. https://www.climate-transparency.org/cp2020-vietnam

EMISSION SECTOR

Argriculture

- Agriculture is the **second-largest** source of GHG emissions in Vietnam, at about 19% of total emissions in 2020.
- Rice production accounts for 48% of these emissions, followed by livestock fermentation, synthetic fertilizers, and manure management.
- Over 70% of emissions are CH4 and N2O, not CO2, while having shorter lifetimes than CO2, these gasses are significantly more potent.



Graph 4.6 Vietnam GHG emissions by sectors from 1990 - 2023

[11] World Bank. (2022). Vietnam country climate and development report.

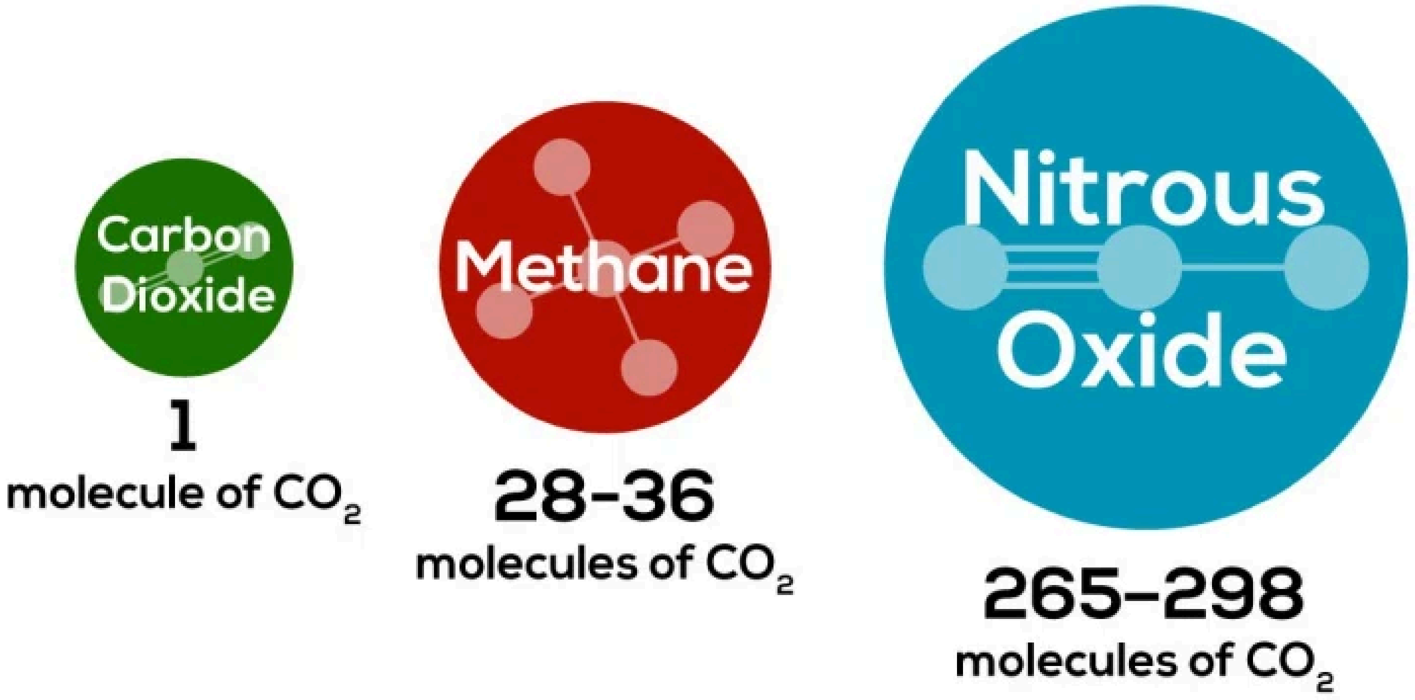
MITIGATION PLAN

Vietnam's agricultural emissions are mainly from rice cultivation, livestock manure, and the use of synthetic fertilizers.

A shift to organic farming, more efficient use of fertilizers, and livestock diet changes can reduce emissions.

A unique feature of the sector's GHG emissions is that CH4 and N2O dominate, which is atmospheric potent.
Reducing these gases could significantly and quickly lower near-term warming.

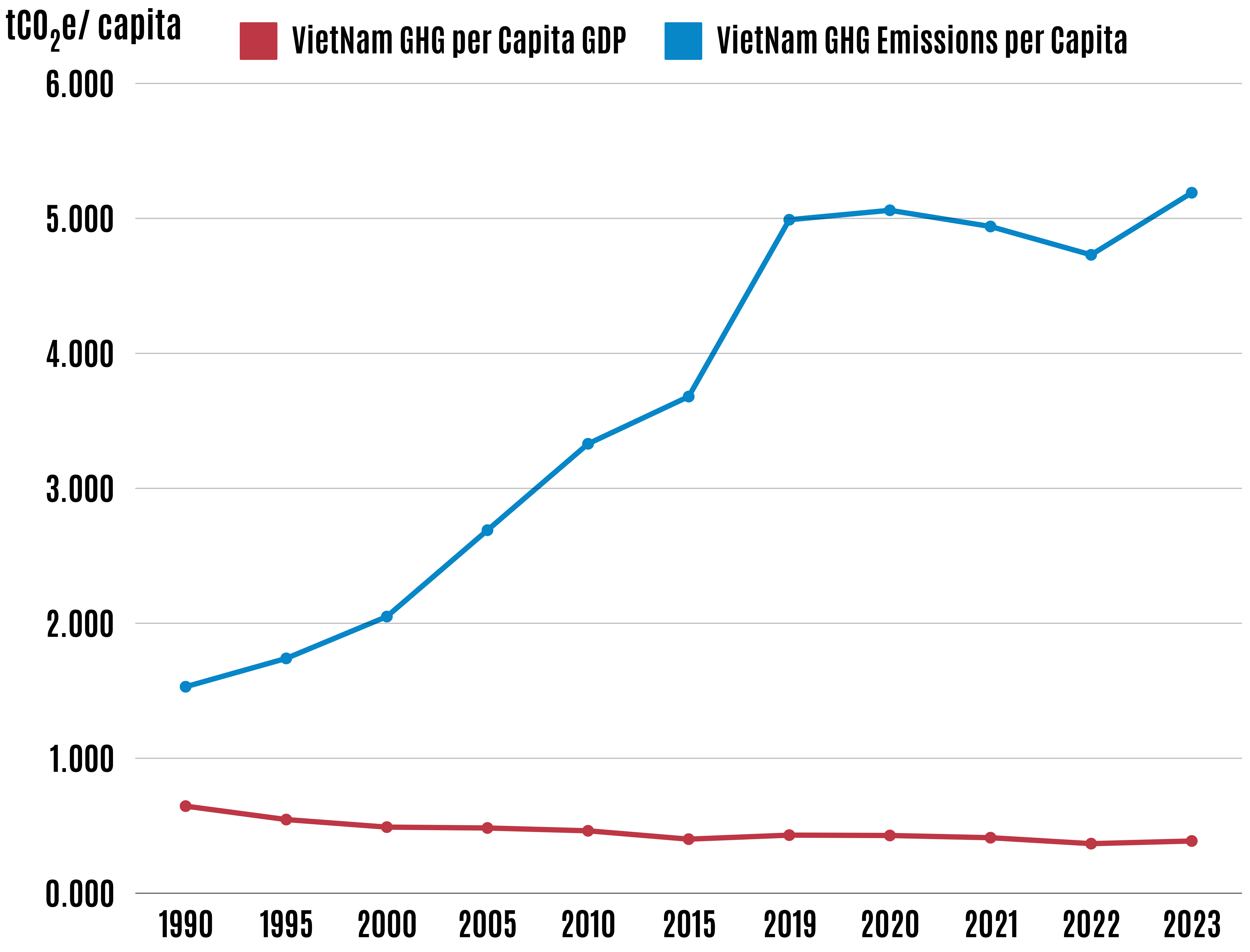
- CH4 emissions need to decline by 35% by 2050 (from 2010 levels).
- N2O emissions need to be reduced by 20% by 2050 (from 2010 levels).



[11] World Bank. (2022). Vietnam country climate and development report.
[12] Aleksandra. (2021b, November 4). CP2020 Vietnam. Climate Transparency. https://www.climate-transparency.org/cp2020-vietnam

EMISSION PER CAPITA & GDP

- It is suggested that in the early stages, environmental contamination tends to increase alongside rising per capita gross domestic product (GDP).
- However, as development progresses, this pattern shifts, resulting in a decline in environmental pollution levels while per capita income continues to rise.



Graph 4.7 Vietnam GHG emissions per Capita and per Capita GDP from 1990-2023

2] Crippa, M., Guizzardi, D., Pagani, F., Banja, M., Muntean, M., Schaaf, E., Monforti-Ferrario, F., Becker, W.E., Quadrelli, R., Risquez Martin, A., Taghavi-Moharamli, P., Köykkä, J., Grassi, G., Rossi, S., Melo, J., Oom, D., Branco, A., San-Miguel, J., Manca, G., Pisoni, E., Vignati, E. and Pekar, F., GHG emissions of all world countries, Publications Office of the European Union, Luxembourg, 2024, doi:10.2760/4002897, JRC138862

THANK YOU

Group: 10 - Class: CC02