2. Carbon Capture and Utilisation- Environment

India is transitioning from viewing CO_2 as a pollutant to a feedstock for the future. While CCS offers a way to hide carbon, CCU offers a way to use it, supporting the 2070 Net-Zero goal through a circular economy. Success depends on lowering conversion costs and integrating these technologies into India's existing hard-to-abate industrial clusters through a robust 2030 Roadmap.

1. Understanding Carbon Capture and Utilisation (CCU)

Definition- A suite of technologies designed to capture CO_2 emissions directly from industrial smokestacks or the atmosphere and chemically convert them into commercially viable products.

The Conversion Cycle- Instead of merely storing the gas, CCU integrates carbon back into the economy as a feedstock for-

1. Fuels- Synthetic fuels, e-methanol, and e-kerosene.
2. Chemicals- Polymers, olefins, and bio-alcohols.
3. Building Materials- Carbonated concrete blocks and aggregate.

2. The Strategic Imperative for India

Global Standing- As the world's third-largest CO_2 emitter, India faces immense pressure to decarbonize while maintaining industrial momentum.

The "Hard-to-Abate" Challenge- Industries like cement (responsible for 7-8% of global emissions) and steel have "process emissions" inherent to their chemical reactions that renewable energy alone cannot eliminate.

Limits of Renewables- While solar and wind clean the power grid, they cannot address the carbon intensity of existing heavy industrial plants.

Economic Value Creation- CCU transforms a liability (CO_2) into an asset, creating new industrial value chains and reducing dependency on fossil-based chemical feedstocks.

3. Comparative Analysis- CCS vs. CCU

Basis	Carbon Capture and Storage (CCS)	Carbon Capture and Utilisation (CCU)
Primary Meaning	Captured CO_2 is permanently buried underground.	Captured CO_2 is converted into useful products.
Objective	Purely climate mitigation via sequestration.	Climate mitigation combined with circular economy value.
End Use	Injected into deep saline aquifers or depleted oil fields.	Converted into fuels, polymers, and building materials.
Economic Output	Generally, provides no revenue (unless used for Enhanced Oil Recovery).	Generates commercial revenue through product sales.
India Example	Proposed CO_2 storage in depleted oil fields (Draft 2030 Roadmap).	Ambuja Cements' project converting CO_2 into fuels with IIT Bombay.
Global Example	Sleipner Project (Norway) under the North Sea.	ArcelorMittal (Belgium) converting CO_2 to Carbon Monoxide.

4. India's CCUS Initiatives and Private Sector Participation

Institutional Support- The **Department of Science and Technology (DST)** is spearheading an R&D roadmap focused on low-energy capture and carbon-to-value pathways.

Policy Framework- The Ministry of Petroleum and Natural Gas has released the Draft 2030 CCUS Roadmap, identifying pilot clusters for large-scale deployment.

Industrial Pioneers-

1. Ambuja Cements- Partnering with IIT Bombay to pilot CO_2-to-fuel conversion under an Indo-Swedish partnership.
2. JK Cement- Establishing a CCU testbed to manufacture lightweight, carbon-sequestered concrete blocks.

3. Organic Recycling Systems Ltd (ORSL)- Leading the first Bio-CCU platform in India, which utilizes biogas streams to produce bio-alcohols.

5. Global Benchmarks in CCU

European Union- Links CCU to its Circular Economy Action Plan, treating captured carbon as a sustainable feedstock.
Belgium- ArcelorMittal's Gent plant is a global leader in converting CO_2 into Carbon Monoxide for high-end chemical use.
United States- Leverages the 45Q tax credit to make carbon capture and conversion financially attractive for private players.
UAE- The Al Reyadah project is integrating CCU with Green Hydrogen to pioneer the next generation of synthetic "e-fuels."

6. Critical Challenges and The Way Forward

Challenges

High Energy Penalty- The process of capturing and converting CO_2 requires significant energy, often making the end product more expensive than fossil-based versions.
Infrastructure Deficit- India lacks the "carbon pipelines" and integrated industrial clusters needed to transport CO_2 from the source to the conversion site.
Regulatory Voids- A lack of standardized "green labels" for CO_2-derived products hampers market demand.

Way Forward

Synergy with Green Hydrogen- Link CCU with the National Green Hydrogen Mission to produce carbon-neutral e-methanol and e-kerosene.
Certification Standards- Task the Bureau of Indian Standards (BIS) with creating clear accounting norms to certify the "greenness" of carbon-derived materials.
Dedicated R&D Grants- Expand DST funding to specifically target the reduction of the "energy penalty" in the capture phase.
Source- https://www.thehindu.com/sci-tech/science/what-are-carbon-capture-and-utilisation-technologies-explained/article70675521.ece