Carbon Capture & Sequestration (Storage) CCS

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Presentation Outline

- Introduction
- CO_2 Capture Processes & Separation Technologies
- CO_2 Transportation & Storage
- Quality Specification of CO_2
- Monitoring & Mathematical expressions
- CCS Status in World & in India
- Alternative Approaches to Capture CO_2

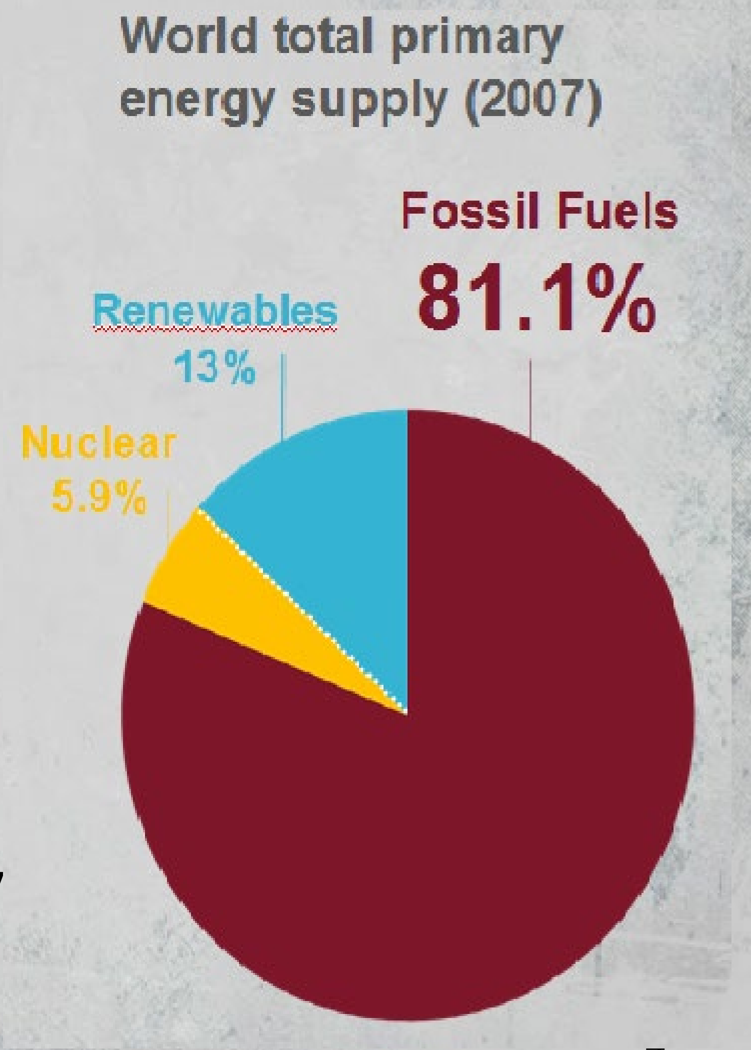
By 2050, global population will rise from

7 → 9 billion people

& the World energy demand is expected to increase by 50% over the next 20 years.

We Still Rely on Fossil Fuels

- Fossil fuels (coal, gas and oil) represent **80%** of the global energy supply
- Renewables supply only account for 13% of our total energy supply

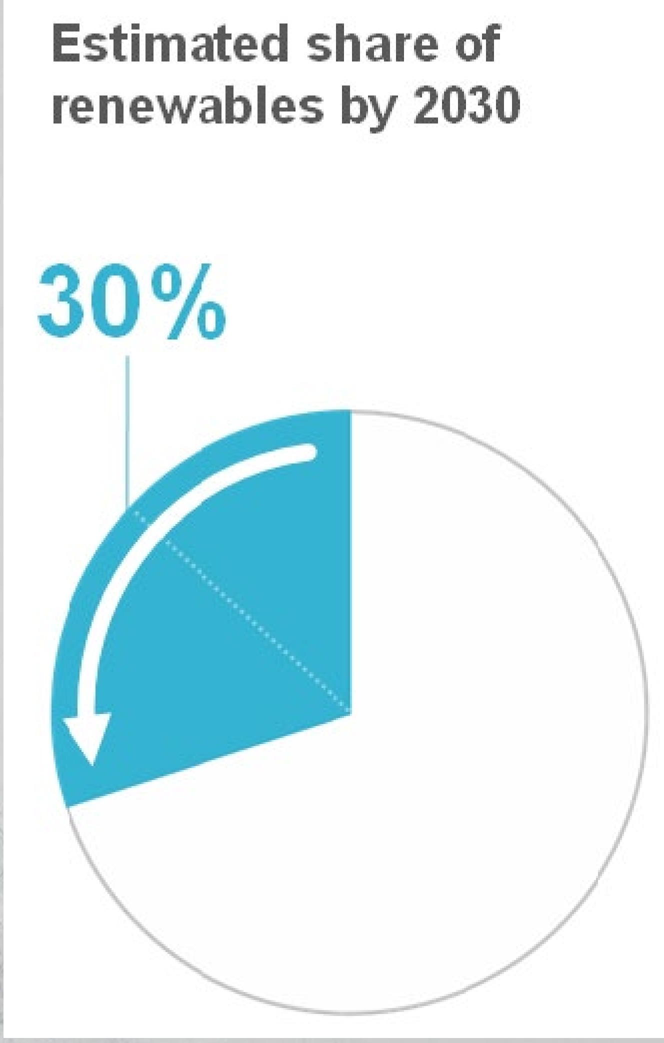


... and will Continue to do so for Decades to Come

By **2030** Renewables could make upto 30% of the global energy supply

⬇

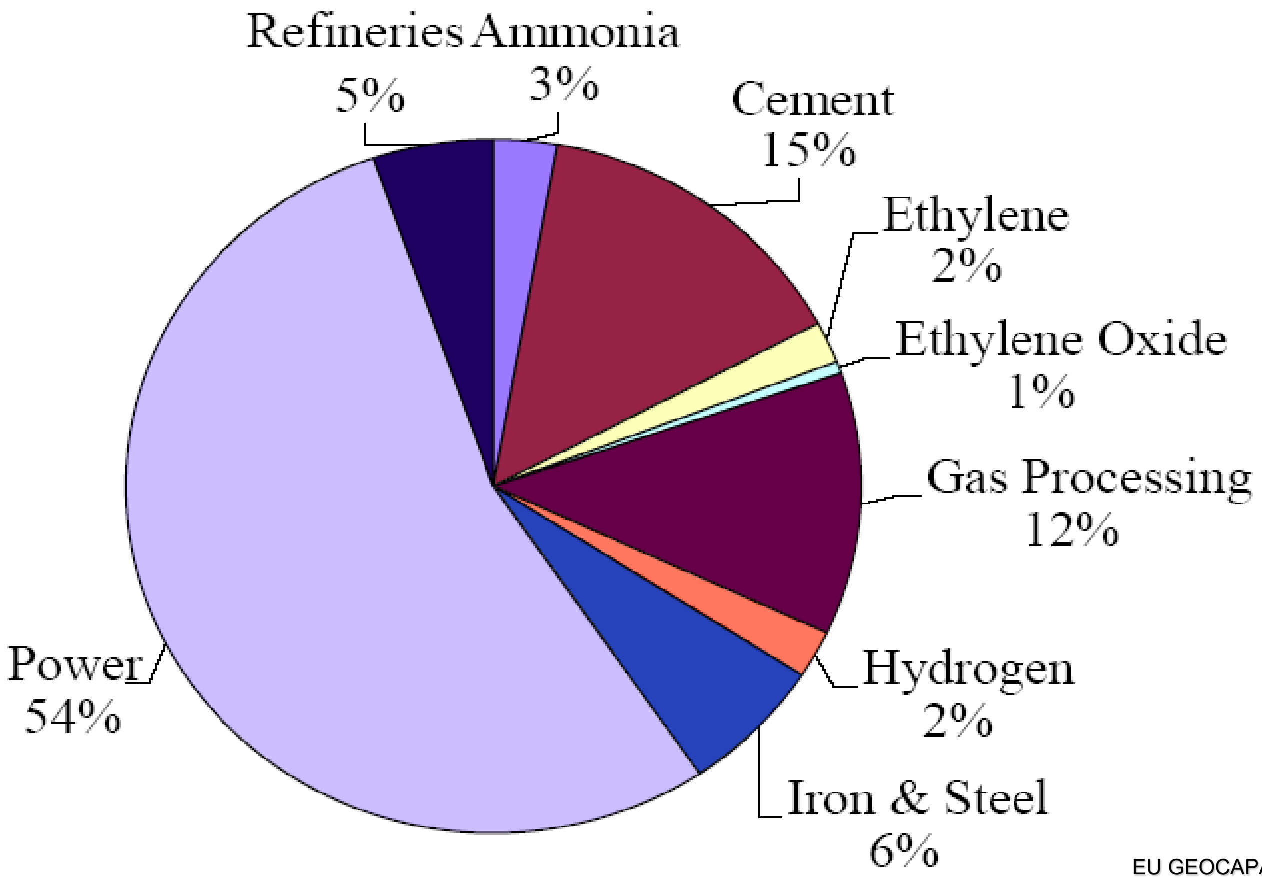
- But fossil fuels will remain our main source of energy for decades to come



Fossil Fuels Power the Largest Emitters of CO_2....

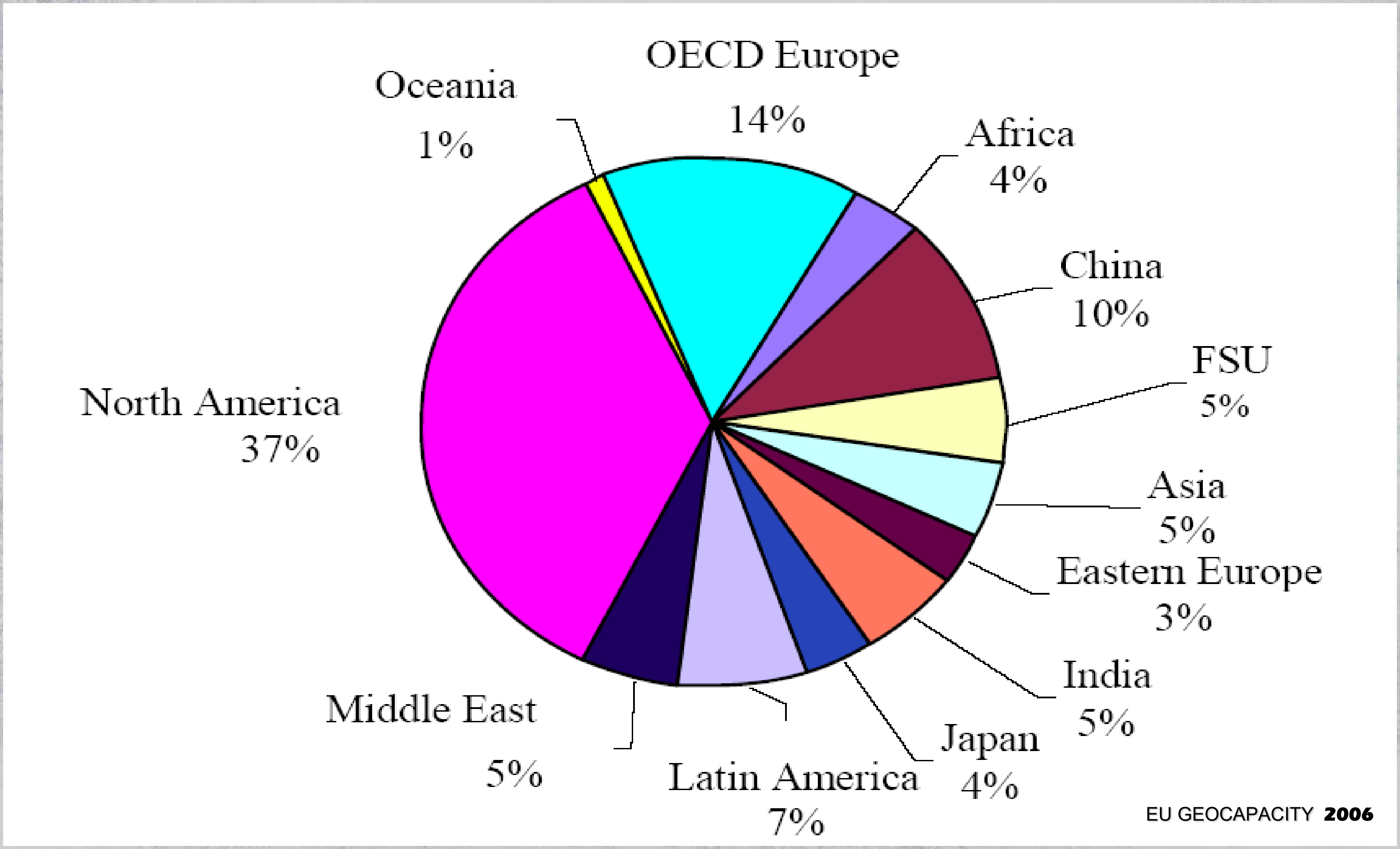
Fossil fuels power plants,
heavy industry and refineries
account for **52%** of the world's
current CO2 emissions
(15 billion tonnes CO2 emissions/year)

CO_2 emissions by industry & power plant



EU GEOCAPACITY **2006**

CO_2 emissions by region



…and too Much CO2 Leads to Global Warming

- … which in turn, produces climate change


Muir Glacier, August, 1941

Muir Glacier, August, 2004

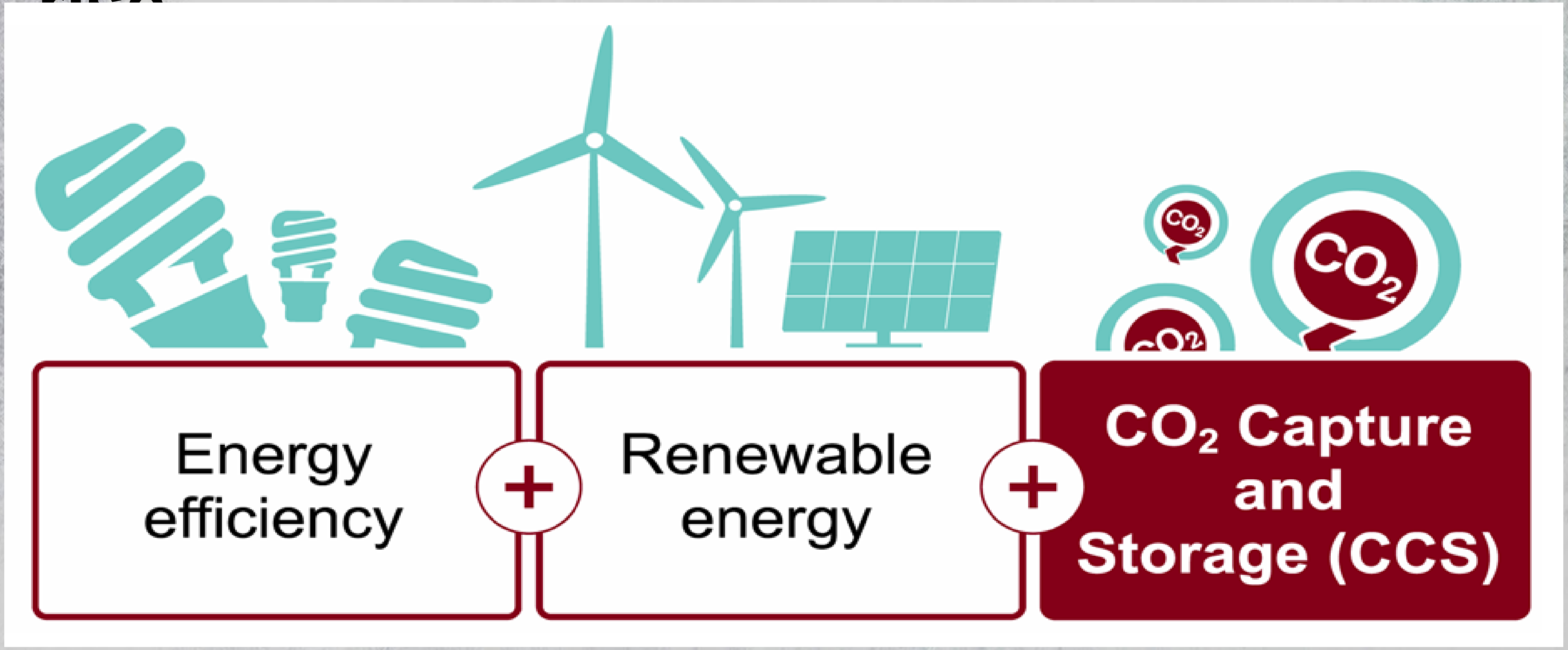

- Unless the rise in average global temperature is kept below 2°C, **devastating** and **irreversible** climate changes will occur.

How do we Meet this Challenge?

...Our climate depends on it

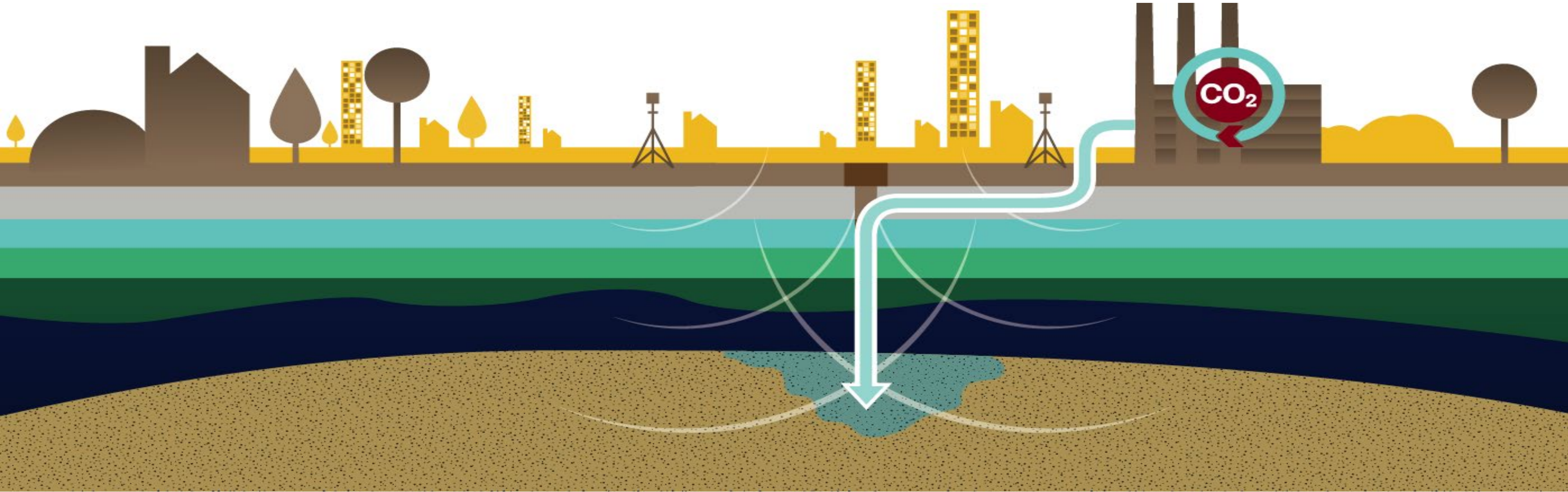
- We need to cut CO_2 emissions fast...

... as energy consumption continues to rise



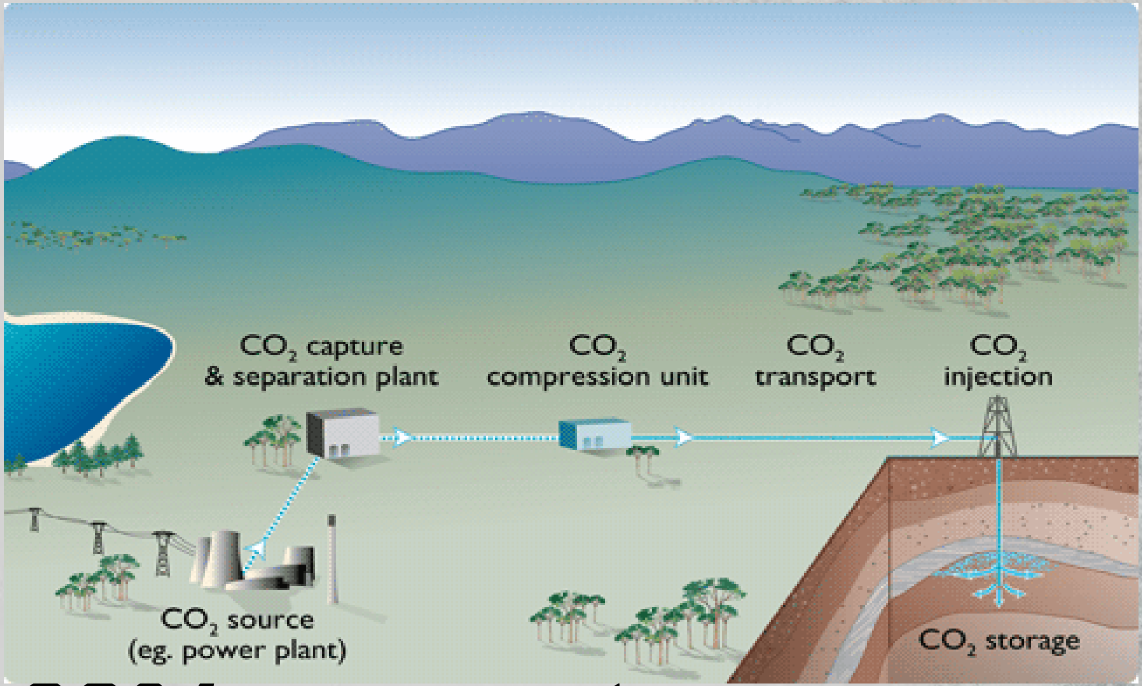
CCS alone will provide up to 20% of the CO_2 emission reductions we need **to make by 2050.**

Here's how it works...



What Is **Carbon Capture** and **Sequestration** (Storage)

Three stage process:

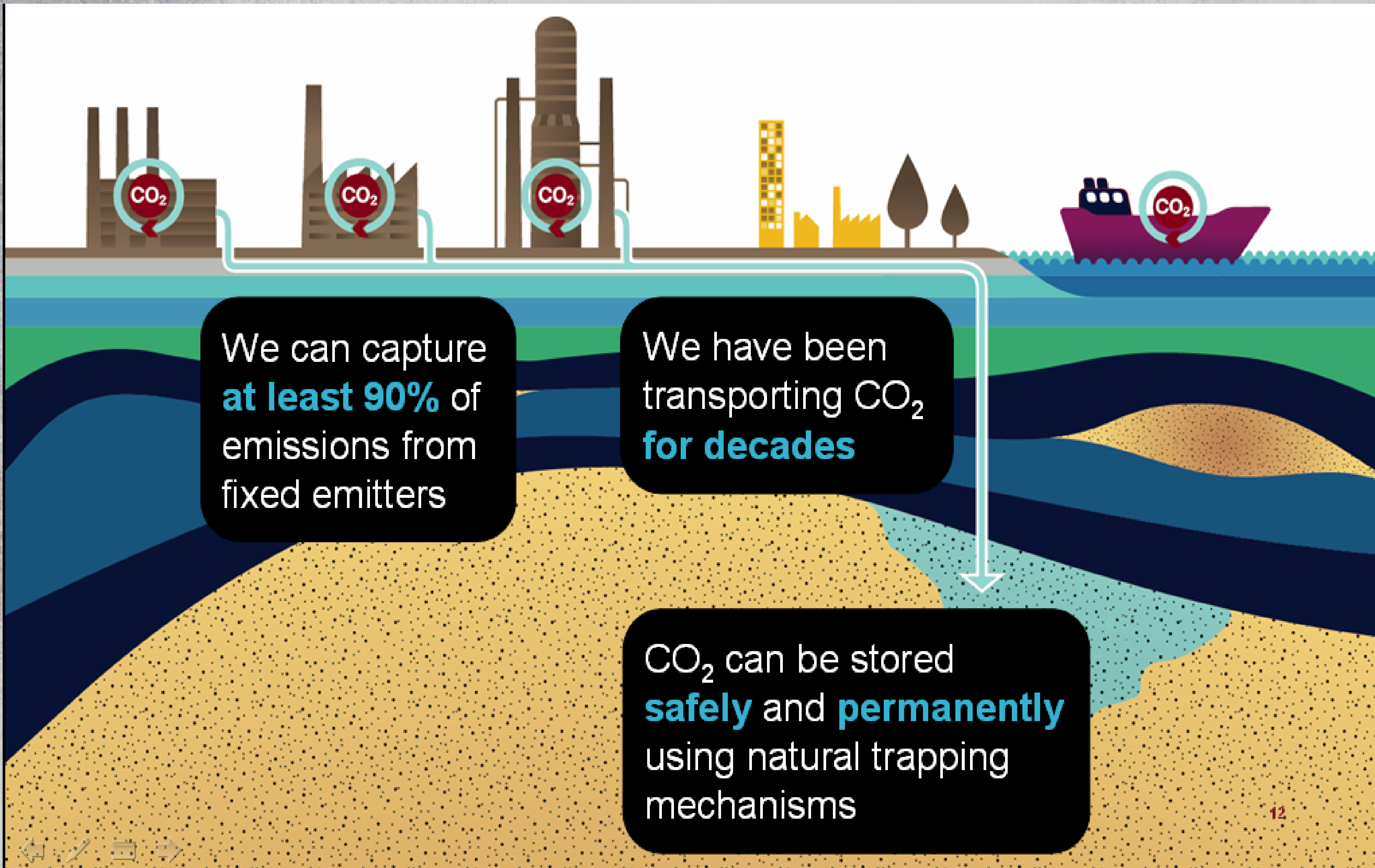


i. **Capturing** CO2 at Large & stationary point sources

ii. **Transporting** the CO2 from source to sink,

iii. **Injecting** the CO2 in suited geological reservoir or sinks

Inside CCS



CO_2
CO_2
CO_2
CO_2
We can capture at least 90% of emissions from fixed emitters
We have been transporting CO_2 for decades
CO_2 can be stored safely and permanently using natural trapping mechanisms
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Carbon Capture Options

- **Capture Processes:**

1. Post-combustion :separation CO_2-N_2
2. Pre-combustion :separation CO_2-H_2
3. Oxy-fuel combustion :separation O_2-N_2

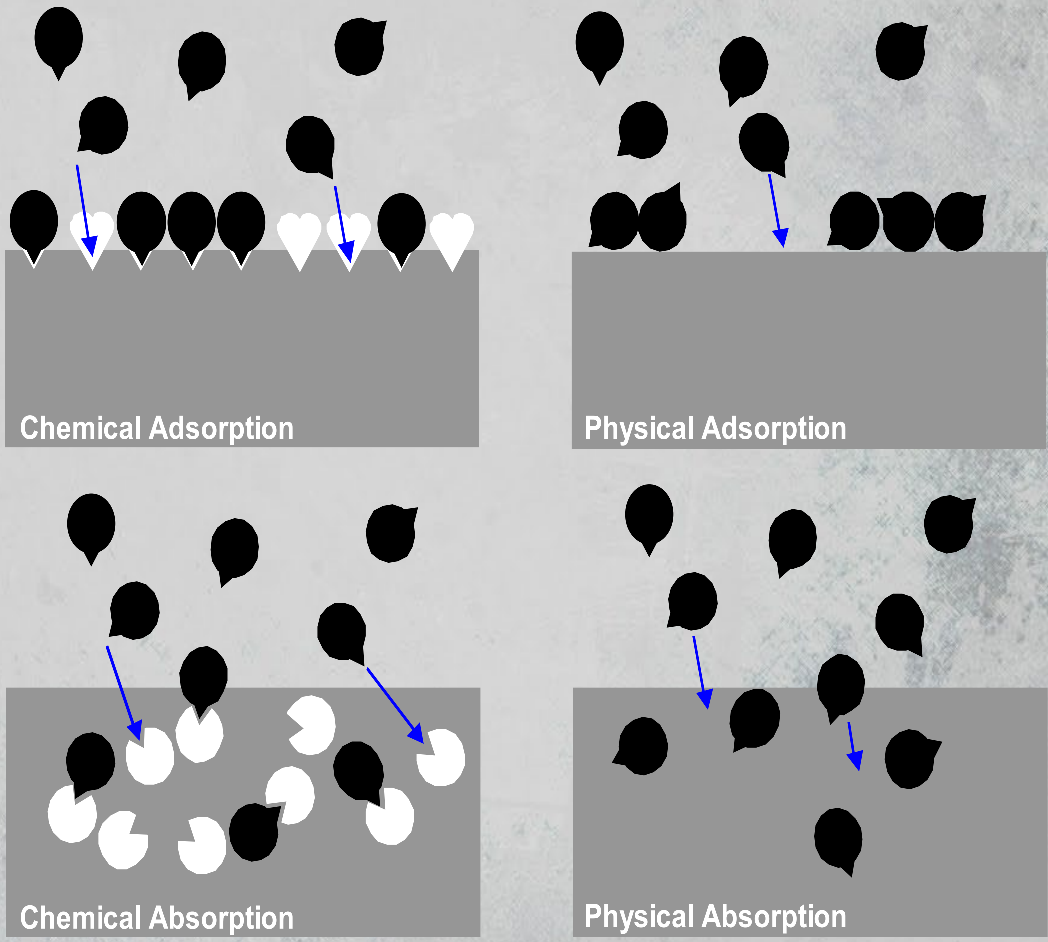
- **Separation technologies:**

1. Adsorption
2. Absorption
3. Membrane Separation
4. Cryogenic distillation

Separation principles

1.Adsorption: attachment of fluid to a solid surface

- Solid sorbents :Lime, zeolite, activated carbon



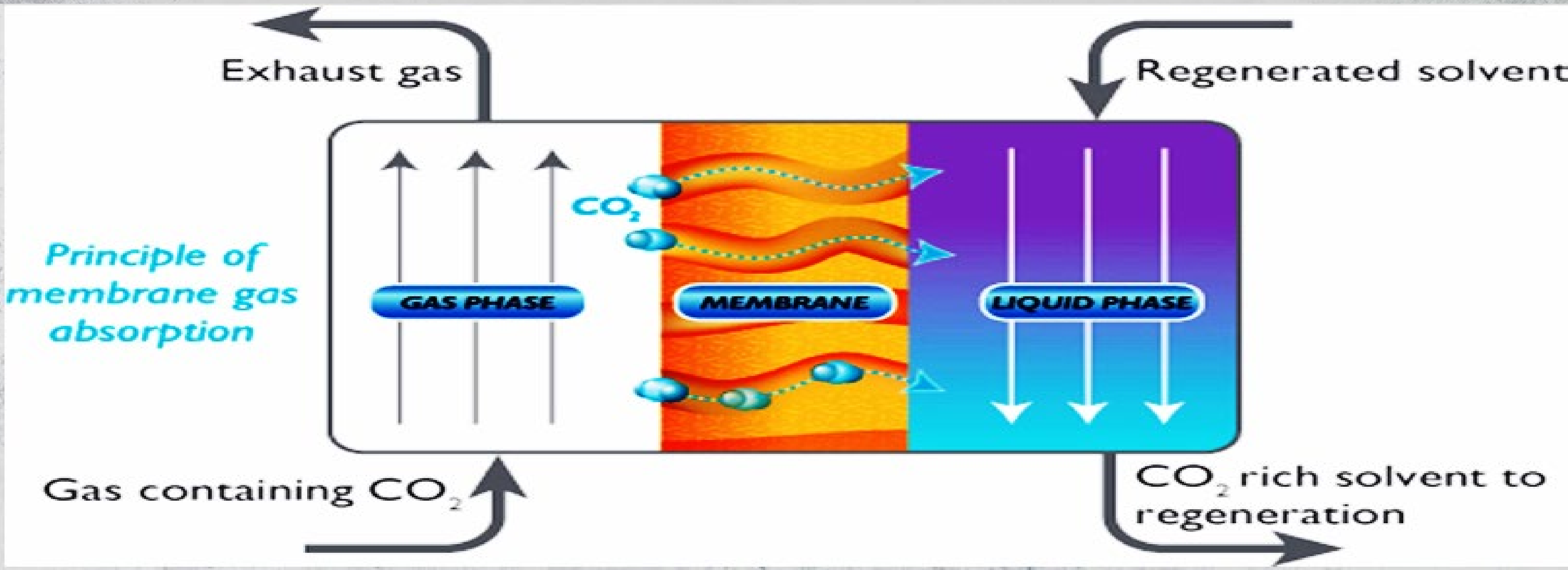
2.Absorption: fluid dissolves or permeates into a liquid

- Solvents :Aqueous amines and salts

Separation principles

3.Membrane Separation: separation which makes use of difference in physical/chemical interaction with membrane

- Membrane provides grater contacting area



Separation principles

4. Cryogenic distillation: separation based on the difference in boiling points

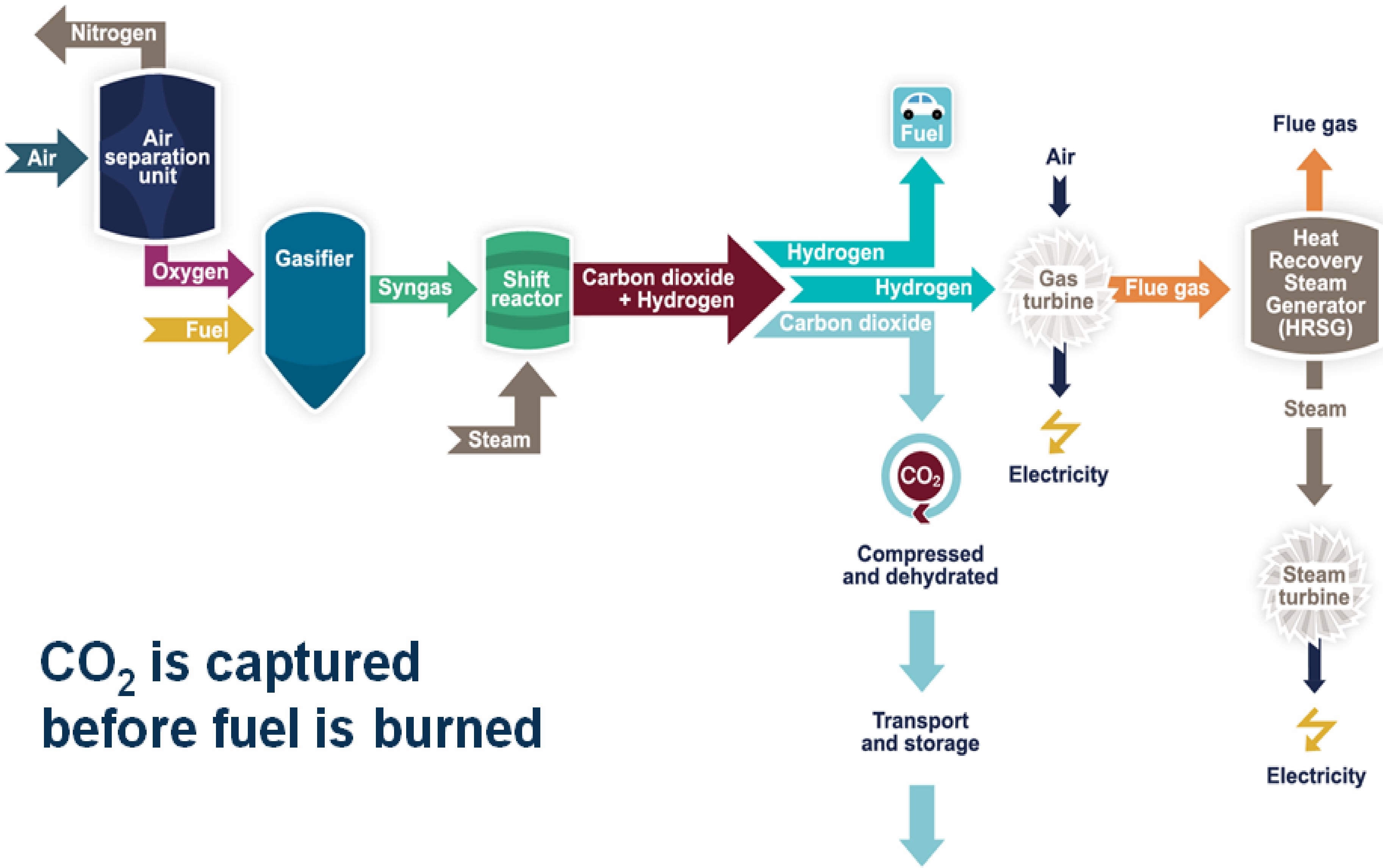
- Distillation at low temperatures.

- Applied to separate

-CO_2 from natural gas or

-O_2 from N_2 and Ar in air.

Pre-combustion capture

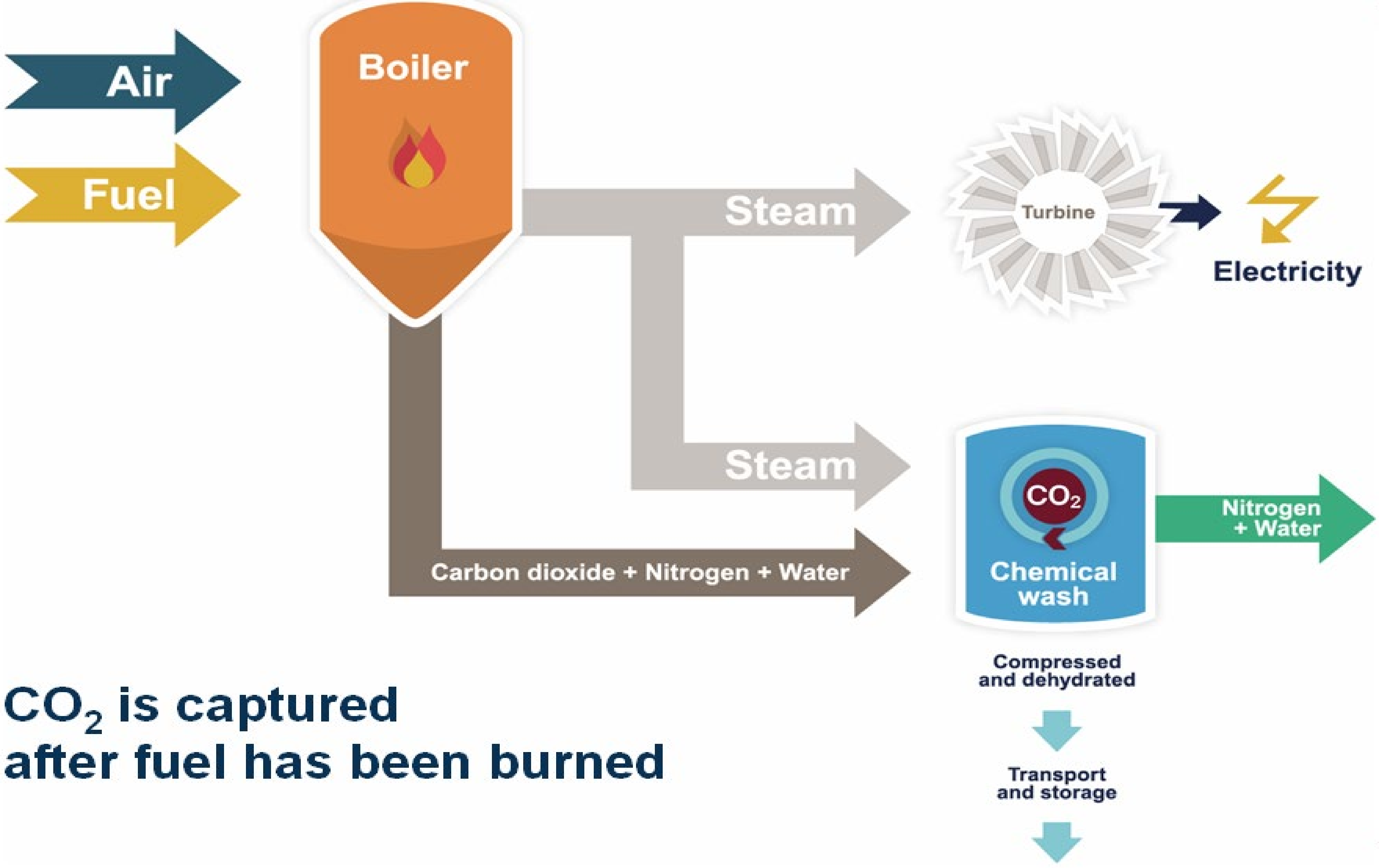


CO_2 is captured before fuel is burned

Pre-combustion capture

- Chemical/physical absorption is currently most feasible technology
- Energy penalty and additional costs in physical absorption are lower in comparison to chemical absorption
- CO_2 capture between 80-90%
- No retrofit possibility

Post-combustion capture



CO_2 is captured
after fuel has been burned

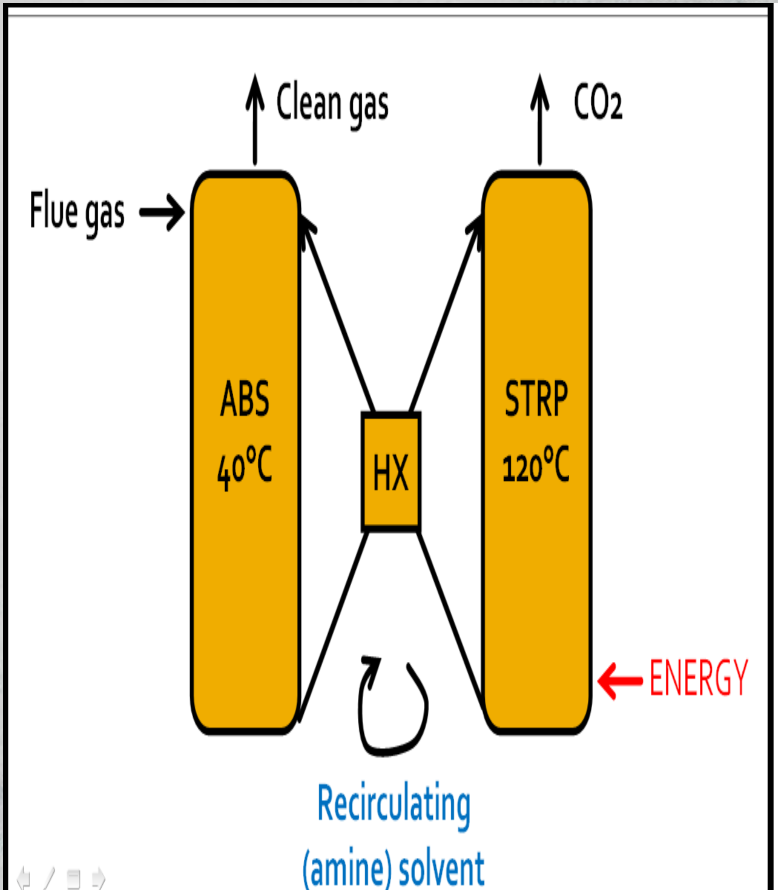
Post-combustion: Absorption process

- Absorption of CO2 by MEA at 40°C

$$C_2H_4OHNH_2 + H_2O + CO_2 \leftrightarrow C_2H_4OHNH_3^{+} + HCO_3^{-}$$ + Heat

- MEA recovery by desorption at 120°C

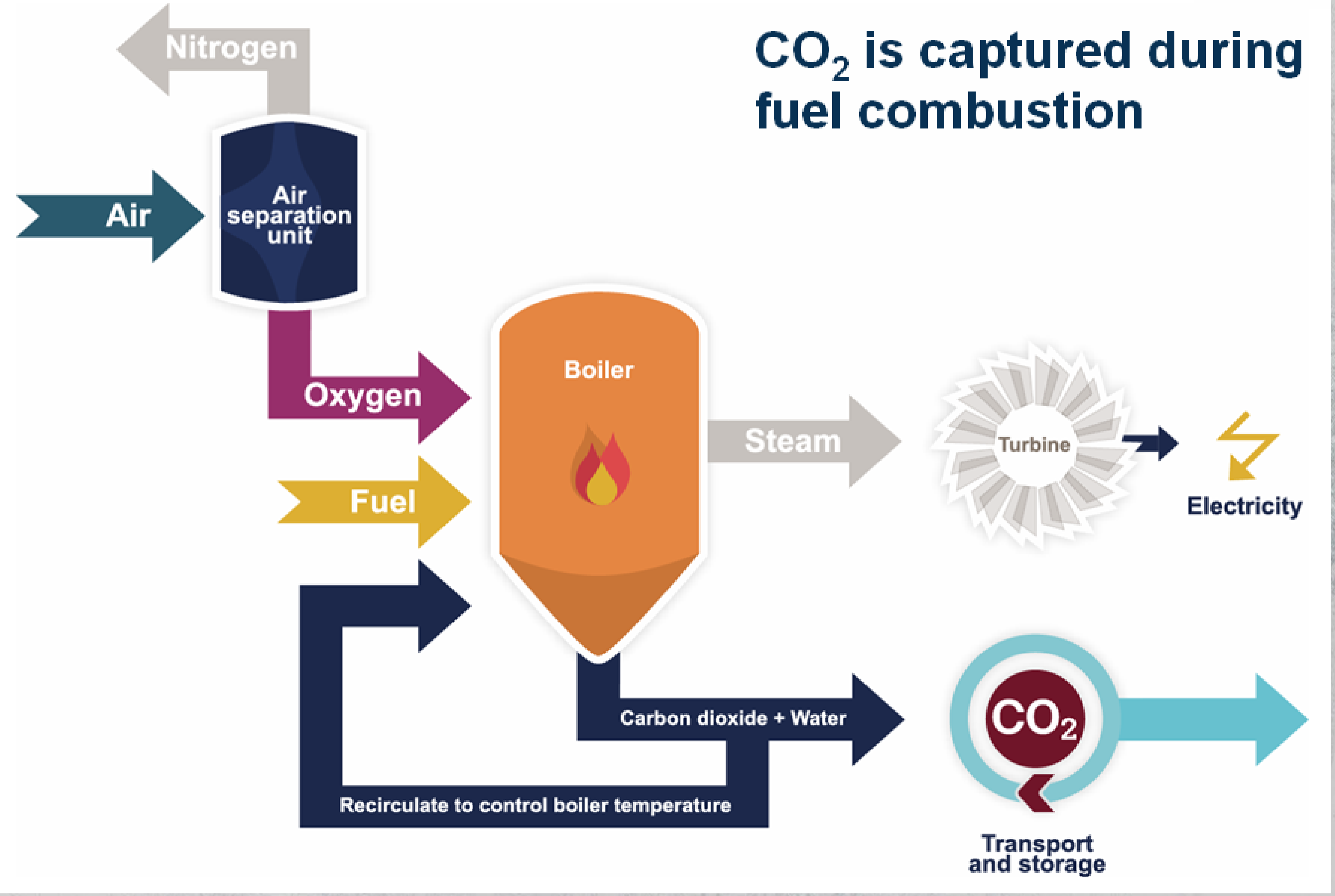
- During the absorption process, the reaction proceeds from left to right; during regeneration, the reaction proceeds from right to left



Post-combustion capture

- Chemical absorption is currently most feasible technology
- Energy penalty and additional costs are high with current solvents.
- Technology is commercially available but on a smaller scale
- CO_2 capture between 80-90%
- Retrofit possibility

Oxyfuel combustion Capture



Oxyfuel combustion Capture

- Cryogenic air separation is currently most feasible technology
- Experienced in steel, aluminum & glass industry
- Energy penalty & additional costs are comparable to post-combustion capture
- Allows for 100% CO_2 capture
- Boilers require adaptations (retrofit possible)

CO2 transport

- Once captured, the CO_2 is compressed into a liquid state and dehydrated for transport & storage.

- CO_2 is preferably transported by pipeline which is generally the cheapest form of transport.

  - Transport conditions: high-pressure (80-150 bar) to guarantee CO2 is in dense phase

CO_2 transport

Alternative: Tankers (similar to LNG/LPG)

- Transport conditions: liquid (14 to 17 bar, -25 to -30°C)
- Advantage: flexibility, avoidance of large investments
- Disadvantage: high costs for liquefaction and need for buffer storage.

This makes ships more attractive for larger distances.

Different Ways of carbon storage

- In plants and soil “terrestrial sequestration (carbon sinks)”

-Underground “geological sequestration”

-Deep in ocean “ocean sequestration”

-As a solid material (still in development)

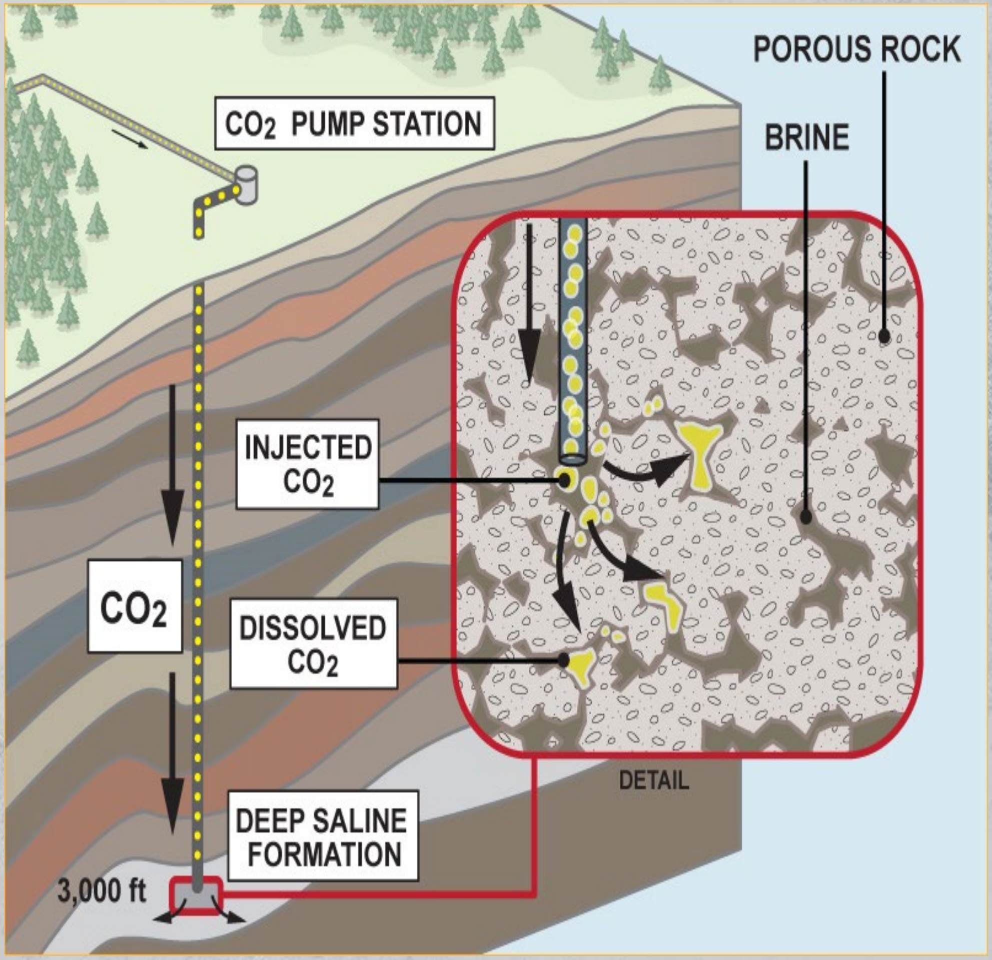
Terrestrial Carbon Sequestration

- CO_2 from the atmosphere is absorbed naturally through photosynthesis & stored as carbon in biomass & soils.
- Reduce greenhouse gases by maintaining existing carbon storage in trees and soils
- Tropical deforestation is responsible for 20% of world's annual CO_2 emissions

Geological storage

Storing of CO_2 underground in rock formations able to retain large amounts of CO_2 over a long time period

- Held in small pore spaces (have held Oil & natural gas for millions of years)



- Inject in:
  - Oil & Gas fields
  - Depleted Coal seams
  - Salt deposits
  - Saline filled basalts

Geological storage

- Problems with oil fields:
  - Limited distribution and size
  - Increase emissions with EOR
- Coal Seams:
  - Coal must be permeable
  - CO_2 adsorbs to coal surface
  - Will displace methane adsorbed
- Salt deposits:
  - Large storage volume, common
  - Not much is known about them

Enhanced oil recovery (EOR)-

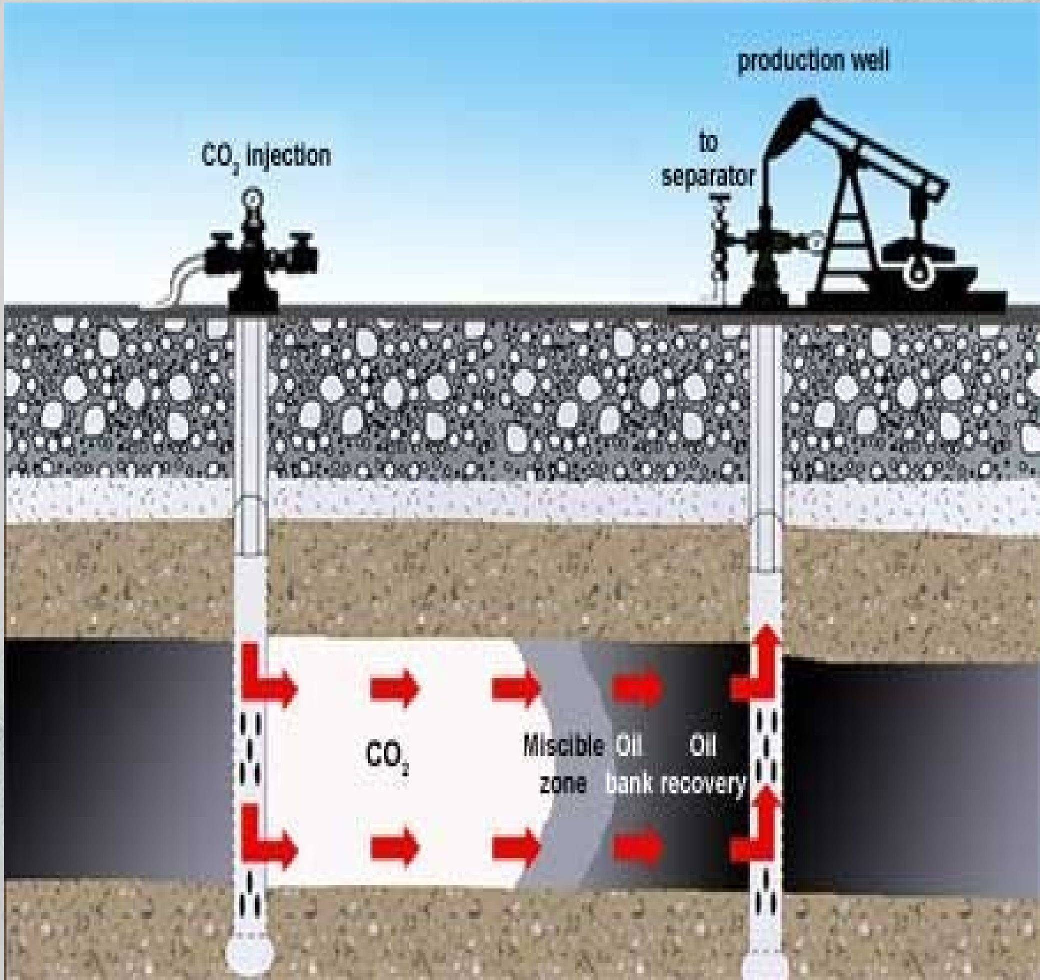
Attractive because the storage costs are offset by the sale of additional oil that is recovered.

– Used to increase oil production from field

– Inject CO_2, N_2 or steam

– Improves recovery of oil up to 30%

– ½ - 2/3 CO_2 returns, rest remains in reservoir



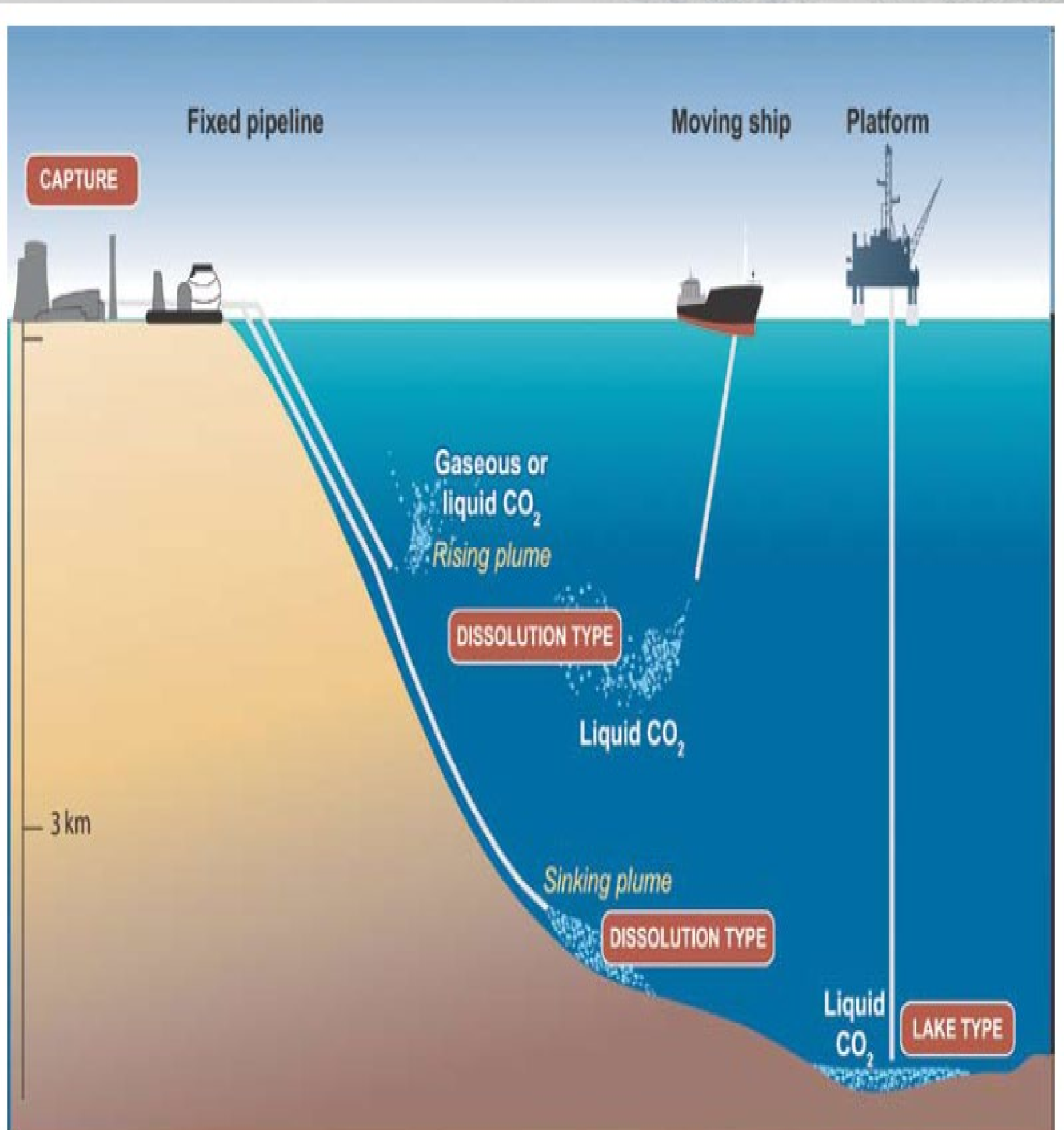
Ocean storage

- At a depth of 3000m CO2 has a negative buoyancy.

- Two main concepts exist:

  -**Dissolution type:** inject CO_2 at depths of 1000 m or more, CO_2 subsequently dissolves.

  -**Lake type**: deposits CO_2 directly onto the sea floor at depths greater than 3000m,where CO_2 is denser than water & is expected to form a lake.



Ocean storage

- 1000-3000 meters in Ocean
    50-80% CO_2 retained for 500 years

- 1/3 of CO2 emitted a year already enters the ocean

- Ocean has 50 times more carbon than the atmosphere

- **Problems with Ocean Storage:**

- CO2 kills organisms

- CO2 increases acidity of water

- Expensive

Mineral Storage

- Minerals having Mg and Ca
  - Added CO_2,Converted to carbonates
- Carbonates are stable
- Minerals are common
- Mineral storage no leakage
- Must have environmentally friendly & economically feasible method

The world wide **capacity** of CO_2 reservoir

Storage option	Word wide capacity(GtC)
Ocean	1000-10000+
Deep saline formations	100-10000
Depleted oil and gas reservoirs	100-1000
Coal seams	10-1000
Terrestrial	10-100
Utilization	Currently<0.1

CO_2 quality specifications

- USA: > 95 mol% CO_2
- **Water content** should be reduced to very **low concentrations** due to formation of **carbonic acid causing corrosion**
- H_2S, O_2 Concentration: ppm level
- N_2 Concentration: few %
- **Desired fluid properties for CO_2 storage**
  - -High density
  - -High viscosity
  - -High solvability
  - -High miscibility

So low temperature and high pressure is desired

Monitoring CO_2 Storage Sites

- Monitoring continues even after a CO_2 injection well is closed and EU legislation requires that stored CO_2 is kept **safely** and **permanently** underground

- **Purpose of monitoring**
  - -To ensure public health and safety of local environment
  - -To verify the amount of CO_2 storage
  - -To track migration of stored CO_2 (simulation models)
  - -To confirm reliability of trapping mechanisms
  - -To provide early warning of storage failure

Mathematical expression for CO2 emission

$$CO_2 \ emissions = GDP \times \frac{Energy \ consumption}{Unit \ GDP} \times \frac{CO_2 \ emissions}{Unit \ energy \ consumption}$$

where

•GDP (gross domestic product) is a measure of the **size of an economy**

•Energy consumption per unit of GDP is a measure of the "**energy intensity**" of the economy.

•CO2 emissions per unit of energy consumption, is measure of the "**carbon intensity**" of the energy we use

Mathematical expression for Energy Penalty

- Energy penalty is the **fraction of fuel that must be dedicated to CCS** for a fixed quantity of work output.

$$\text{Energy penalty} = (x-y)/x,$$

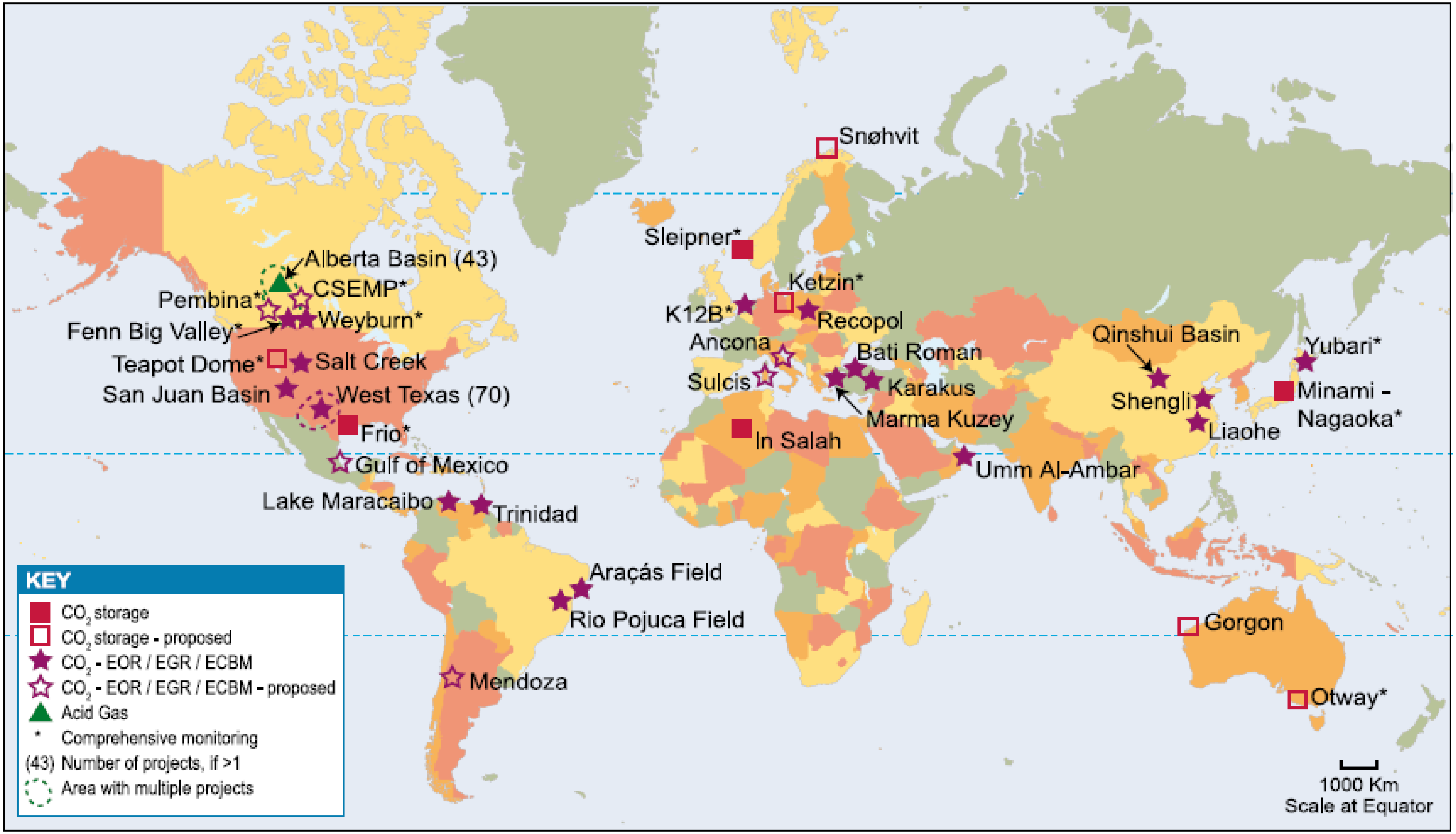
where

x = output in kW of a reference power plant **without capture**

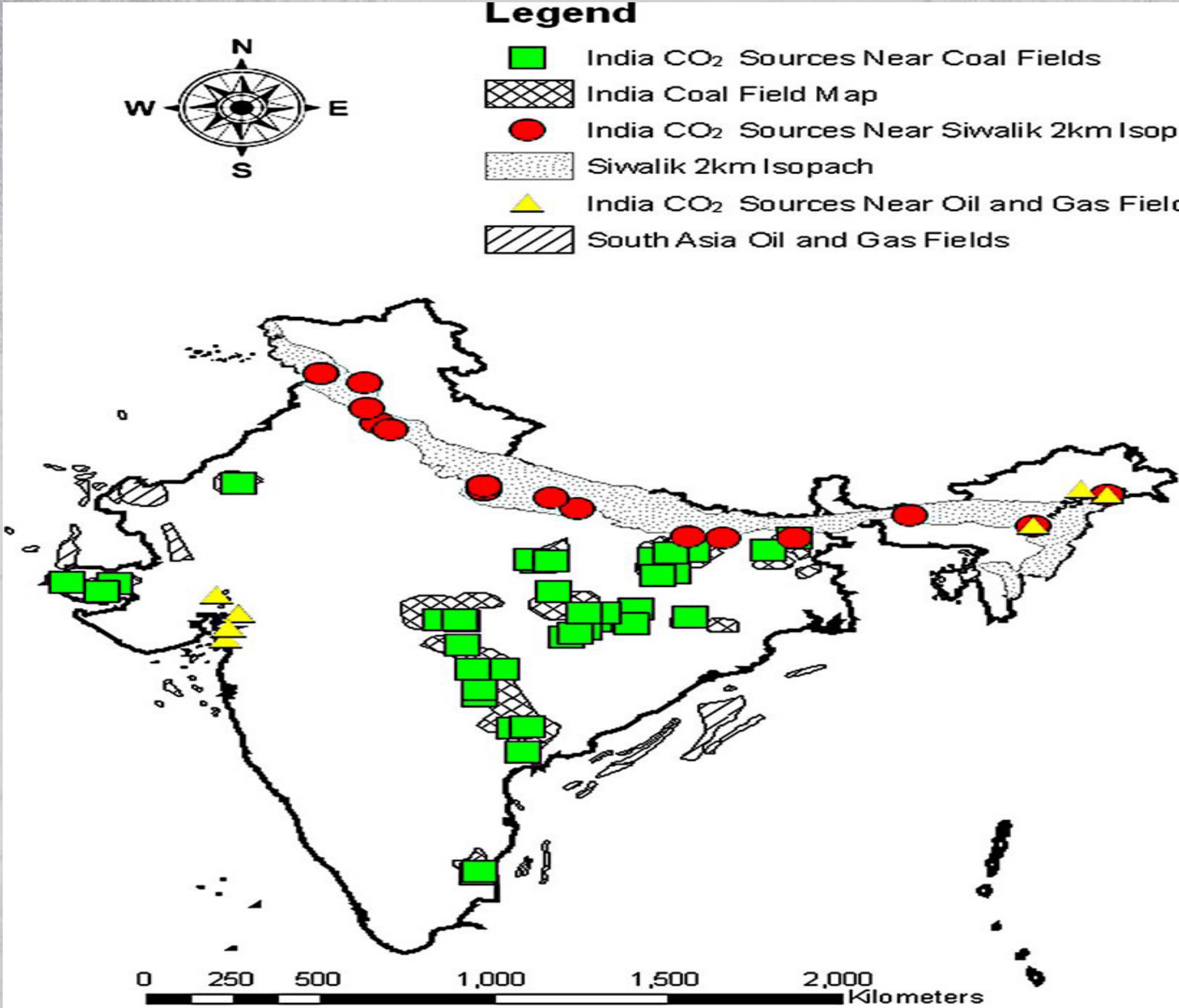
y =output in kW of the same plant **with capture.**

- The calculation requires that the same fuel input be used in both cases.

Location of major current and planned CCS projects worldwide



Potential sites for CO_2 Storage in India



Potential sites for CO_2 sequestration within 20 km of known oil and gas fields, saline aquifers and coal fields.

Current CCS Activities in India

- India is a member of CSLF & IEA(GHG) R&D Programme

- The Government of India has plans to invest in CCS related activities in the XI & XII Five Year Plan.

- Institute of Reservoir is carrying out Studies for CO2 capture & EOR field in Gujarat

- NGRI is testing the feasibility of storing CO2 in basalt formations

Problems with CSS

- High Price of Installing Carbon Capture Systems
- Capturing CO_2 requires much energy
  - About 25-40% more fuel for coal plants
- Risks of leakages & collateral damage to storage media (geological formations, oceans, landfills etc)
  - Well selected site, CO_2 trapped millions of years
- Increment in costs of energy production
- Non-accessibility to technologies on fair & equitable terms

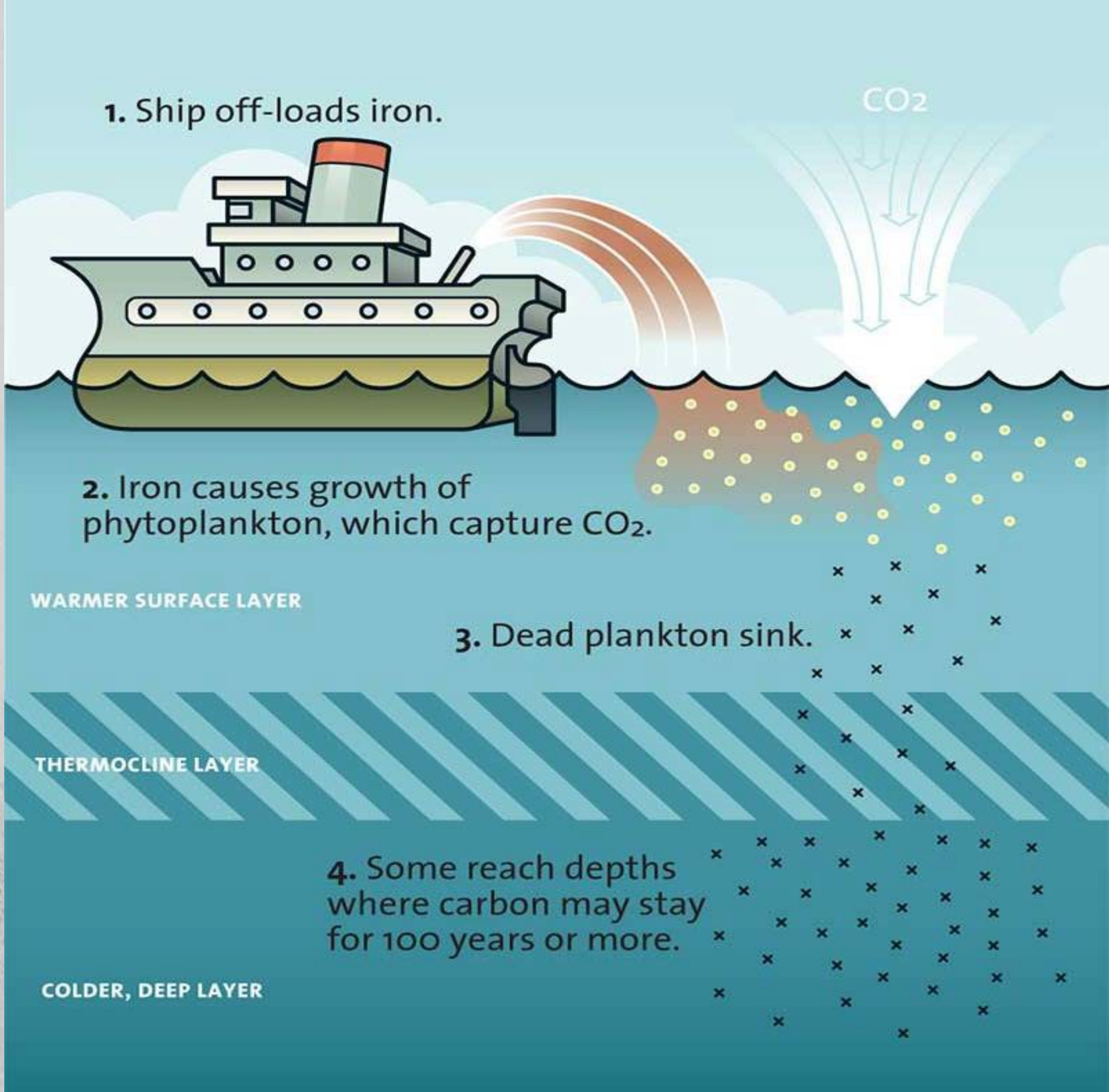
Alternative Approches

- Reforestation
- Forest preservation from logging, clearing
- Substitute bio-based fuels for fossil fuels
- **Enhanced weathering:** dissolution of natural or artificially created minerals to remove CO2
- Conservation tillage
  - Leave some percentage of biomass in ground

Ocean Iron Seeding or Iron fertilization

- Enhance biological productivity, which can Benefit marine food chain

- Under investigation



Synthetic Trees

- Removes CO_2 by combining with minerals

- Air flow through NaOH inside trees

- Creates Na_2CO_3 liquid

- Liquid pumped to sediments below ocean
  - Stored for millions of years

- 1 tree removes 1000x more than real tree

- 250,000 trees need to remove 22 billion tons of CO_2 produced annually from fossil fuels

References

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- Clinton V. Oster, J. C. Randolph, Kenneth R. Richards ,”Carbon Capture and Storage An Assessment” Indiana University School of Public and Environmental Affairs
- “CO2 CAPTURE AND STORAGE PROJECTS” European Commission, http://ec.europa.eu/research/research-eu
- “CO2 capture and geological storage - state of the art”, ongoing projects EC FP6 EU GEOCAPACITY CO2 EAST www.co2neteast.rgn.hr
- www.zeroemissionsplatform.eu

Thank you


Up here, too much
CO_2 is a problem
Deep down there,
we have a solution