

CCUS Technologies & Way Ahead





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Blue Hydrogen: Energy Security and Hydrogen Economy 9th June, 2023



The Energy and CO₂ nexus: The current scenario





www.scics.gc.ca

Further increase in energy in near future is predicted Especially in India and China



Fossil fuel is the major resources CO_2 is the side product Skyrocketing atmospheric $CO_2 > 400$ ppm Adverse effects on our climate



How can we stop this adverse effects?





United Nations meeting in Paris, 2015 & Glasgow, 2021 Need to reduce greenhouse gas emission

India has pledged to lower the CO_2 emission by 45% by 2030 & Carbon neutral by 2070



Learning from nature: Storing natural energies in chemical bonds



Following nature's blue print

Storing energy in H-H bond





Hydrogen Market in India





TERI, ICRA Research

> A significant presence

Rapid increase in demand expected



The H₂ spectrum



Hydrogen Color Spectrum

GREEN Hydrogen produced by electrolysis of water, using electricity from renewable sources like hydropower, wind, and solar. Zero carbon emissions are produced.

TURQUOISE Hydrogen produced by the thermal

BLACK/GRAY

Hydrogen extracted from natural gas

using steam-methane reforming.

splitting of methane (methane pyrolysis). Instead of CO₂, solid carbon is produced.

PINK/PURPLE/RED

Hydrogen produced by electrolysis using nuclear power.

BLUE Grev or brown hydroge

Grey or brown hydrogen with its CO₂ sequestered or repurposed.

WHITE

YELLOW

Hydrogen produced by electrolysis

using grid electricity.

Hydrogen produced as a byproduct of industrial processes.

BROWN Hydrogen extracted from fossil fuels, usually coal, using gasification.



Note: There are no official definitions of these colors, but the above represents common industry nomenclature.



H₂ spectrum and prospective future



H, production cost

- 1. Coal/methane
- 2. Biomass
- 3. Water

Balancing cost of production and environmental impact



Our global stand on Hydrogen map



Large-scale H_2 utilization for energy utilization

India: An emerging force in the global level





- H_2 is a clean energy vector
- Can support variable applications
- Industrially proven
- Compatible with existing infrastructure

Green Hydrogen Roadmap for India is developed

INDIA GREEN HYDROGEN ROADMAP

Energy transition whitepaper prepared by FTI Consulting









H2 Bharat Trucking Project on Delhi- & Lo Mumbai Industrial Clu: Corridor

2 Bharat Port H2 Industrial & Logistics Clusters Clusters (Steel, Fertilized





Al Coal-Gasification H2 project

DESIRED OUTCOMES BY 2030



USD 500 mm 75,000 GW-scale Expanded Hydrogen Fund (by 2030) New Hydrogen Economy jobs, potential Electrolyser capacity in India

Questions remain on proper H_2 generation and storage





Current Hydrogen Chain





Different Sources & Multiple Utilization of Hydrogen



Chemicals from Hydrogen









Current Hydrogen Chain





Different Sources & Multiple Utilization of Hydrogen



Managing CO₂: A closer look at the CO₂ cycle





Biogeochemical carbon cycle

Redox conversion between reduced carbon and CO₂

Managing CO₂: A closer look at the CO₂ cycle





Anthropogenic activities disbalance the biogeochemical carbon cycle

Require to remove the excess CO₂

Managing CO₂: A closer look at the CO₂ cycle





Steps for appropriate CO₂ management

1. CO₂ capture

2. CO₂ utilization

3. CO₂ storage

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The CO₂ management: CCUS Technology







The CO₂ Capture Technology







Capturing CO₂: An acidic gas



Rectisol Technology



Relatively expensive



T1-Absorption Tower; T2-Desorption tower; T3-N₂ Stripping Tower; T4-Heat Regeneration Tower; T5-Methanol-Water Separation Tower; P3-Pump



Uses methanol

➢ Operates at -50 °C

Yang *et al.,* Ind. Eng. Chem. Res. 2016, 55, 6186–6193

MOF materials

- Specific separation
- Scaling up is an issue

CO₂ capture: Using Aqueous Solution

Following biological blueprint for CO₂ capture





Effendi *et al.*, Proc. Biochem., 87, 4, 2019, 55-65 <u>Features</u>

- Evolutionarily proven process
- ▶ Rapid hydrolysis of CO₂ to bicarbonate (solution)
- Fragility of enzyme and purification expense are problems
- Biomimetic chemistry a potential solution

Bhagat et al., J. Appl. Microbiol., 124, 2, 2018, 316-335



Dutta, Vishal

CO₂ capture: Using Aqueous Solution

Direct Air Capture, Carbonic Anhydrase Mimic, and Mineralization



CO₂ purging in water

Features



Addition of CaCl₂





Production of CaCO₃

Use of omnipresent water \succ

- Rapid conversion of CO_2 to carbonate (solution) \geq
- \blacktriangleright Addition of Ca(II) salt to produce solid CaCO₃
- \blacktriangleright Removing ~1.0-40.0 kg CO₂ from air (0.04% CO₂) /day

Dutta, Vishal, Indian Patent Application No : 202221039765



CCUS at Coal Sector







Water Source

 Sustainable and Cost-effective
Use of CaCO₃ in coal industry (prevents explosions)



Green H₂ and CCUS





➢ Green Hydrogen a vertical for CCUS

- > CO_2/CO conversion and H_2 production catalysts will be essential
- > Appropriate use of renewable energy with existing carbon-based infrastructure



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