Which gas is keeping the Earth warm?

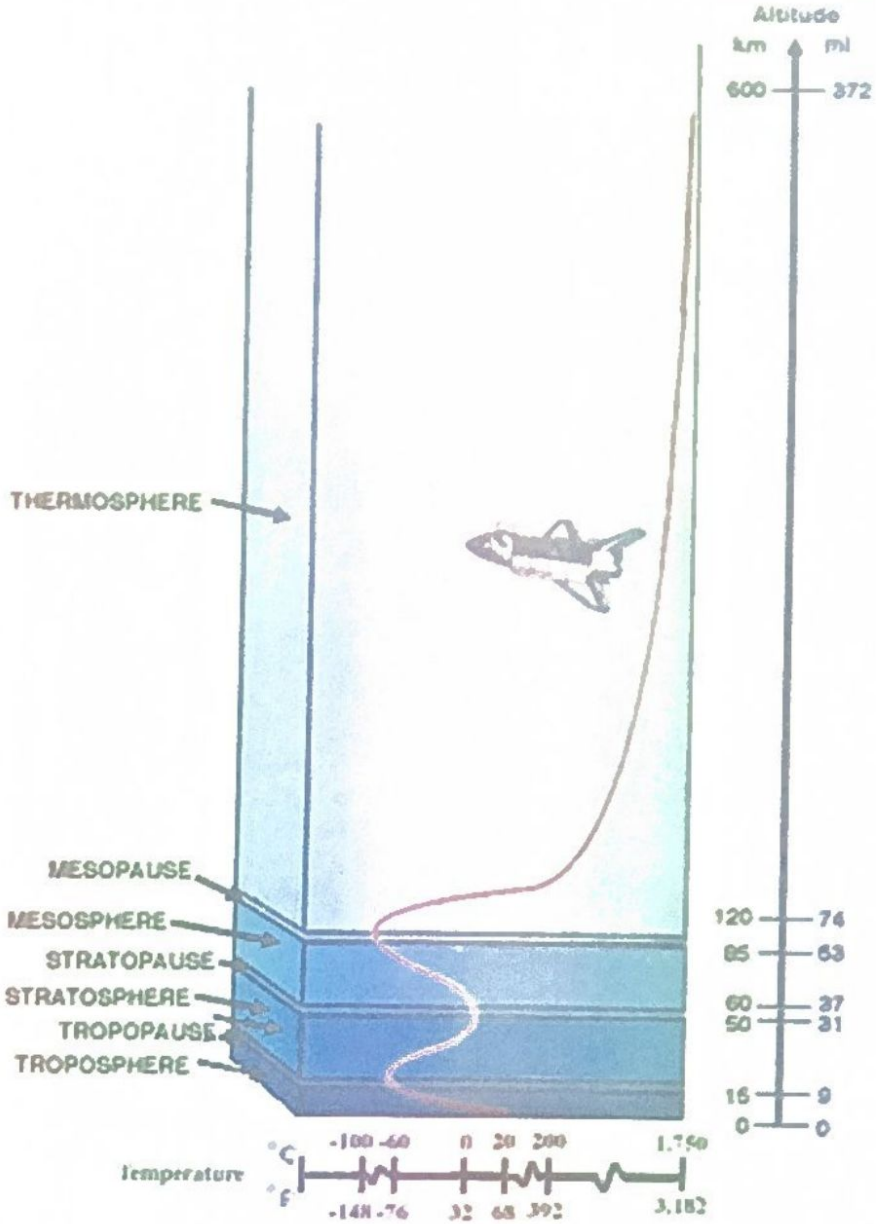
- ✓ The major natural greenhouse gases are
  - o water vapor, which causes about 36-70% of the greenhouse effect on Earth (not including clouds);
  - o carbon dioxide, which causes 9-26%;
  - o methane, which causes 4-9%, and
  - o ozone, which causes 3-7%.

A. N_2?
B. O_2?
C. CO_2?
D. H_2O?

- ✓ Note that it is not really possible to assert that a certain gas causes a certain percentage of the greenhouse effect , because the influences of the various gases are not additive.
  (The higher ends of the ranges quoted are for the gas alone; the lower ends, for the gas counting overlaps.)

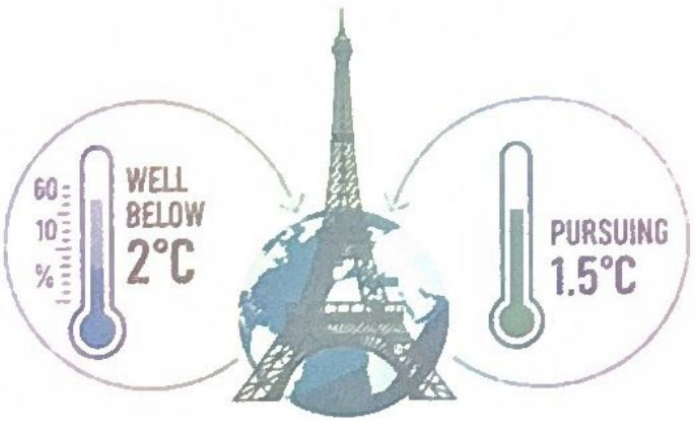
What's the big deal if human CO_2 causes 1 °C temperature increase?

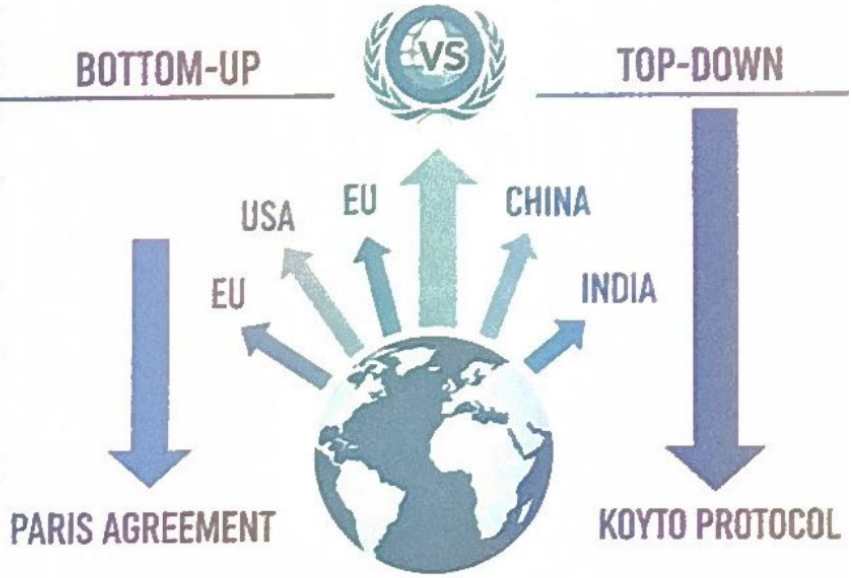
- ✓ An increase in atmospheric temperature (human or natural origin) will lead to the increase in the water vapor content of the troposphere.
- ✓ Water vapor is a strong greenhouse gas, the increase in H_2O vapor in turn causes enhanced greenhouse effect, raising the temperature more.
- ✓ Higher atmospheric temperature will cause more evaporation of water
- ✓ Which leads to even higher temperature…
- ✓ ⇒ Runaway Green House Effect!



The Paris Agreement - A New Era of Global Climate Action

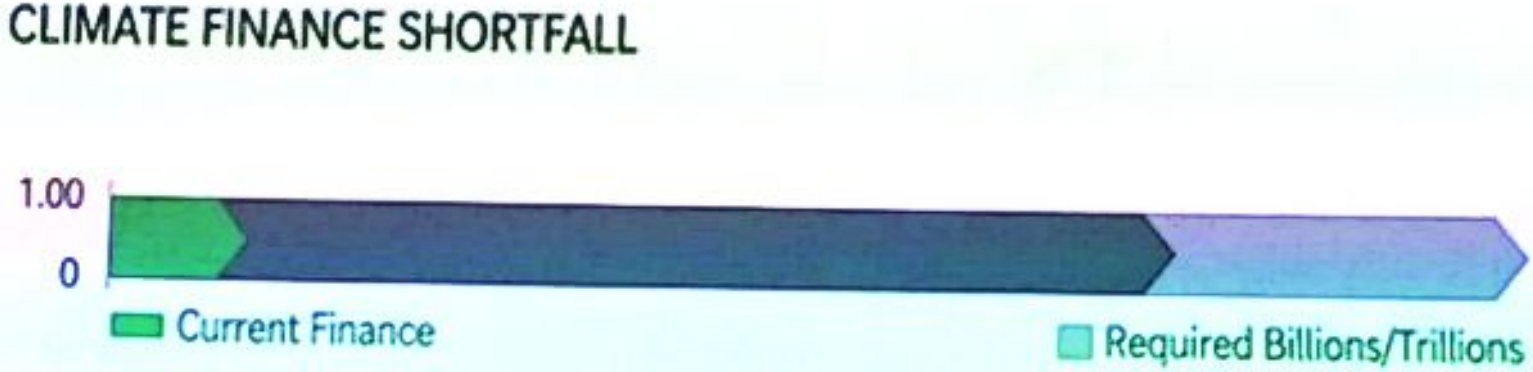
- ✓ **What is it?** The Paris Agreement is a landmark international treaty adopted in 2015 by 196 countries. It is the first legally binding, universal agreement that brings all nations together in a common cause to combat climate change.
- ✓ **What are its core goals?** The central aim is to strengthen the global response to climate change by holding the increase in the global average temperature to well below 2°C above pre-industrial levels and pursuing efforts to limit it to 1.5°C. It also seeks to enhance countries' abilities to adapt to climate impacts and to align financial flows with a climate-resilient pathway.
- ✓ **How is it different from the Kyoto Protocol?** Unlike the Kyoto Protocol, which prescribed top-down, legally binding emission reduction targets only for developed countries, the Paris Agreement uses a flexible, "bottom-up" approach. It requires all nations, both developed and developing, to submit their own targets, known as Nationally Determined Contributions (NDCs).





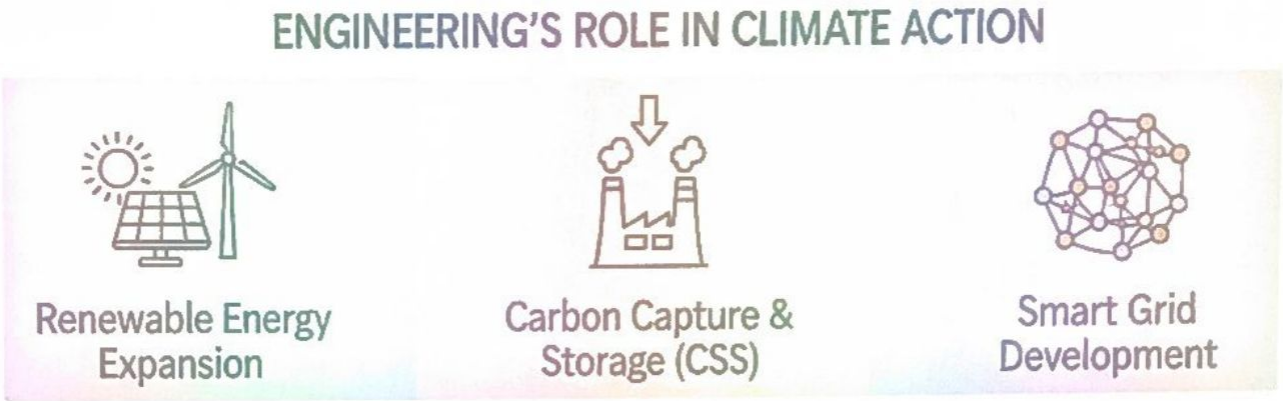
Implementation, Challenges & The Technical Nexus

- ✓ The world is currently "off-track" to meet the Paris Agreement's 1.5°C goal.
  - The collective climate action plans would only lead to a 2.6% decrease in global greenhouse gas emissions by 2030, far short of the 43% reduction required by science to limit warming.
- ✓ **Climate Finance:** A key criticism is the persistent shortfall in climate finance from developed to developing nations.
  - At COP29, a new goal was agreed for developed countries to provide at least $300 billion per year to developing countries by 2035, an amount many developing nations, including India, have called - far short of the trillions needed.



Implementation, Challenges & The Technical Nexus

- ✓ **The Engineering Imperative:** agreement's goals translate into a need for massive technological innovation and deployment.
  - **Renewable Energy**: The first Global Stocktake at COP28 called for a global tripling of renewable energy capacity and doubling of energy efficiency by 2030.
  - **Carbon Capture**: Technologies like Carbon Capture, Utilization, and Storage (CCUS) and Bioenergy with Carbon Capture and Storage (BECCS) are considered necessary to achieve net-zero emissions, especially for "hard-to-abate" industries like cement and steel.
  - **Smart Grids**: The deployment of smart grids is critical to integrate the growing, but variable, renewable energy sources into the electricity system.



How about Clouds and Ice?

- ✓ **Water vapor (water in gaseous phase) is one of the most potent and abundant greenhouse gas…but**

- ✓ Clouds (water in liquid form) reflect sunlight, decreasing the solar energy input into Earth's atmosphere during the day, but they trap IR radiation from the Earth during the night. It's net effect is not well know so far…
  - o Albedo of clouds range from close to 0 to 70%.
  - o Testing climate impact of clouds after Sept. 11, 2001…

- ✓ Ice has a very high albedo , ~ 80 to 90%.
  - o Thus, reduction of the polar ice cap can cause more heating…

Contrails and Climate

- ✓ Contrails are artificial clouds made by the exhaust of the aircraft engines, or the wingtip vortices

- ✓ Contrails produced by the heavy air traffic over the US may have noticeable influences on the weather…
  - o Commercial air traffic were suspended for three days after the Sept. 11, 2001 attack. This provided a rare chance for the climate scientist to test their theory…
  - o Measurements show that without contrails the local difference of day and night-time temperatures was about 1 degree Celsius higher than immediately before the attack…