

## Carbon capture and storage technology for sustainable energy future\*

IWCCS-07 was held as a joint initiative of the Department of Science and Technology (DST) and the National Geophysical Research Institute (NGRI), Hyderabad taken up in association with an Economic Ministry of Government of India, Ministry of Power. The workshop was attended by experts from 11 countries. Deliberations involved five sessions and 32 papers. Along with scientists there were participants from Government ministries, R&D laboratories, Industries, namely NTPC, ONGC, GSI and Coal India. Major International companies like BP, Shell International and Schlumberger Carbon Services evinced interest in the workshop. Another unique feature was the participation of 10 young scientists/students from academic or industry background, viz. Mahandi Coal Fields, Shidhant College of Engineering, GSI, NEERI, ISM and others, fully supported by DST.

In his inaugural address, R. V. Shahi (Ministry of Power) said that India is poised to become a superpower in energy and hopes to have an installed capacity of 800 GW by 2032. With its low per capita energy consumption and carbon emissions, there is need to follow a path of sustainable energy development in power generation through solar energy, biomass and nuclear energy. India has a huge hydro potential that should be usefully harnessed. Coal will continue to be used for meeting the basic needs of energy. He suggested greater initiatives to research on carbon capture and storage (CCS) technology and R&D challenges to be met for building scientific strengths in the Indian context. A technology becomes deployable only when it is cost-effective and therefore it becomes one of the greatest challenges before the scientific community. Harsh K. Gupta (NGRI) released the Abstract book and expressed concern about shrinking of glaciers as a result of climate change impact.

In the first session on R&D challenges in CCS technologies there were six in-

vited papers. Malti Goel (DST) summarized the research priorities in CCS. With growing concerns about energy security emerging from climate change considerations, the world is witnessing rapid growth in CO<sub>2</sub> sequestration technology innovations. The multidisciplinary nature of CCS can have several research focuses. Priority should be given to pre-combustion carbon capture research as well as modelling and monitoring studies in geological storage to assess the risk and safety concerns. R. R. Sonde (NTPC) described challenges in carbon abatement, role of solar and biomass energy, coal gasification, etc. and managing of these issues through R&D.

Identifying research priorities in CO<sub>2</sub> sequestration in flood basalts, B. Peter McGrail (Pacific Northwest National Laboratory, USA) presented new findings from the research carried out at the Columbia River Basalts. He said considerable research is needed to understand the kinetics of rapid mineralization reactions as predicted in different basalts across the world. Lateral dispersions and vertical transport of CO<sub>2</sub> to overlying basalt flows are expected to be important limiting factors controlling *in situ* mineralization rates. V. P. Dimri (NGRI) discussed new tools for enhanced oil recovery using time lapsed 4D seismography. He also presented results from a study on thermal EOR monitoring in heavy oil fields of ONGC conducted under NGRI-NTNU project (Indo-Norwegian collaboration). K. V. Subba Rao shared his research experiences with Deccan basalts, highlighting the role of vesicles for carbon flows and enhanced reactivity.

Christian Fouillac (BRGM, France) presented an in-depth overview of ongoing CCS research projects in France. He described predictive modelling studies carried out on CO<sub>2</sub> behaviour for estimation of storage capacity in geological reservoirs and sedimentary basins in France. For realization of demonstration projects, risk-assessment studies have also been undertaken. He hoped to establish international cooperation with Indian partners in these areas. Dag Nummedal (Colorado Energy Research Institute) presented the luminosity graph of the

world, role of CO<sub>2</sub> in EOR, business opportunity and possibility of sale of carbon credits. He described various options for zero-emission energy production from unconventional hydrocarbon resources in recent energy industries. 'In contrast, the cost of action – reducing greenhouse gas emissions to avoid the worst impacts of climate change – can be limited to around 1% of global GDP each year' he quoted from a recent British economic report. Jeremy Boak (Colorado School of Mines) presented the world scenario of Oil Shale production, which is likely to consist of trillion barrels of hydrocarbon products. He suggested framing the carbon balance from increased oil shale production, which is a nascent area in India.

On post-combustion carbon capture research, several R&D laboratories have mounted efforts. A. N. Goswami (IIP) highlighted potential of PSA processes for higher CO<sub>2</sub> recovery from power plant flue gases. Giving an overview of the current status he suggested further work required in development of non-conventional PSA cycles for CO<sub>2</sub> recovery. S. S. Rayalu (NEERI) presented the scope of amine functionalized materials including natural biopolymers and synthesized nitrogenous activated carbon for CO<sub>2</sub> capture. The results on zeolites and alumina were also presented. Asha Masohan (IIP) described enhanced absorption studies carried out for gas separation at IIP and their applicability of multi-phased absorbents in CO<sub>2</sub> capture. G. Parthasarathy (NGRI) talked about possibility of using hydrotalcites-materials as anionic clays for carbon-dioxide adsorption.

A special session on sharing experience with experts from UK was also held on carbon capture research. Tim Dixon (Department of Trade and Industry, UK) talked about the international initiatives in abatement of greenhouse gas emissions, the IPCC guidelines and recent developments towards implementation of CCS technology. This was followed by the status of near-zero emission coal project started in China through UK collaboration. Andy Timms (Doosan Babcock Energy Ltd) presented a case for developing oxy-fuel firing technology for high ash coals as one of the best solutions

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among other options as pre-combustion carbon capture. Jon Gibbins (Imperial College, London) gave a conceptual journey on how to make a transition towards capture ready power plants. S. Holloway (British Antarctica Survey) discussed the potential of GIS for mapping CO<sub>2</sub> sources and for analysing potential for storage sites. The British High Commission supported experts' participation from UK in the workshop.

Initiating the deliberations on carbon storage, B. Kumar (NGRI) presented preliminary results of geological CO<sub>2</sub> sequestration studies in basalt formations of Western India under the multi-agency collaborative CCS research in association with USA. He said that Deccan Province is one of the continental flood basalts and its feasibility is being studied under the project supported by NTPC/Ministry of Power and DST. Sandeep Sharma (Schlumberger Australia) described challenges faced in developing a monitoring and verification scheme for Australia's first Geosequestration Project in Otway basin. He said that up to 100,000 tonnes of CO<sub>2</sub> can be injected into depleted gas fields. Laura Charamonte (Stanford University, USA) made a presentation on the role of geo-mechanics and seal integrity for geologic sequestration of CO<sub>2</sub>. She highlighted the importance of geo-mechanical characterization and modelling studies of heterogeneities in different types of geological formations ranging from deep saline aquifers, unmineable coal beds and mature gas oil fields. In case of saline aquifers low permeability is a limitation. Anil Bhandari (GHS) said that there is hardly any data on saline aquifers in India, which appear to have permanent storage potential for CO<sub>2</sub> in the long run. P. S. R. Prasad (NGRI) suggested formation of CO<sub>2</sub> clathrates in fluid inclusions as a mechanism of CO<sub>2</sub> sequestration.

An important aspect of carbon sequestration is recovery of value-added products while CO<sub>2</sub> is injected in oil or coal fields. M. Suresh Kumar (IRS) described various mechanisms involved in enhanced oil recovery (EOR) using CO<sub>2</sub>. He presented scoping studies carried out and preliminary results from application of

CO<sub>2</sub> EOR in a mature oil field of Ankleshwar. In his paper, Mahmut Sengul (Schlumberger Carbon Services) emphasized the critical role of project cycle activity. Highlighting main areas of R&D needs with respect to injectivity, reactive fluid, transport, reservoir monitoring, etc. for CO<sub>2</sub> sequestration, which is likely to become an important part of exploration and production operation in oil fields, he shared results from the FRIO project. In this international project 600 tonnes of CO<sub>2</sub> was injected in geological formations and has been monitored. A team of scientists from the Central Mining Research Institute (CMRI) led by A. K. Singh described stratigraphic horizon of coal deposits in India and possibility of further research on coal bed methane from CO<sub>2</sub> storage in coal seams. V. A. Mendhe (CMRI) presented the results of a laboratory simulation on coal samples from the southern part of Raniganj Coalfield, West Bengal. Devleena (NGRI) focused on various possible monitoring techniques and their relevance to geological sequestration of CO<sub>2</sub>.

A number of ideas and suggestions came up as breakthrough concepts and innovative approaches in mitigating carbon dioxide in the atmosphere. Kuldeep Chandra talked of storage and disposed CO<sub>2</sub> vs CO<sub>2</sub> sequestration with value-added products. He proposed the design of prototype magnesium carbonate reactor for producing elemental carbon which could be used to produce exotic materials like, fullerenes and carbon nanotubes. A pilot integrated converter may pave the way to overcome the vagaries of greenhouse gas emissions. Christian Fouillac gave an overview of EU initiative on CO<sub>2</sub>GeoNet European Network of Excellence playing an important role in strengthening capabilities in this area. He described the need for creation of infrastructure with examples of scientific and joint research activities undertaken on CCS. The network also provides knowledge support to policy makers and is collaborating with Canada and Japan. It is open to research collaborations in other countries.

Iain Wright (British Petroleum Alternative Energy) presented BP's experi-

ence to date. He said that CCS being one of the seven technology options to address climate change concerns, there are many future challenges in this area including production of hydrogen-based power with CO<sub>2</sub> capture and storage. He described the In Salah project in Algeria wherein 1 million tonnes/year of CO<sub>2</sub> is being injected in the gas leg of the reservoir. BP has plans to set up the first industrial scale project (475 mW) to generate low carbon power from hydrogen and expanded possibilities of collaboration with India on clean coal development towards carbon capture. Vilas Pharande (NCL) described international initiatives on carbon capture and storage. On carbon free use of coal, Mudit Narain highlighted his thesis perspectives from MIT, USA. He presented his findings in a study on the future of coal use by India and China, predicted emission scenario and a need for creating incentives for adoption of CCS.

It was heartening to note that very encouraging feedbacks were received in the concluding session. For young researchers, the workshop was quite educative in creating awareness about latest developments.

In the 21st century, as climate change concerns are assuming global dimensions, no country can remain isolated in finding scientific and technological solutions. CCS research offers a technology approach towards sustainable development. In this respect, the workshop has been very productive in identifying technology gap areas, which could result in taking concrete steps. Multi-institutional large scale collaborative projects in research areas flagged during the workshop should be visualized with clear goals taking an intersectoral approach. The Indian CO<sub>2</sub> Sequestration Applied Research (ICOSAR) network launched by DST is a first step in this direction and the workshop was part of this initiative. Further strengthening of the network to develop a framework of activities and policy studies for a sustainable future is needed.

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