Challenges and Approach to GHG capture

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Organization of Presentation

- Personal Introduction
- GHG Emission, Global Warming and its after effects
- Challenges against GHG capture
- CO_2 and H_2S capture from Syngas (pre-combustion)
- Calcium Looping CO_2 capture (post-combustion)
- Other CO_2 capture research

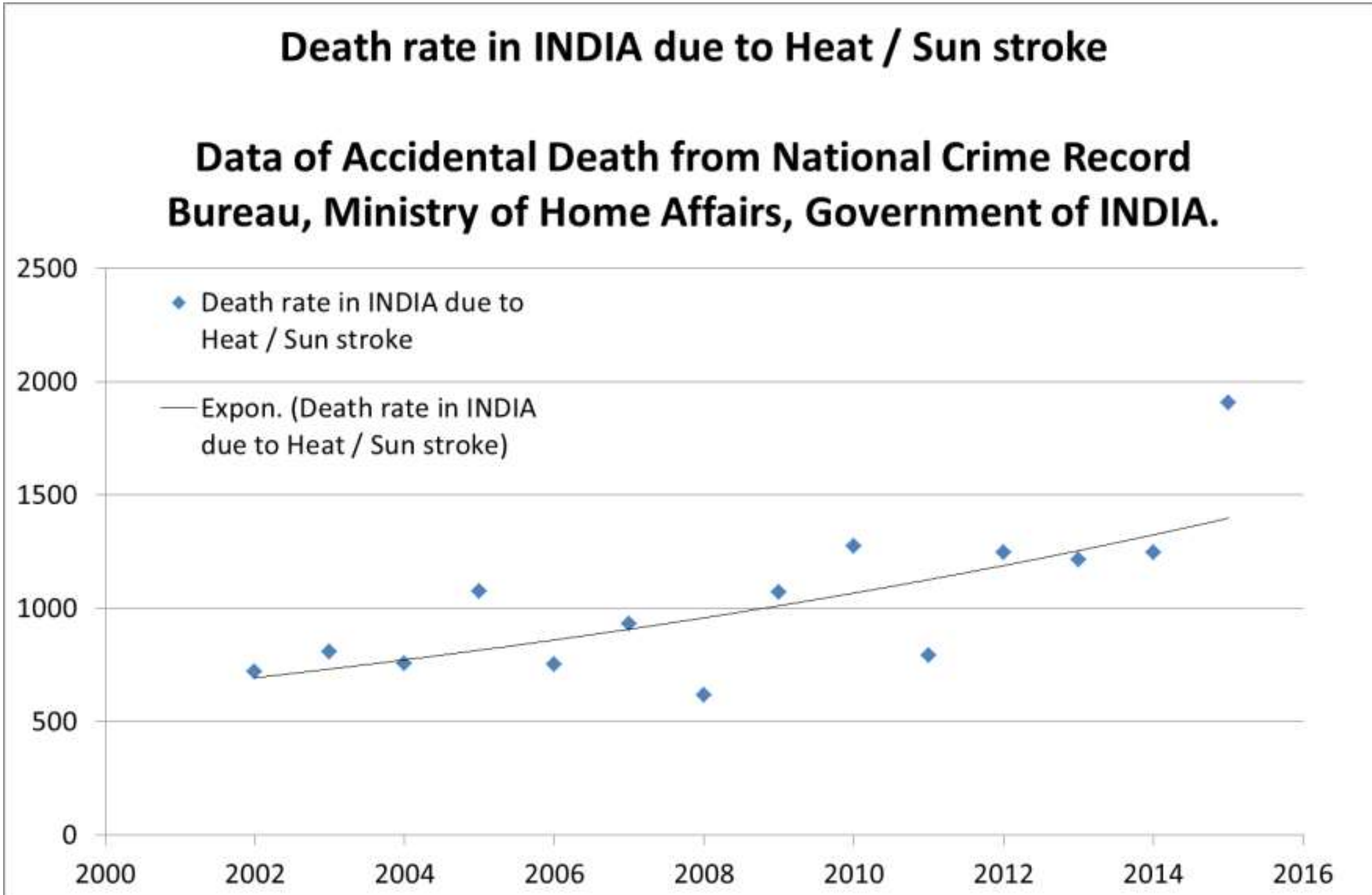
Personal Introduction

- earned Mechanical Engineering Degree from The M. S. University of Baroda – B.E. in 2004 and M.E. in 2006
- earned Ph.D. for research in pre-combustion GHG Capture from Ulster University, U.K. in 2013-14
- Experience of several European and British research projects related to energy systems and CO_2 capture
- Currently working at Indrashil University – a Life Science focussed university established by CADILA Pharmaceutical Ltd., Ahmedabad
- interested in Interdisciplinary Research topics integrating Mechanical or Energy systems, Thermo-Chemical Processes, etc.

GHG Emission and its after effects

- Global demand for fossil fuel energy will continue to rise in tandem with the aspiration for improved standard of living – particularly in the developing countries
- carbon neural Renewable energy sources have been unable to match the pace of energy demand due to :
  - lacking resources
  - lagging research
  - commercial and social-political consideration
  - absence of global consensus on mitigation strategy
- Ever increasing exploitation of fossil fuel resources is continuously adding to the worldwide GHG emissions causing
  - Global warming and its after effects
  - Threat to global economic and social balance
  - Extreme weather incidences occurring at increasing frequency
  - Epidemics; Endemics and Pandemics, Diminishing Food security
- Ahmedabad and INDIA are the live example of effect of sun stroke
- NCRB (MHA, GoI) has reported steady rise in Death rate due to heat stroke

GHG Emission and its after effects



Challenges against GHG capture

- Emission margin for maintaining global average temperature rise below 2 °C (or even 1.5 °C) is fast diminishing – thus necessitating
  - Global consensus on action plan
  - Early action
- Developed countries have been eyeing profiteering from technologies controlling GHG emissions
- Globally, the cost premium of technologies controlling GHG emissions emerges from
  - Lack of technological and operational experience
  - Risk premium and IPR
  - Penalty on utility consumption
  - Profiteering motives
  - Limited utilization potential of CO_2 (or other GHG)

Global Warming Potential (GWP)

GWP measures the influence of greenhouse gases (GHG) on the natural greenhouse effect, including following phenomenon :

- Ability of greenhouse gas molecules to absorb or trap heat
- Duration of sustenance of GHG molecule in atmosphere (or retaining the trapped heat) before being removed or broken down

GHG	Carbon Dioxide	Methane	Nitrous Oxide	CFC etc. (19 as per Montreal protocol)	HFC (11)	PC (11)	Fluorinated Ether (15)	Perfluoropropyl ether (1)	HC etc. (3)
100 year GWP	1	25	298	5-14400	124-14800	7390-22800	59-14900	10300	1-13

CO_2 and H_2S capture from Syngas

- Coal is important for global energy security
- Syngas produced by coal gasification consists of Sulphur compounds including H_2S
- Sulphur compounds are corrosive to process hardware, harmful to life and causes environmental risk
- 100 year GWP of H_2S is 5.8 compared to CO_2 (by researchers outside IPCC)
- 830 TPD Syngas feed, 38 % CO_2, 0.31 % H_2S to power 460.5 MWe gross power generation by CCPP

CO_2 absorption from Syngas

- Reliable Techno-Economic assessment necessitates detailed process data

Contents lists available at ScienceDirect

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Process design for CO_2 absorption from syngas using physical solvent DMEPEG

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A R T I C L E I N F O

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Selective Absorption/Desorption

A B S T R A C T

Pre-combustion IGCC is one of the leading technologies having potential for effective control of greenhouse gas emission. Process design for CO_2 Capture from power plant is becoming increasingly important in the past decades in view of the need for optimization of Capital Cost and Utility consumption. In this article, a configuration of the process design for CO_2 absorption using physical solvent DMEPEG is proposed, which is described using the process flow diagram (PFD) and the Flowsheet. CO_2 absorption performance of DMEPEG solvent is assessed based on a rate based mass transfer model using ProTreat® simulation software. The rate based mass transfer simulation by ProTreat software adds to the reliability of the simulation result (as evident by its acceptance within industry). The trade-off between H_2 recovery (by syngas recycle) and CO_2 re-absorption is described which reveals that more than 55% H_2 recovery may significantly increase the load on the system (in terms of syngas processing and CO_2 re-absorption).

Objective of this research is to develop a detailed process model for CO_2 absorption by DMEPEG solvent (to enable detailed techno-economic assessment by bottom up approach). In the second section of this article, the process of CO_2 capture by physical solvent DMEPEG is explained. In the fourth section, the boundary conditions such as the inlet pressure, temperature and composition of syngas and solvent feed are defined. In the fourth and fifth section, the design and performance of the packed tower is described and the utility consumption is estimated. Moreover, the outlet condition of the solvent is described and its saturation (by CO_2) is estimated. In the fourth section, the strategy of solvent heating to recycle the syngas to CO_2 absorber (for H_2 recovery) is described. Importance of CO_2 absorption in solvent (at high concentration) for minimization of equipment size and utility consumption for CO_2 capture is explained.

Using RSR packing (6.4 m Dia., 16 m Ht. (9+6+1)) results in 90.7% CO_2 absorption and 89% saturation of CO_2 dissolved in DMEPEG solvent. Out of 3.34 kmol/s H_2 fed to the CO_2 Absorber (as part of syngas), 1.464% (equivalent 5.9 MW power generation by Gas Turbine in open cycle) is co-absorbed (along with CO_2) in DMEPEG solvent. Out of this co-absorbed H_2, 55.7% is recovered which is equivalent to 3.267 MW Power Generation.

In terms of hydraulic design, the CO_2 Absorber using RSR packing operating at 72.5% flood condition results in packing pressure drop of 87.5 Pa/m (1.4 kPa). Packed section diameter and height is suggested for various random packing materials (tower internal) to achieve almost comparable gas absorption performance.

- Desorption Design

- 88 % CO_2 Capture

- 50.7 kW-Hr/Ton CO_2

H_2S capture from Syngas

- The process for H_2S capture from Syngas is licensed by Honeywell / UOP
- Reliable Techno-Economic assessment necessitates detailed process data
- Earlier publications :

H_2S Absorption from Synthetic Natural Gas in Physical Solvent DMEPEG

Ashok Dave, Bhumika Pathak, Medha Dave, Poonam Kashyap and Ye Huang

Ashok Dave, Bhumika Pathak, Medha Dave, Poonam Kashyap and Ye Huang, Chapter titled “H2S Absorption from Syngas in Physical Solvent DMEPEG” of the book titled “Innovations in Infrastructure” , chapter DOI being https://doi.org/10.1007/978-981-13-1966-2_30

Abstract H_2S is removed from sour syngas upstream of CO_2 capture, thus producing sweeter syngas. Simulation results of H_2S absorption in a physical or chemical solvent may be unreliable due to assumptions like the equilibrium-based modelling, theoretical number of stages, tray efficiency, height equivalent of theoretical plate, as also due to the lack of prior experience and the lack of pilot plant data at appropriate scale of operation. Rate-based process simulations carried out using ProTreat software are described in this publication using process flow diagram (PFD) and simulation flow sheet—to describe the packed tower design and process design for H_2S Absorption from syngas in physical solvent DMEPEG. Consideration of physical model of packed tower (packing type, size and material) imparts credibility to the simulation results. Sensitivity analysis is conducted for process parameters. Performance of packer tower is analysed and compared with process requirement and recommended practice. Similar performing tower internals is suggested.

Keywords H_2S absorption · Packed tower · HETP · DMEPEG · PFD

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Process design for H_2S Enrichment in physical solvent DMEPEG

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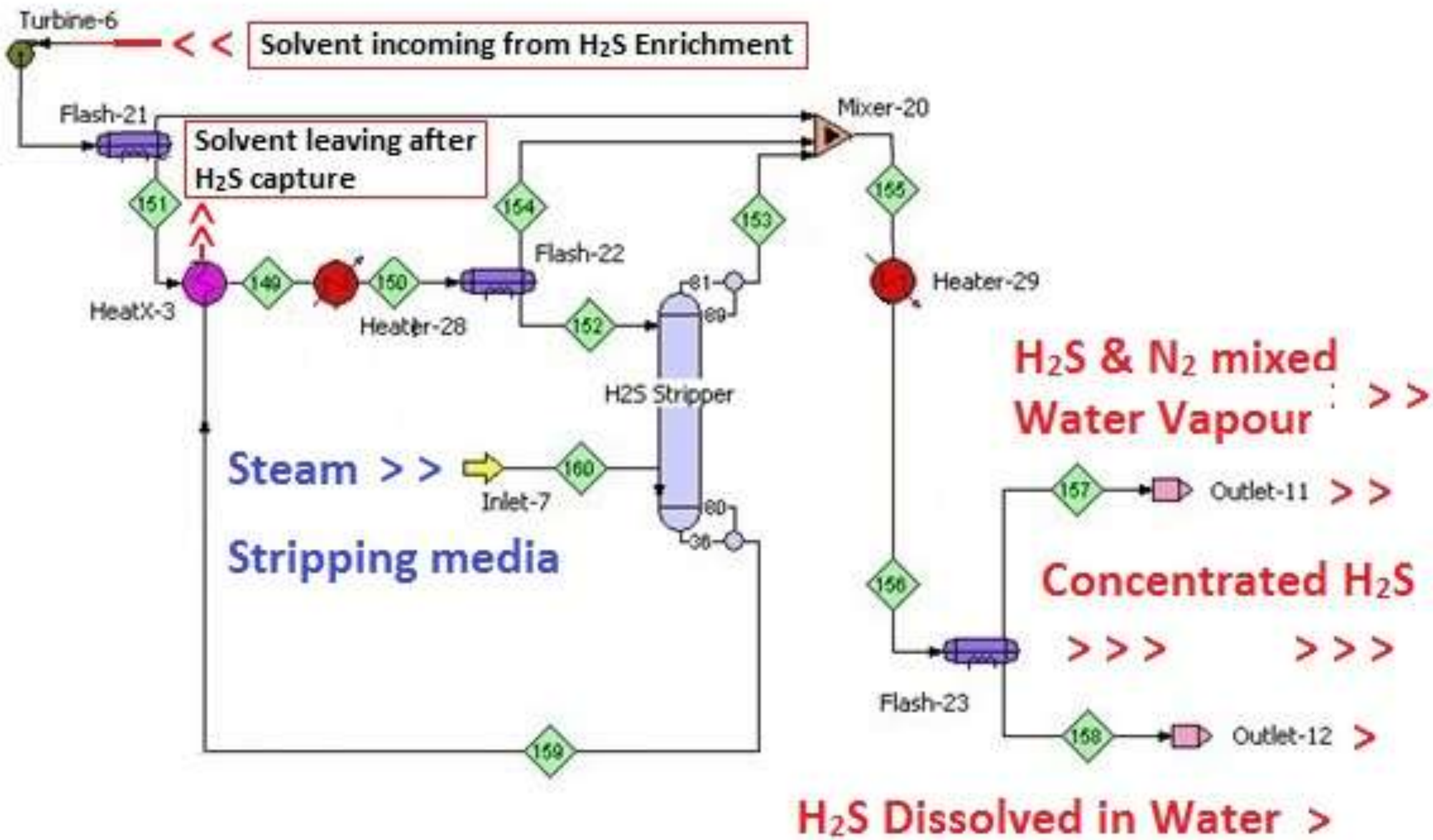
ABSTRACT

Acid gas removal from syngas is an important process upstream of CO_2 capture in a pre-combustion IGCC power plant. Enrichment of previously absorbed H_2S in DMEPEG solvent (by stripping out the CO_2 co-absorbed with H_2S) is described in this publication. The unique capability of ProTreat software to conduct rate based mass transfer simulation is described and applied for H_2S Enrichment simulation. Non-ionic liquid property model and its implementation in ProTreat software is described. Solubility of CO_2 and H_2S in DMEPEG solvent is described. Process condition for H_2S Enrichment is justified in terms of its integration within the overall IGCC power plant. Sensitivity study is conducted for various important process parameters. systematic development and optimizations of H_2S Enrichment process is described considering optimization of techno-economic performance parameters. Interaction and integration of H_2S Enrichment with H_2S absorption and H_2S Stripper is analyzed. Performance and mass balance across H_2S Enrichment is described. Limitations of this process design are also described. Various options are suggested for tower internals resulting in similar performance. This kind of detailed process design necessary for accurate detailed CAPEX assessment (by bottom-up approach) and techno-economic assessment.

Thermal stripping of H_2S



Enriched H_2S in incoming solvent

- Solubility data of DMEPEG solvent is summarized in earlier publications
- 1.914×10^{-2} kmol/s H_2S (1.25 % mole fraction) dissolved in 1.137 kmol/s DMEPEG solvent flowrate
- Average M.W. of polymer compounds of DMEPEG = 280 gm/mol
- Feed at 140 °C and 33.5 bara

Utility consumption

- 20 MW heat input to the Reboiler
- 0.576 kg/s steam injection to Reboiler i.e. 0.8856 kg steam / kg H_2S

Separated H_2S

- 33.8 % of the dissolved H_2S is separated by solvent de-pressurization from 33.5 bara to 3 bara
  - H_2S mole-fraction 7.64 %
  - Water vapour mole fraction = 36.8
  - N_2 mole fraction = 53.22 %

- 1.25 % of the dissolved H_2S is separated by solvent de-pressurization from 3 bara to 2.3 bara
  - H_2S mole-fraction 9.74 %

- 64.9 % of the dissolved H_2S is separated by thermal stripping of solvent by steam and water vapour from reboiler
  - H_2S mole-fraction 83.52 %
  - Water vapour mole fraction = 4.4
  - N_2 mole fraction = 8.89 %
  - CO_2 mole fraction = 3.22 %

Process Performance

- 100 % H_2S recovery from stripper

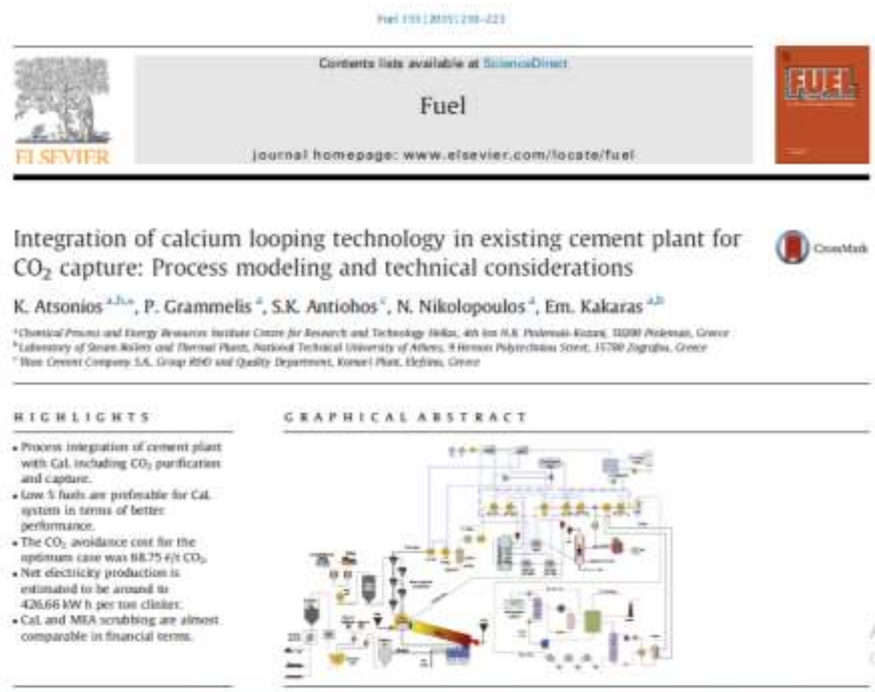
(as part of 10800 TPD syngas entering the H_2S capture plant having 0.31 % H_2S (mole %)

- Rate of Heat input = 30.7 GJ / Ton H_2S capture

= 20 MW / (0.01913 kmol/s x 34.0809 g/mol)

Post Combustion Calcium Looping CO_2 capture

- Post Combustion CO_2 capture from Cement Plant (or even Steel Plant) by Calcium Looping seem to be an attractive proposition for INDIA considering the expected growth rate of Construction Industry



Contents lists available at ScienceDirect

Fuel

journal homepage: www.elsevier.com/locate/fuel

ELSEVIER

Integration of calcium looping technology in existing cement plant for CO_2 capture: Process modeling and technical considerations

K. Atsonios[a,b,*], P. Grammelis[a], S.K. Antiohos[c], N. Nikolopoulos[a], Em. Kakaras[a,b]

HIGHLIGHTS

- Process integration of cement plant with CaL including CO_2 purification and capture.
- Low S fuels are preferable for CaL system in terms of better performance.
- The CO_2 avoidance cost for the optimum case was 68.75 €/t CO_2.
- Net electricity production is estimated to be around to 426.66 kW h per ton clinker.
- CaL and MEA scrubbing are almost comparable in financial terms.

GRAPHICAL ABSTRACT

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ELSEVIER

Technical and environmental study of calcium carbonate looping versus oxy-fuel options for low CO_2 emission cement plants

A. Rolfe[a], Y. Huang[a,*], M. Haaf[b], A. Pita[c], S. Rezvani[a], A. Dave[a], N.J. Hewitt[a]

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Calcium carbonate looping
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Carbon capture
Cement plant
Technical and life cycle analysis

ABSTRACT

The process of cement production emits large amounts of CO_2 through both chemical reactions and fossil fuel combustion. Reducing CO_2 emissions from the cement industry is becoming a global imperative. This work focuses on the technical and environmental evaluation for the integration of calcium carbonate looping (CCL) and oxy-fuel combustion processes into a cement plant for carbon capture and storage. Three scenarios have been established: 1. the base case cement plant without CO_2 capture, 2. Cement plant with integrated CCL and 3. Oxy-fuel cement plant. The process models of the CCL capture plant and the oxy-fuel cement plant are developed. To better understand the technical parameters and benefits of each scenario, the ECLIPSE modelling software is used to a technical analysis. Life cycle analysis (LCA) has been conducted using the SimaPro software to determine the environmental impact of the capture technologies.

Technical results showed that the cement plant equipped with the CCL illustrated better performance with specific CO_2 emissions avoided of 1.21 t CO_2/$t_{clinker}$ and the specific primary energy consumption of 2.39 GJ/t CO_2 compared with the oxy-fuel cement plant with 0.71 t CO_2/$t_{clinker}$ and 3.31 GJ/t CO_2. The main conclusion indicated that the CCL unit had a lesser environmental impact than the oxy-fuel combustion because of the additional benefit of electricity generation through the heat recovery system.

Other CO_2 capture research

- Membranes
- Chemical Solvent

Sincere Thanks you for for your kind attention

Wishing ALL THE BEST !!

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Indian firm makes carbon capture breakthrough

theguardian

Carbonclean is turning planet-heating emissions into profit by converting CO_2 into baking soda - and could lock up 60,000 tonnes of CO_2 a year

https://www.theguardian.com/environment/2017/jan/03/indian-firm-carbon-capture-breakthrough-carbonclean

QUARTZ India

ARTICLE

CARBON CAPTURE

Two Indian engineers have solved one of the biggest hurdles in the fight to make lower carbon-emissions targets a reality

http://qz.com/878674/two-indian-engineers-have-drastically-reduced-the-cost-of-capturing-carbon-dioxide-emissions/

How a startup is favourably using carbon dioxide

By HARI PULAKKAT, ET Bureau | Updated: Nov 03, 2016, 12.35 AM IST   Post a Comment

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http://economictimes.indiatimes.com/small-biz/startups/how-a-startup-is-favourably-using-carbon-dioxide/articleshow/55213921.cms

Why Carbon Capture and Storage is Important

Despite the rise of renewable energy, coal and natural gas will continue to be important for four or five decades from now

India will continue to depend on coal and gas for base load, as nuclear energy is unlikely to provide a large share

Capturing and storing the carbon dioxide emitted by power plants is thus necessary to fight rapid climate change

Carbon capture is expensive, and so electricity from a clean thermal plant will cost more than current prices

Growing Investor Interest

- **2009** — **₹60,000:** Indian angel investors
- **2011** — **$1.1 million:** Angel investment from India and Europe
- **2012** — **$6 million:** UK Department of Energy and Climate Change
- **2014** — **$3 million:** US Department of Energy for demonstration in a US plant
- **2015** — **$5.7 million:** Private equity funding from the UK

THE HINDU
INDIA'S NATIONAL NEWSPAPER SINCE 1878

ENVIRONMENT

Carving out a model for enhancing CO2 sinks

Malti Goel Vandana Maurya

JANUARY 17, 2016 17:00 IST
UPDATED: SEPTEMBER 23, 2016 00:46 IST

http://www.thehindu.com/sci-tech/energy-and-environment/Carving-out-a-model-for-enhancing-CO2-sinks/article14001561.ece

Initial steps have been taken. They need to be sustained to be beneficial in the long run. Photo: C.V. Subrahmanyam | Photo Credit: C_V_SUBRAHMANYAM