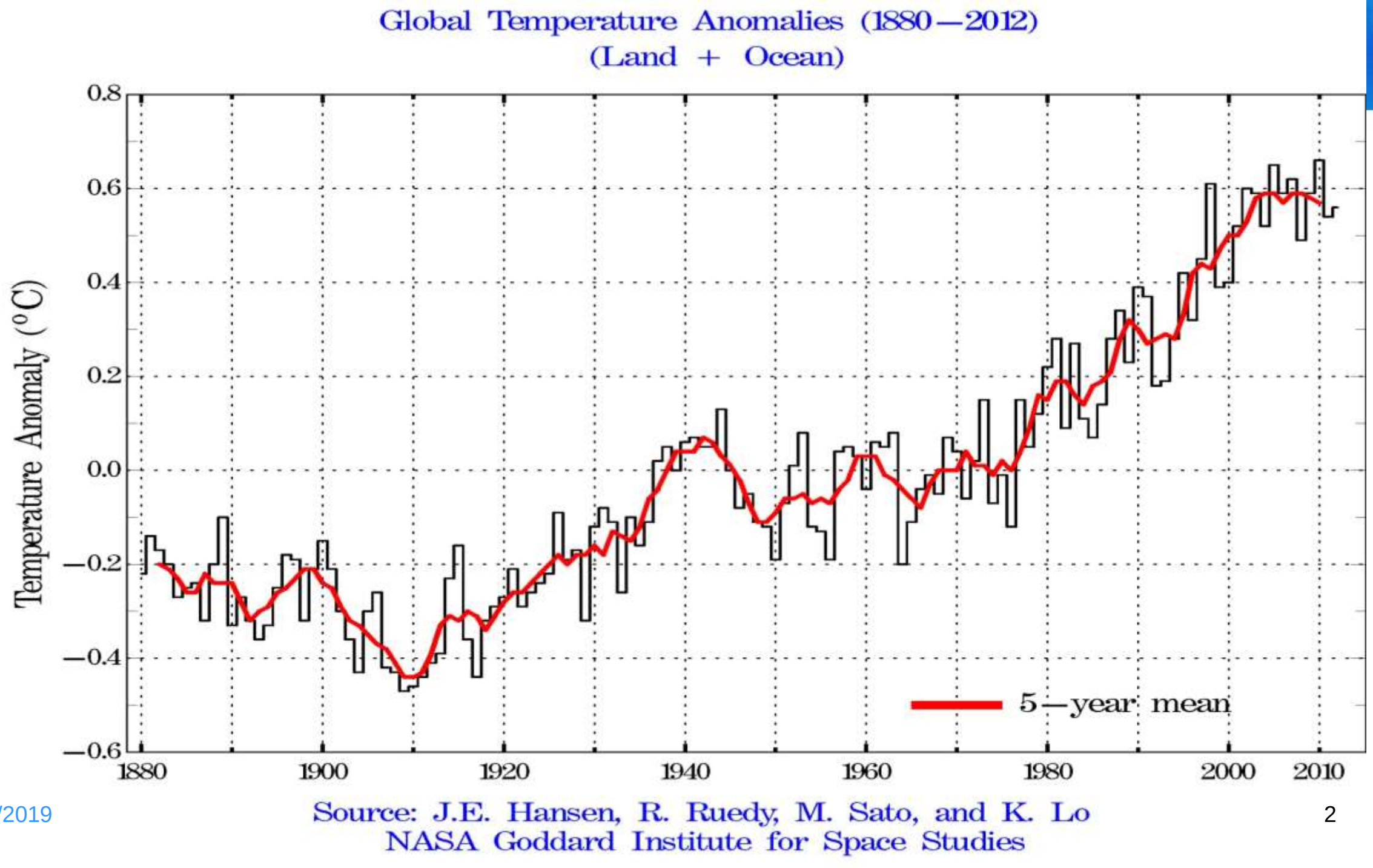
CCUS Technology Overview: Challenges in Scaling up

ACBCCUS-2025

Awareness and Capacity Building in Carbon Capture, Utilization and Storage

India International Centre , 11th June – 13th June 2025


Global Temperature Anomalies (1880—2012)
(Land + Ocean)
Temperature Anomaly (°C)
0.8
0.6
0.4
0.2
0.0
−0.2
−0.4
−0.6
1880
1900
1920
1940
1960
1980
2000
2010
5—year mean
Source: J.E. Hansen, R. Ruedy, M. Sato, and K. Lo
NASA Goddard Institute for Space Studies

Climate Change and International Protocols

- **Predictions of Climate Change and Its Impacts**

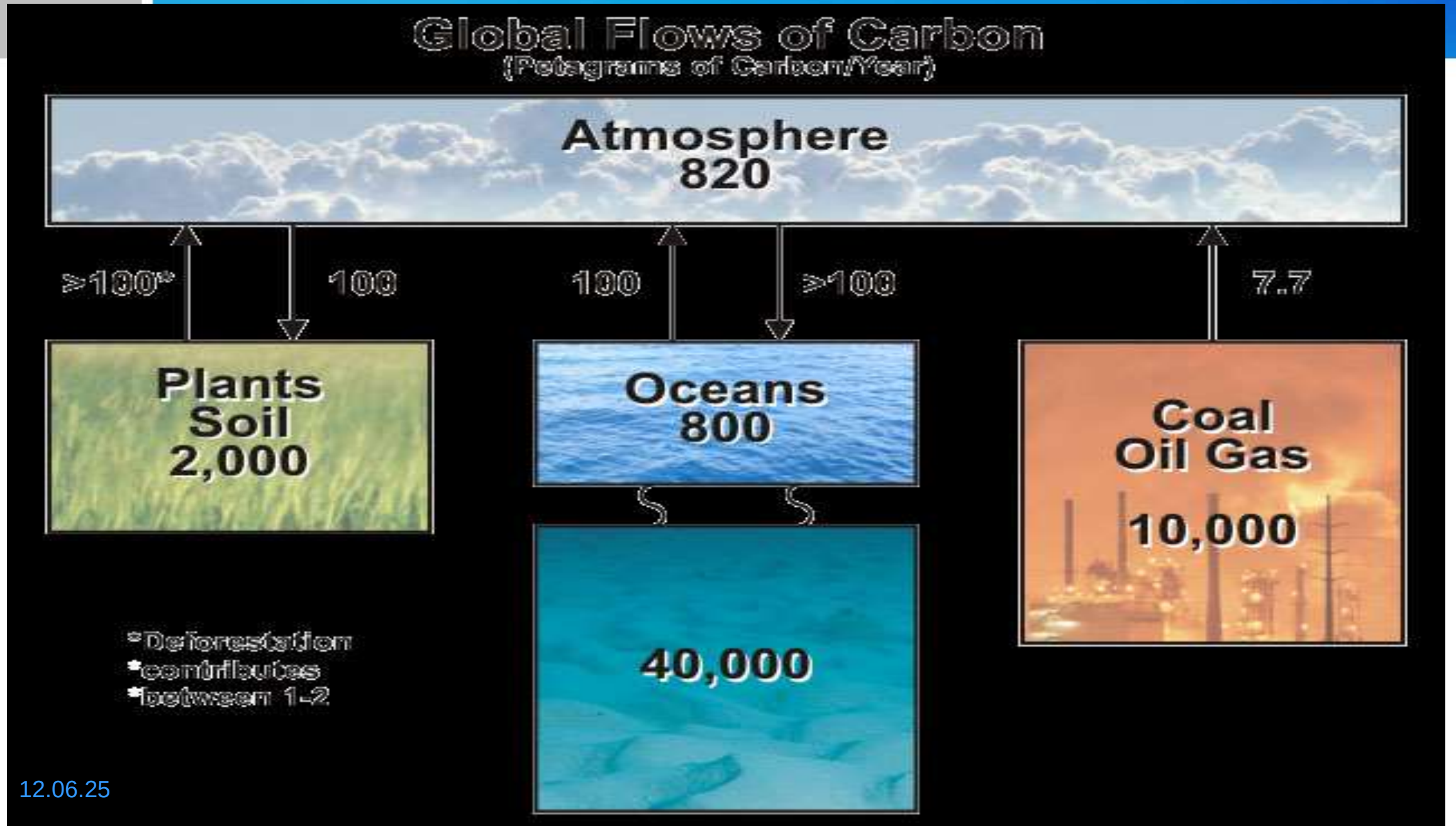
  General Circulation Model (GCM), is developed as a set of equations of motion for the fluid, equations for conservation of energy (including radiative transfer), mass and water vapour for prediction

- **Climate Change Actions & Global Binding Treatise**
  - Montreal Protocol
  - Kyoto Protocol
  - Convention on Biodiversity
  - Paris Agreement

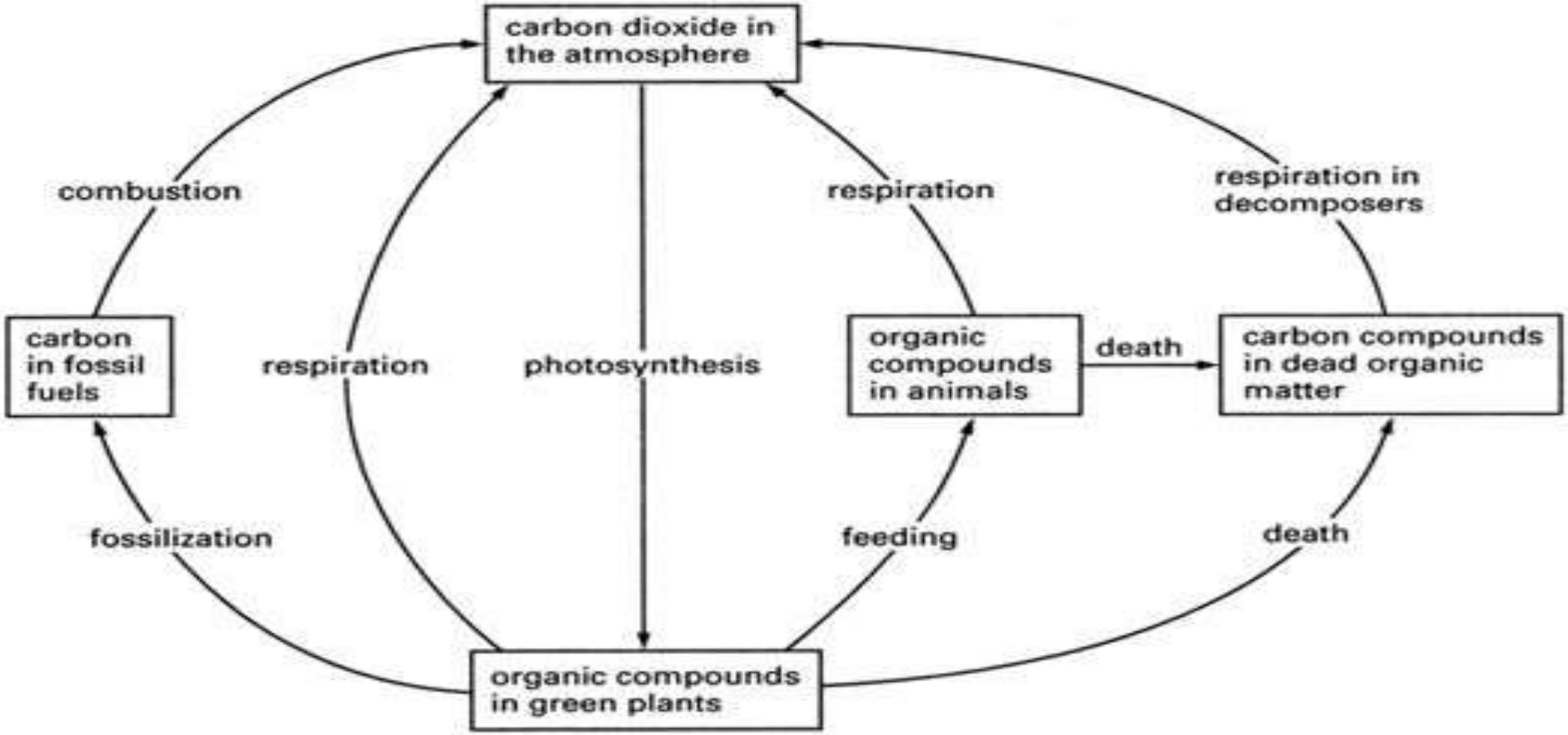
Carbon Cycle

Natural Carbon Cycle

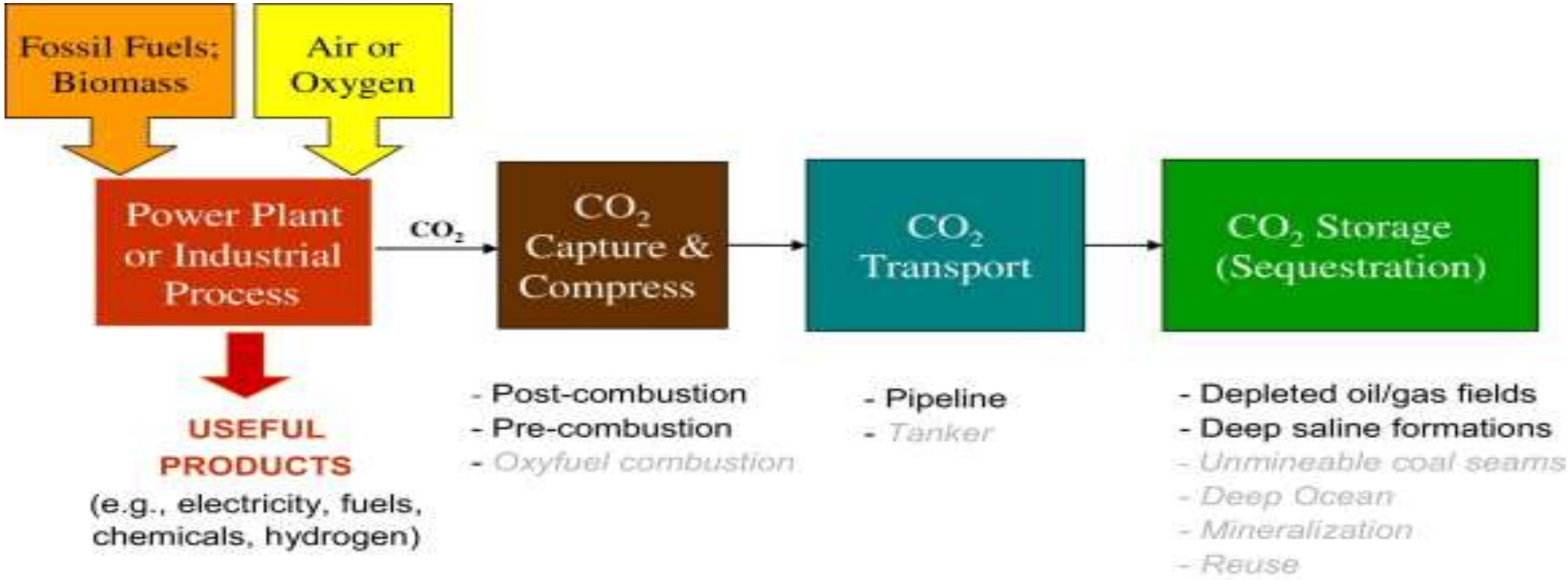
- The ***carbon cycle*** is the circulation and transformation of ***carbon dioxide*** back and forth between living things and the environment as a part of the ocean, air, and even rocks.
- It is the biogeochemical ***cycle*** by which ***carbon*** is exchanged among the biosphere, lithosphere, geosphere, hydrosphere, and atmosphere of the Earth**.**


Global Flows of Carbon
(Petagrams of Carbon/Year)
Atmosphere
820
≥100*
100
100
≥100
7.7
Plants
Soil
2,000
Oceans
800
40,000
Coal
Oil Gas
10,000
*Deforestation
*contributes
*between 1-2

Carbon Cycle Exchanges in Atmosphere



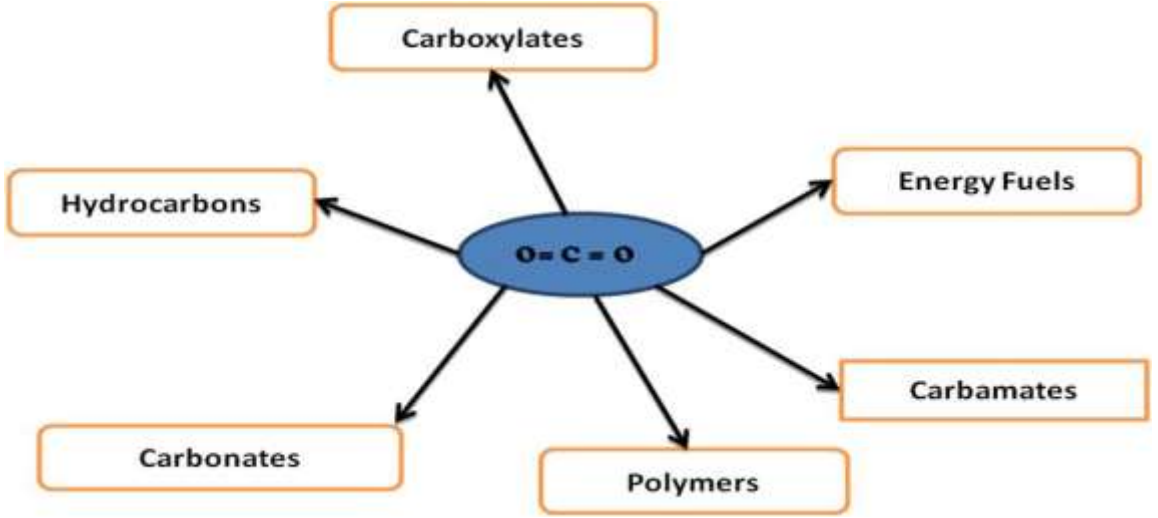
Carbon Sequestration – manmade carbon cycle



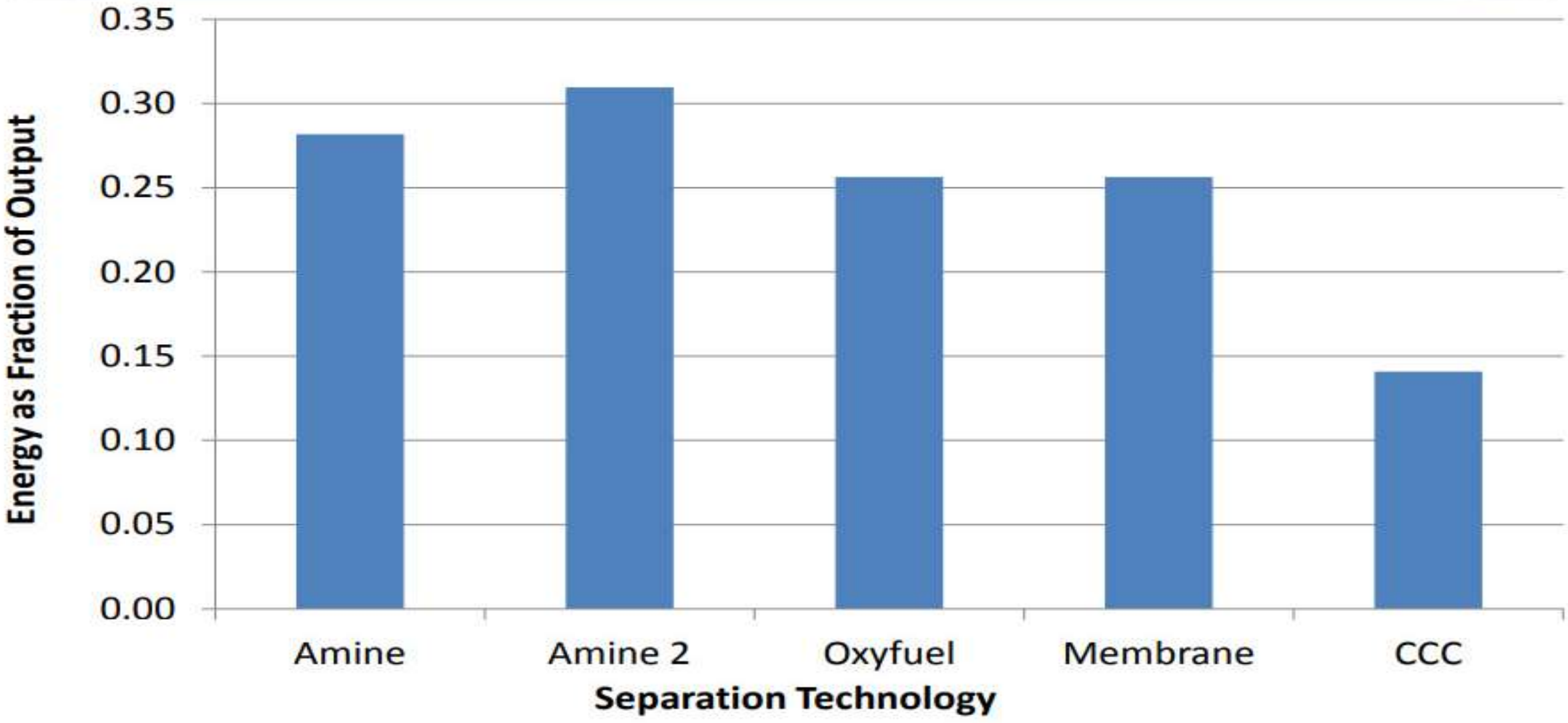
Edward S. Rubin , Hari Mantripragada , Aaron Marks , Peter Versteeg , John Kitchin

Carbon Capture Storage and Utilization

- Carbon dioxide emissions in the global atmosphere have increased to 37Gt after reaching a plateau in 2015 at 35.5Gt and could range from 39Gt to 44Gt in 2025
- Even with unprecedented growth in the deployment of renewables and energy efficiency, CO_2 capture and storage (CCS) is one of the option to mitigate the emissions from large point sources ~ 8000 in number,
- CO_2 capture and utilization (CCU) is an option; producing fuels, polymers, carbonates and carbamates; which is more consistent with the basic principles of Industrial Ecology than CCS



Energy in capturing methods



Carbon Storage and Utilization Options

- Non Biotic Engineered systems
- Biotic- Photosynthesis-Plants -Algae

Non Biotic or Engineering Processes

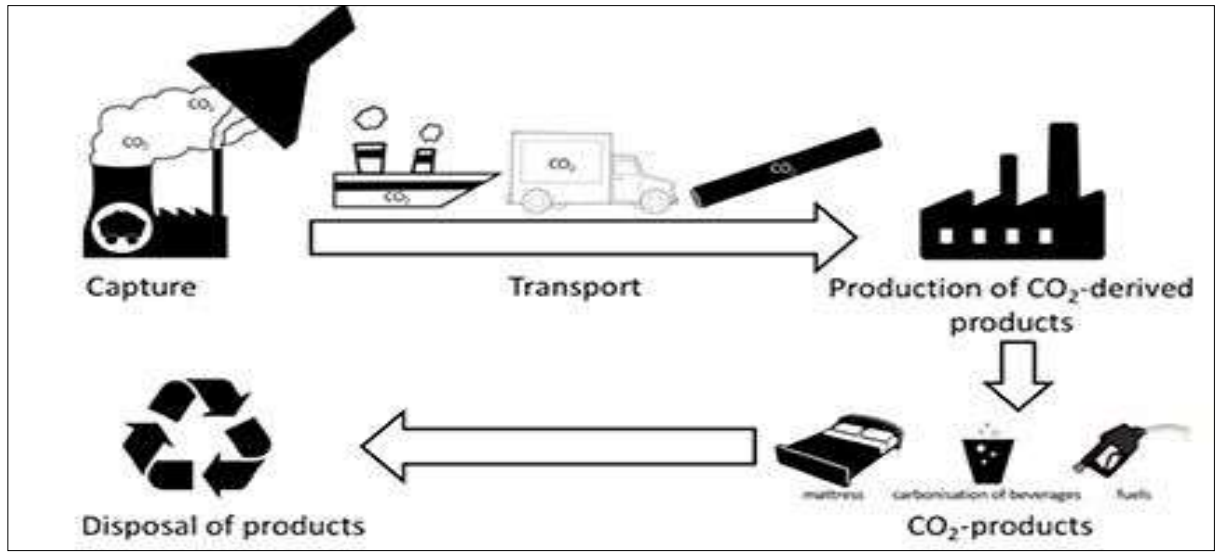
- **Carbon Capture and Storage**
- **Underground Injection**
- **Enhanced Oil Recovery**
- **Oceanic Storage**

Geological Injection of Captured CO2

- Saline aquifers located below fresh water reservoirs separated by a permeable layer are porous sediments filled with water.
- CO2 is sequestered hydro-dynamically and by reacting with other dissolved salt to form carbonates.
- It form gas like phase and also aqueous phase in dissolve from, creating multi-component environment
- CO2 injection in oil & gas fields to extract more oils
- CO2 can be injected into unmineable coal seams where it is absorbed to produce methane

CCU Product Acceptance

CCU PRODUCT CYCLE



ACCEPTANCE

Potential users' acceptance of CCU products is triggered by:

- Perceived costs to stakeholders
- Risks & benefits
- Credibility of product
- Conceptual, technological and social issues in acceptance

Track 1 Products – To remove CO2 for minimum hundred years
Ex- Precast concrete and aggregates

Track 2 Products – To remove CO2 for less than 100 years
Ex- Jet fuel and methanol

Techno-economic challenges

- Cost of capture from flue gases is high
- Capturing processes are energy Intensive
- Technology of deep injection over land and in oceans is under development
- Risk of leakage, seismicity & safety
- Monitoring, reporting and verification (MRV) techniques are expensive, required for a long time
- MRV standards vary from place to place

Techno-economic challenges (2)

- Thermodynamics – Life Cycle Analysis
- Geo-stratographic constraints
- Other technologies for CO2 reduction are more mature
- Use of Renewable / solar energy to replace conventional energy for CO2 Conversion processes
- Commercial scale of operation not achieved
- Legal and regulatory hurdles for CO_2 testing
- Benefits are not fully quantified

Scaling-up challenges in CCUS

Techno-economic and Life cycle studies

- The Techno-economic analysis helps decision making by determining the cost-effectiveness of scalability of CCUS technologies in achieving net-zero emissions.
- In a cement industry the techno–economic evaluation demonstrated that CO_2 capture with amine scrubbing is favorable for new investments, presenting the lowest CO_2 capture cost (~56$/tonne).
- Guidelines for analyzing techno-economic feasibility of CO_2 utilization provide decision tool for policy makers involved in planning for scaling-up CCU.

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Scaling-up challenges in CCUS (2)

Key elements of CCUS Policy Framework for India –Niti Aayog

- Policy pathways -Carbon credit based policy is more suitable for India
- Hub & cluster business model
- Low carbon products- Carbon Capture Finance Corporation (CCFC)
- Environmental and social justice
- Accounting and regulatory framework
- Risk mitigation

Scaling-up challenges in CCUS (3)

Key Enablers for advancement of CCUS - G20 Study

- Policy framework and Government support
- Development of CO_2 utilization technologies:
- Addressing technology gaps through international collaboration:
- Availability and flexibility of options for CO_2 disposition at scale
- Hub and cluster frameworks
- Development of markets

CCUS- International Status

- International Energy Agency future outlook study has predicted that CCS may have a share up to 17% by 2050 in reduction of concentrations.
- According to Global CCS Institute 85 CCS demonstrations are currently in pipeline.
- CCU technologies are being demonstrated as promising business models.
- Mission Innovation has 23 Countries as its members with India as a partner country.
- Worldwide number of programmes have been held supported by World Bank, ADB and other multi-lateral organizations

Indian Participation in CCUS Research

- India has been one of the active member of CSLF and has supported R&D and Capacity Building activities within Country Policy Guidelines. Was signatory to Framework Protocol on FutureGen, world's first zero emission CCS project, USA.
- Launched National Programme on CO_2 Sequestration Research (NPCS) in the Department of Science & Technology in 2006 involving stakeholders, R&D laboratories and Universities.
- India is partner country in Mission Innovation on Clean Energy. 'Carbon Capture Innovation Challenge' is one of the seven areas.
- Under Mission Innovation India, a new thrust being given to advancement of CCUS research through Industry participation and International collaborations
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Carbon Capture, Storage & Utilization

Infrastructure is needed to link generators of CO_2 to ensure a reliable source of CO_2

IIP Dehradun

NTPC, Faridabad

Free Air Carbon dioxide enrichment (FACE) facility aseembled in the campus of Jawaharlal Nehru University in a DST sponsored project by Professor B. C. Tripathy. Mustard (Brassica) plants are grown inside two FACE Rings maintained at elevated CO_2 (600 ppm)

National Status on Technology Front

- India's first commercial-scale plant to capture CO_2 emissions from a coal-powered boiler to converts into soda ash was built in 2017 at Tuticorin Alkali Chemicals and Fertilizers Limited (TFL), Tamilnadu. The plant captures approximately 60,000 tonnes of CO2 annually.
- Fully modular technology – CycloneCC for implementation at scale in steel industry. Feasibility of Carbon Clean's CycloneCC modular technology to capture up to 100,000 tonnes per year of CO2 emissions is being carried out at JSW Steel's Vijayanagar site in Karnataka.

National Status on Technology Front (2)

- NETRA in collaboration with Carbon Clean Solutions and Green Power International Pvt. Ltd is setting up the carbon capture plant at Vindhyachal plant for producing 10 tonnes per day of methanol through a catalytic hydrogenation process.
- Tata Steel has commissioned a 5-tonne-per-day (TPD) carbon capture plant at its Jamshedpur plant using amine-based technology to extract CO2 from blast furnace gas, supporting a circular carbon economy.

ACBCCS Workshops

- Awareness and Capacity Building in Carbon Capture and Storage – 27-31 July 2009
- Awareness and Capacity Building in Carbon Capture and Storage: Earth Processes – 15-19 Jan 2013
- Awareness and Capacity Building in Carbon Capture, Storage and Utilization: Towards a low Carbon Growth Strategy – 27-31 July 2015.
- Recent Advances in CO Capture Technology and Its Sectoral Applications 29th August – 1st September, 2018
- Carbon Capture and Utilization plus Net-Zero Future, 4th February 2022
- 'Recent Advances in Carbon Capture, Utilization and Storage (CCUS) Technology, Policy and Regulations: towards a Net Zero strategy', June 11th - 13th, 2025
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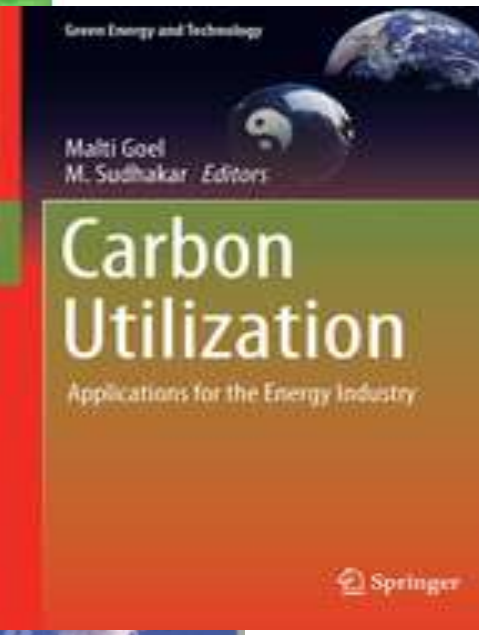
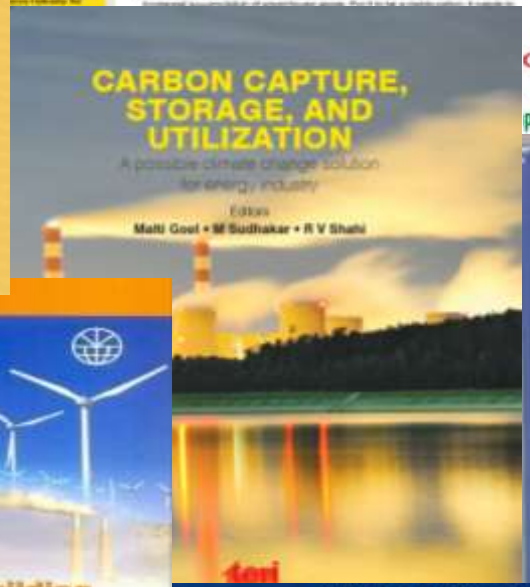
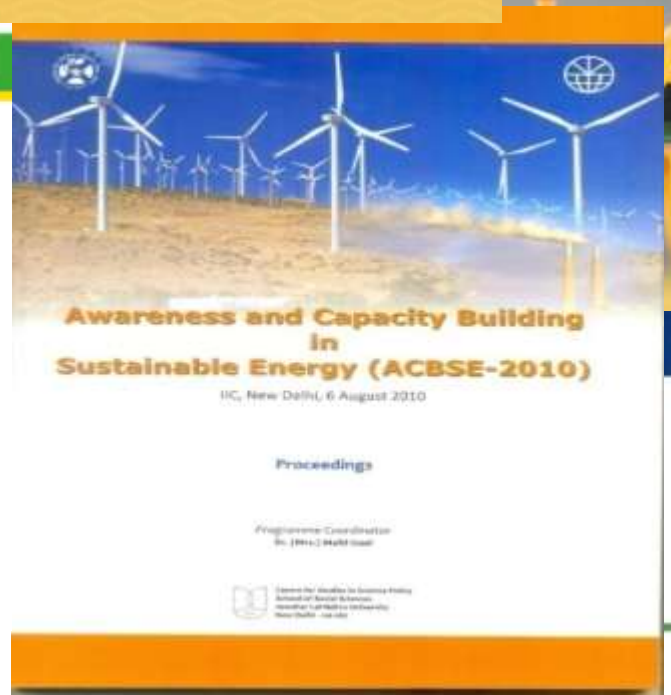
Huge Capacity Building efforts needs to be taken for the encouragement of massive scale-up of CCUS technology

Our Publications







Thank You

A presentation by Dr. (Mrs.) Malti Goel
Chief Executive, Climate Change Research Institute
Feedback at malti.goel@yahoo.com