CSIR Mission Mode Project
CARBON CAPTURE, UTILIZATION AND STORAGE (CCUS)

Presentation on Solar Integrated CCUS Pilot Plant at RKDF University - Utilization of Facility by CSIR Labs

[Sponsored by MOP/ CPRI & MNRE]

Dr. Vinod Krishna Sethi
Member CSIR Monitoring Committee
DG (Research) & Ex.VC, RKDF University, Bhopal
Retd. Director - CEA / MOP & Ex. Director - UIT, RGPV

Collaborating Organizations
Rensselaer Polytechnic Institute (RPI), University, New York, USA & USLLC, (LLC of NASA) California, USA

Sir J C Bose Integrated Interdisciplinary Research Centre @ RKDF University, Bhopal Established 2016

CCUS PILOT PLANT SPONSORED BY MOP (CPRI)

- The Solar Integrated Carbon Capture Pilot Plant at RKDF University Bhopal has been reported in Annual report (2020-21) of NITI Aayog
- Under Collaboration with RPI, USA (CO-PI: Dr. Partha S Dutta), the University has completed two projects of MNRE which have also got appreciation in the MNRE Annual report to NITI Aayog (2016-17)
- **Facility being used by Students and Faculty for Technology Incubation:**
  - Solar Air Conditioning
  - Thermo-Electric device application in Bukhari for Army bunkers
  - Bio-diesel production through Algae route
  - Gray Hydrogen and Methanol Production (Under development)
  - Solar Chulha with thermal storage in association with NRDC , MOS
  - Fortified Vermi-compost under MOA with NRDC
  - Catalyst development in collaboration with USLLC, USA (Subsidiary of NASA)
  - Dental Conduction Device for deaf persons

Asia's First & World's Third

Solar Integrated Carbon Capture Plant

Sponsored by Ministry of Power (CPRI)

Capture Capacity 400 Tons/ year CO_2

TECHNOLOGY INCUBATION OF THERMAL STORAGE

TES Solid Media Innovation at RKDF University: MNRE Project

Collaborator: RPI, USA (2015-17)

TECHNOLOGY INCUBATION OF CCS

CO_2 Capture set-up installed under the DST Project : Proof of Concept

DST File No.: DST /IS-STAC / CO2-SR-77 /09(G) Dt. 23-03-2012

Carbon Capture Plant Running @ Capture capacity of 50 kg/hr. CO_2

40 days continuous trial run of CCS Pilot Plant at RKDF University by the plant manufacturer M/S SUNRISE CSP (I) Pvt. Ltd Baroda (Nov 1, 2020 to Dec. 15, 2020)

CCS PILOT PLANT SPONSORED BY CPRI (MOP) UNDER ERECTION (2019) AT RKDF UNIVERSITY BHOPAL

SOLAR INTEGRATED CCS PLANT WITH BOILER

ALGAE FORMATION FOR BIO-DIESEL PRODUCTION AT CARBON CAPTURE & UTILIZATION PLANT

CCS PILOT PLANT WITH SCADA SYSTEM CONTROL ROOM , ALGAL POND AND HYDROGEN GENERATING PLANT

Solar Thermal Plant with TES Device under erection(2019)

Broad Specifications of the CO_2 Capture Pilot Plant at RKDF University

- Rated capacity of the capture of CO_2 : 6 Tons/ day Flue Gas (CO2 about 18%)
- CO_2 Source : Flue gas from Coal Fired Boiler Plant Chimney
- Solvent for CO_2 capture : Mono Ethanol Amine (MEA) (2M solution of MEA)
- SOx and NOx removal : Scrubber unit NaHCO3, NaOH
- Solar Thermal Plants : 10 (8 + 2 Additional) Scheffler Units - Total 50 kg/hr. Steam flow at 6-8 bar pressure and over 180 degree Celsius
- Algal bio-reactor : Trans-esterification Unit for Bio-diesel production using Algae
- Table-top Hydrogen generation plant with Gasifier for WGS reaction

Current status & Future plans

❑ Current Status (project completed/pilot plant in working condition):

- Installation of Solar Integrated Carbon Capture Pilot Plant of Capacity 45 kg/hr. of CO2 in which 250 kg/hr. flue Gases are drawn from the associated Coal Fired Boiler installed for the purpose. 30 days continuous trial run results have demonstrated over 80% capture efficiency at a very low (2.16-2.18 GJ/ Ton CO2) energy penalty on account of integration with solar generated steam.

❑ Future plans for scaling up of CO2 Capture Plant on a 500 MW Coal fired Thermal Unit

- Water, Power, Land requirement and project authority's perspective have been presented, which will pave way to the future development of technology of Mega Scale CCS PLANT. Heat / Energy Balances, HBD/ PI DIAGRAMS for a 500 MW Unit

❑ Feasibility Study of Installation of Retrofit Post Combustion Carbon Capture Plant on 500 MW ANPARA B TPS – 2x500 MW in Singrauli region of MP

- The feasibility study has examined various options like:
  - Captured CO_2 to depleted Coal mines
  - Captured CO_2 for EOR & Other NOVEL Options of Sequestration
- Pilot Study of Production of Multi-purpose Fuels
  - Production of Hydrogen, Methane & Methanol
  - Bio-diesel through Algae Route

CSIR Mission on 'Carbon Capture, Utilization and Storage-'CSIR-CCUS'

CSIR PROJECTS – Utilization of CPRI's CCUS Plant at RKDF University

Ref: First Meeting of the Monitoring Committee held on 26th June 2023 (Online)

- **The new members of MC have got the ideas of the work of the PIs and the proposal details. All members are expected to be deeply engaged with the PIs. The MC members can setup a one-to-one meeting with PIS and are encouraged to visit the facilities and discuss with PIs.** Some of the Labs agreed to use RKDF Facility Sponsored by CPRI (MOP)

- **The industry-academia meet was held on 4th Aug 2023 at IIT/B. All PIs provided their inputs.** Visit to CBRI Roorkee & IIP Dehradun are scheduled between 17-19 Sept.

CSIR Mission on 'Carbon Capture, Utilization and Storage-'CSIR-CCUS'
CSIR PROJECTS UNDER 3 VERTICALS

Ref: First Meeting of the Monitoring Committee held on 26th June 2023 (Online)

1. MMP-1.1: Synthesis and Screening of Bench Mark Adsorbent for CO_2 Capture under Flue Gas Conditions

Central Electro-chemical Research Institute (CECRI), Karaikudi, TN- **PI: Dr. Ravi Babu**

- ✓ **We have offered this facility to be used by the PI to get more data for the adsorbent reactor.**
- ✓ **We offer to add a solid Adsorbent Column at our RKDF University CCS Plant to enable CECRI to carry out their experimentation and DATA analysis, screening using SCADA system which will also be upgraded with additional online inputs.**
- ✓ **There will be two sets of reactor columns one each for CECRI and other for NML Project as discussed further. (Platform required for reactor is being extended & SCADA system is being up-graded for fast response)**

Requirements:

- ✓ **Coal of different quality (C to F Grade)**
- ✓ **Adsorbent Reactor**
- ✓ **Solid Adsorbent Column**
- ✓ **Screening using upgraded SCADA system that fast response under PSA, TSA & VSA**

CSIR Mission on 'Carbon Capture, Utilization and Storage'
'CSIR-CCUS'

2. MMP-1.3: CO2 Capture (CC) by Amine Absorption Process with Sequestration by Modified Mineral Carbonation (MC) and Recovery of Marketable Products and Waste Heat (WH)- A Holistic Technology Development Approach

National Metallurgical Laboratories (NML), **PIs: Dr. Abhilesh & Dr. Satyajit Mukherjee**

Project Objectives:

Utilization of RKDF CCUS Plant using:

Mixed Amine-based selective >90% absorption process using formulated aqueous amine solvent for selective post-combustion CO2 capture

MMP-1.3: CO2 Capture (CC) by Amine Absorption Process with Sequestration by Modified Mineral Carbonation (MC) and Recovery of Marketable Products and Waste Heat

1.	Project title:	Scale-up validation and testing of CO2 Capture by Amine Absorption Process
2.	CSIR Laboratory undertaking the Project:	National Metallurgical Laboratory
3.	Client Name & Address:	RKDF University, Airport Bypass Road, Gandhi Nagar, Bhopal (M.P.), 462033
4.	Name, mail ID, and mobile no of contact person :	Dr. V. K. Sethi vksethi1949@gmail.com 9713902378
5.	Background:	The CO2 absorption-stripping process using pre-validated amine shall be tested in the available facility to generate engineering data and simulation via SCADA
6.	Project Objective	Mixed Amine-based selective >90% absorption process using formulated aqueous amine solvent for selective post-combustion CO2 capture
7.	Scope of Work:	CO2 Capture by Amine Absorption Process in pilot scale facility and data generation and analysis
8.	Project Duration:	1 year starting October 2023
9.	Project Fees as proposed by NML:	10 Lakhs inclusive of 18% GST
10.	Payment Schedule:	Within 15 days after completion of work as certified by PI Advance as decided by CSIR / NML
11.	Key Deliverable with duration:	1. Simulation of pre-generated data on SCADA 2.100L amine application in existing setup at RKDF, and generation of plant data
12.	Responsible of Client (if any)	Necessary support including data and information required for the project, experimental facility for pilot scale run, local hospitality, facilitate field visits, chemicals storage, and handling facility

3. MMP-2.1: Carbon Capture, Utilization and Storage (CCUS): CO2 Utilization in Building Construction:

CBRI & CECRI, PIs : Dr. L P Singh & Dr. Kishore S Kulkarni; CBRI Roorkee

CO2 in Curing of Cement

The CO_2Concrete technology turns carbon dioxide emissions into CO_2Concrete products that can replace traditional concrete, with a much lower CO_2 footprint. The technology is based on the concept of "CO_2 mineralization" – the conversion of gaseous CO_2 into solid mineral carbonates (e.g., CaCO3) within the CO_2Concrete products. The mechanism of the carbonation reactions between hydration products and CO_2 is presented in the following equation

$$Ca(OH)_2 + CO_2 \rightarrow CaCo_3 + H_2O$$

$$xCaO.ySiO_2.zH_2O + xCO_2 \rightarrow xCaCO_2 + y(SiO_2.zH_2O) + (z - yt)H_2O$$

This chemical reaction is robust, and strengthens the fresh CO_2Concrete products into components exceeding industry standard performance metrics.

3. MMP-2.1: Carbon Capture, Utilization and Storage (CCUS): CO2 Utilization in Building Construction

Project Category:		**Technical Service/Testing Service**
Effective date of PP		**October 1 , 2023**
1.	**Project title:**	**Carbon Capture , Utilization and Storage (CCUS) : CO2 Utilization in Building Construction**
2.	**CSIR Laboratory undertaking the Project:**	**Central Building Research Institute (CBRI) & Central Electro-chemical Research Institute (CECRI)**
3.	**Client Name & Address:**	**RKDF University, Airport Bypass Road, Gandhi Nagar, Bhopal (M.P.), 462033**
4.	**Name, mail ID, and designation of the client contact person:**	**Dr. V. K. Sethi, Chair Prof. Sir J C Bose Chair Mail: vksethi1949@gmail.com**
5.	**Background:**	**A set-up of Cement curing & Test –rig for Mineral Carbonation shall be tested in the available CCUS facility of RKDF University to generate engineering data and simulation via SCADA**
6.	**Project Objectives:**	**CBRI to provide**
7.	**Scope of Work:**	**CBRI to provide**
8.	**Project Duration:**	**1 year**
9.	**Project Fees:**	**CBRI to decide**
10.	**Payment Schedule:**	• **Within 15 days after completion of work as certified by PI** • **Advance of Rs. ……(CBRI to provide) for CCUS Plant R&M & Civil works of the Test Rig set-up**
11.	**Key Deliverable with duration:**	**1. Simulation of pre-generated data on SCADA 2. Cement Curing Set-up with steam & CO2 (details at next slide) 3.Amine application in existing setup at RKDF, and generation of plant data**
12.	**Responsible of Client (if any)**	**Necessary support including data and information required for the project, experimental facility for pilot scale run, local hospitality, facilitate field visits, chemicals storage, Manpower and handling facility**

CO2 in Curing of Cement

Key advantages of the technology include the following:

- **Direct utilization of CO_2 from flue gases without a need for carbon capture systems (e.g., amine strippers)**
- **Process flexibility to accommodate flue gas streams with widely varying CO_2 concentrations, and presence of acid gases**
- **Process operates at ambient pressure and temperature, minimizing extrinsic energy requirements**
- **Material formulation requires no ordinary Portland cement (OPC) to exceed industry standards for component performance**

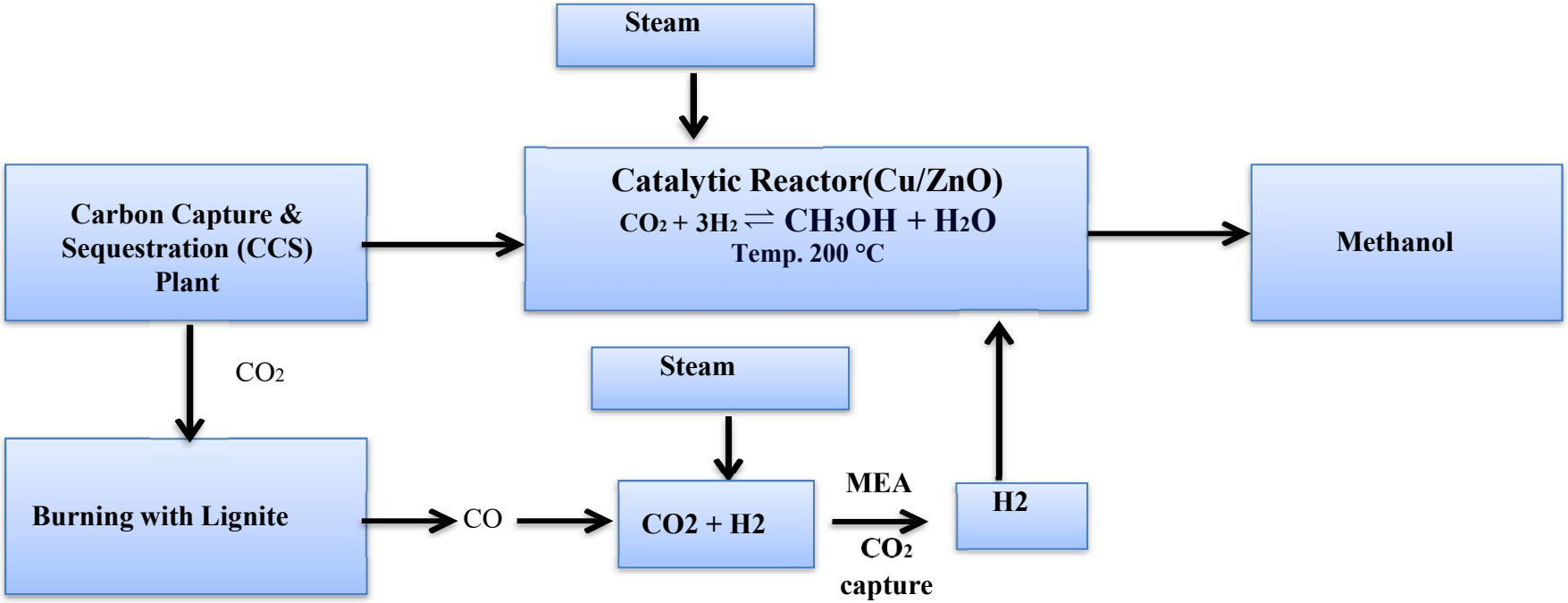
Deliverables

[1] Rapid strength achieve due to use of CO2 gas.
[2] CaCO3 present in cement is unstable so use of CO2 gas stables the CaCO3, results in binding of cement to other member of concrete.
[3] Carbon is a component of increment of global warming, so use as curing agent for concrete results use of CO 2 and reduces the carbon element. Only 4 hours curing is sufficient, results rapid strength
[4] The presence of water in carbonation is critical. The moist CO_2 could be another approach to improve the carbonation efficiency and requires a further investigation

4. MMP-2.2: Catalyst Development and scale-up for the selective reduction of CO2 to CO, methane and methanol.

NCL/IIP :PIs: Dr. C P Vinod & Dr. Ankur Bardaloi

At CPRI sponsored Solar Integrated CCS Plant at RKDF we are in the process of augmentation of the plant by incorporating a reactor with Catalytic converter to produce Methane in collaboration of USLLC USA. We will provide all technology support based on our technology transfer on-going activities from USLLC as shown below:



4. MMP-2.2: Catalyst Development and scale-up for the selective reduction of CO2 to CO, methane and methanol

Project Category:		Technical Service/Testing Service
Effective date of		October 1 , 2023
1.	Project title:	Catalyst Development and scale-up for the selective reduction of CO2 to CO , Methane and Methanol
2.	CSIR Laboratory undertaking the Project:	(National Chemical Laboratory) NCL & IIP (Indian Institute of Petroleum)
3.	Client Name & Address:	RKDF University, Airport Bypass Road, Gandhi Nagar, Bhopal (M.P.), 462033
4.	Name, mail ID, and designation of the client contact person:	Dr. V. K. Sethi Mail: vksethi1949@gmail.com Contact: 9713902378
5.	Background:	IIP to provide
6.	Project Objectives:	IIP to provide
7.	Scope of Work:	IIP to provide
8.	Project Duration:	1 year
9.	Project Fees:	IIP to provide
10.	Payment Schedule:	Within 15 days after completion of work as certified by PI Advance for: • Project Advisor Dr. Partha S Dutta from USA – consultancy of Catalyst development & accommodation International travel arrangements (OPTIONAL) • SCADA Up-gradation & Technology incubation for Catalyst development IIP to provide amount of advance as they decide
11.	Key Deliverable with duration:	Simulation of pre-generated data on SCADA

5. MMP: 3.4 Algae-based flue gas CO2 sequestration with co-production of high-value bio-chemicals

Central Salt & Marine Chemical Research Institute (CSMCRI) , Bhavnagar (Guj.) PI: Dr. R Dinesh

The results of on-going activities of Bio-diesel plant at RKDF University using a variety of Algal stain that can survive in Ash pond /decantation well (having heavy metal) will be shared in due course.

Green Hydrogen Plant an Off-shoot of Carbon Capture Plant (In-house Manufactured)

We are presently pursuing Coal /Lignite Gasification option for Hydrogen Generation (Option -5)

Process	Type	Reaction	Desciption
Steam Methane Reforming (SMS)	✖	$CH_4 + H_2O \rightarrow CO + 3\ H_2$/ $CO + H_2O \rightarrow CO_2 + H_2$	H_2 Is Produced Form Natural Gas [Mostly Methane (CH_4)] & Currently The Cheapest Source Of Industrial H_2. Nearly 50% Of The World's H_2 Is Being Produced By This Method.
Methane Pyrolysis		$CH_4 \rightarrow C + 2\ H_2$	Here Also H_2 Is Produced From Natural Gas [Mostly Methane (CH_4)]. H_2 Separation Occurs In One Step Via Flow Through A Molten Metal Catalyst In A "Bubble Column". It Produces Low-Cost H_2 But Requires High Temperatures (1065 °C). It Also Produces The Industrial Quality Solid Carbon Which Is A Green Waste.
Partial Oxidation	✖	$CxHy + x/2\ O_2 \rightarrow x\ CO + y/2\ H_2$ [$C_{12}H_{24} + 6\ O_2 \rightarrow 12\ CO + 12\ H_2$ $C_{24}H_{12} + 12\ O_2 \rightarrow 24\ CO + 6\ H_2$]	In This Process H_2 Production Is Done From Heavy Hydrocarbons, Which Are Unsuitable For Above Two Processes. It First Generates H_2 And CO Rich Syngas & Then More H_2 And CO_2 Are Obtained Via The Water-Gas Shift Reaction.
Plasma Reforming		$CxHy \rightarrow xC + y/2\ H_2$	Also Knwon As "The Kværner Process (1980)" & Produces H_2 As Well As Carbon Black From The Liquid Hydrocarbons (CxHy). CO_2 Is Not Produced In The Process.
Coal/ Petroleum Coke	✖	$3\ C\ (Coal) + O_2 + H_2O \rightarrow H_2 + 3\ CO$ $CO + H_2O \rightarrow CO_2 + H_2$	The Process Of Coal Gasification Uses Coal, Steam And Oxygen To Form A Gaseous Mixture Of H_2 And Carbon Monoxide Which Again Is Made To React & Produce More H_2 Along With CO_2.
Electrolysis	 ✖	$2\ H_2O \rightarrow 2\ H_2 + O_2$	H_2 Is Produced By Splitting The Water Molecule (H_2O) Into Its Components H_2 And O_2 Using Electricity. When The Source Of Electricity Is Green, The H_2 Produced Is Referred As Green H_2. However, This Method Is Generally Expensive Than Fossil Fuel Based Production Methods.
Depleted Oil Wells	✖	N/A	Injecting Appropriate Microbes Into Depleted Oil Wells Allows Them To Extract H_2 From The Remaining, Unrecoverable Oil In The Wells.

CERTIFICATE OF REGISTRATION

ISO

50001:2018

THIS IS TO CERTIFY THAT THE

ENERGY MANAGEMENT SYSTEM

of

RKDF UNIVERSITY

Address

AIRPORT BYPASS ROAD, GANDHI NAGAR
BHOPAL - 462033, MADHYA PRADESH, INDIA

Has been assessed and registered as complying with the requirements of the International Standard shown above for the following activities. Further clarifications regarding the scope of this certificate and the applicability of ISO 50001:2018 requirements may be obtained by consulting the organization

Scope

BESIDES IMPARTING EDUCATION OF UNDERGRADUATE (UG), POSTGRADUATE (PG) AND PH.D. IN VARIOUS DISCIPLINES FOR STUDENTS, UNIVERSITY IS ACTIVELY INVOLVED IN RESEARCH ON ENERGY, ENVIRONMENT AND ESTABLISHED CARBON CAPTURE PLANT AT CAMPUS

Certificate No. ISO/ENMS/1889

Initial Certification Date	15.06.2021	First Surveillance Date	15.06.2022
Certificate Expiry Date*	14.06.2024	Second Surveillance Date	15.06.2023

ISO

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AUTHORIZED SIGNATORY

International Standards Registrations

This registration is a Energy Management System Certificate
**Validity of this certificate is depend on successful completion of surveillance audit visit for verification of this certification on www.isoregistrations.com*

India is committed to use Renewable Energy Technologies through deployment of Solar PV plants and Innovative R&D Projects in Solar

RKDF CERTIFIED for deployment of CCS Technology towards mitigation of Climate Change WITH ISO 50001:2018