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Role of Geology in Climate Change Mitigation

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Introduction to Climate Change

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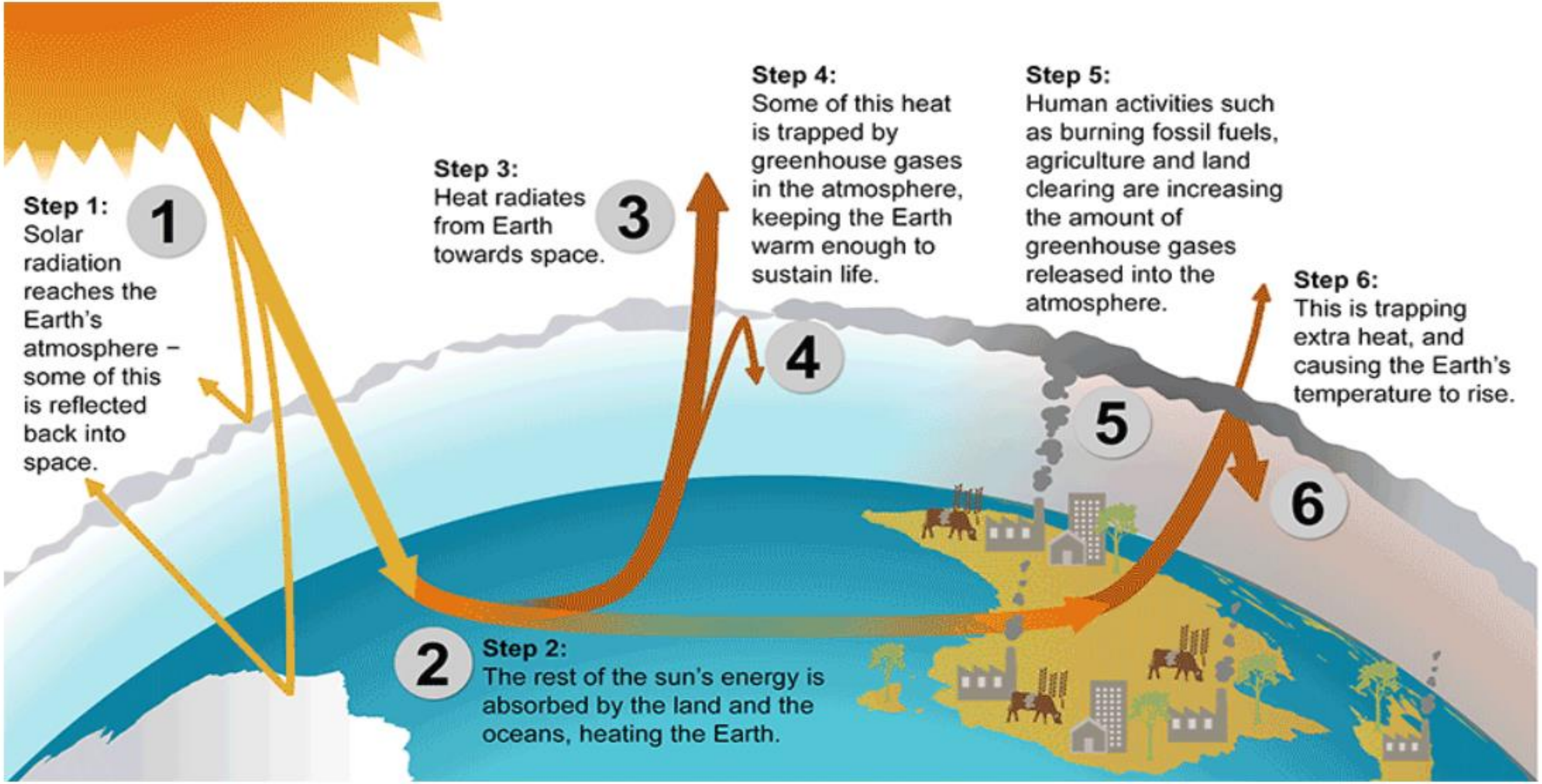
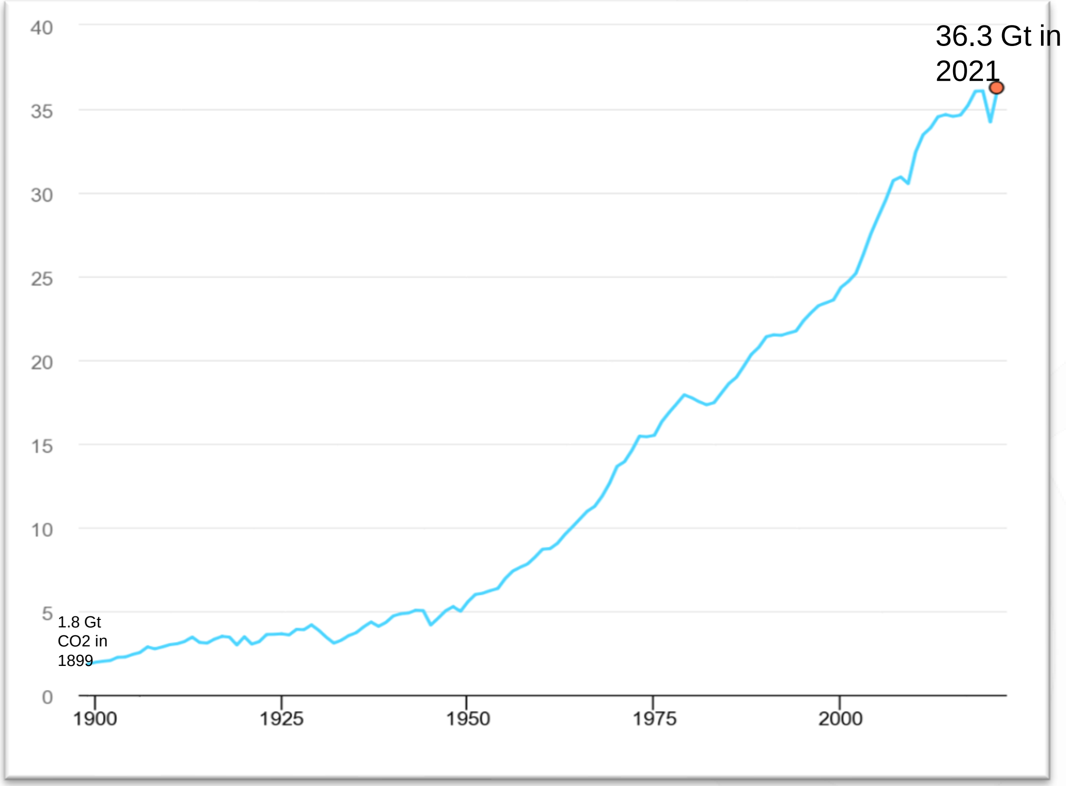
The problem we now face is human activities –particularly burning fossil fuels(coal, oil, and natural gas), agriculture, and land clearing –increasing the concentration of greenhouse gases. This is increasing the greenhouse effect, which is contributing to the warming of the earth.



CO_2 emissions from energy combustion and industrial processes, 1900-2021



Coal accounted for over 40% of emissions in 2021.

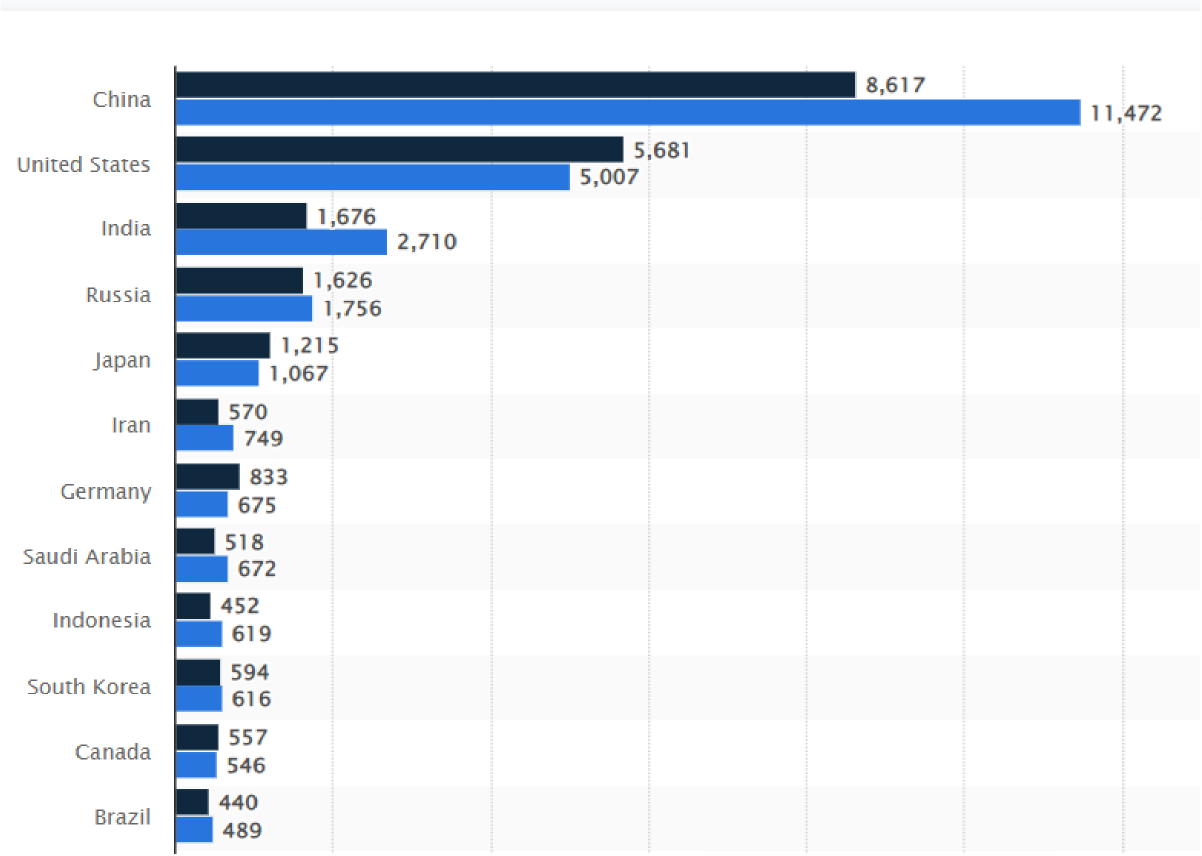
Coal emissions now stand at an all-time high of 15.3 Gt,.

CO_2 emissions from natural gas also rebounded well above 2019 levels to 7.5 Gt,

At 10.7 Gt, emissions from oil remained in global transport activity in 2021.

Source: IEA: Global Energy Review: CO2 Emissions in 2021

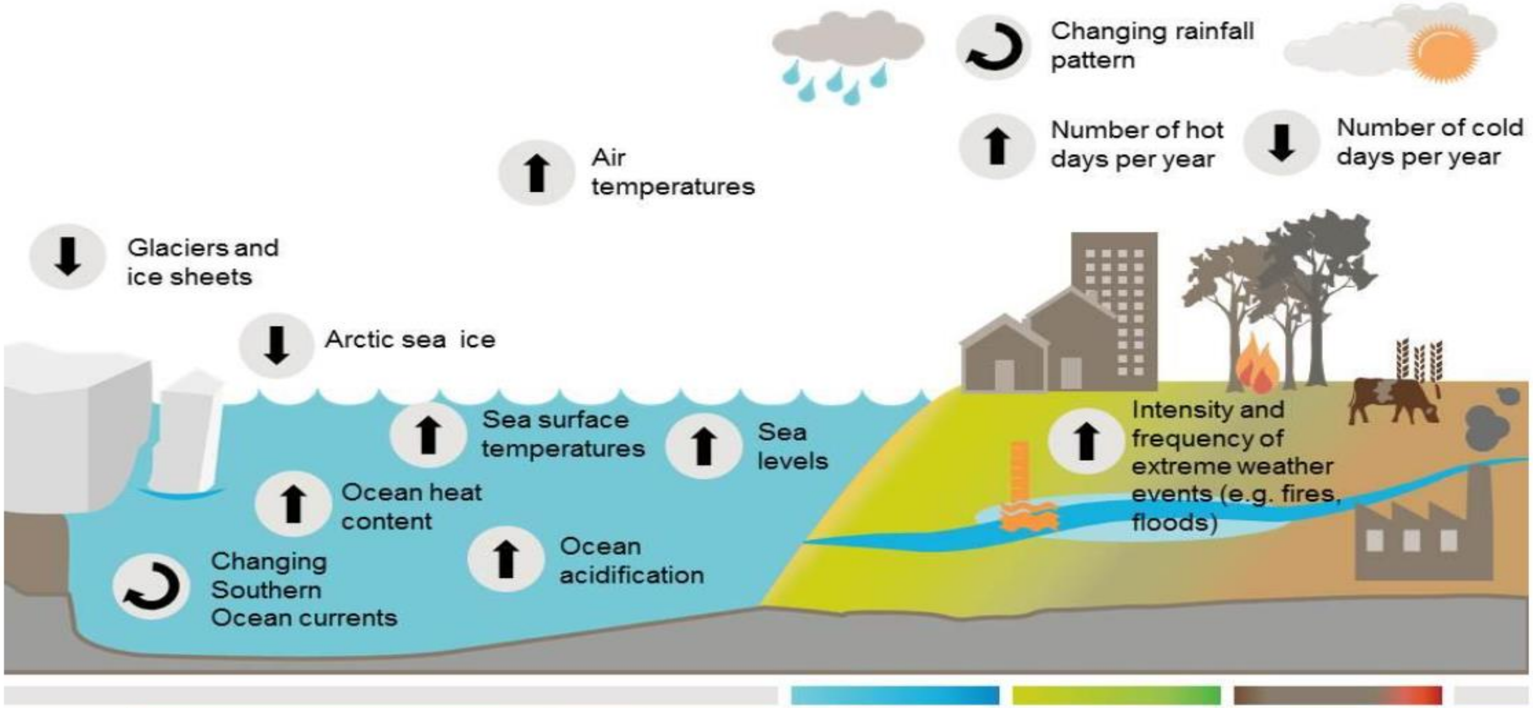
Carbon dioxide emissions worldwide in 2010 and 2021, by select country (in million metric tons)



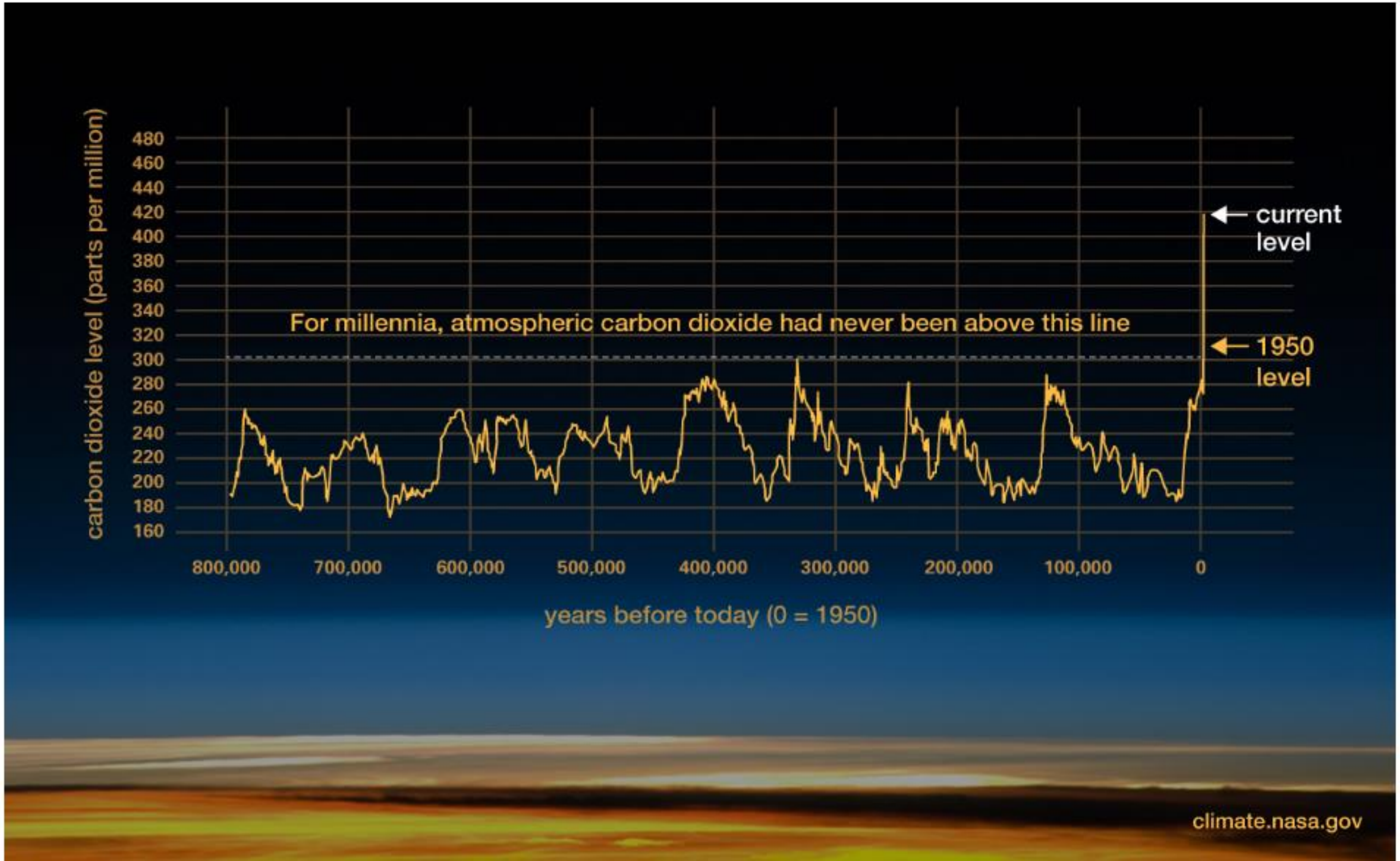
Source: Statista

Observed Changes

There are multiple lines of evidence that show the climate system is changing



The relentless rise of carbon dioxide



Paris Agreement on Climate Change

The Paris Agreement is a **legally binding international treaty on climate change**. It was adopted by 196 Parties at COP 21 in Paris on December 12, 2015, and entered into force on 4 November 2016.

Its goal is to **limit global warming** to below 2, **preferably to 1.5 degrees Celsius**, compared to pre-industrial levels.

To achieve this long-term temperature goal, countries aim to **reach global peaking of greenhouse gas emissions as soon as possible** to achieve a climate-neutral world by mid-century.

The Paris Agreement is **a landmark** in the multilateral climate change process because, for the first time, a binding agreement brings all nations into a common cause to undertake ambitious efforts to combat climate change and adapt to its effects.

Source: UN Climate Change

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Carbon Capture and Storage

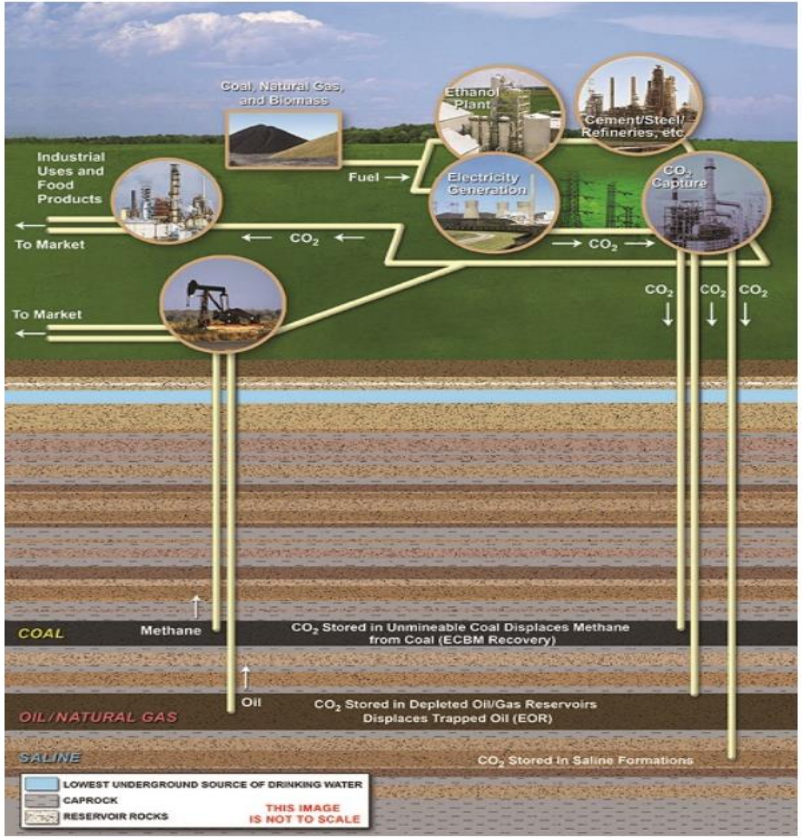
Carbon Capture and Storage

The carbon dioxide (CO_2) gas emitted by thermal power plants and other heavily emitting industrial sources can be channeled into protected and safe storage as carbon capture.

However, storage must be safe, environmentally sustainable, and cost-effective. The U.S. Department of Energy (DOE) has investigated five types of underground formations for geologic carbon storage:

- **Saline formations**
- **Oil and natural gas reservoirs**
- **Unmineable coal seams**
- **Organic-rich shales**
- **Basalt formations**

CHARACTERISTICS OF A SUBSURFACE CARBON STORAGE COMPLEX



- **Saline formations**
- **Oil and natural gas reservoirs**
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HOW CAN CO2 BE STORED UNDERGROUND?

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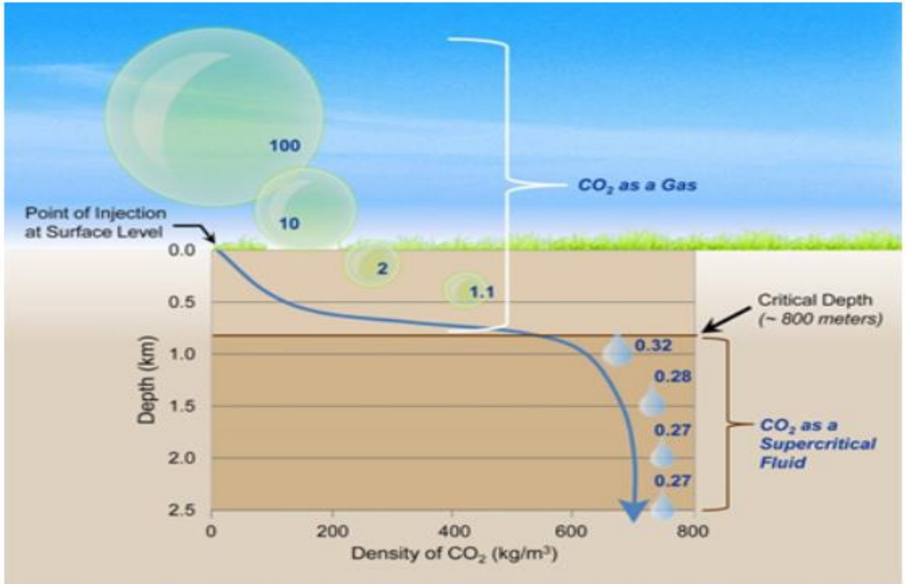

Illustration of Pressure Effects on CO2 (based upon image from CO2CRC). The blue numbers show the volume of CO2 at each depth compared to a volume of 100 at the surface.

Carbon dioxide (CO_2) can be stored underground as a supercritical fluid. Supercritical CO_2 means that the CO_2 is at a temperature in excess of 31.1°C (88ºF) and a pressure in excess of 72.9 atm (about 1,057 psi);

This temperature and pressure defines the critical point for CO_2. At such high temperatures and pressures, the CO_2 has some properties like a gas and some properties like a liquid.

Source: NETL

WHERE AROUND THE WORLD IS CO2 STORAGE HAPPENING TODAY?

- Carbon dioxide (CO_2) storage is currently happening across the United States and worldwide.
- Large, commercial-scale projects, such as the Sleipner CO_2 Storage Site in Norway, Weyburn-Midale CO_2 Project in Canada, have been injecting CO_2 for many years. Each of these projects stores more than 1 million metric tons (MMT) of CO_2 per year
- Large-scale efforts are also underway in China, Australia, and Europe. These commercial-scale projects demonstrate that large volumes of CO_2 can be safely and permanently stored
- To date, more than 200 CO_2 capture and/or storage operations (including in-development and completed) have been carried out worldwide
- In India, public sector undertakings such as NALCO, ONGC, and BHEL are taking up CCS pilots. NALCO has commissioned a pilot-cum-demonstration CO2 sequestration plant
- ONGC signed a memorandum of understanding (MoU) with ILFS Energy and Tamil Nadu Power Company (ITPCL) in 2018 to inject CO2 captured at the ITPCL plant into the oil fields of ONGC Cauvery Asset

Fig: Sleipner Project (Norway)

Fig: Weyburn-Midale CO2 Project (Canada)

BASALT FORMATIONS AS CARBON CAPTURE AND STORAGE

- The chemical and physical properties of these basalts and the other formation types in between basalt layers make them good candidates for CO_2 storage systems.

- The chemistry of basalts potentially allows injected CO_2 to react with magnesium and calcium in the basalt to form the stable carbonate mineral forms of calcite and dolomite.

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Minerals for Climate Change Action

Green Energy Raw Materials

Aluminum, copper, nickel, and zinc are strategic to producing for most technologies (solar photovoltaics, wind, electric cars, electricity networks, etc.).

Rare earth elements (REEs) for permanent magnets(used in Wind energy and EVs) , silicon and tellurium for solar panels, lithium and cobalt for batteries, platinum group metals(PGM), and nickel and scandium for hydrogen.

Alloying metals such as vanadium, molybdenum, and manganese are harder to assess. They are mainly used to alloy steel, and these special types of steel will also be needed in many clean energy technologies depending upon each application.

Critical mineral needs for clean technologies

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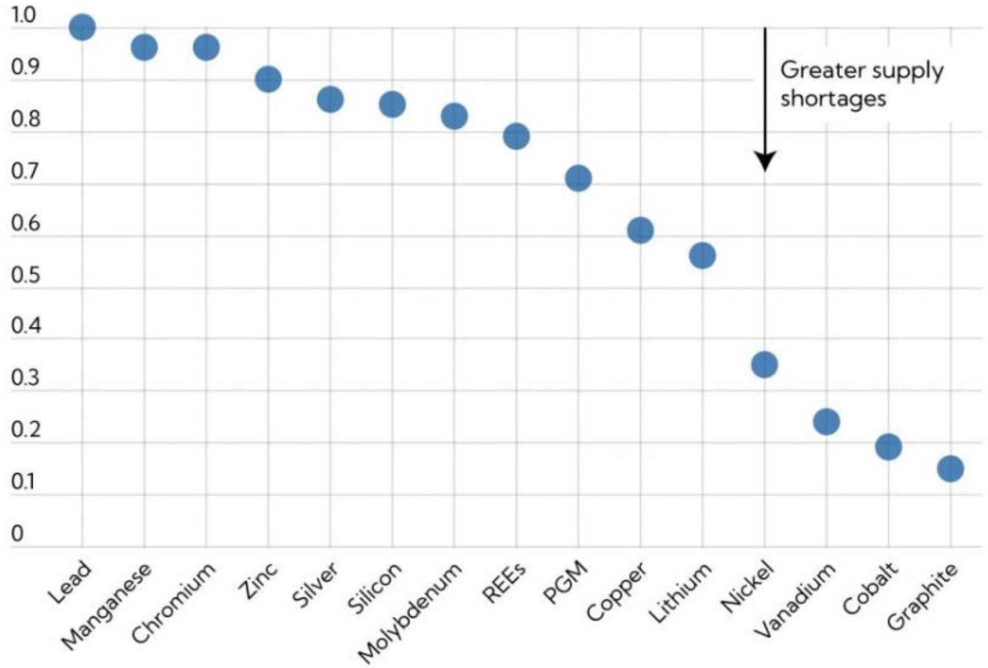
	Copper	Cobalt	Nickel	Lithium	REEs	Chromium	Zinc	PGMs	Aluminium
Solar PV	High	Low	Low	Low	Low	Low	Low	Low	High
Wind	High	Low	Moderate	Low	High	Moderate	High	Low	Moderate
Hydro	Moderate	Low	Low	Low	Low	Moderate	Moderate	Low	Moderate
CSP	Moderate	Low	Moderate	Low	Low	High	Moderate	Low	High
Bioenergy	High	Low	Low	Low	Low	Low	Moderate	Low	Moderate
Geothermal	Low	Low	High	Low	Low	High	Low	Low	Low
Nuclear	Moderate	Low	Moderate	Low	Low	Moderate	Low	Low	Low
Electricity networks	High	Low	Low	Low	Low	Low	Low	Low	High
EVs and battery storage	High	High	High	High	High	Low	Low	Low	High
Hydrogen	Low	Low	High	Low	Moderate	Low	Low	High	Moderate

Relative importance of minerals for a particular clean energy technology: High: ● Moderate: ● Low: ●

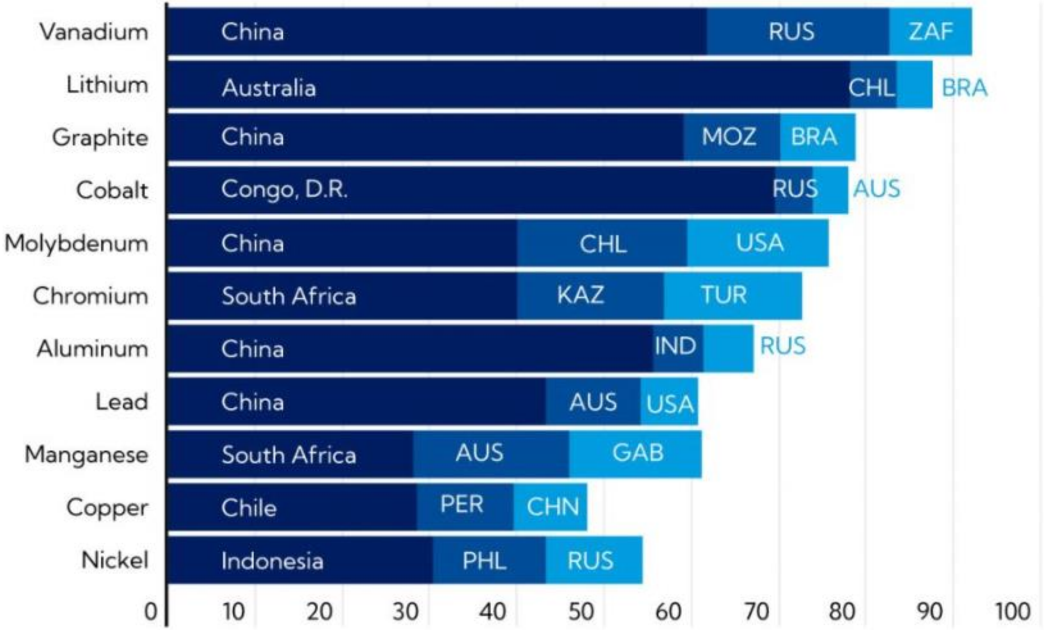
Metals in a net-zero scenario



Current production rates of some important metals, including copper, are likely to be inadequate to satisfy future demand .
(Supply/demand ratio, energy and no-energy demand coverage)

Source: International Energy Agency, US Geological Survey 2021, and IMF Staff calculation. Note PGM=Platinum-group metals. REEs (Rare-earth elements. Supply -The demand ratio is the ratio of supply to demand. Supply= Cumulative production volume for 2021-2050 fixed at 2020 output level. Demand= Total metal demand 2021-2050 for renewable energy and other uses.

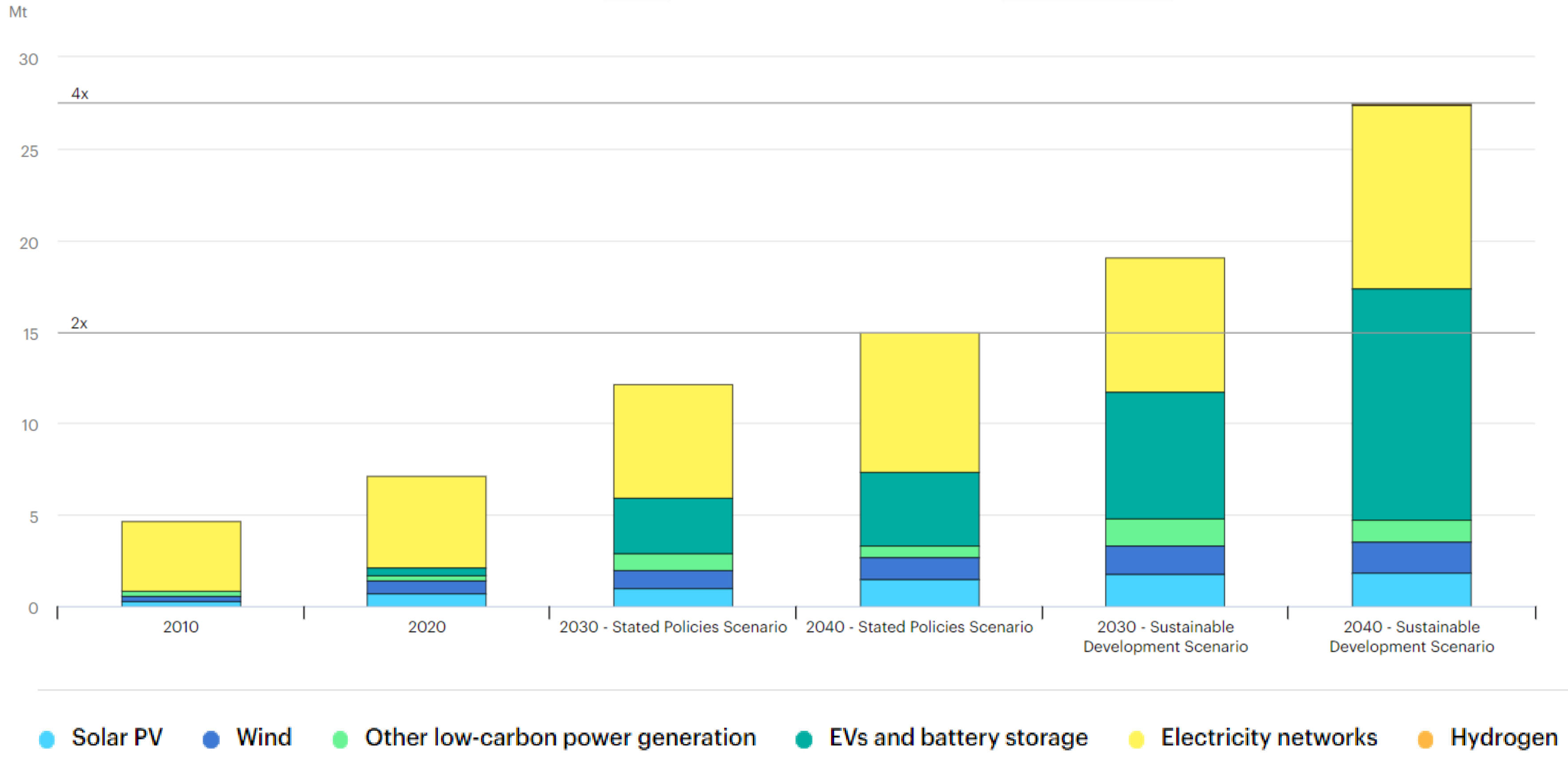
Biggest Producers



Supplies of several metals that are crucial to the green energy are heavily concentrated in just hand full of nations.
(Percent of market)

Source: International Energy Agency, US Geological Survey 2021, and IMF Staff calculation. Note: AUS=Australia, BRA=Brazil, CHL=Chile, CHN=China, COD=Congo D.R.,IDN=Indonesia=India, KAZ=Kazakhstan, MPZ=Mozambique, PER=Peru, PHL=Philippines, RUS=Russia, TUR=Turkey, USA=United States of America, ZAF =South Africa

Total mineral demand for clean energy by scenario, 2010-2040



Indian Scenario of Critical Minerals

Mineral Inventory and Select Mineral Needs for Clean Energy Manufacturing (2020–40)

Mineral	Reserves (KT)	Total Resources (KT)	Typical Share of Metal in Ore (%)	Mineral Needs (KT)
Copper#	2,375	12,158	100	3244
Nickel	0	189	1.5	145
Manganese	93,475	4,95,874	35	208
Cobalt	0	44,910	0.5	7
Chromium	1,02,210	3,44,016	40	354
Molybdenum	0	19,372	0.5	42
Zinc#	10,000	36,363	100	1400
Rare earths oxides ##	6900		100	19
Silicon	17,283	1,83,963	100	2709
Bauxite	6,56,422	38,96,864	20	14827
Lead #	2,482	13,004	100	16
Titanium	14,420	4,13,626	6	3
Neodymium oxide	1173		N/A	19
Silver#	7	30	100	26
Indium	None		N/A	N/A

Note: # Mineral inventory includes reserves and resources of the metal content rather than the ore;
Rare earth oxide reserves are in monazite associated with beach sands

Mineral Inventory and Select Mineral Needs for Electric Vehicle Manufacturing (2020-30)

Mineral	Reserves (KT)	Total Resources (KT)	Typical Share of Metal in Ore (%)	Mineral Needs (KT)
Copper#	2,375	12,158	100	1,569
Lithium	None		N/A	262
Nickel	0	189	1.5	1,177
Manganese	93,475	4,95,874	35	723
Cobalt	0	44,910	0.5	392
Graphite	7,961	1,94,887	25	1,955
Zinc#	10,000	36,363	100	3
Rare earths oxides ##	6900	25	100	15

Note: # Mineral inventory includes reserves and resources of the metal content rather than the ore;

Rare earth oxide reserves are in monazite associated with beach sands

Nuclear Energy

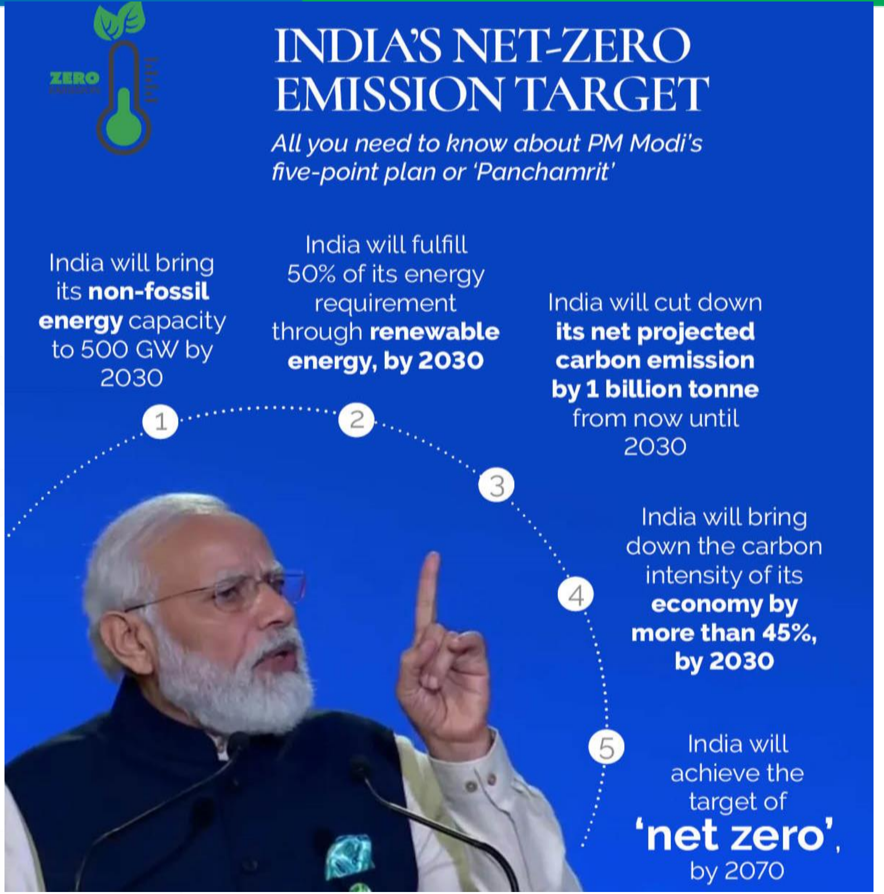
Another critical material for green energy is uranium to make nuclear energy. Nuclear power is clean as it does not emit any Green Houses Gases. Many countries are now switching to atomic energy.

India currently generates 6.7 Gw of nuclear power by operating 22 atomic reactors all over India. The resource base Uranium in India is 2,70,636 tons, and uranium production is about 400 tons.

To increase electricity generation from Nuclear sources, identifying indigenous uranium resources with high grades of uranium ore will be required. With this, the role of geologists will be enhanced to locate new deposits of uranium to make nuclear fuel.

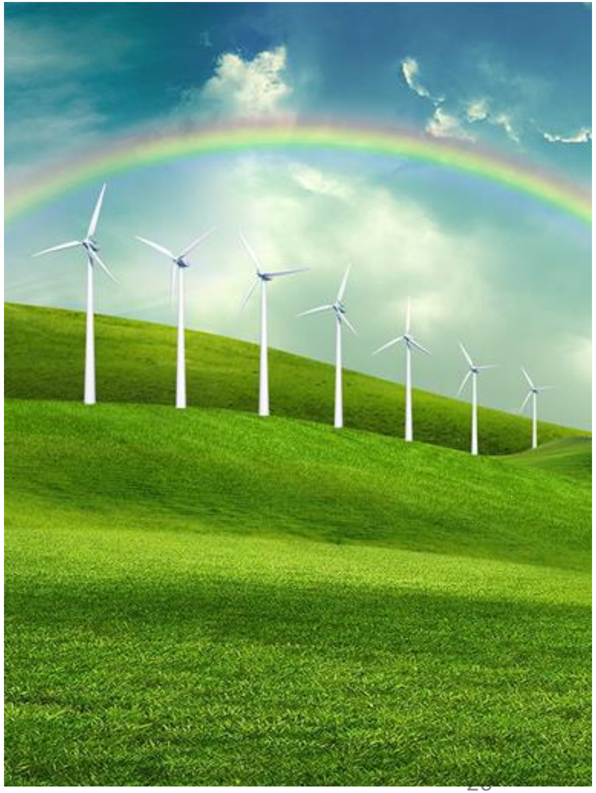
Climate Change Mitigation : UNFCCC Mandate of India

- The Government of India has articulated and put across the concerns of developing countries at the 26th session of the Conference of the Parties (COP26) to the United Nations Framework Convention on Climate Change (UNFCCC) held in Glasgow, United Kingdom
- India presented the following five nectar elements *(Panchamrit)* of India's climate action in the UNFCCC



To Conclude:

- India is a significant contributor to CO_2 emission
- It intends to achieve net-zero emissions by 2070
- To achieve this target, we need to reduce fossil fuel consumption and switch over to wind, solar, nuclear etc
- Clean energy technology needs critical minerals
- India is deficient in many critical minerals
- India needs to look for indigenous resources of critical minerals
- It requires exploration efforts by government agencies and private companies, hence a significant role of geologists
- Present auction-based policy is not favorable in the quest for discoveries by private companies



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Thank You