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THEME

IPCC AR6 : Implications for Earth Science and Policy

THE MINING GEOLOGICAL & METALLURGICAL INSTITUTE OF INDIA
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PRESIDENT'S MESSAGE

IPCC AR6 : IMPLICATIONS FOR EARTH SCIENCE AND POLICY

Climate change has emerged as the defining challenge of this century and the Government of India has shown its firm commitment to countering it via mitigation and adaptation. The Hon'ble Prime Minister of India announced in the Glasgow Climate Summit that India shall reach net-zero greenhouse gas emissions by 2070. This was in consonance with similar net-zero targets announced by other heads of states. These targets, and specific strategies to achieve them, need to be informed via a rigorous scientific assessment of the science, engineering, and policy around climate change. In this role, the Intergovernmental Panel on Climate Change (IPCC) has been the 'gold standard' for conducting robust assessments around this subject.

IPCC's role in helping policymakers is highly evident. Even within the last decade, two important consequences of their reports are visible. First, the scientifically informed target of the Paris Agreement to keep global temperatures below 1.5°C was largely derived from the 5th Assessment Report of the IPCC. As policymakers agreed on this target, the IPCC was again tasked with understanding the key ramifications associated with it. In doing so, the Special Report on 1.5°C concluded that a number of scenarios converging at this temperature target met net-zero emissions close to the mid-century. In a way, that helped the governments of different countries declare their respective carbon neutrality targets. The most recent iteration of these assessments, i.e., the 6th Assessment Report, provides concrete, quantitative representations of the key characteristics of net-zero energy systems. This shows an excellent back and forth knowledge exchange between the scientific community and the policymakers.

While the primary objective of the IPCC is to inform policy making, it has also taken an important role in communicating about climate change to civil society, journalists, and the industry. A clear example of this may be seen in increased awareness of school children towards climate change and sustainable development. The Hon'ble Prime Minister of India, in an address last year, stressed on the importance of incorporating climate adaptation and resilience in the school curriculum. In the past, Coal India Limited and its subsidiaries have also supported work in India to further refine scientific knowledge at the Indian level to improve the data repositories of the IPCC. For instance, CCL supported a project to assess the carbon footprint of its opencast mines, which helped in developing best-practices of green house gas inventory for coal mining. Another project funded by the CMPDI to CSIR-CIMFR helped develop emission factors for opencast coal mining for various

Indian coalfields. The data generated in this project was directly featured in the IPCC Emission Factor Database. Thus, the Indian mining community has shown clear foresight in this effort to counter climate change.

The MGMI has also been thinking about a variety of ways to engage in this subject. Last year, we organized a webinar on the opportunities for the Indian coal sector to co-exist in a net-zero economy. Many of our recent special issues have focused on decarbonization. At the recent 9th Asian Mining Congress and a previous workshop on estimation of greenhouse gas emission, we had speakers who were directly involved in the preparation of the 6th Assessment Report and other critical reports of the IPCC. The reception to such initiatives in the MGMI community has been very positive and we welcome perspectives from our august membership on ways of furthering these approaches.

This special issue of the ***MGMI News Journal*** is another excellent example of our willingness to tackle this subject. This issue compiles a series of important contributions from authors of different chapters of the sixth assessment report. In doing so, it provides a multidisciplinary platform for scientists, economists, engineers, and social scientists to foster a collaborative dialogue and reach innovative solutions. Several key insights have emerged both from the report and this special issue. For instance, climate mitigation is a key priority alongside other societal needs for the people of India, such as clean drinking water, health, food security and employment avenues. I congratulate the Honorary Editor and our editorial board for bringing out this timely special issue of urgent global importance.

P.M. Prasad
President, MGMI

FROM THE DESK OF EDITOR

INTRODUCTION TO THE SPECIAL ISSUE

At the outset, let me take this opportunity to announce some editorial changes. First, we welcome our new editorial board members, Prof. Keka Ojha of IIT (ISM) Dhanbad, and Prof. Amit Kumar Verma of IIT (BHU) Varanasi. In addition, our distinguished Past Honorary Editor Prof. Khanindra Pathak, IIT Kharagpur has also agreed to continue on the editorial board, where his guidance will be much appreciated. Finally, Shri Ranjit Datta has come on board as the Associate Editor. These changes will hopefully accelerate the improving trend of MGMI publications.

The readers may be aware that the Intergovernmental Panel on Climate Change (IPCC) is the UN body set up in 1988 by the World Meteorological Organization (WMO) and the United Nations Environment Programme (UNEP) for assessing the science related to climate change. The IPCC routinely provides assessments of the scientific basis of climate change, its impacts and future risks, and options for adaptation and mitigation for governments to formulate climate related policies.

The IPCC in its sixth assessment cycle has prepared the Sixth Assessment Report (AR6) with contributions by its three Working Groups viz. Working Group I (the physical science basis), Working Group II (impacts, adaptation and vulnerability) and Working Group III (mitigation). The historic Sixth Assessment Report (AR6) of the IPCC was accepted and verified on 4th April 2022 after three years of hard work including myself and authors of the perspective piece and technical papers of this issue of MGMI News Journal. Three Special Reports on more specific issues between assessment reports have also been released in the sixth assessment cycle. Besides these reports, the 2019 Refinement to the 2006 IPCC Guidelines on National Greenhouse Gas Inventories, an update to the methodology used by governments to estimate their greenhouse gas emissions and removals has also been published with contributions from myself and one of the authors of a technical paper of this issue.

This issue's topic on "IPCC AR6: Implications for Earth Science and Policy" is really a continuation of our efforts to showcase the breadth of research happening in the interface of climate and energy. Over the past few months, energy security concerns have become paramount, owing to rising heat waves throughout the world that stressed global electricity systems, and some geopolitical reasons that have shifted the nature of fossil fuel trade. Since the publication of our last issue, prominent heat waves have been seen in India, China, Europe and the United States. Data from Power System Operation Corporation Limited (POSOCO) shows that India's power output increased by 6.1% from 2021 and 24.3% from 2020 levels (Varadhan, Reuters, 19 May 2022). Nevertheless, increase in demand outpaced production with multiple observable blackouts. This was even seen in the developed world with the Texas grid operators suggesting conservation measures in midst of rising temperatures. Clearly, climatic factors have a role to play in this. At the same time, there is often a supply-demand mismatch seen in electricity grids. As solar penetrations increase in India and around the world, it is imperative that system integration drives down these mismatches either by storing excess renewable energy or changing demand patterns. In this vein, this iteration of the IPCC's Assessment Report is the first to feature a chapter on demand-side interventions.

The past few months have also seen a transformative change in energy trade patterns. Recent news reports have pointed to increasing oil and gas, and coal imports in India. Global patterns also show that new players are emerging in the coal export business. For instance, coal exports from Kazakhstan have risen in the past few months. There a number of factors at play here. Notably, the Government of India has a long-standing ambition of reducing fossil fuel imports. This could be achieved through increase in underground coal production, as indicated by Coal India Limited. Similarly, improved extraction of coalbed methane and coal mine methane could reduce reliance for gaseous fuel imports. Moreover, liquid fuel (or energy carrier) alternatives in the form of biofuels and methanol are also being aggressively targeted by the government. At the same time, the AR6 points to the possibility of changing energy trade patterns in clean energy as well, if 1.5^{0}C targets are to be met. This could pertain to trade in low-carbon electricity, fuels and materials. For instance, countries in Africa and Latin America could become net exporters of biomass, with such trade representing as much as 10% of their annual gross domestic product (refer to Chapter 6 of the report). Thus, there is a strong interlinkage of climate action with development in the Global South.

To better emphasize this report, we invited contributions from experts in this field. The perspective piece for this issue is authored by Dr. Leon Clarke, who served as a Coordinating Lead Author in Chapter 6 of the AR6 Working Group III Contribution. He has summarized the modeling projections compatible with net-zero energy systems. Dr. Clarke points to the need of increased electrification, low-carbon energy carriers such as hydrogen and ammonia, and the need for widespread carbon dioxide capture, storage and removal technologies.

While modeling projections are influential in shaping climate policy discourse, there is a focus to back these modeling projections with realistic on-the-ground information. For instance, we have featured – in a past issue – the DDP-BIICS project's efforts to capture realistic trends in India's coal trajectory. In this vein, this issue's interview is with Shri U. Kumar, Past President, MGMI, who has a distinguished career in both mining and the thermal power sector. He has provided his insights on the future coal demand, as well as associated technologies across the coal supply chain.

The technical notes in this issue comprise subjects such as the envisioned role of CO_2 capture and storage in decarbonization pathways, and the interlinkages of climate mitigation with sustainable development goals. We are also thankful to the authors of the additional features in this issue.

Ajay K. Singh

Honorary Editor, MGMI

Minutes of 892nd Meeting of the Council

(Held through hybrid mode in Physical and Virtual Platform through Zoom
https://us02web.zoom.us/j/84083856566?pwd=Y0JocW1pc280R25XSWFrSC8wMmo5Zz09)

Date & Time: Sunday, 27th February 2022 at 12:00 Noon

The report of the 892nd Council Meeting (3rd meeting of the 116th Session) at MGMI Bldg, GN-38/4, Sector-V, Salt Lake, Kolkata on Sunday, 27th February 2022 at 12:00 Noon (duly approved in the 893rd Council Meeting held on 29th May 2022).

PRESENT : Shri Prasad P M, President in the Chair. The meeting was attended by Prof Banerjee Sakti Pada, Prof. Dhar B B, Dr. Nanda N K, S/Shri Jha N C, Ritolia R P, Saha R K, Jha Anil Kumar, Goenka J P, Lochan Rajiw, Singh Chandra Shekhar, Chakrabarti Bhaskar, Dr. Singh Ajay Kumar, Roy Prasanta, Gautam N N, Barnwal J P, Biswas Anup, Chakrabarti Smarajit, Prof Dey N C, Prof Sarkar Bhabesh Chandra, Dr Sinha Amalendu, Mishra P S, Wadhwa I P and Talapatra Ranajit.

Item No. 0 Opening of the Meeting

0.1 The meeting held in a hybrid mode due to the still existent virus scare, was called to order by the President. The President welcomed the Vice Presidents and Past Presidents, immediate 2 Past Secretaries, Present Secretary, existing Council Members, Shri P.S. Mishra, Chairman – Organising Committee, 9th AMC and Shri I.P. Wadhwa, Tafcon, who was present physically as well as virtually in the meeting.

0.2 President requested the Honorary Secretary to take up the Agenda for deliberations.

03. Leave of absence was granted to those who could not attend the meeting.

04. Members observed one minute silence as a mark of respect to Life Members Sri Hiranmoy Niyogi (LM-416,1946-47) who passed away on 15th December, 2021 and Sri Amar Kumar Mazumder (2901-LM, 1978-79), Former Director, GSI, and former Honorary Joint Editor of MGMI who passed away on 19th January, 2022 at Kolkata.

0.5. Honorary Secretary thanked and welcomed everyone including the President, Past Presidents, Vice Presidents and Council Members alongwith invitees.

891.1.0 To Confirm the Minutes of the 891st meeting of the Council held on physical and virtual platform at MGMI Bldg. Kolkata-700091 on 11th December 2021 at 3:30 P.M.

The draft minutes had been circulated to all the Council Members. No comment was received. The Council resolved that :

Resolution: The Minutes of the 891st (2nd meeting of 116th session) meeting of the Council held on Saturday, 11th December 2021 at 3:30 P.M. is confirmed.

891.1.0 To confirm matters arising out of the Minutes

The Council considered the Action taken Report in respect of the minutes of 891st Council Meeting held on 11th December 2021 at 3:00 P.M. (on hybrid mode).

Honorary Secretary informed that due to the serious pandemic situation in the period leading up to the week of 16th January, the Foundation Day Lecture, as decided in 891st Council Meeting could not be organised. However, he assured that it would be organised at some suitable time.

892.2.0 To discuss on the progress of the 9th Asian Mining Congress and Exhibition (i.e., 04-07th April, 2022)

The President informed the Council that due to the Parliament being in session during that time, the Minister of Coal and Mines will not to be able to be the Chief Guest of the event as he is also the Minister of Parliamentary Affairs.

Accordingly, he said that Secretary (Coal), who had confirmed his participation in the Congress, will be invited as the Chief Guest on 4th April and hence the Capacity Assessment Seminar must be held in the afternoon of the 1st Day of the Congress instead of the 2nd day as previously planned.

The Honorary Secretary informed that President, MGMI has proposed the name of Sri B Veera Reddy, Director (Technical), CIL as the Chairman of the Capacity Assessment Seminar. The council unanimously agreed to the proposal. Then he requested Shri I.P. Wadhwa, Managing Partner, M/s. Tafcon India Pvt. Ltd to brief on the progress of the 9th IME.

Shri Wadhwa at the very outset thanked for excellent support by the President, MGMI, Chairman, 9th IME and other Council Members. He further mentioned that due to change in dates, many companies want to confirm their decision in March 2022. Shri Wadhwa requested for kind help of MGMI President for Coal India Ltd, Neyveli, Jharkhand Government and NTPC stalls. President informed that M/s. NTPC have agreed and others he will speak to them shortly. Shri Wadhwa informed that the Minister of Steel and Mines, Government of Odisha may attend 9th AMC/9th IME. The inauguration time of exhibition was agreed at 11:30 hours by him: while Buyers' Seller meets is planned at IME on April 05, 2022, after lunch with support from Shri V.K. Arora. However, Sri Arora informed the Council that since he will not be able to preside over the Buyer Seller Meet due to a pressing family engagement, he was suggesting the name of Mr R P Ritolia in his place.

The Honorary Secretary requested the Convenor of the 9th AMC Shri Rajiw Lochan to update the Council about 9th AMC. Shri Rajiw Lochan informed that all the organizations who have been approached earlier for sponsorship of different categories and support have been intimated about the rescheduled date of the 9th AMC under the signature of the President/Honorary Secretary/Convenor of 9th AMC. He informed the Council that only ONGC, Singareni Collieries and BEML has so far proposed Sponsorships (Rs 5 Lakhs each).

On the request by Honorary Secretary, the Convenor of the 9th IME Shri Prasanta Roy updated the Council and informed that the inauguration of the Conference will be at 10:30 AM and thereafter the Chief Guest will inaugurate the Exhibition at 11:30 AM.

Shri P.S. Mishra, Chairman – Organising Committee said that though the time is very short, he is very optimistic that both the Conference and the Exhibition will be held in befitting manner like previous years.

The Honorary Secretary requested Chairman, Technical Committee, Dr. Amalendu Sinha, to brief the Council about the present position of the papers and keynote addresses. Dr. Sinha briefed the Council that 10 (ten) persons agreed to give keynote addresses out of which so far 4 (four) keynote addresses have been receivedand 54 abstracts received for paper presentation out of which 20 full papers have been received. Honorary Secretary informed that a request has been received from the office of the MD of Gujarat Mineral Development Corporation, Sri Roopwant Singh, IAS for a slot for him as a speaker. Discussions have been undertaken with the concerned resource person regarding the technical and non-promotional nature of the speech. A brief of the speech would be submitted by 15.3.2022.

892.3.0 To consider and constitute a Board of scrutineers to conduct the Election of Council Members for the years 2022-25

The Council constituted a Board of Scrutineers to conduct the election of Council Members for the years 2022-25. Comprising of Shri R.K.Saha, Chairman, Shri Anup Biswas, Member, Shri Bhaskar Chakraborti, Member, Shri Prasanta Roy, Member and Shri Ranajit Talapatra, Honorary Secretary–Ex-Officio Member.

The retiring members are S/Shri (Dr.) Jai Prakash Barnwal, Smarajit Chakrabarti, Tapas Kumar Nag, (Dr.) Abani Kanta Samantaray, Prof. Ashis Bhattacharjee, L.K. Bose, J.P. Goenka, Prof (Dr.) G.P. Karmakar, Anil Kumar Singh and Dr. Amalendu Sinha. There will be a total of ten vacancies in the Council for the years 2022-25.

892.4.0 To consider applications for membership and the membership position of the Institute

The Honorary Secretary informed that five (05) Life Membership applications have been received including the application of Sri B Veera Reddy, Director (Technical), CIL. All the applications were approved by the Council for life membership of MGMI.

Membership Position
(As on 27.02.2022)

	11.12.2021	Add	Trans	Loss	27.02.2022
Member	41	-	-	-	41
Life Member Associate	1918 18	05 -	- -	02 -	1921 18
Student Associate	04	-	-	-	04
Life Subscriber	27	-	-	-	27
Subscriber	01	-	-	-	01
Life Donor Donor	01 01	- -	- -	- -	01 01
Patron Corporate Life Corporate	05 08 02	- - -	- - -	- - -	05 08 02
	2026	05		02	2029

892.5.0 Any other matter with the permission of the Chair

The following points have received from Dr. Khanindra Pathak, Former Honorary Editor, MGMI for discussion in any other matter :

1. MGMI transactions can publish selected relevant papers from the conference and webinars of various reputed institutions free of service charge till we get our Scopus indexing. The papers may be subjected to MGMI review by its panel reviewers.
2. Printed journal and transcriptions will be distributed to the subscribing members and subscribers and authors only. All members will be receiving the digital version only.
3. All the Council Members may be requested to assist in commercialization of the journal by getting subscribing members and buyers and corporate sponsors to buy the advertisement spaces.
4. A special mega issue of the journal for the private sector of Mining and Metallurgical

Industries may be approved with approval of inviting non-member Guest Editor.

Dr. Ajay Kumar Singh being the Honorary Editor of MGMI was requested to focus some light on these points submitted by Dr. Pathak. Dr. Singh informed that in case of inadequate number of papers for publication in MGMI Transactions, selected relevant papers from the Conference and Webinars of various reputed Institutions may be printed. However, it will be subjected to an MGMI review. One of the Former Presidents of MGMI said that once a paper is published or presented in a Conference/Webinar, it should not be published again in the MGMI Transaction. He also mentioned that the budget for cost of publication of News Journal for the Year 2021-22 is Rs. 4 lacs whereas Rs. 4,12,777/- have already been spent for three issues. One more issue is yet to be printed with Rs. 1,25,000/- (approx.) including postage.

Regarding the proposals, it was decided that the full editorial Board will discuss it among themselves, and put forward a proposal considering the brand of MGMI as well as the interests of the members of this Institute.

It was pointed out that a good no. of Journals are being returned due to change of address and members hardly take care to update their addresses though repeatedly requested in MGMI News Journals. It was suggested that a drive may be undertaken by MGMI office after the AMC is over to contact as many members as possible to update their details if not done already.

MGMI President's Cup Golf Tournament

Shri J.P. Goenka pointed out that due to pandemic situation, Covid-19 the MGMI President's Cup Golf Tournament could not be organized for last 2 years. Shri Rajiw Lochan suggested that this year Golf Tournament will be held in Ranchi tentatively in the last week of April as there is a very good Golf Ground. Preliminary talks have been held with the Army Golf Course authorities.

Opening of MGMI Transit House during the days of AMC and IME

Some of the Council Members based out of Kolkata informed that they plan to attend the 9th Asian Mining Congress and requested to temporarily open the Transit House rooms for their stay from April 03rd - 08th, 2022. It was informed by Honorary Secretary that this request has already been considered and directions given for appointing a casual staff for 4-5 days for looking after the rooms and general errands as F&B arrangements have ceased following withdrawal of the Transit House facilitator.

Honorary Secretary requested the President to formally close the meeting with a few words. The President thanked all present in the meeting once again for sparing their valuable time and taking part in the deliberations.

The meeting ended at 1:30 PM with a vote of thanks to the Chair and others present both physically and virtually by Honorary Secretary, Shri Ranajit Talapatra and he requested the physical attendees to join in the Council Lunch.

REPORT OF THE 9TH ASIAN MINING CONGRESS

4th and 5th April 2022

The 9th Asian Mining Congress (9th AMC) organized by the Mining, Geological and Metallurgical Institute of India (MGMI) at the Biswa Bangla Convention Centre, New Town, Kolkata on 4th and 5th April 2022 was the latest milestone in a series of biennial events of Asian Mining Congress (AMC) and International Mining Exhibition (IME) since 2006. Central theme of the Congress was **"Technological Advances in Mining Industry: Status and Challenges".** The Congress witnessed a participation of nearly 400 registered delegates including executives, practicing engineers, planners, policy makers, equipment manufacturers, regulators, scientists, researchers and other professionals from various organizations from India and abroad, who shared expertise and broad experience, through lively and dynamic presentations and discussions. To encourage students' participation in the Congress, students were supported to attend through subsidized registration costs. In spite of being organized at Asia level, it owes to its credit key note lectures from Norway and United States of America. The congress created a lot of excitement in the research fraternity, which was reflected in the form of over 75 abstracts and 50 full-length research papers received from all over the world. During the two-day conference there were 8 sessions and 52 papers were presented. The event was supported by funding from:

- Coal India Limited (CIL)
- Steel Authority of India Limited (SAIL)
- Bharat Earth Movers Limited (BEML)
- Oil and Natural Gas Corporation Limited (ONGC)
- Singareni Collieries Company Limited (SCCL)
- NTPC Limited (NTPC)
- NMDC Limited

The Congress took place over two days and featured the inaugural session and two plenary sessions on 4th April 2022 and 6 technical sessions, a panel discussion and the valedictory session on 5th April 2022. It also included networking coffee spaces. This congress was designed to provoke as much debate as possible and to obtain as many critical and constructive views from stakeholders. Each plenary and technical session consisted of a Session Chair, a Rapporteur and few speakers. The papers presented by the speakers were made available ahead of the Congress.

The Hon'ble Chief Guest **Dr. Anil Kumar Jain, IAS**, Secretary, Ministry of Coal, Government of India inaugurated the event on 4th April 2022 at 10:00 AM. In his address, Dr. Jain raised many important issues being faced by the mining industry. He emphasized on better quality of minerals being produced and highlighted the emerging market of rating companies that assess environmental, social, and governance (ESG) risks and opportunities of investments globally. The President MGMI, **Shri P. M. Prasad,** CMD, CCL, Ranchi in his welcome address dealt upon the need for organizing the congress. The Chairman, 9th AMC, **Shri P. S. Mishra,** CMD, SECL presented the theme of the congress in a lucid manner for the understanding of the audience. Theme of the 9th IME was introduced by **Shri Bhola Singh,** Chairman, 9th IME and CMD, NCL. It was followed by the address of the Guest of Honour **Shri M. Nagaraju, IAS,** Additional Secretary, Ministry of Coal, Government of India. **Shri Pramod Agrawal, IAS,** Guest of Honour and Chairman, Coal India Limited addressed the gathering of experts from the Industry, R&D Institutions and the Academia. The Souvenir and Abstract of the congress were released by the dignitaries and a vote of thanks was proposed by **Shri Ranajit Talapatra,** Honorary Secretary, MGMI. Luminaries and young professionals from the world of mining industries, research institutions, academics and business graced the event.

Soon after the Inaugural session, the first plenary session began.

Plenary Session – I

Session Chair : Shri N. C. Jha, Past President MGMI

Five key note lectures were delivered in the Plenary Session – I. The first key note lecture was delivered by **Prof S P Banerjee,** Former Director Incharge, ISM, Dhanbad, India. Prof. Banerjee Spoke on the availability of minerals needed for a green energy transition in the world and the Indian context. The demand and availability of selected critical metals for green energy transition, both from the world and Indian context were discussed. Padma Shri **Dr. Rabi Narayan Bastia** presented the incredible journey of seismic from petroleum to coal and to minerals. He summarized that now, since, the exploration for coal and mineral deposits is moving to greater depths, application of seismic tools and techniques have to be used for deep and expensive exploration and borehole drilling. A key note lecture on processing of bauxite residue for the recovery of metal values was given by **Prof. Suddhasatwa Basu,** Director, CSIR-IIMT Bhubaneshwar and CSIR-CIMFR, Dhanbad. The R&D efforts of CSIR-IMMT, Bhubaneswar on the processing and utilization of bauxite residue were deliberated. **Mr Roopwant Singh,** IAS, MD, GMDC, Gujarat highlighted the present activities of GMDC and discussed about upcoming lignite blocks, opportunities for capital partners for limestone and Silica sand, exploration agencies to unearth the vast multi-metal and REEs, EPC contractors for value addition and processing and lignite beneficiation, technology partners, O&M operators for their thermal Power plants and customers for our vast Bauxite, Bentonite and Silica Sand reserves. **Dr N K Nanda,** past president, MGMI made a presentation on start-ups in mineral and mining ecosystem in India. It was summarized that start-ups in mining and mineral sectors can be the growth engine for the sector. Adoption of new technology, digitalisaion of mining process and outsourcing non-core activities to start-ups in large mines improve the productivity and enhance viability of new projects to meet the future mineral demand of the country.

Plenary Session – II

Session Chairs : **Dr. Amalendu Sinha,** Former Director, CSIR-CIMFR and **Shri M. K. Singh,** Executive Director (Coordination), Coal India Limited

Dr. Leon Clarke, Director of Decarbonization Pathways at the Bezos Earth Fund, USA threw some light on key characteristics of net zero energy systems in his key note lecture and **Dr Sukanta Roy,** Advisor, Ministry of Earth Sciences, Government of India presented the challenges, results and perspectives of geophysical exploration of the Koyna (India) intraplate seismogenic zone through scientific deep drilling to 3 km depth. The last key note lecture on tunnels, caverns and slopes in discontinua – a critical assessment of continuum analyses, GSI, Hoek-Brown and Mohr Coulomb, with focus on discontinuum analyses and geology was of **Dr Nick Barton,** Norway, who concluded that joint and rock mass characterization for discontinuum models is needed if we are to return closer to reality.

Report on Capacity Assessment Seminar

- During the meeting on the directions of the Hon'ble Prime Minister, chaired by Secretary (Coal) on 27th September 2021, Coal India Limited (CIL) was advised to organise a seminar on Capacity Assessment inviting all coal companies, CMPDI, and private sector for stakeholder consultations.
- Subsequently, Ministry of Coal, vide file no. A-60/12/2021-ESTABLISHMENT dated 2nd November, 2021 requested CMD, CIL to organise this Seminar during the 9th International Mining Exhibition (IME), organised by the Mining Geological and Metallurgical Institute of India (MGMI).
- Accordingly, CIL, in collaboration with MGMI, organised this event to assess stakeholders' capacity and preparedness required to meet the future coal demand, on 4th April

2022 from 3:00 PM at Biswa Bangla Convention Centre, Kolkata, by dedicating an entire session during the 9th Asian Mining Congress.

- The seminar was chaired by Shri M. Nagaraju, Additional Secretary to the Govt. of India, Ministry of Coal, and graced by Shri Anil Kumar Jain, Secretary, Govt. of India, Ministry of Coal – the Chief Guest of the seminar, in the august presence of Shri Pramod Agrawal, Chairman, CIL, Shri B. Veera Reddy, Director (Technical), CIL, Shri P.M. Prasad, Chairman-cum-Managing Director, CCL/ President, MGMI and other dignitaries from reputed organizations. The seminar was coordinated by Shri Achyut Ghatak, GM (Corporate Planning), CIL.
- Altogether eight senior officials from pan-Indian reputed organizations expressed their valuable views and shared innovative ideas to enhance overall preparedness, with the objective of catering to the requirements of achieving 1 BT coal production target, with special emphasis on wherewithal, equipment and roadmap to 1.5 BT production for the country as a whole.
- The enriching ideas also threw light on the wide gamut of elements of capacity, that definition-wise is the comprehensive ability of assets & resources to perform and enhancement of which leads to larger output, better economics and greater shock absorbing ability.
- The details of presenting organizations and the dignitaries are as follows: -
  - o NCL : Shri Bhola Singh, CMD
  - o CMPDI : Shri R.N. Jha, Director (RD&T)
  - o DVC : Shri Ram Naresh Singh, Chairman
  - o SCCL : Shri S. Chandrashekhar, Director (O)
  - o BEML : Shri M. V. Rajshekhar, Director (Mining & Construction)
  - o NLC : Shri Suresh Chandra Suman, ED (Mining)
  - o SAIL : Shri Bijendra Pratap Singh, ED (Works), DSP
  - o GMMCO : Shri Anuj Keolia, Vice President
- NCL expressed that coal shall continue to remain the primary player in the energy mix of the country in coming years due to major drivers like Make in India, 24X7 power for all, Rise of e-mobility, rural electrification & sustained economic growth. With large capacity equipment (Draglines, Shovels & Dumper), efficient dispatch (through MGR, CHPs and Silos) and evacuation (mostly through MGR & Rail mode), NCL contributes significant share of overall production of CIL, with consistent growth. Well planned mechanization, standardization and capacity building with matching geo-mining condition has enabled NCL to achieve planned coal targets, improvement in production, productivity & safety, better environment management, flexibility in production system for quick response to dynamic market scenario, and has further strengthened the foundation for future plans towards optimum extraction of coal resources.
- CMPDI projected Skill Development of human resources as a necessary tool for achieving 1 BT production by 2024-25, by enhancing human resource capabilities in overall management of project, contracts, supply chain, operations and statutory clearances & compliances, through reskilling & upscaling of human resources. For smooth implementation of skill development, a structured approach was proposed in the form of Talent Management Policy, which harnesses leadership abilities of potential executives & readiness to assume critical responsibilities. Towards capacity enhancement, need-based training of existing & newly recruited executives is required with focus on future thrust areas like IT application, enhanced production from UG mining, mass production technology, indigenization of technology, digitization & techno-managerial leadership improvement, so as to analyse, identify and redress likely

impediments & constraints in enhancing coal production. CMPDI has taken up some reskilling/upskilling activities like training in latest software, training of geologists in other areas, thrusts on diversification initiatives etc. IICM can be upgraded to spearhead skill development initiative, by remodelling it into a dynamic centre of excellence. Skill development of both upper & lower levels of workforce would lead to cope with the automation and mechanization being planned in mining operation and maintenance activities.

- In their pursuit towards capacity enhancement, DVC has taken up diversification in a large way into solar power and coal mining to fulfill the needs of its assets.
- BEML stressed more & more on R&D activities as a successful tool for capacity enhancement, which have aptly delivered India's largest indigenous mining trucks - 150 Te and 205 Te payload carrier Electric Drive Dump Trucks. High capacity Rope shovels & backhoes, hydraulic excavators, walking draglines, dozer, tyre handlers etc. are being manufactured for coal sector. Launching of 240 Te Electric Drive Dump Trucks is in pipeline. AI & IoT projects like Vehicle Health Monitoring System, AI based predictive maintenance through data analytics & telematics, AI based 360° surrounding view monitoring system, Drivers Fatigue Monitoring System, Payload Monitoring System etc. are being introduced in equipment for better safety & health management and greater productivity improvement.
- SCCL showcased its pioneering initiatives in implementation of ERP-SAP system, commissioning largest capacity longwall project, production of thermal power & solar power and adopting sand processing plant using OB. With limited reserves amenable for OC mining, SCCL has converted a number of UG mines to OCfor augmenting production. SCCL deploys Shovel Dumper combination, In-Pit crushing & conveying, Surface Miner in the OC mines and Longwalls, Continuous Miners and LHDs & SDLs in the UG mines. Future plans of SCCL towards capacity expansion include new mining projects within & outside Telangana state, upcoming CHPs, new railway infrastructure construction and Diversification initiatives like existing Thermal power plant (installed capacity 2X600 MW), Solar power plants (300 MW by '22), Floating Solar power plants (250 MW by '22-'23), capacity expansion of explosive manufacturing plants and processed OB plants.
- NLCIL, the largest OC lignite mining CPSE in Asia and nodal agency for lignite mining in India, emphasized on strong in-house capabilities in its core business of diversified & integrated lignite mining, coal mining, power generation and power trading, leading to doubling of mining capacity & 50% increase in power generation capacity in last 3 years. As a part of Vision 2030, NLC has envisaged to enhance both its coal and lignite mining capacity and expansion of power generation capacity, both in thermal & renewables like solar & wind. In its constant endeavour towards capacity enhancement, NLC intends to foray in areas of potential business opportunities like allied areas in power sector, EV charging infrastructure, application of AI, commercial coal mining, lignite blending and diversification initiatives like solar wafer manufacture, lignite to methanol, lignite to diesel, lignite to hydrogen and waste to wealth efforts like OB to sand & minor minerals.
- SAIL highlighted the fact that dearth of indigenous coking coal has led to major import of the same & resultant blending. In its bid to enhance its capacity to 50 Mty by 2029-30, the projected Prime coking coal requirement is also likely to be considerably higher to about 100 Mty. Accordingly, the projected import of high-quality low ash coking coal shall increase steeply. The option of blending with the indigenous coal may also be thought of.

- To keep pace with the need of the industry and facilitate the coal sector to achieve 1.5 BT aspirational target, GMMCO provided details of various manufacturing capacities and the capacity expansion programs. It was remarked that currently GMMCO has a major export market and has the capability to look inwards if demand arises.
- The seminar was followed by an informative Q&A session & concluded with vote of thanks to the Chair.
- The seminar was successful in that it brought out some extremely innovative thoughts & ideas for overall improvement in Capacity Assessment and Enhancement through R&D, better industry interface and more investments for 'Make in India' for achieving the aspirational target of 1.5 BT coal production nationwide, thereby contributing to the energy security of the nation and making the country 'Atmanirbhar' in the days to come.

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The second day of the Congress comprised six technical sessions, a panel discussion and the valedictory session on Tuesday, 5th April, 2022.

The technical sessions were held parallelly in two breakout groups, with 5 – 9 speakers per session. Each speaker was given 10-15 minutes to present, followed by 2-3 minutes for questions. All accepted papers had been categorized into the following six sessions:

Sessions I & III : Challenges in underground and opencast mining and rock excavation;

Session II : Exploration and investigation in geoscience, coal and mineral beneficiation;

Session IV : Management of environment, carbon footprint, energy transition and miners' health;

Session V : Application of AI, ML, wireless communication in smart mining and digital oil field;

Session VI : Production and Utilization strategies of unconventional gases and clean fuels.

Sessions I : Challenges in underground and opencast mining and rock excavation

Session Chairs : Shri B. Veera Reddy, Director (Technical) of Coal India Limited (CIL) and **Shri Manoj Kumar,** CMD, WCL, Nagpur

Rapporteur : Shri Chandra Shekar Singh, DGM (M)/TS to D (T), Coal India Limited (CIL)

The following nine papers were presented in this session :

Prediction of heat stress in underground coal mines by multivariate regression analysis (MVRA) and 3D simulation modelling authored by Siddhartha Roy, Hemant Agrawal, D.P. Mishra, Manoj Kumar, Chiranjeeb Patra and Rakesh Pradhan;

Long-term mining sequence optimization under uncertainty in open-pit mines using an effective metaheuristic-based framework authored by Kamyar Tolouei and Ehsan Moosavi;

Precautions against premature blasting during lightning and thunderstorm- suggestive guidelines authored by Pijush Pal Roy and Amalendu Sinha;

Numerical simulation and mathematical modelling-based approach for predicting blast induced ground vibration for a greenfield mining project authored by Vivek K Himanshu, Ashish K Vishwakarma, R. S. Yadav, M. P. Roy and P. K. Singh;

Review of continuous highwall miner performance in Indian mines authored by Chandrani Prasad Verma, John Loui Porathur, Sheikh Amir Sajjad and Pijush Pal Roy;

Numerical modelling and monitoring of slope movements vis-à-vis development of trigger action response plan for opencast coal mines authored by S. Jayanthu, Pritiranjan Singh, Sridhar K and Gokul Satheesh;

Critical investigation of pit and dump slope stability in a specialized real-time situation authored by A. K. Verma and Piyush Rai;

Ground control study on bulking factor and caving angle for Indian coalfields authored by Ashok Kumar, Sahendra Ram, Arun Kumar Singh, Dheeraj Kumar, Rakesh Kumar and Amit Kumar Singh; and

Design and application of a comprehensive support system for drifts to cross faults under fragile (Motur) formations authored by Sonu Kumar, B. S. Chaudhary, Amalendu Sinha and Rajendra Singh.

Session II : Exploration and investigation in geoscience, coal and mineral beneficiation

Session Chair : **Shri Samiran Dutta,** CMD, BCCL, Dhanbad

Rapporteur : **Dr Anupendu Gupta,** Former Dy. Director General, GSI

Eight papers were presented in Technical Session – II :

Economic modelling of exploration projects authored by B C Sarkar and P P Kala;

Significance of paleoclimatic condition on organo-inorganic matter preservation and hydrocarbon generation in coal/shale of Talcher Basin India authored by Shashanka Pandey, Vinod Atmaram Mendhe, Srikanta Murthy and Priyanka Shukla;

Optimizing coal beneficiation of Indian LVMC and non-coking coal by utilizing in-pit dry deshaling followed by wet jigging/heavy media process at washery authored by K S Ashvani, Mustafi Gurudas and Chiranjib Banerjee;

Digital optimization technologies that continue to enhance productivity, increase asset availability and drive sustainability for minerals processing industry authored by Nuser Bilal and Rizwan Sabjan;

Increasing usage of Indigenous coking coals by adopting pre-carbonization techniques and optimizing battery operation authored by B Chakraborty, B Ghosh and P Banerjee;

Utilizing curved conveyor technology for efficient long-distance material transport authored by Kilian Neubert and Andrea Prevedello;

Digitalization and innovation in mineral beneficiation process and dry tailing management to enhance mining operation authored by Subhasis Das; and

Use of x-ray transmission technology for real-time analysis of GCV in Indian coal in running conveyor authored by G.V.Ramana, Lingaraj Sahu, Biswajit Dutta and Sourav Chakraborty.

Sessions III : Challenges in underground and opencast mining and rock excavation

Session Chair : **Shri Manoj Kumar,** CMD, WCL, Nagpur

Co-Chair : **Dr. Anindya Sinha,** Director (Technical), NCL, Singarauli

Rapporteur : **Shri A. K. Roy,** GM(PMD), Coal India Limited (CIL)

The following nine papers were presented and discussed :

Strata control considerations to ensure safety of underground workplaces during extraction of inclined coal seam authored by Prabhat Kumar Mandal, Arka Jyoti Das, Ranjan Kumar, Subhashish Tewari and Rana Bhattacharjee;

Mitigation of environmental and safety hazards in blasting process: a case study at Jagannath OCP, MCL authored by Sunil Guduru, Debashis Mandal and Manish Sinha;

Optimum combination of long and short tendons for stable roadways intersections in coal mines authored by Ranjan Kumar, Prabhat K. Mandal, Arka J. Das, Jagapthal V. Kumar, Kumar Gaurav, Rana Bhattacharjee and Subhashish Tewari;

Excavation of large underground surge shaft of Their-Pump Storage project, India authored by Prakhar Ghosh, Harsh K Verma, Ashok Kr Singh and Rajeev Prasad;

Geotechnical considerations and numerical modelling approach for preparation of strata control

and monitoring plan (SCAMP) of highly stressed depillaring panel in underground coal mines – A case study authored by Rana Bhattacharjee, Subhashish Tewari, Arka Jyoti Das, Awanindra Pratap Singh and Prabhat Kumar Mandal;

Geotechnical considerations in design of crown pillar during transition from open pit to underground mining authored by Chandrani Prasad Verma, Amir Sheikh and Tushar Kawale;

Optimization of operational parameters of a raise borer machine for rock excavation in an underground metalliferous mine authored by Ashish Kumar Vishwa karma, Vemavarapu Mallika Sita Ramachandra Murthy, Vivek Kumar Himanshu and Murari Prasad Roy;

Paste backfilling for underground mines: Present scenario in India and future perspective authored by Santosh Kumar Behera, Prashant Singh, Sujit K. Mandal, K. Mishra, Phanil K. Mandal and C. N. Ghosh; and

Assessment of loading characteristics of resin grouted rock bolts under different confinement pressure through laboratory and numerical modelling studies authored by KolichalamRajashekhar, Sahendra Ram, Ashok Kumar, Petr Waclawick, Malothu.

Session IV : Management of environment, carbon footprint, energy transition and miners' health

Session Chair : **Shri Vinay Ranjan,** Director (Per sonnel & IR), Coal India Limited
Rapporteur : **Shri Shankar C Subramanian,** GM (Environment), Coal India Limited (CIL)

The following six papers were presented in Session IV:

Association of occupational risk factors with safety performance of workers and prioritization of interventions using Axiomatic principle authored by Ashish Kumar, Amrites Senapati and Ashis Bhattacherjee;

Reclamation index on managed land for coal mining complexes authored by Manoj Kumar and Kumar Ranjeev;

An account of possible energy transitions in India in the context of climate change negotiations authored by Debadutta Mohanty, Sudipta Mukherjee;

Postural risk assessment of heavy earthmoving machinery operators in opencast coal mines authored by Khane Jithendar Singh, Sanjay Kumar Palei and Netai Chandra Karmakar;

A case study for estimating carbon content stored in different tree species and elaboration of existential equations authored by Manoj Kumar, K S Gaiwal; and

Impact of NPV revision on cost benefit ratio under forest clearance process for opencast coal mine in Central Jharkhand authored by Manoj Kumar, Kumar Ranjeevand Meena Kumari.

Session V : Application of AI, ML, wireless communication in smart mining and digital oilfield

SessionChair : **Shri Bhola Singh,** CMD, NCL, Singarauli
Co-Chair : **Prof. S. Jayanthu,** NIT Rourkela

The presentations and discussions included the following six papers :

Application of Artificial Intelligence for prediction of mine hazards authored by Preity, M. Nadeem, J.K. Singh, S.K. Chaulya, G.M. Prasad, S.K. Mandal and G. Banerjee;

Digital oilfields : the challenges and prospects in India and abroad authored by Neeraj Kumar and G.P. Karmakar;

Wireless audio streaming system for underground mines authored by P.K. Mishra, Amit Swain;

AI/ML, digitization and smart mining authored by Nishant Singh, Krishan Aggarwal, Amitava Dutta and Satish Penmetsa;

Vision enhancement system for foggy weather in opencast mines authored by Swades Kumar Chaulya, Girendra Mohan Prasad, Monika Choudhary, Naresh Kumar, Virendra Kumar, Vikash Kumar and Abhishek Chowhury; and

Modernization of mines through digital transformation : NCL Perspective authored by Anindya Sinha and Shivraj Singh.

Session VI : Production and Utilization strategies of unconventional gases and clean fuels

Session Chair : **Dr. Anand Gupta,** Additional Director General (Development), DGH, New Delhi

Co-Chair : **Shri Sanjay Kumar Singh,** Director (Technical) P&P and OP, BCCL, Dhanbad

Rapporteur : **Shri Peeyush Kumar,** Chief Manager CIL/Former Director (Technical), Ministry of Coal, Government of India

The following five papers were presented in the sixth technical session :

Abandoned mine methane : Energy resource and climate mitigation potential in India authored by Ajay Kumar Singh;

Carbon dioxide (CO_2) and methane (CH_4) sorption in coal and its application in enhanced coalbed methane recovery (CO_2-ECBM) - A review authored by Jaywardhan Kumar, Vinod Atmaram Mendhe, Arun Kumar Samanta and Harendra Singh;

Study of gas generating potential of Permian shale of Raniganj coalfield, West Bengal authored by Bhaskar Bhattacharyya;

Indigenous gasification and methanol technology development program: a step towards AatmaNirbhar Bharat Abhiyan authored by R.K. Singh, P.D. Chavan, V. Chauhan, A. Sahu, N.D. Dhaigude, G. Sahu, S. Saha and S. Datta; and

Assessing fugitive methane emissions from an underground coal mine: A case study from Jharia coalfield, India authored by Debadutta Mohanty, Nilabjendu Ghosh, Debabrata Nayak and Swadeep Sagar.

All the speakers conducted very engaging and fruitful technical sessions.

Valedictory Session

The concluding session of the 9th Asian Mining Congress (AMC) commenced with the following Guests and Office Bearers on the Dias.

- Dr. S. Raju, Director General, GSI, Chief Guest
- Shri P.M. Prasad, President MGMI & CMD, CCL
- Shri Bhola Singh, Chairman, Exhibition (9th IME) & CMD, NCL
- Shri P.S. Mishra, Chairman, Conference (9th AMC) & CMD, SECL
- Dr. Amalendu Sinha, Chairman, Technical Committee (9th AMC) & Former Director CSIR-CIMFR
- Shri J.P. Goenka, Co-Chairman (Exhibition), MD, NMC
- Shri Prasanta Roy, Convenor (Exhibition) & HOD (Geology) CIL
- Shri Ranajit Talapatra, Honorary Secretary, MGMI & DGM (WS) CIL
- Shri Rajiw Lochan, Convenor (9th AMC) & Former GM (CED/CBM), CMPDI
- Shri I.P. Wadhwa, Managing Partner, Tafcon India Ltd

Shri R. Talapatra, Honorary Secretary, MGMI welcomed the Guests in the session and thanked the participants for taking active interest at the Congress. He specially thanked the foreign delegates. Dr. Amalendu Sinha briefed about the Congress and he said 52 technical papers including Keynote addresses were presented which would help in formulation of some guidelines for green mining. Yet, he admitted that full justice could not be done to the Speakers due to shortage of time and sought apology for the same. He thanked all the Speakers specially the eight Keynote Speakers and invitee Speakers. He presented in short the main points of the recommendations that immerged from the two days deliberations and interactions concerning creation of Mineral Development Strategy.

Shri I.P. Wadhwa talked about the IME, 2022 being held at Eco Park, Rajarhat, Kolkata, concurrently with 9th AMC. He said that there has been a very good encouragement response from the participants.

Dr. S. Raju, after thanking the organizers of the 9th AMC, said that the 9th AMC is a grand success considering the present scenario, participants in the Conference is really beyond expectations and exhibitors too. With increasing awareness Mining and associated steps are needed to be taken.

Shri Bhola Singh thanked the participants and specially thanked the organizations those who have been exhibited in the 9th IME to showcase their machineries etc. He also thanked the visitors of the exhibition stalls. He was very much hopeful that the coming IME would be having much more participation in the Exhibition.

Shri P.M. Prasad welcomed the Guests in the session and thanked the participants for taking active part in the Congress for two long days keeping behind their busy schedule. He also hoped that important and fruitful recommendations would come out from the Congress and expected that the deliberations have contributed a lot. He liked the IME and felt it would help the investors.

Shri Rajiw Lochan thanked the organizations those who supported financially by sponsoring the event to make it a grand success. He thanked the participants, delegates and the speakers of the different technical sessions and with special mention to the Keynote Speakers. He expressed his grateful thanks to the colleagues who have been helping him for last few months to give a good shape of the Congress.

The session and the 9th AMC came to an end with vote of thanks by the Honorary Secretary Shri Ranajit Talapatra. Thereafter Shri Talapatra, Honorary Secretary cordially invited all the participants, Guests and invitees to be present in the Cultural Programme followed by Dinner at the Rang Manch, Raj Kutir by Taj, Swabhumi, Kolkata.

Social Programmes

Congress Dinner

Venue : Local at The Royal Pavillion 1, Taj Taal Kutir Convention Centre, Eco Tourism Park, New Town, Kolkata on Monday, 4th April 2022, 7:00-10:00 pm.

Cultural Programme and Dinner

Venue : Rangmanch, Raajkutir by Taj, Swabhumi, Kolkata on Tuesday 5th April 2022, 7:00 - 10:00 pm Congress participants and guests were invited to attend the Cultural Programme followed by Congress Dinner hosted by MGMI. Approximately 300 participants and guests attended these sesocial programmes.

REPORT ON THE 17TH FOUNDATION DAY LECTURE

The 17th Foundation Day Lecture, one of the important annual events of The Mining, Geological & Metallurgical Institute of India (MGMI) was delivered by Prof. S. P. Banerjee, Past President, MGMI and Former Director (In-charge), IIT (ISM) Dhanbad on 25th June 2022 evening at The Imperial, Hotel Pride Plaza, Kolkata.

The event commenced with the Hony Secretary, MGMI welcoming the guests and members, thanking them for coming, and being present online on Facebook Live. It was formally inaugurated with the traditional lighting of lamps by past Presidents and dignitaries present.

Shri P.M. Prasad, President, MGMI, addressed the gathering online, as he could not be present in person due to pressing engagements. He welcomed the audience, profusely thanked them and expressed gratitude to Prof Banerjee for agreeing to deliver the lecture on a very interesting topic in spite of his other prior engagements.

Hony. Jt Secretary, MGMI introduced Prof. Banerjee highlighting his academic and professional achievements. Prof. Banerjee was felicitated with shawl and flower bouquet by Shri N.C. Jha, Past President, MGMI and with a shawl and copper plaque by Shri Arun Shukla, CMD, HCL.

As many as 59 members attended the lecture physically besides other guests along with 52 online viewers.

The topic of Prof Banerjee's talk was 'A discussion on the spectre of Mineral Resources Exhaustion, and the relevance of "The Limits to Growth" in the 50th year of its publication'. Professor initiated his speech with reference to the above best seller book, published in 1972, which was the outcome of a seminal study on long-term predicaments facing mankind due to population growth, resource depletion and environmental pollution. He explained the concept of Intergenerational Equity as that which meets the needs of the present without compromising the ability of future generations to meet their needs.

He then proceeded to discuss Sustainable Development (SD) in the context of the mining sector, which focuses on the rapid consumption of mineral resources. Consumption of non-renewable resources by any generation deprives the future generations of utilizing the same resource and thus, in a strict sense, violates the principle of sustainability. Therefore, the mining sector has come out with an alternative definition of SD. The Ecologically Sustainable Development Working Groups (ESDWG) formed by the Australian Government implies the definition of SD can be considered as the rate of exploitation of mineral resources not exceeding the capacity to find new mineral resources. The world mineral sector has more or less met this criterion for the last five decades and thus the predictions in 'Limits to Growth' have not come true. The flaws in the estimates were – the inability to foresee the slowing down of population growth rate, the failure to appreciate human ingenuity leading to a vast improvement in technology in all spheres of mineral exploration, extraction, beneficiation, utilization, and development of substitute materials for costly and scarce minerals. Technological improvements have permitted the discovery of many large mineral deposits and made economical extraction possible from previously inaccessible or uneconomic mineral deposits, thus vastly expanding the mineral resources base in the world.

Figures of growth of mineral consumption for 15 selected mineral commodities in the world between 1900 and 2019 show that consumption of 10 commodities (petroleum, natural gas, bauxite, copper, zinc, chromite, nickel, steel, cement, and rock phosphate) had a high CAGR of 3.0 or above between 1950 and 2000. Those with such a high rate of consumption growth (CAGR of 3.0 or above) between 2000 and 2019 were coal, bauxite, chromite, nickel, steel and cement and four further minerals (copper, silver, rock phosphate and natural gas) have CAGR between 2 and 3. Four more minerals (cobalt, lithium, graphite and rare earths) with exploding growth in recent years help the world achieve a Green Energy transition. Summing up, minerals of future concern are chromite, cobalt, copper, graphite, lithium, natural gas, nickel, rare earths, rock phosphate and silver.

The concept of Intergenerational Equity being outdated was discussed. According to some, it is an outdated concept, while others believe that we have some responsibility towards the future in the present. Many oil and gas-rich nations like Norway, Kuwait, Abu Dhabi, UAE, Qatar etc. have amassed great wealth from the sale of oil and gas but have realized that the non-renewable mineral resources will get exhausted with time. Instead of squandering the whole money for the benefit of current generation, they have created huge endowment funds for their own use in future or for the benefit of mankind at large.

Besides the spectre of the scarcity of some minerals, the unbridled use of fossil fuels has brought the world to the brink of a climate change disaster. The warnings of global warming due to rising GHG concentration in the atmosphere from increasing fossil fuel use have been voiced repeatedly by many scientists. The solution for a sustainable world would be there only when world citizens, especially from the developed countries, reduce their consumption of scarce resources and make a change in their lifestyles. The authors of The Limits to Growth were right in pointing out that the world must take steps to eliminate poverty in the developing world. The Report acknowledged that their world model may have some shortcomings but nevertheless the idea that trends in world population, industrialization, pollution, food production, and resource depletion must be changed to achieve sustainable growth on this planet is of relevance today, even after 50 years of publication of the Report.

After the discourse by Prof Banerjee, he held interactive discussions with the informed audience, after which, he was presented a memento as a token of appreciation by 2 past presidents of MGMI, Sri R P Ritolia and R K Saha.

The Hony Secretary concluded the event with the Vote of Thanks and invited all members and Guest to join the Cocktails and Dinner.

17th Foundation Day Lecture

The 17th Foundation Day Lecture, one of the important annual events of The Mining, Geological & Metallurgical Institute of India (MGMI) was delivered by Prof. S. P. Banerjee, Past President, MGMI and Former Director (In-charge), IIT (ISM) Dhanbad on 25th June 2022 evening at The Imperial, Hotel Pride Plaza, Kolkata.

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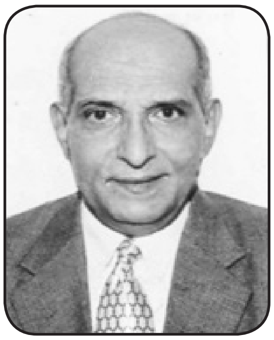
INTERVIEW

CHALLENGES OF COAL MINING

A conversation with Shri U Kumar



Mining coal is incredibly challenging that includes carbon emissions and climate change and there is a growing need to elicit views from leaders of coal mining industry. Our Honorary Editor, Dr. Ajay Kumar Singh interviewed Shri U. Kumar, who after graduating from the prestigious Indian School of Mines, Dhanbad in Mining Engineering in 1958, joined National Coal Development Corporation (NCDC) and rose to the rank of Dy. Chief Mining Engineer when NCDC was merged into Coal India Ltd. Moving forward and working as General Manager and Chief General Manager, he was appointed Director (Tech) in CMPDI and then CCL, where from he moved as CMD to NCL, Singrauli and then to SECL, Bilaspur. After his superannuation in 1997, he has worked for prestigious Mining Companies like Essel Mining and Industries Ltd., a constituent of one of the top business houses in India namely Aditya Birla Group which he served more than 16 years as Advisor (Coal). He is currently associated with Bajaj Hindustan and Sarda Energy and Minerals Ltd. He has served as Vice - Chairman, Standing Committee of Ministry of Coal under MMD and R Act for 6 years and Director, World Coal Institute, Member, Central Pollution Control Board, Government of India, President, Mining Geological and Metallurgical Institute of India (MGMI), President, All India Public Sector Sports Control Board and on Board of Governors, Indian Institute of Coal Management (IICM). He has received several awards like Indira Priyadarshini Vriksha Mitra Award, Government of India; D.D. Thacker Gold Medal from MGMI, Distinguished Alumnus Award from Indian School of Mines, and Engineer of the Year Award by Institution of Engineers. He has authored large number of papers on various aspects of Coal mining.

1. *Previous policy statements by the Ministry of Coal and Coal India Ltd. mention demand of 1.5 - 2 billion tonnes of coal by 2030-40. Do you think that has changed in recent years?*

When that (1.5-2 billion tonnes of coal production by 2030-40) projection was made, it was anticipated that the growth of the Indian economy would be at a rate of 9 to 10%. But that did not materialise and since then, the rate of economic growth has slowed down. The main reason being the Pandemic. Naturally, the anticipated growth in power sector has also not materialized. The major share of demand for Indian coal comes from the power sector – unfortunately, however even this demand which has been lower than anticipated has not been met by domestic production. Efforts are being made by the Indian Coal Industry as well as the Government for achieving the required increase in coal production rate so that the country's requirement for at least power grade coal is met in full. But I am very doubtful whether it will reach 2 billion tonnes even by 2040. Probably it (coal production) may reach close to 1.4 billion tonnes by 2040.

2. *In your opinion, what have the limitations been for India for effective coal production increase to reach the billion tonne target?*

The immediately visible reasons are the delays in the approvals. But the major impediment has been the land acquisition and rehabilitation and resettlement. India is a very densely populated country, and unfortunately, the coal bearing areas are also thickly populated. A large number of people are living in these areas. Moreover, expectations and aspirations of the people residing in coal bearing areas like in other parts of the country are rising continuously but coal sector, by itself is not in a position to meet all of them. Employment opportunities in this sector, like in other sectors of the country's economy are limited and the sky-high ambition in respect of R&R simply is impossible to meet. Though, the coal sector generally has been very generous in providing employment as well as R&R facilities, we Indians have deep emotional attachment to the land in which they have inherited from generation to generation and this land has been the sheet anchor of their existence and the very thought of the current as well as future generations living without land causes them great unease and net result is that they find it very difficult to part with their land.

I was associated with a very famous and ambitious project viz. "Rajmahal" project. I had the privilege of starting it, way back in the 1980's. Rajmahal has achieved a production level of 17 million tonnes per annum and even in the recent past they had achieved this target or nearly achieved it year on year. But today, it is producing just about 1 million tonnes per annum because the land is just not available. The villagers are not prepared to move out from their habitat despite all the facilities offered to them.

Though not as extreme as in case of Rajmahal, the situation in respect of land is generally difficult all over Jharkhand and West Bengal. In my opinion, the land constraints will be the main hurdle in achieving quantum growth in coal production.
The difficulties associated with the permissions and the approvals can be taken care of by tightening the administrative system, but the problems associated with land acquisition are likely to become more difficult as time passes.

3. Do you see climate change constraints (such as the coal cess or GST Compensation Cess) as becoming a limitation to Coal India Limited's revenue at some point?

I really don't see that the Rs.400/tonne of coal cess will have much of an impact. It has been existing now for several years, but it has not had any impact on coal demand. I agree that it is little unfair to domestic coal because the calorific value of our domestic coal is low and if the impact of this cess is assessed on the basis of calorific value, it (coal cess) becomes very high on domestic coal as compared to the imported coal. Fortunately, our domestic coal is so cheap compared to imported coal that in normal circumstances imported coal cannot substitute domestic coal except in certain circumstances like coast-based power stations which are designed for superior grade coal and imported coal of this variety becomes cheaper at these power stations on account of high rail freight for these grades of coal which is available in ECL.

4. What are the key challenges to solar and wind energy, from the perspective of generation and transmission issues?

I think this question would be best answered by Power Sector People. But as far as I understand frequency maintenance and acceptance of the renewables-based power in the grid are going to be some of the technical issues which would be encountered. There are very brilliant people working on these issues and hopefully we will find a solution.

5. Recently, the government opened up commercial coal mining to the private sector. Do you see a major impact on coal productivity and/or sustainability – either positive or negative?

I think, it is a positive development. Indian coal sector has been the least reformed among all the sectors of Indian economy and we have not made many technological advances even after Nationalisation of Coal Mines which happened way back in 1971-73. The basket loading component of the old underground mining technology has, no doubt, been upgraded to intermediate level technology such as Side Discharge Loaders (SDL's)/Load Haul Dumpers (LHD's) etc., use of Continuous Miners and Longwall technology are still in learning stage and we have to go far before we reach any respectable level of efficiency thereon. Hopefully, Commercial Coal Mining will bring the necessary change since the Commercial Miners who are in the private sector will not have the constraints that Coal India limited (CIL), being a government organization, is saddled with even for introduction of new technologies which have the promise of changing the face of Indian Coal Industry.

Even for introducing new technologies, Coal India has to grow through competitive bidding route and then it has to accept the L1 Bid (Lowest Cost Bid) and they have no choice, even if they know that this bid is unworkable. The argument Vigilance/ CBI/CAG advances is that if it is unworkable, it is L1 bidder will suffer the consequences but they don't realize that the Coal Company suffers bigger losses for the simple reason that anticipated production is not achieved. It is unfortunate that they are not prepared to change their attitude irrespective of heavy financial losses that Coal Companies have suffered on account of assignments being given against unworkable L1 bids.

It is high time that fundamental changes are made in the mindset of these Agencies.

It takes a lot of time and entails lot of cost before we learn from our failures but even such costly learning is not enough to change the mindset of these Agencies and CIL's hands are so tied that they cannot make a departure from the established norms. But hopefully, the private sector will not have that sort of compulsion and they will be able to increase the level of mechanisation and the level of technological developments which would help to increase productivity. CIL is often blamed for low productivity as compared to all other countries. However, we have made good advances in case of opencast mining where we have made commendable progress and we have almost reached the international standards. It is Underground Mining where the performance has been dismal. We need to improve it by large margins and hopefully the commercial miners would bring that improvement.

6. Is biomass blending with coal something that the Indian power sector should look at strongly?

I definitely feel so, although biomass blending may be a little costlier by 5-10% compared to 100% coal. But use of biomass doesn't have to be looked at in isolation as it has nationwide repercussion and nationwide implications. It could add a little income to the farmers who are in the current set-up, probably the most neglected people. Leave aside the recent farmers agitation it has got admitted that the farmers get very little value for their produce. For example, if the consumer purchases an item for say, Rs. 10, the poor farmer gets only around Rs. 1. So, this initiative (biomass blending) will add a little to the farmers' income and they will also be spared the expenses that they have to incur on disposal of the agricultural waste. Also, the waste utilisation will improve because after all the waste has to be disposed of and instead of disposing it off for no value, the Nation can utilise it and get something positive out of it. So, even though it will increase the power cost a little, it will be worth its while from the national perspective and from the farmers' perspective. We are all aware of the heavy pollution load that Delhi suffers for 3-4 months in a year and it is attributed mostly to stubble burning in Punjab. By resorting to biomass blending with coal, this pollution problem can definitely be taken care of.

7. Nowadays, Hydrogen is getting a lot of importance because it is carbon free. Could you talk about the scope of diversification or Indian power companies into sectors such as green Hydrogen?

I agree that Hydrogen is the fuel for the future. Power sector has a natural role in producing Hydrogen in as much as whenever a situation arises wherein power from renewables is not needed, it can be utilized for producing Green Hydrogen.

In so far as coal-based power stations are concerned, admittedly their PLF has been going down with greater emphasis on renewables but these power stations can survive only if the PLF is maintained at a certain level say about 60% and not allowed to go lower. If a situation arises where there is a danger of PLF not being maintained at this lowest permissible level the power station can continue to run with the power being utilized for producing Grey Hydrogen. This will avert the possibility of coal - based power station becoming unviable.

8. What are the key policy reforms that you would wish to see in the Indian coal mining industry?

The structure of the industry (coal mining industry) is already undergoing changes. The regulatory regime has proved to be effective so far. But it will have to be strengthened with the advent of commercial mining. Earlier, practically entire coal came from government owned companies and hence the regulatory agencies did not have much of a role, but now with the private sector coming in a big way, these agencies like DGMS (Directorate General of Mines Safety), Coal Controller and all the regulatory bodies will have to be strengthened. Probably, a Coal Regulator will become a necessity.

Though the commercial miners have been given the freedom to fix their coal price, but it cannot be total freedom in the economic setup that we have. So, some sort of regulation will be required, maybe, not for fixing the prices but for moderating the price.

Also, there is a lot of scope for technological improvements that will have to be brought in because, as the Land Acquisition becomes more difficult, instead of expanding horizontally, we would have to expand vertically and work deeper seams. We have been confining ourselves to a depth of about 300 metres in opencast mining. In future, it appears natural that we have to go for large-scale underground mining but before a decision in this respect is taken, the matter will have to be considered in all its dimensions- particularly the total quantity of extractable coal from open cast mining. Country's total requirement of coal and number of years for which coal is likely to remain relevant in the country considering the global call for coal being totally phased down. It will also have to examine whether the limited capacity of underground mines in the country dictated by geological conditions will produce substantial quantity of coal to replace open cast coal. Another issue will be the land degradation caused by opencast mining and whether the land reclamation and restoration can be done economically to take care of this problem.

Safety issues involved in underground mining will also have to be taken into account.

9. Are there any key bottlenecks on the coal utilisation side either power or industry that could be sorted through technology or policy levers?

Leave aside the requirement of coking coal, we are right now not even able to meet our requirement of coal for the power sector. Our highest priority, therefore, is to augment our coal production so that the country becomes self-sufficient at least in respect of non-coking coal.

We have also to take into account the hard fact that life of coal as a fuel is limited and the global campaign would lead to coal being phased down sooner or later. But then, coal is a very versatile commodity and it consists of constituents which can be utilized for producing products more valuable than power.

We are using coal mainly as a fuel for the power sector. Taking its different constituents into account, it could be used as feedstock to produce various useful products such as chemicals, fertilisers. We have already made a start and while a coal-based fertilizer plant is coming up at Talcher, another ambitious plant for producing methanol is already under construction at Dankuni.

In fact, the country's commitment in this respect can be seen from the fact that Coal India Ltd. has already planned investment of Rs. 30,000 crores on projects for producing various valuable products like Coal to Oil.

10. How much is the welfare of the employees, workers and their families at the core of India's coal industry?

The total outgo on the welfare measures is about 40% of the coal production cost (which is a very sizable amount). During my initial days of training, the miners used to sleep in multiple shifts in rooms which were eight feet by six feet. Now people have got houses, people have got hospitals, people have got healthcare and a lot of other facilities are now being made available. So, worker welfare is a very major sector of activity of the coal industry, and this is the right thing to do because after all, it is the workers who deliver the results and unless their morale is kept very high, success for the coal industry will not be possible. Future will bring new challenges and these can be overcome only with whole hearted commitment of the work force and their well-being therefore has to occupy the highest priority in coal sector.

11. *A few years back, we had a policy regarding coal washing. But recently, the government has removed the regulations regarding coal washing and has removed the restrictions on the transport of high ash coal over long distances. So, what were the challenges and bottlenecks that prompted the government to stop such an important and useful process?*

It's a very important question and I completely agree that the stopping of coal washing is a very retrograde (backward looking) step. Initially, transportation of unwashed coal was allowed up to 1000 kilometres distance from coal mine to power stations, then we reduced it to 750 kilometres and then to 500 kilometres and we were proceeding in the right direction in trying to make all the power stations to use only washed coal. As the Indian coal is dirtiest across the world and the phenomenal growth in coal consumption for power sector has created conditions that the quality of coal deposit that we work becomes dirtier day by day. Higher level of mechanisation involving bigger excavators up to 40 cubic meters bucket capacity has made it impossible for stones and extraneous matters being picked out from coal.

Washing is the only way that the coal quality can be improved and the trials in 1986 at Satpura Power Stations of MPEB with coal from Nandan Washery had clearly established the economic advantage of coal washing on multiple fronts. In fact, this study even established that washed coal even in Pit-Head Power Stations would be economically viable.

With atmospheric pollution inviting greater scrutiny day by day, the time is not far off when we ourselves will not accept heavy pollution that combustion of dirty coal for power generation causes.

While admittedly, the withdrawal of the mandate providing for use of washed coal in power stations is a retrograde step, we have also to do some introspection to find out the extent of the responsibility of washery operators behind this unfortunate decision.

What happened was that some washery operators did not play fair with the result that whatever was expected to be achieved from coal washing was not forthcoming. And when the coal producers as well as coal consumers saw that the results were not forthcoming, they felt that coal washing could well be dispensed with. I still feel that this matter should be visited afresh. The solution lies in correcting the wrong doing by certain washery operators and certainly not by punishing the entire power sector as well as the Nation by loading it with avoidable pollution. As they say it will be a wrong "to throw the baby with bath water"

If the system was faulty, it deserved to be corrected. Just because the system was faulty, we cannot give up the concept. But I do hope that going forward, the consumers themselves will ask for washing of coal to be carried out.

There was a difference of opinion when Coal India Limited (CIL) said that our job is to produce coal and if they (consumers) want to have cleaner coal, then they need to clean it themselves. But the consumers said that as CIL supplies coal from different sources and it was difficult to take care of the differing characteristics of coal from multiple sources and ensure that the washing technology would fit the mix of coal from different sources. I think that coal producers like producers in any sector of economy must take the responsibility to clean the coal and ensure that consumers will be supplied with clean coal so that the problems that they are facing right now could be addressed to a large extent. The carbon space is very limited.

Of course, we (India) are not consuming as much carbon space as we are entitled to. But we must aim to further reduce our carbon space utilisation and coal washing would definitely be one of the steps in ensuring the same.

12. *The coal quality/grade available in India is one of the worst in the world when we compare to other imported coal varieties available. With the recent talks about coal phasedown and as India has a lot of coal reserves available, is there a possibility that we (India) could export coal to other developing or neighbouring countries as fuel or as electricity?*

Coal can definitely be exported in the form of electricity. It can also be exported in the form of fuel, provided we meet our own requirements first. But we must wash the coal (to improve its quality) before we export it. We can definitely export our washed coal to neighbouring countries like Sri Lanka, Nepal, Bangladesh. Even Pakistan would definitely be interested. But it would be not be fair on our part that we ask our neighbours to consume the high ash coal that we produce (more than 40-45% ash content).

13. *The CCS/CCUS technologies and the CBM technologies have been talked about recently and there have been some pilot projects that are going on. So, is there a probability of that scaling up in India or it depends on the state and the central government and/or the consumers and users themselves?*

CBM (Coal bed Methane) is a very welcome proposal. But people who have surveyed are of the opinion that our CBM prospects are not very good. Our coal seams do not contain that much of adsorbed gas, as would be economical to harness. But experiments and projects are going on in the Eastern and the South Eastern Coalfields and we must wait for the results. If the results are promising, more efforts will be taken for the development of the CBM technology.

CCS/CCUS is a very important technology. But with the existing set up that we have in our power stations it is very difficult to capture the carbon dioxide or implement the CCUS technologies. The set up will have to be modified to make the capture of carbon dioxide (CO_2) easier. We will also have to look at potential usage (utilisation) of the captured CO_2. But for reducing the carbon footprint, capture of CO_2 is very important. Some projects were carried out in the USA, but unfortunately those did not proceed ahead and they were given up. Only some laboratory scale experiments are going on currently and we have not progressed so far. Hence, we need the CCS/CCUS technologies to develop further in order to utilise them effectively at our existing power plants. I personally feel that India being one of the largest consumers of coal it has a responsibility of its own in respect of CCS/CCUS. I would therefore appeal that CIL together with NTPC and BHEL should take up R&D projects for capturing Carbon-Dioxide for utilizing it for manufacturing valuable products.

14. *Recently, there have been talks regarding development of a methanol economy and Coal India limited and other companies are also trying to get involved in this. Is that (coal-to-methanol) something that you see as getting developed in the coming future?*

Coal India Limited has already launched a project and they are going to spend around 10,000 crores in their coal gasification plant at Dankuni. The concept appears to be very good and attractive. Methanol is a very useful chemical and it can reduce our burden of oil imports to a large extent. Let's hope that the project succeeds and it should prove to be economical.

15. *Do you think there are some discussions already taking place regarding coal phasedown or do you think that coal is here to stay for the next 20-30 years in India?*

Looking at the situation in which our country is in right now or the type of resources that we have, we cannot wish away coal. But having said that, we have to make coal utilisation and even coal mining cleaner and greener to the extent possible. If we just want to rely on power from renewables, the investment and land requirement would be so high that the country would not be able to afford it. Further, irrespective of how much we generated from renewables, coal-based power will still be required for meeting the base load requirement. Hence the dependence on coal will continue till an economic solution for the problem of storing power can be developed. Nuclear power will make more contributions but that will change things only marginally. So, we will have to depend on coal till the storage technology for Renewables evolves and becomes economical. Only after that can we think about the phase down of coal. At least till 2040, the quantum (total quantity) of coal consumed for power generation will continue to increase. However, its percentage contribution will decrease from say, around 60% to around 46-52%.

16. Nuclear may be a replacement for coal for baseload operations. Among nuclear, hydro or natural gas, which option do you think will come up in a big way?

Nuclear Power, except for the fear regarding its safety vulnerability, is obviously the best option subject of course, to proper location of the Nuclear Plants, intensive training to persons employed there and the highest level of precautions that science has come out with so far.

PERSPECTIVE PIECE

KEY CHARACTERISTICS OF NET-ZERO ENERGY SYSTEMS

Leon Clarke

HIGHLIGHTS :

- Net-zero energy systems will be very different than those of today with minimal and targeted use of fossil fuels, widespread electrification of end uses, and use of energy much more efficiently. They will also require alternative fuels in sectors not as amenable to electrification.
- Carbon dioxide removal will likely be critical to achieving economy-wide net-zero emissions. There are multiple technological and nature-based options, each with its own tradeoffs.
- The implications of deep decarbonization on fossil fuels depend on the fuel and the broader mitigation strategy.
- Net-zero will have critical implications for international trade in fossil fuels, electricity, biomass, energy carriers, food, and critical materials.

Thank you very much for the opportunity to speak at the 9th Asian Mining Congress - it's a real pleasure and honor to be able to speak. I have been asked to talk about net-zero energy systems, what they might look like and what the implications might be with respect to fossil fuels and energy in general. I'll note that that I was recently involved in the Intergovernmental Panel on Climate Change (IPCC) Sixth Assessment Report. That concluded after a long discussion with a wide range of delegates from a range of countries including, of course, India. So, for today, since I'm going to be talking about net zero energy systems, I'll have to use a lot of charts that are not about today's energy system because we don't have net zero energy systems today. As such, we are talking about something in the future and this is relevant in the context of many countries. It is relevant in the context of India after Prime Minister Modi announced a 2070 net-zero goal for India. I will talk in general around about net-zero across the world but I think the implications hopefully will be useful for the thinking of this group as well.

Let me just first make some comments about what a net-zero energy system might look like and what are the key characteristics. One of the most important characteristics is minimal, and targeted, use of fossil fuels. I think that's obviously quite relevant here at the 9th Asian Mining Congress. The second is that we will see very little CO_2 coming out of the electricity systems. I will talk a little bit about what that means but that certainly means more use of solar power, wind power and potentially nuclear power. But it also entails coal or natural gas coupled with carbon dioxide capture and storage. We are expecting to see much more use of electricity

[1]*Keynote lecture delivered at the 9th Asian Mining Congress by Dr. Leon Clarke on 4th April 2022. Dr. Clarke is currently the Director of Decarbonization Pathways at the Bezos Earth Fund. He has served as a Coordinating Lead Author for both the IPCC's Fifth and Sixth Assessment Reports.*

across energy systems, and that can be coupled with increased energy access for those who do not actually have access to reliable electricity today. It also means substituting for fossil fuels wherever possible - so for example in light duty transport using electric vehicles. So, we expect to see alternative fuels in sectors that are not amenable to electrification. Net-zero energy systems would involve efficient use of energy and greater reliance on integrated energy system approaches. Lastly, I want to note the use of carbon dioxide removal technology.

I would like to first discuss the last point that I mentioned i.e., carbon dioxide removal. When we are trying to envision a net-zero energy system or meeting net-zero, it means that overall CO_2 emissions must be zero. For that to occur, either all of the emissions from the energy system need to go to zero or there have to be other mechanisms that can actually pull CO_2 emissions from the atmosphere. That is called carbon dioxide removal. There are several different modes for doing carbon dioxide removal. One is growing more forests to sequester CO_2. There are also mechanisms for enhanced agriculture where we store more carbon in the soil. In other methods, we may grow biomass and then we use the biomass for electricity, capturing the CO_2 and then putting the CO_2 underground. This is similar to enhanced oil recovery today but potentially not putting CO_2 just in oil wells but in deep saline aquifers. Then there are other mechanisms for capturing CO_2 from the atmosphere and then again putting in underground, for example, direct air capture of CO_2. These methods are expensive today, but rapid investments are occurring in the government and private sectors. The key point here that I just want to emphasize is if CO_2 emissions from fossil fuels do not go to zero, then there have to be mechanisms to remove CO_2 from the atmosphere to make up for any existing fossil emissions.

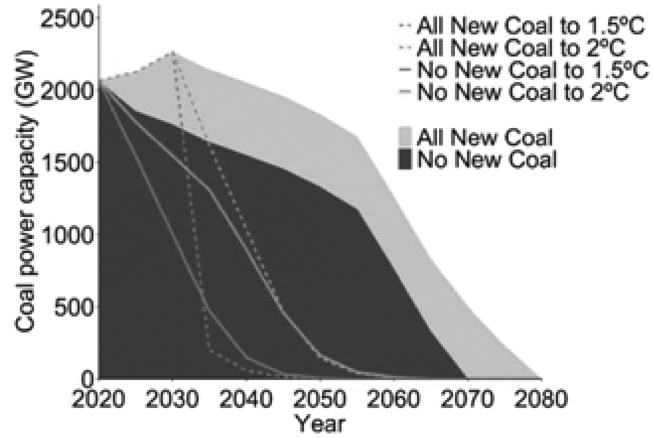


Figure 1. Comparison of coal capacity pathways for no new coal and all new coal scenarios under 1.5 and 2°C goals (lines) or if plants live out their historical average lifetimes (shaded regions). Source: Edwards et al (2022). Figure reproduced under the Creative Commons Attribution 4.0 license.

This raises the question of the role of fossil fuels in future net-zero energy system. A key insight that emerges from the literature on net-zero energy systems is that moving towards 1.5°C or 2°C has the potential to strand assets. Coal assets are most vulnerable. The specifics depend on the timing of net-zero. Figure 1 shows global coal capacity in 1.5°C and 2°C scenarios. An important observation is that CO_2 emissions from coal fired power plants need to rapidly go down to zero in a net-zero energy system. Of course, the timing for reducing emissions from coal-fired power plants depends on the timing of net zero. This chart is focused on a global timing of reaching net-zero by 2050. This is different than the Indian timing of 2070, which actually gives a little bit more headroom.But the point of this chart is still very clear: as we get towards net-zero, coal emissions from electric power plants are expected to be zero or near-zero.The question is how will that happen. There are two mechanisms for reducing coal emissions in the power sector. One of those is to deploy carbon dioxide capture and storage. This implies capturing CO_2 from burning of coal or natural gas, and then storing the captured CO_2 in geologic reservoirs permanently. Carbon capture has an important influence on how much coal could be viable in future net-zero energy systems. Systems that have a large amount of carbon dioxide capture and store storage can allow for coal power to continue at a modest level, even as you reach a net-zero economy. Because it is difficult to capture 100% of the CO_2 emissions from power plants, the use of carbon dioxide capture and storage will not eliminate electricity CO_2 emissions.

The second option is, of course, to use other energy sources to supply electricity. Figure 2 shows results looking across a wide range of different scenarios at what energy systems might look like when they are at net-zero. We will need to replace emitting fossil fuels with a number of options, including renewable power (wind, solar, hydropower, geothermal). These renewable sources all can be used to produce energy whether it's electricity or fuels for sustainable aviation. But few studies envision that all energy in a net-zero economy will be supplied by renewable power. Many studies show that there will continue to be some energy that is produced from non-renewable sources, for example, from fossil energy with carbon dioxide capture and storage or nuclear energy. As noted above, even with carbon dioxide capture and storage, there will still be some emissions from using fossil power, which would need to be offset with carbon dioxide removal.

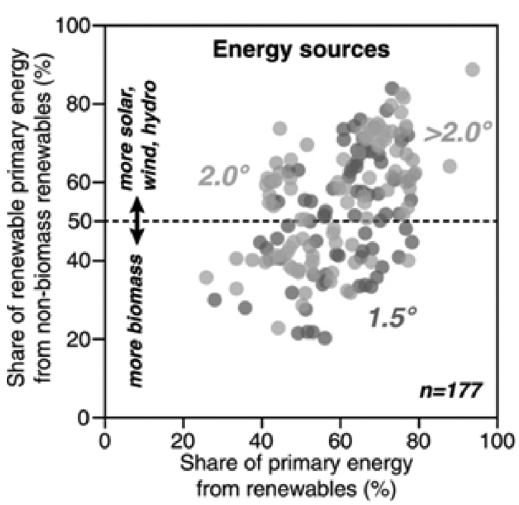


Figure 2. Scenarios that reach net-zero emissions show differences in energy sources particularly with respect to warming levels (blue = <1.5 °C, green = <2.0 °C, orange = >2.0 °C). Source: DeAngelo et al (2021). Figure reproduced under the Creative Commons Attribution 4.0 license.

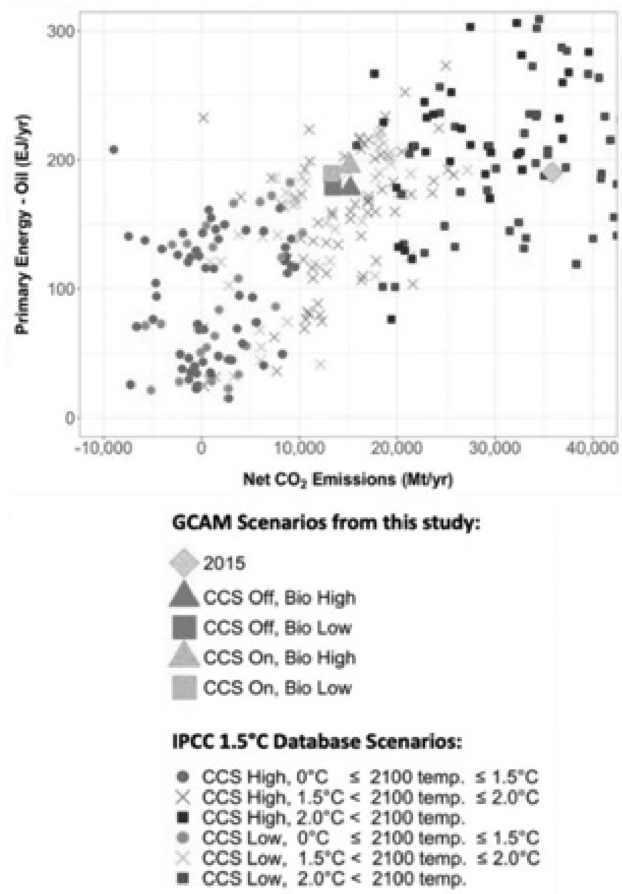


Figure 3. Global oil primary energy versus global CO_2 emissions in 2050 for scenarios in the database associated with the IPCC Special Report on 1.5 °C. Source: McJeon et al (2021). Figure reproduced under the Creative Commons Attribution 4.0 license.

I think one of the important things to note is that coal has a substantially higher carbon intensity than oil and gas. It is also used in different circumstances. As such, the literature has a very different impressions of the role of oil and gas typically than what we see for coal. In Figure 3, we see the horizontal axis shows net emissions and vertical axis shows oil consumption. The reason oil would still be used in a net-zero economy is because it could still be advantageous for long-distance transport and aviation, and for other applications that are very difficult to replace with electricity.

The green dot shows the current energy supply. The reduction in oil use may be very dramatic or not that dramatic, and this depends crucially on how much we might be relying upon carbon dioxide removal to offset remaining fossil fuel emissions

Thus, there is general consensus looking across all the scenarios is that when you're getting down to net-zero, you will use substantially less fossil fuel from them today. In particular, the expectation is that there will be almost no use of coal with out carbon dioxide capture and storage. There may still be some oil and gas. Oil - in particular - might be used in applications that are not amenable to using electricity.

There are a couple of other points I want to make. One is that one of the big questions is how you actually supply end users with energy if we are not going to be using for example as much oil in light duty transporting cars and trucks. In general, what you see from analysis is that net-zero energy systems will use substantially more electricity than we do currently. We are already seeing this in light duty vehicles where we see a rapid expansion in battery electric cars. We can imagine that they may dominate light duty transport in 20-30 years, or may be before. For heating, we can use heat pumps, and there are also ways to use electricity for high temperature heat. And we can imagine going to electric arc furnaces for steel as much as possible to be moving away from other methods. So, the idea is that electricity will be used more broadly. But, of course, you cannot use electricity for everything. Thus, most analyses find that we will continue to use some fossil fuels for particular applications or move to alternative fuels like hydrogen, advanced biofuels, and ammonia to supply energy for sectors that are not amenable to electricity.

One final point is that moving to net-zero emissions of CO_2, will have important implications for international trade. Fossil fuel trade will be very different than today. We will need more integration of electricity systems and, possibly, larger trade in bioenergy. Some scenarios suggest substantial trade even in hydrogen and ammonia. Also note that if we begin to grow more bioenergy and at the same time if we are trying to reforest long-term, it could add pressures on food systems and then it would be important to re-envision food trade. Today, energy trade is very much about fossil fuels, but it is also increasingly now becoming about materials to produce batteries and solar cells. Which countries are taking leadership on critical materials? Which countries are taking leadership on electric vehicle batteries? Those are all going to become critical questions if we are to reachnet-zero.

My goal in this talk has been to give a sense of what a net-zero economy might look like, with a focus on the role of fossil fuels. Moving to a net-zero energy system likely means removing carbon from the atmosphere. It entails substantially less use of fossil fuels than today; it could mean using carbon dioxide capture and storage in some instances with fossil fuels. It would require a large expansion of renewable energy sources, and it would require alternative energy carriers, increasing electrification, and changes in international trade patterns.

References and suggested readings

Clarke, L., Wei, Y. M., de la Vega Navarro, A., Garg, A., Hahmann, A. N., Khennas, S., ... & Veldstra, J. (2022). Energy Systems. In Climate Change 2022: Mitigation of Climate Change. Working Group III Contribution to the IPCC Sixth Assessment Report. Cambridge University Press.

De Angelo, J., Azevedo, I., Bistline, J., Clarke, L., Luderer, G., Byers, E., & Davis, S. J. (2021). Energy systems in scenarios at net-zero CO_2 emissions. Nature communications, 12(1), 1-10.

Edwards, M. R., Cui, R., Bindl, M., Hultman, N., Mathur, K., McJeon, H., ... & Zhao, A. (2022). Quantifying the regional stranded asset risks from new coal plants under 1.5° C. Environmental Research Letters, 17(2), 024029.

McJeon, H., Mignone, B. K., O'Rourke, P., Horowitz, R., Kheshgi, H. S., Clarke, L., ... & Edmonds, J. (2021). Fossil energy deployment through midcentury consistent with 2° C climate stabilization. Energy and Climate Change, 2, 100034.

TECHNICAL NOTE

LINKAGES BETWEEN ENERGY AND HUMAN DEVELOPMENT INDEX: INSIGHTS AND PRELIMINARY TRENDS

Udayan Singh[1] , Amit Garg[2]

Introduction

The most recent report of the Inter governmental Panel on Climate Change provides an important focus on the synergies and trade offs of decarbonizing energy systems with achieving key societal priorities such as human health and reduced poverty (Clarke et al, 2022). A key observation in the report that improved energy access and electrification provide improvements in societal priorities, as measured by the human development index (HDI). The HDI is a widely used indicator suggested by the United Nations Development Programme, which is a composite metric considering the per capita income, literacy rate (education) and life expectancy (health). Currently, India has an HDI of 0.645, which corresponds to medium level of human development. It is targeted to increase India's HDI to high levels (0.7-0.79) and ultimately, to very high level (0.8 and above). Some projections indicate that this may happen through the next two decades (Rami, 2021). As such, it is imperative to understand the implications of increases in HDI, both historical and projected, on energy and electricity consumption.

There has been a substantial amount of work linking energy consumption with HDI. Initial work by UNDP showed that very high levels of HDI were achievable with an annual per-capita energy investment of 100 GJ in 1975, which reduced to 60 GJ in 2005 and further to 50 GJ in 2012. Clarke et al (2022) used updated data to show that this threshold has fallen to 40 GJ in 2019, with multiple countries achieving very high HDI at even lower energy investments. Based on historical observations, it is also seen that different priorities become influential at different levels of development. For instance, when the HDI of a country is below 0.5 or the so-called "elastic" region, human development is more strongly coupled with education and health. On the other hand, HDI in very developed economies is largely correlated with increases in per-capita incomes (Reddy, 1999). More recent work by Zahid et al (2021) has pointed to the need for increased penetrations of renewable energy to hasten the increase of HDI at similar levels of energy consumption. This can be observed because of direct linkages of low-carbon energy with healthcare (Dholakia, 2018) and education (Mehmood, 2021). Thus, more recent work has also begun to incorporate linkages between HDI and greenhouse gas emissions, in addition to per-capita energy consumption.

Several analyses have been carried out by using analytical formulations (discussed below). However, nearly all such analyses consider national HDIs. Given wide levels of differences in development in India, it is prudent to carry out a similar analysis across different states. For instance, the IEA World Energy Outlook shows that per-capita final energy consumption in Bihar is less than 10 GJ/year, while it exceeds 45 GJ/year in Gujarat (IEA, 2021). Another reason to evolve these analyses is because they have largely used per-capita energy consumption. However, the IPCC also points to electrification as a key parameter here,

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which should also be accounted for. Many Indian states have been able to achieve high levels of HDI (0.7 and above) at much lower levels of energy of 10-15 GJ per capita annually (Rao et al, 2019). This is because of robust investments in healthcare and education across states. Finally, as several Indian states move to high and very high levels of HDI, key priorities are also changing. Thus, it is critical to evaluate the variable (income, education, or health) which leads to the highest "bang per buck", i.e., most optimal growth in human development at the lowest energy inputs. This analysis aims to address some of these research gaps and help project future per-capita energy consumption to help inform other work packages.

Methods

Data sources

The key data sources in this study correspond to energy and human development metrices. For the former, we used a combination of different Government of India sources. First, the final energy consumption in India is largely composed of electricity, coal (for non-electricity purposes such as steel making), oil and natural gas. Some states – particularly with large agricultural sectors – rely upon traditional biomass for meeting rural energy requirements (Srinivasan et al, 2018; Gupta et al, 2019). Most of the consumption of renewables is for electricity generation. The data for electricity generation for each state is available in several reports of the Central Electricity Authority, which was compiled by the India Stat database (2020). Data for oil and gas consumption per state is obtained from the reports of the Petroleum Planning & Analysis Cell of the Ministry of Petroleum and Natural Gas (PPAC, 2022). It may be noted that the petroleum consumption data is presented in these reports in terms of the mass of total petroleum products consumed. This is converted to energy values by assuming a crude oil heating value of 42 MJ/kg. Data for traditional biomass consumption is obtained from Yawale et al (2021). An important consideration here is the completeness of the energy availability data. As mentioned earlier, the key fuels in the final energy mix are coal, oil, gas, traditional biomass and renewables. About 89% of the domestic coal consumption is for electricity generation purposes, and as such, directly incorporated in our analysis (NITI Aayog, 2022). Industrial coal consumption may not directly affect the standard of living in the state where such facilities are located. Data for oil and gas are considered in completeness. Also, most non-biomass renewable energy is also incorporated into the analysis as it is consumed via electricity. The dataset for traditional biomass consumption is not yet incorporated into the results below. As such, we have underestimated the energy consumption by 20-25%.

The data for human development indicators are obtained via the Global Data Lab's Human Development Indices v5.0. This dataset provides the human development index for all states and union territories, in addition to individual indices: health index (HI), education index (EI) and income index (II). Moreover, the actual data values for the life expectancy, school enrolment and per-capita income on a purchasing power parity (PPP) basis. The Global Data Lab dataset has been by others to further improve the granularity of the data (Smits and Permanyer, 2019).

Table 1. Data availability for key variables

Data	Years available
Electricity generation	1997-2019
Petroleum and natural gas consumption	2009-2021
Traditional biomass consumption	2004, 2009, 2011, (2019 calculated)
Subnational human development indicators	2002-2019
Population	2001, 2011, 2019

Table 1 shows the years for which the sources provided the data. We made an extrapolation for traditional biomass – for which reporting by Yawale et al (2021) only extended up until 2011. In order to obtain 2019 projections, we applied national growth rate in traditional biomass consumption, as projected by Ekholm et al (2010). Moreover, the energy consumption data need to be divided by state population to obtain per-capita estimates. The Census of India provides decadal data off late, estimates have been published by the Unique Identification Authority of India (UIDAI, 2022). By considering this data availability, we carried out our baseline calculations for the years 2011 and 2019. Analyses for other years, where presented, have been calculated using interpolation for missing variables.

Analytical approach

A number of different formulations have been suggested in the literature for understanding energy-HDI linkage. As the shape of the energy-HDI graph is intuitively logarithmic, Pasternak (2001) used a semi-logarithmic fit, as shown below:

$$HD=A+B \cdot log\ (EC)$$

Here, HD is the human development index and EC is the per-capita energy consumption. A and B are the coefficients of regression obtained from the observed data. While this formulation was useful in constructing a 'trendline', it did not offer acceptable goodness of fit for the regression. As such, Preston (2007) used a logistic form, as shown below :

$$HD = \frac{HD_{SAT}}{1 + e^A \cdot EC^B} \Leftrightarrow \log\left(\frac{HD_{SAT}}{HD} - 1\right) = A + B\log(EC)$$

Here, the HDSAT value corresponds to the saturation value of HDI. The coefficients calculated here offered an appreciable goodness of fit at higher HDIs. However, the error observed at lower HDIs (especially below 0.6) was higher. This makes the particular formulation unsuitable for historical analysis in the Indian context. In order to reduce this error, Martinez and Ebenhack (2008) suggested the following formulation:

$$HD = A + B\log(EC) + \mathrm{C} \cdot \left\{\log(EC) - \overline{\log(EC)}\right\}^2$$

While this formulation offered a good quality of fit, the complicated form with two coefficients and one intercept prohibited estimation of threshold function. In other words, this format could help predict the HDI at a given energy consumption. However, it could not estimate the threshold energy consumption required to reach a particular level of HDI.

The most widely used formulation has been proposed by Steinberger and Roberts (2010), as shown under :

$$HD = HD_{SAT} - e^A \cdot EC^B \Leftrightarrow \log(HD_{SAT} - HD) = A + B\log(EC)$$

In this approach, we use the natural log of the annual per-capita energy or the electricity consumption as the independent variable. The natural log of the difference between the saturated HDI and the HDI is represented as the dependent variable. The saturated value of HDI corresponds to 10% higher HDI than the highest HDI in the observed dataset. Based on the equation shown above, these two variables can be represented as the equation of a straight line, i.e., y = mx + c. Linear regression is used to obtain the values of the coefficients A (as the slope) and B (as the intercept). The R-value is also calculated to evaluate the goodness of fit for each correlation.

The regression may not provide similar goodness of fit as past analyses looking at international data. This is because international energy transport (both via grid electricity and liquid fuels) is much more common within a country than between two countries. Because of a large-time series data across several states, it is notable that some outliers may skew the regression. For instance, union territories with predominantly urban populations have high energy consumption. As such, the "1.5 IQR" rule is used to remove the outliers and obtain more accurate predictions for HDI, with per-capita energy/electricity consumption as the x-variable. In this method, the independent variable is sorted in increasing order, and the interquartile range (25th to 75th percentile) is calculated. The values less than 1.5 times the 25th percentile and those larger than 1.5 times the 75th percentile are considered as outliers in the dataset and are not included in the regression (Rousseeuw and Hubert, 2011). These values are, nevertheless, considered when calculating the maximum and minimum indices.

As discussed above, the formulation adopted by Steinberger and Roberts (2010) enables calculation of the threshold function. In doing so, the A and B coefficients are themselves regressed over the time period based on the following formulation:

$$EC(HD, t) = \left(\frac{HD_{SAT}(t) - HD}{\exp\,(A(t))}\right)^{1/B(t)}$$

The threshold functions are applied to estimate the trends in threshold energy consumption to reach HDI, HI, EI and II of 0.805 respectively.

Results

HDI versus energy consumption

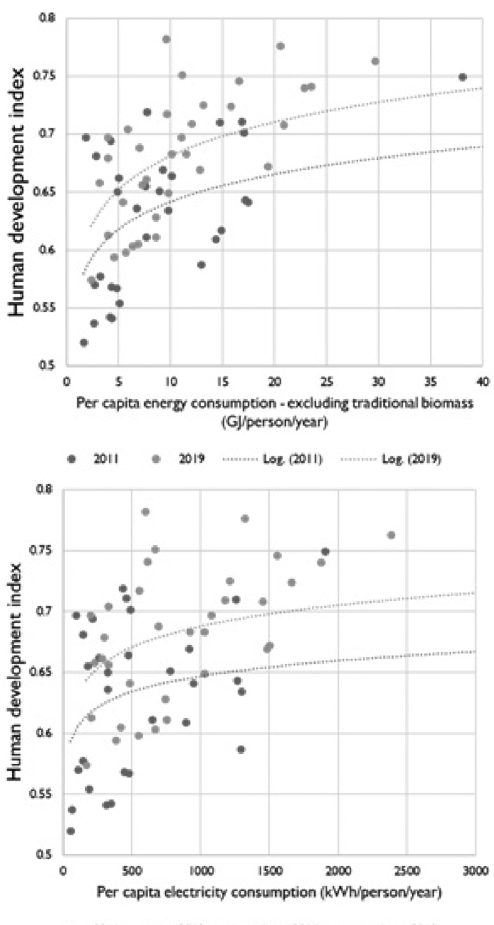

Figure 1. State-level HDI in 2011 and 2019 versus (left) per-capita energy consumption and (right) per-capita electricity consumption

The first key feature of our analysis is to report the HDI versus energy consumption and understand temporal trends. Figure 1 shows the plot of HDI versus per-capita energy and electricity consumption for all the states and union territories. For data completeness reasons, only 2011 and 2019 data are reported here. It is clear that state-level trends in HDI also follow a logarithmic trend, as in the case of national-level data for both final energy and electricity consumption (Bhattacharyya et al, 2022). It is notable that none of the state's HDI is in the saturation region of the graph. This is because the maximum HDI observed in 2011 is 0.75 and that in 2019 is 0.78. Thus, none of the Indian states or union territories have yet achieved very high HDI levels. As such, any increase in energy access would likely lead to growth in human development parameters for all the states and union territories. The results show an increase in human development between 2011 to 2019.

An important trend observable in Figure 1 is that there are no states with low HDI (i.e. below 0.55) in 2019. In 2011, five states had an HDI of less than 0.56. These were Bihar, Uttar Pradesh, Rajasthan, Odisha and Madhya Pradesh. However, significant improvements in education and healthcare indices (next section) have substantially improved the HDI equity across various states. Moreover, improved equity in the energy parameters between states has also been observed. For instance, the ratio of the maximum and minimum per-capita electricity consumption across states was 40 in 2011, which has reduced to 13 in 2019.

Another important trend visible in these graphs is the reduced energy thresholds for achieving high HDI between 2011 and 2019. Both the graphs show increased human development at a corresponding level of energy investment between 2011 and 2019. For instance, per-capita energy consumption of 15 GJ/a would likely result in an HDI of 0.65 based on the trend analysis in 2011. In 2019, a similar energy input would result in an HDI of 0.70. This increase in HDI is much more pronounced for Indian states than international-level data, where an HDI increment of ~0.01 is seen between 2012 and 2017 at a similar energy level. This is likely because of availability of more efficient energy accessibility through electrification and liquified petroleum gas connections across the country, especially in rural areas. Similar results are seen for electricity consumption as well. Here, the increase of 0.05 units of HDI at a per-capita electricity consumption of 1500 kWh/person/year is seen. This is important because this value is close to India's per capita electricity consumption. Thus, if electricity access in all the states can be improved to the current average levels, a high HDI can be achieved even at the present threshold energy levels.

State-level trends

While Figure 1 shows the overall trends in HDI versus energy, it is also critical to understand trends in individual states. Several important trends are noticeable here.

First, there is a significant difference between achievement of nationwide human development goals. For instance, the average HI in 2019 was 0.80 (0.77 in 2011), and the HI is higher than HDI in most states. These increased values of HI are seen because of increased life expectancy in India. The HDI parameters are a function of the highest and lowest values of respective variables globally. Because India's life expectancy (70 years) is higher than the lowest life expectancy (~54 years), the HI values are comparably higher. Contrastingly, the educational index is much lower than the HDI across states. In 2011, the average EI was at designated low levels (0.55). This has improved to 0.59 in 2019, but there is still a substantial scope for improvement. Particularly, the mean number of schooling years is averaged a 6.5 years, and this is as low as 4.6 years in Bihar. For females, the national mean is 5.4 years and it is 2.9 years in Bihar. Globally, the aspirational value for this parameter is 14 years. Thus, the current per-student investment is $8000 annually in countries with very high EI but this been achieved through private/parental finance (UN, 2019).

Second, several states which are in the bottom 33% in the HDI are also in the bottom 33% of individual categories within human development (HI, EI and II). These states are Assam, Bihar, Chhattisgarh, Jharkhand, Madhya Pradesh and Uttar Pradesh. The per-capita energy consumption in these states is also within the bottom 33%, i.e., below 6 GJ/a. This again significies a state-level relationship between the per-capita energy consumption and individual human development parameters, in addition to the composite HDI. It is also noticeable here that for some of these states, such as Jharkhand and Madhya Pradesh, electricity generation does not rank within the bottom 33%. This signifies a greater linkage for per-capita energy consumption than electricity consumption with HDI. A number of reasons may be possible here. For instance, the key source of electricity generation in these states is coal, which might result in higher levels of air pollution, that are detrimental to human health. For instance, Gohlke et al (2011) found that increased coal consumption in many regions globally led to lower life expectancy and higher infant mortality. Moreover, electricity generation in a particular state might not be entirely representative of the state's consumption. Both Jharkhand and Madhya Pradesh are locations of high capacity power transmission corridors. As such, per-capita electricity consumption is a worse indicator of human development as compared to final energy consumption, when studying state-level trends. While these states are typically characterized by lower energy consumption, recent years have seen a comparatively higher level of incremental energy use (between 2011-2019) in some of these states. For instance, the per-capita energy consumption in Chhattisgarh, Rajasthan, Odisha and Madhya Pradesh are 77%, 68%, 56% and 52% respectively. This increase in energy consumption has been instrumental in improvement of human development parameters, even though they are significantly below the national average. For instance, Chhattisgarh's EI and II both increased by 0.06 points during 2011-2019.

Third, some states/union territories with very high human development metrics do have high energy consumption as well. This is particularly the case in highly urbanized regions, with high petrol and LPG consumption. For instance, Delhi, Goa, Lakshwadeep and Puducherry all are ranked in the top 33% across all human development parameters as well as per-capita energy consumption. But this is not necessarily the case in all states. For instance, Kerala is ranked within the top 33% in all the human development parameters, and the highest in education and health parameters. However, the per-capita energy consumption is ~10 GJ/a and the per-capita electricity consumption is 600 kWh/a. These are both lower than the national average. This has largely been achieved through public spending in healthcare and education facilities (Kutty, 2000).

Finally, a key observation regarding the decoupling of the HDI-energy linkage is seen in the case of northeastern states. Many of these states have achieved higher human development at comparably lower energy investment. For instance, Mizoram and Manipur have been ranked among the top 33% states among various human development parameters in 2011 and 2019. However, their per-capita energy and electricity consumption are ranked within the bottom 33%. However, the largest state in the region, Assam, has traditionally had low energy consumption as well as human development metrics (Nayak, 2013). It is likely that increased energy investments in these states may propel economic opportunities to increase the per-capita income, the key deterrent to human development index in this region.

Regression results

Once the key trends have been observed, the analytical formulations discussed above are used to calculate the regression coefficients A and B. The slope of this regression, A is critical in identifying the parameter most influenced by increases in energy consumption and therefore the "bang per buck" for each sector. Table 2 shows the key regression parameters here. Note that the coefficients here are negative because of the negative sign of the left-hand side in front of the 'HD' parameter.

Table 2. Key regression outputs for HDI-energy and HDI-electricity relationships

2011 Data	HDI	HI	EI	II
Energy coefficient	-0.26	-0.25	-0.16	-0.25
R	0.46	0.51	0.27	0.46
Electricity coefficient	-0.11	-0.09	-0.11	-0.01
R	0.34	0.45	0.36	0.27
2019 Data	HDI	HI	EI	II
Energy coefficient	-0.65	-0.25	-0.70	-0.89
R	0.58	0.43	0.48	0.72
Electricity coefficient	-0.18	-0.08	-0.30	-0.44
R	0.35	0.18	0.28	0.49

The first key conclusion here is that the energy coefficients for all the parameters were relatively similar in 2011. Thus, any increase in energy investments would accrue nearly equitably in HDI, HI and II. However, in 2019, the absolute value of the energy-II coefficient is much higher than other indices. This implies a greater "bang per buck". In fact, Reddy (1999) had concluded that beyond a certain point in development (say after HDI > 0.65), the coupling of income with HDI goes strongly. In other words, improvements in income are the most predictable way of improving human development as societies move to situations where basic human needs are already met. This is evident from the low level of energy-HI coefficient, that implies that benefits from health improvements might have stagnated in so far as their influence on overall HDI.

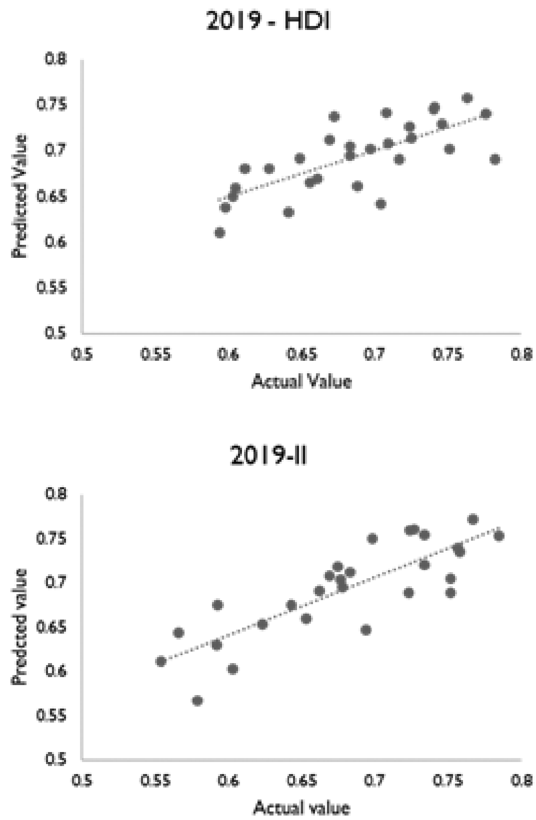

Figure 2. Comparison of predicted value obtained via regression to the actual value of (left) HDI and (right) income index

It may be noted that the goodness of fit for our state-level analysis is much lower than national-level analyses. For instance, the R-value of 0.58 is lower than that calculated by Steinberger and Roberts (2010), who obtained an R-value of 0.82 for national-level data. This is because of several reasons. As already noted, the interstate transport of electricity and liquid fuels across states is much higher than international transport. As such, the consumption data might not be exactly representative of the actual in-state consumption. Furthermore, due to a lower number of observations (~30) as compared to international data (~190), the fitness might be affected. That said, we plotted the predicted values versus the actual values of our regression in Figure 2. The results show that even though the R-values are small, there is acceptable match between the predicted and observed values.

Disclaimer

Authors reserve the right to extend this work further and publish it in alternate venues. The views expressed in this analysis are those of the authors, and they do not represent the official position of the Government of India.

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References

Bhattacharyya, R., Singh, K. K., Grover, R. B., & Bhanja, K. (2022). Estimating minimum energy requirement for transitioning to a net-zero, developed India in 2070. Current Science (00113891), 122(5).

Clarke, L., Wei, Y. M., de la Vega Navarro, A., Garg, A., Hahmann, A. N., Khennas, S., ... &Veldstra, J. (2022). Energy Systems. In Climate Change 2022: Mitigation of Climate Change. Working Group III Contribution to the IPCC Sixth Assessment Report. Cambridge University Press.

Dholakia, H. H. (2018). Solar powered healthcare in developing countries. Nature Energy, 3(9), 705-707.

Ekholm, T., Krey, V., Pachauri, S., &Riahi, K. (2010). Determinants of household energy consumption in India. Energy policy, 38(10), 5696-5707.

Gohlke, J. M., Thomas, R., Woodward, A., Campbell-Lendrum, D., Prüss-Üstün, A., Hales, S., & Portier, C. J. (2011). Estimating the global public health implications of electricity and coal consumption. Environmental health perspectives, 119(6), 821-826.

Gupta, D., Ghersi, F., Vishwanathan, S. S., & Garg, A. (2019). Achieving sustainable development in India along low carbon pathways: Macroeconomic assessment. World Development, 123, 104623.

IEA (2021). India Energy Outlook, Paris, 2021, https://iea.blob.core.windows.net/assets/1de6d91e-e23f-4e02-b1fb-51fdd6283b22/India_Energy_Outlook_2021.pdf. Accessed: March 28, 2021.

IndiaStat (2020). Power Consumption and Sale, https://www.indiastat.com/data/power/consumption-power. Accessed: June 19, 2022.

Kutty, V. R. (2000). Historical analysis of the development of health care facilities in Kerala State, India. Health policy and planning, 15(1), 103-109.

Martinez, D. M., & Ebenhack, B. W. (2008). Understanding the role of energy consumption in human development through the use of saturation phenomena. Energy Policy, 36(4), 1430-1435.

Mehmood, U. (2021). Contribution of renewable energy towards environmental quality: The role of education to achieve sustainable development goals in G11 countries. Renewable Energy, 178, 600-607.

Nayak, P. (2013, May). Human development in north-eastern region of India: issues and challenges. In Proceedings of the National Seminar on'Poverty and Human Development: Issues and Challenges', organized by the Dept. of Economics, Doomdooma College, Assam, INDIA (pp. 10-11).

NITI Aayog (2022). India Energy Dashboards, https://www.niti.gov.in/edm/. Accessed: June 19, 2022.

Pasternak, A. D. (2001). Global energy futures and human development: a framework for analysis, https://www.osti.gov/etdeweb/servlets/purl/20264287. Accessed: June 19, 2022.

PPAC (2022). Consumption of Petroleum Products, https://www.ppac.gov.in/content/147_1_ConsumptionPetroleum.aspx. Accessed: June 19, 2022.

Preston, S. H. (2007). The changing relation between mortality and level of economic development. International journal of epidemiology, 36(3), 484-490.

Rami, G. (2021). India's Human Development Index: Components, methodological issues and forecasting 1. In The Routledge Handbook of Post-Reform Indian Economy (pp. 459-478). Routledge India.

Rao, N. D., Min, J., & Mastrucci, A. (2019). Energy requirements for decent living in India, Brazil and South Africa. Nature Energy, 4(12), 1025-1032.

Reddy, A. K. (1999). Goals, strategies and policies for rural energy. Economic and Political Weekly, 3435-3445.

Rousseeuw, P. J., & Hubert, M. (2011). Robust statistics for outlier detection. Wiley interdisciplinary reviews: Data mining and knowledge discovery, 1(1), 73-79.

Smits, J., & Permanyer, I. (2019). The subnational human development database. Scientific data, 6(1), 1-15.

Srinivasan, S., Kholod, N., Chaturvedi, V., Ghosh, P. P., Mathur, R., Clarke, L., ... & Sharma, K. (2018). Water for electricity in India: A multi-model study of future challenges and linkages to climate change mitigation. Applied Energy, 210, 673-684.

Steinberger, J. K., & Roberts, J. T. (2010). From constraint to sufficiency: The decoupling of energy and carbon from human needs, 1975–2005. Ecological Economics, 70(2), 425-433.

UN (2019). Financing for Sustainable Development Report.

Yawale, S. K., Hanaoka, T., & Kapshe, M. (2021). Development of energy balance table for rural and urban households and evaluation of energy consumption in Indian states. Renewable and Sustainable Energy Reviews, 136, 110392.

Zahid, T., Arshed, N., Munir, M., & Hameed, K. (2021). Role of energy consumption preferences on human development: A study of SAARC region. Economic Change and Restructuring, 54(1), 121-144.

TECHNICAL NOTE

ROLE OF CO_2 CAPTURE AND STORAGE IN MEETING GLOBAL DECARBONIZATION TARGETS

Ajay K. Singh [1]

Introduction

The Sixth Assessment Report (AR6) of the Intergovernmental Panel on Climate Change (IPCC) concludes that a widespread change in energy and industrial systems would be necessary if global temperatures are to be limited to 1.5°C by the end of the century (IPCC, 2022). A number of mitigation options have been presented. For instance, the first approach would be to use energy more efficiently, through reducing losses throughout the supply chain, increasing appliance efficiencies and reducing leakages where possible. Another approach is through fuel switching. This includes reduction in the share of fossil fuel usage and supplementing them by low-carbon energy sources such as renewables, nuclear, hydro and bioenergy. In some countries such as the United States, fuel switching has also meant replacement of coal use with natural gas, which has brought down emissions by 3% annually in the last two decades (Singh and Dunn, 2022). A final and key mitigation strategy associated with decarbonization pathways is in the larger umbrella of carbon dioxide sequestration. As we will discuss in this paper, this may take several diverse forms, based on the capture source and the end fate of the product. In this article, we use the term CO_2 capture and storage (CCS) quite generally to encompass any supply chain where CO_2 is injected underground for long-term isolation from the atmosphere.

Figure 1 shows the costs and potential of CO_2 reduction in the year 2030, as synthesized in AR6. It is clear that adding the potential of CCS from both fossil fuels and bioenergy comes to about 1 Gt-CO_2 annually. Moreover, the costs of CO_2 avoidance for this mitigation are \$50-200/t-CO_2. Thus, the cost investments towards CCS may be around hundreds of billions of dollars annually (McCollum et al, 2018). As such, it is worth pondering about the role of CCS given that its potential is substantially lower than wind/solar energy and the costs are among the highest in the suite of options shown in Figure 1.

The first reason why CCS is an important part of mitigating CO_2 emissions is to help decarbonize some hard-to-decarbonize sectors. While solar and wind energy are critical to reducing power sector emissions, they may not readily reduce emissions in the industry and transport sectors. Consider the case of steel or cement plants, where large amounts of fossil fuels are utilized to produce relatively high-purity CO_2. Alternatively, when we think of heavy-duty transport, electrification may not readily be adopted there. Instead, CCS may be useful in such sectors to reduce emissions without compromising on economic activity.

The second critical feature of CCS is its ability in the long-term to reduce stranded assets in the fossil fuel sector. The AR6 defined stranded assets as those assets that "suffer from unanticipated or premature write-offs, downward revaluations or [conversion] to liabilities". For instance, Mercure et al (2018) showed that the risk of global stranded assets under deep decarbonization scenarios could be as high as \$1-4 trillion. This includes the infra-

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structural assets such as power plants. In addition, several fossil fuel reserves may be rendered under- or unutilized as well (McGlade and Ekins, 2015). Thus, Malik et al (2020) show that 133-237 GW of coal capacity could become stranded in India if early policy action is not adopted. Vishal et al (2021) used a first-order estimate to show that this value could translate into monetary losses in excess of $6 billion annually for India.

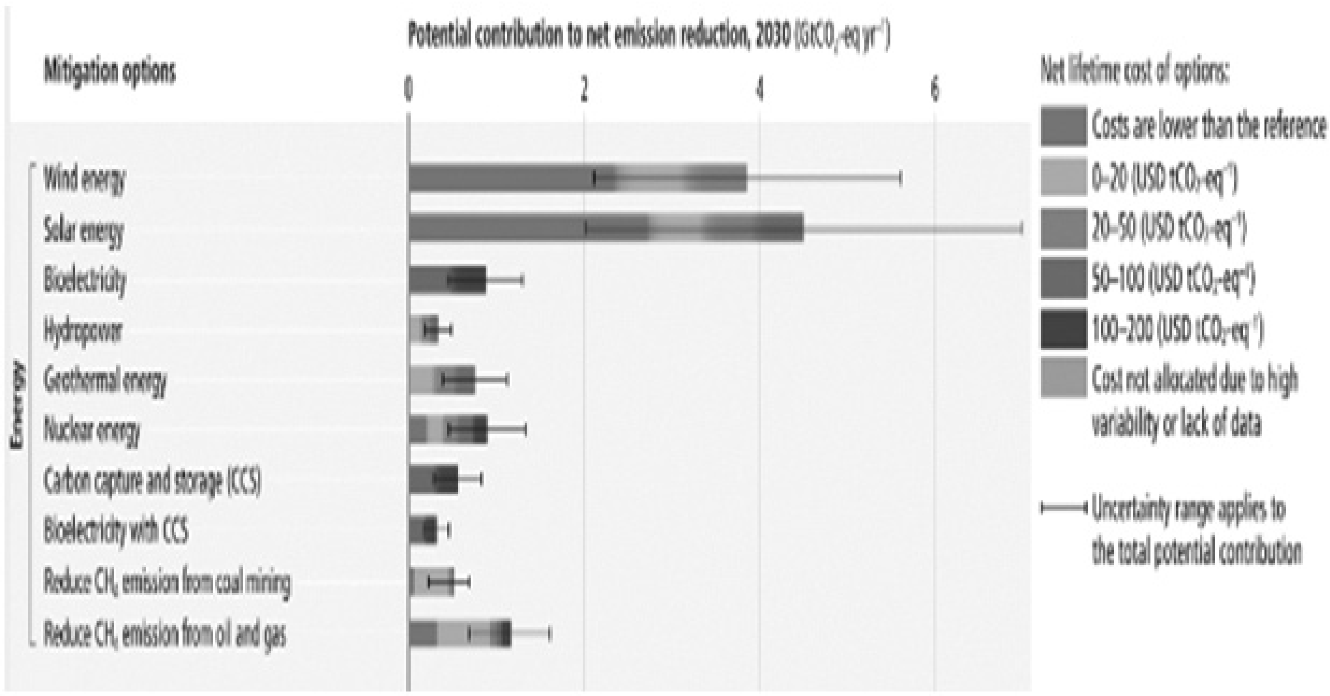

Figure 1. Overview of mitigation options and their estimated ranges of costs and potentials in 2030 in the energy sector (IPCC, 2022).

Other advantages of CCS include providing a diversification of the grid, which translates to resilience. The Global Energy Assessment (Cherp et al, 2012) pointed out that reliance on multiple sources in the energy mix offers a better risk aversion to geopolitical disruptions. In fact, this argument could be extended to extreme weather conditions that affect the energy systems too. Vishal et al (2021) used ensemble modeling data to show that scenarios in which the role of CCS of was higher were accompanied by a higher grid diversity in 2050.

The objective of this article is to discuss the variety of approaches available in the CCS domain, including its close linkages to carbon dioxide removal (CDR) and CO_2 capture and utilization (CCU) in section 2. Some of the benefits and tradeoffs of CCS with sustainable development goals are then expanded upon in section 3. This is followed by a discussion of some field-level intricacies associated with CCS deployment at scale in India, and suggestions for future research directions (Section 4).

What are CCS, CDR and CCU?

The overarching field of CO_2 capture and storage does often have significant terminology differences. It is often useful to be clear in the language so as to avoid ambiguity in the terms being mentioned. This section explains the similarities and differences between CCS, CDR and CCU.

The term CCS was initially meant to broadly encompass the capture of CO_2 from large-point sources of CO_2, its transport and then storage in geologic formations. Because of the large share of CO_2 in the late 90s and early 2000s coming from coal-fired power plants, this usually translated to capture from such plants. But other sources of CO_2 were also considered. These includes natural gas combined cycle (NGCC) power plants, coal power plants with integrated gasification combined cycle (IGCC), as well as facilities cement, steel, refined petroleum products, fertilizers, and others (IPCC, 2005). The key idea involved here was the tradeoff between CO_2 concentration in the flue gas stream and the overall emissions from a particular source of CO_2. For instance, during the time of the publication of the IPCC Special Report on CCS, 60% of global LPS emissions were derived from coal-fired power plants and the concentration of the CO_2 in such plants ranged from 12-15%. On the other hand, some facilities such as ammonia products involved so-called "process emissions" that were derived from the chemical breakdown of carbon into CO_2. As such, these facilities had nearly a 100% concentration of CO_2, which meant that the cost of capture was close to \$0/t-CO_2. However, process emissions from ammonia production plants were less than 1% of global emissions (IPCC, 2005).

The downstream end of the CCS supply chain involved a variety of geologic sink. Here again, there is a tradeoff between overall sink availability and the feasibility/readiness of storage. For instance, CO_2 could be injected into oil formations where primary and secondary recovery have already depleted substantial reserves. Injection of CO_2 helped in recovery of extra oil from such formations, thus leading to higher profit margins and supplementing of costs associated with CO_2 capture. This was called as enhanced oil recovery (EOR). EOR has been practiced in the United States since the 1970s at a commercial scale. However, continued reliance on EOR has two issues. First, it would continue to emit CO_2 due to combustion of fossil crude. Second, the global EOR potential is limited. For instance, our prior assessment indicates that EOR potential in India is 3-5 Gt-CO_2, which is enough only for about five years of the required CCS deployment needed for meeting 1.5°C constraints (Singh et al, 2006). Instead, another sink for captured CO_2 could be saline aquifers. While there are limited financial incentives for such storage, these reservoirs have much larger pore space availability. This translates to 200-300 Gt-CO_2 storage potential in India alone, and more than tens of thousands of gigatons of CO_2 globally. Table 1 shows the indicative geologic storage potential in different types of formations globally, as adapted from AR6.

Table 1. Geologic storage potential across underground formations globally. These represent order-of-magnitude estimates. Source: Clarke et al (2022) Data: [Data from (Selosse and Ricci 2017)]

Reservoir type	**Africa**	**Australia**	**Canada**	**China**	**CSA**	**EEU**	**FSU**	**India**	**MEA**	**Mexico**	**ODA**	**USA**	**WEU**
Enhanced oil recovery	3	0	3	1	8	2	15	0	38	0	1	8	0
Depleted oil and gas fields	20	8	19	1	33	2	191	0	252	22	47	32	37
Enhanced coalbed methane recovery	8	30	16	16	0	2	26	8	0	0	24	90	12
Deep saline aquifers	1000	500	667	500	1000	250	1000	500	500	250	1015	1000	250

CSA : Central and South America, EEU : Eastern Europe, FSU : Former Soviet Union, MEA: Middle East, ODA : Other Asia (except China and India), WEU : Western Europe.

One factor that is clear from Table 1 is that geologic pore space is not distributed uniformly across the globe. Thus, the middle east and former Soviet Union countries have more than 50% of the global storage potential in EOR. Even when such storage is possible, there may be issues associated with it. Geologic storage requires detailed characterization of underground formations, which may not have been done rigorously in all cases. Detailed monitoring of such wells is required for several decades to ensure that no CO_2 leakage is occurring. Communities living around locations where large volumes of CO_2 have been stored may also have concerns around safety.

As such, another mechanism of dealing with captured CO_2 may be CO_2 utilization, in which CO_2 is converted into products or chemicals instead of being stored geologically over large timescales. Depending on the type of product, the CO_2 may be stored for long periods of time or shorter durations. For instance, CO_2 may be converted to methanol or algae-based biofuels, which are eventually combusted, thus re-emitting the CO_2 into the atmosphere. This may be perceived as temporary sequestration of CO_2, as it delays emissions but does not completely avoid it. Other products such as plastics and cement may hold the CO_2 for longer durations (Hepburn et al, 2020). Some surveys shows that the general public may prefer CCU over CCS. That said, the potential for CCU is limited (Arning et al, 2019). The total amount of CO_2 that may be converted into useful products could nominally be of the order of 1 Gt-CO_2 annually, which is significantly less than the volumes of CO_2 shown in Table 1.

Another concern associated with CO_2 utilization is that it may or may not deliver sizeable emission reductions depending on the fate of CO_2. For long-term reductions via CCU to be compatible with the target of net-zero emissions, the end required for CO_2 capture would need to be sourced from zero-emission sources, or the produced commodities would need to store CO_2 permanently (de Kleijne et al, 2022).

Finally, recent reports of the IPCC, starting from the Fifth Assessment Report have increasingly focused on CDR or negative emissions technologies. CDR implies throughout the life-cycle, CO_2 is taken from the atmosphere and stored into the 'geosphere' through a variety of means. The two methods of CDR with the highest potential have close intersections with the described CCS approach. The first method is called bioenergy with CCS or BECCS. In this method, the large-point source from which the CO_2 may be captured emits biogenic carbon instead of fossil carbon. By combining carbon sequestration from photosynthesis and geologic sequestration, the net sequestration nominally exceeds GHG emissions throughout the supply chain. Thus, these processes result in negative GHG emissions. Another potential approach involves capture of CO_2 directly from the ambient air, and its sequestration in geologic formation. This approach may be called direct air capture of CO_2 and sequestration (DACCS). However, other methods of CDR also exist which do not necessarily interface with CCS in the same way. For instance, afforestation/reforestation and soil carbon sequestration are two nature-based solutions, which do not involve engineered geologic sequestration of CO_2. Irrespective of the method of CDR, it is notable that it would be required on the order of about 10 Gt-CO_2 annually around the mid-century in most scenarios meeting the 1.5°C target. Figure 2 shows a representative scenario of CDR and its interaction with residual CO_2 emissions.

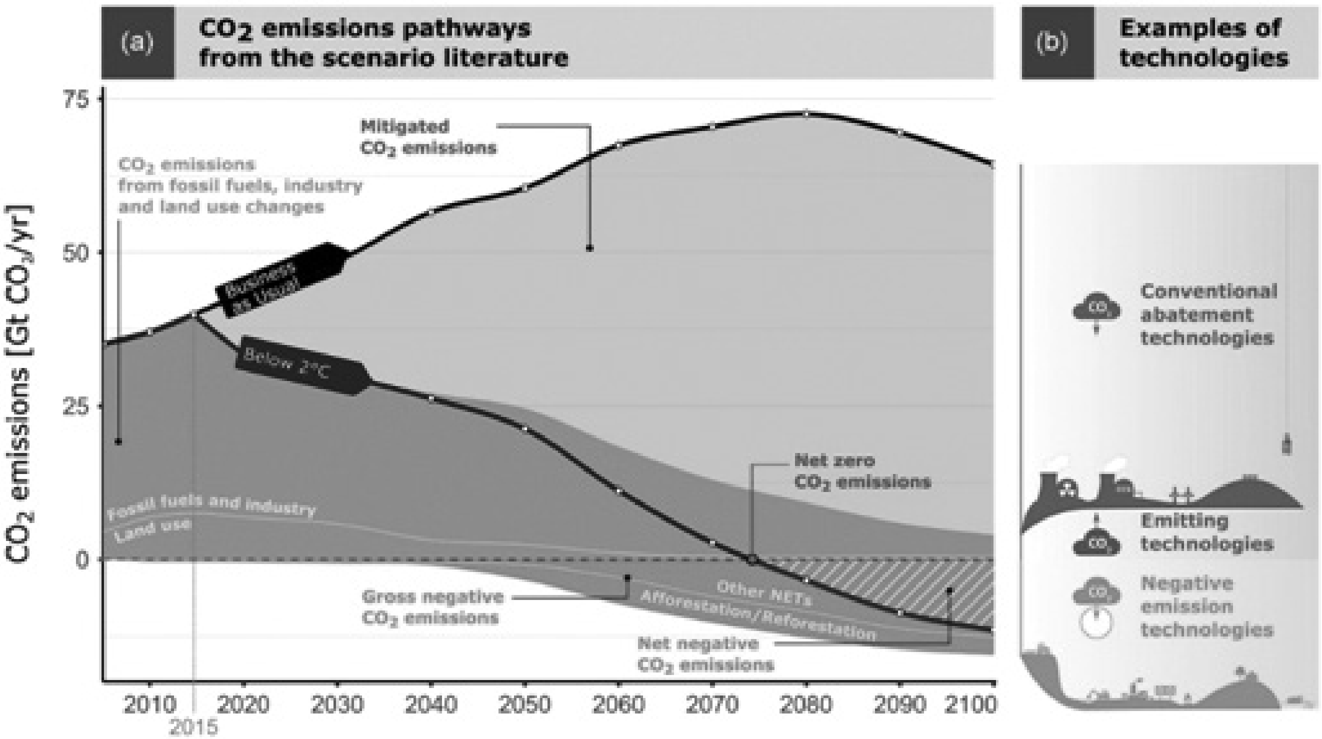

Figure 2. The role of negative emissions in climate change mitigation. The graph juxtaposes emission reductions from conventional mitigation technologies (panel A) with the removal of carbon dioxide via negative emissions technologies (panel B) in an exemplary scenario consistent with a 66% chance of keeping warming below 2 °C relative to a baseline scenario. Global emission levels turn net negative towards (hatched blue area) the end of the century to compensate for earlier carbon budget overshoot. Cumulative gross negative emissions represented by the entire blue area (Fuss et al, 2018).

A number of key constraints apply for due vetting of technologies for meeting the CDR requirement of negative emissions. Overall, the gross sequestration associated with the entire supply chain must exceed the gross CO_2 emissions. This should not include reductions that are achieved via substitution of conventional products and instead should involve physical removal of CO_2 (Terlouw et al, 2021).

Interaction of CCS with sustainable development goals

While reduction of greenhouse gas emission is an important global target, the AR6 report also emphasizes the linkage of several of mitigation targets with sustainable development goals (SDGs). Climate action is only one of the 17 SDGs, announced by the United Nations. It is imperative to ensure that other SDGs are also achieved in consonance with climate targets. This is necessary because SDGs focus on societal goals in addition to environmental goals. It may also be the case that policymakers may be more inclined to opt for mitigation measures that benefit other SDGs, in view of the public interest. Figure 3 shows the interactions between several mitigation avenues in the energy sector (including CCS) and the 17 SDGs, adapted from the summary for policymakers of the Working Group III contribution of AR6.

CCS has a number of synergies and tradeoffs with SDGs, which we describe here. First, the inclusion of CCS in large point sources require reduction in criteria of air pollutants as well. For example, a conventional coal-fired power plant emits significant amounts of SO_2, NOx and particulate matter, in addition to CO_2. These air pollutants may inhibit continuous CO_2 capture in a post-combustion capture system due to salt formation (Rao and Rubin, 2006). Thus, post-combustion capture often requires use of polishers and other equipment to reduce these emissions well below current regulatory standards. Reduction in air pollutants is often associated with reduced incidence of respiratory illnesses and positive health outcomes. Thus, CCS may broadly lead to a synergy with SDG-3 (Good health and wellbeing).

As described above, CCS may help in reducing the emissions associated with industrial facilities. Thus, it has a synergy with SDG-9 (industry, innovation and infrastructure). Moreover, it could also generate employment for engineers, geologists and other workers throughout the supply chain. Thus, it has a positive interaction with SDG-8 (decent work and economic growth).

The key tradeoff associated with CCS occurs in the form of large water consumption, which impedes the SDG-6 target. Power plants equipped CCS may require 50-200% more water withdrawals due to efficiencies as well as different steam cycle heat rates (Singh and Rao, 2014). Moreover, injection of CO_2 in saline aquifers and other geologic formations may result in production of high-salinity brines rich in sodium and chloride ions. The total dissolved solids content of such brines may be of the order of 100-200 ppm (Arena et al, 2017), which would require substantial treatment before disposal/reuse. Such desalination operations may result in additional energy penalty, which would correspond to 4-35 kWh per tonne of CO_2 stored (Bartholomew and Mauter, 2017).

Scope of CCS in India

Coal is likely to remain India's key energy resource for meeting its primary energy demands as well as electricity generation requirements (Garg and Shukla, 2009). However, CCS may help in reducing the emissions intensity of the coal supply chain. Shukla et al (2015) project that the total CO_2 sequestered by 2050 may be as high as ~10000 million tons in a conventional mitigation scenario. One of the key storage locations for CO_2 storage includes deep coal seams. It has a value-added benefit due to enhanced and incremental recovery of coal bed methane (CBM) associated with it. Several authors have pointed out the necessity of the study and the development of technology for recovering coalbed methane as well as the successive adsorption and sequestration of CO_2 in coal seams. Vishal et al (2013; 2015) have carried out a few interesting studies pertaining to mathematical and experimental feasibility of this technology in Indian conditions.

Carbon dioxide sequestration in coal seams requires an understanding of various aspects of the selected coal block such as the geological structure of the coal seam, its depth and thickness, hydrology, gas saturation, quantity and quality of coal available. Secondary reservoir parameters including coal rank, coal maceral composition (high vitrinite content preferred), low ash content (because ash does not adsorb methane or CO_2), and gas composition are also vital.

India is the second largest coal producer in the world and has enough coal reserves to meet our energy requirement for the next 200 years. While the coal resources are huge, recoverable reserve has been estimated as 63.3 billion tonnes only. A sizable fraction of the rest of the coal resources can be utilized for the ECBM technology.

Laboratory isotherm measurements reveal that medium to high rank coal can adsorb approximately twice as much CO_2 by volume as methane. The common assumption is that, for higher rank coals, the ECBM process stores 2 moles of CO_2 for every mole of CH4 desorbed. Laboratory experiments showed that this ratio could be even larger at depths greater than 800 m, where the gaseous CO_2 changes to supercritical CO_2.

Our group has been involved in CO_2 sequestration potential estimation for Indian geologic formations. Singh et al (2006) projected that the total CO_2 storage potential for Indian geologic formations is 572 Gt. The storage potential in Indian coalbeds is estimated to be 4459 Mt, using an efficiency factor of 90% (Singh and Mohanty, 2015). However, further research on selection of suitable candidates for CO_2 storage at a specific site requires a detailed economic appraisal taking into consideration the daily CO_2 generation from the point sources and total gas likely to be generated during the life time of the power station with the present rate of consumption of coal. Also, the above storage estimates are theoretical values, which need to be refined to include practical geological and engineering considerations.

References

Arena, J. T., Jain, J. C., Lopano, C. L., Hakala, J. A., Bartholomew, T. V., Mauter, M. S., & Siefert, N. S. (2017). Management and dewatering of brines extracted from geologic carbon storage sites. International Journal of Greenhouse Gas Control, 63, 194-214.

Arning, K., Offermann-van Heek, J., Linzenich, A., Kätelhön, A., Sternberg, A., Bardow, A., &Ziefle, M. (2019). Same or different? Insights on public perception and acceptance of carbon capture and storage or utilization in Germany. Energy policy, 125, 235-249.

Bartholomew, T. V., &Mauter, M. S. (2021). Energy and CO2 Emissions Penalty Ranges for Geologic Carbon Storage Brine Management. Environmental Science & Technology, 55(8), 4305-4313.

Cherp, A., Adenikinju, A., Hernandez, F., Hughes, L., Jansen, J., Jewell, J., Olshanskaya, M., de Oliveira, R., Sovacool, B.K., Vakulenko, S. (2012). Energy and security. Global Energy Assessment, pp. 325–383.

de Kleijne, K., Hanssen, S. V., van Dinteren, L., Huijbregts, M. A., van Zelm, R., & de Coninck, H. (2022). Limits to Paris compatibility of CO_2 capture and utilization. One Earth, 5(2), 168-185.

Fuss, S., Lamb, W. F., Callaghan, M. W., Hilaire, J., Creutzig, F., Amann, T., ... & Minx, J. C. (2018). Negative emissions—Part 2: Costs, potentials and side effects. Environmental Research Letters, 13(6), 063002.

Garg, A., & Shukla, P. R. (2009). Coal and energy security for India: Role of carbon dioxide (CO_2) capture and storage (CCS). Energy, 34(8), 1032-1041.

IPCC (2005). IPCC Special Report on Carbon Dioxide Capture and Storage, Cambridge University Press, Cambridge.

IPCC, Climate Change 2022: Mitigation of Climate Change. Intergovernmental Panel on Climate Change, 2022. Accessed: May 23, 2022. [Online]. Available: https://report.ipcc.ch/ar6wg3/pdf/IPCC_AR6_WGIII_SummaryForPolicymakers.pdf

Malik, A., Bertram, C., Despres, J., Emmerling, J., Fujimori, S., Garg, A., ... &Vrontisi, Z. (2020). Reducing stranded assets through early action in the Indian power sector. Environmental Research Letters, 15(9), 094091.

McCollum, D. L., Zhou, W., Bertram, C., De Boer, H. S., Bosetti, V., Busch, S., ... &Riahi, K. (2018). Energy investment needs for fulfilling the Paris Agreement and achieving the Sustainable Development Goals. Nature Energy, 3(7), 589-599.

McGlade, C., & Ekins, P. (2015). The geographical distribution of fossil fuels unused when limiting global warming to 2 C. Nature, 517(7533), 187-190.

Mercure, J. F., Pollitt, H., Viñuales, J. E., Edwards, N. R., Holden, P. B., Chewpreecha, U., ... & Knobloch, F. (2018). Macroeconomic impact of stranded fossil fuel assets. Nature Climate Change, 8(7), 588-593.

Rao, A. B., & Rubin, E. S. (2006). Identifying cost-effective CO_2 control levels for amine-based CO_2 capture systems. Industrial & engineering chemistry research, 45(8), 2421-2429.

Selosse, S., & Ricci, O. (2017). Carbon capture and storage: Lessons from a storage potential and localization analysis. Applied Energy, 188, 32-44.

Shukla, P., Dhar, S., Pathak, M., Mahadevia, D., & Garg, A. (2015). Pathways to deep decarbonization in India.

Singh, A. K., & Mohanty, D. (2014). CO_2 Sequestration potential of Indian coalfields. Carbon Capture, Storage and, Utilization: A possible climate change solution for energy industry, 133-147.

Singh A. K., Mendhe VA, Garg A (2006). CO_2 sequestration potential in Indian geologic formationsIn: Proceedings of the 8th International Conference on Greenhouse Gas Control Technologies, Elsevier.

Singh, U., & Dunn, J. B. (2022). Shale Gas Decarbonization in the Permian Basin: Is It Possible?. ACS Engineering Au, 2, 248-256.

Singh, U., & Rao, A. B. (2014, December). Estimating the environmental implications of implementing carbon capture and storage in Indian coal power plants. In 2014 International Conference on Advances in Green Energy (ICAGE) (pp. 226-232). IEEE.

Terlouw, T., Bauer, C., Rosa, L., &Mazzotti, M. (2021). Life cycle assessment of carbon dioxide removal technologies: a critical review. Energy & Environmental Science, 14(4), 1701-1721.

Vishal, V., Chandra, D., Singh, U., & Verma, Y. (2021). Understanding initial opportunities and key challenges for CCUS deployment in India at scale. Resources, Conservation and Recycling, 175, 105829.

Vishal, V., Singh, L., Pradhan, S. P., Singh, T. N., & Ranjith, P. G. (2013). Numerical modeling of Gondwana coal seams in India as coalbed methane reservoirs substituted for carbon dioxide sequestration. Energy, 49, 384-394.

Vishal, V., Singh, T. N., & Ranjith, P. G. (2015). Influence of sorption time in CO_2-ECBM process in Indian coals using coupled numerical simulation. Fuel, 139, 51-58.

NEWS AND VIEWS

HUTTI GOLD MINES CO LTD: THE PRIDE OF INDIA COMPLETES 75 GLORIOUS YEARS

Prabhakar Sangurmath

Introduction

India's major gold producer is Hutti Gold Mines Company Limited (HGML), a Government of Karnataka undertaking. The HGML is active in the exploration, mining and metallurgy of Gold and Copper deposits of Karnataka. The Company's Corporate Office is situated in Bengaluru and operates two units – the Hutti Gold Unit (HGU) in Raichur district and Chitrdurga Gold Unit (CGU), Chitrdurga district, Karnataka.

The world class Hutti Gold Mines, situated in Hutti, Lingsgur taluk, Raichur district, Karnataka is owned by the Karnataka Government. In 1939, Hutti was a small village with hardly 60 to 70 huts and houses. Now it is a town and the population is over 40,000. Half of this population lives in the colony constructed by the HGML.

Evolutionary Stages of Exploration and Mining in Hutti :

The pursuit of gold has been there since time immemorial. There are about four periods of exploration and mining in Hutti with widely separated historical time spans as follows :

a. Pre-Ashokan Era (more than 2000 years old): Ancient Mining.
b. Nizam's Period (1886-1920).
c. Nizam's and British Period (1937-1947).
d. Modern Mining (1947-till date).

Methods of Old Mining and Metallurgy at Hutti : The Hutti Gold Mines are reckoned among the most ancient metal mines in the world dating back to the pre-Ashokan period. The ancient miners worked down to a depth of over 600 feet. During the period, they had probably broken the rock by "fire-setting" a process of heating it in fire and pouring water suddenly on the heated rock thereby causing it to crack and splinter. The carbon dating of the timbers found in the old workings have been considered to be about 1900 years old. For crushing the ore to extract its gold, they used a grinding stone similar to that one used now for making massalas in rural areas. A few of these can be found in the area even now. The gold was recovered by passing the crushed ore mixed with water over goat's - skins for the trapping the heavy gold particles, while associated lighter minerals were washed off.

In addition to the ancient mining in Hutti, there was further mining in the area between 1890 to 1920, when the price of gold was about Rs.18 for 10 gram (Rs.20.97 a tola). During this period, the Main Mine reached a depth of about 1,100 meters. The industry was closed down in 1920 due to technical difficulties and lack of funds.

In 1937, the Hyderabad Nizam Government had decided to prospect the area again with a view of possible re-opening of the mines, as this was the only industry in the area, apart from agriculture, so as provide employment. The area was a backward district and perpetual famine affected area. In 1940, after some satisfactory exploratory work, it was decided to install a plant to treat 100 metric tonnes of ore per day, but before the plant could be obtained, the operations were suspended from 1942 to 1946 due to World War-II, the mine was shut down except for pumping. The Hyderabad Gold Mines Co Ltd was founded on 8th July 1947. The mine works were resumed and production

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started in September, 1948 at the rate of 13 tonnes per day (TPD). After the war regular mine production started in 1949 at the rate of 130 TPD, progressively increased to 600 TPD in 1972, 910 TPD in 1979, currently 2400 TPD. The present depth of the Hutti Gold Mine is 960 meters and it can be mined down to 3 km depth as per gravity geo-physical exploration. It was renamed in 1956 as Hutti Gold Mines Co Ltd (HGML) with the formation of erstwhile Mysore State (now Karnataka).

HGML has gold reserves of around 18.87 million tonnes @ 4.10 g/t in its mining lease hold areas (Hutti, Uti and Hira-Buddinni). At present, it is operating three eco-friendly underground gold mines [Hutti, Uti and Hira-Buddinni]. M/s HGML has produced (1947-2022) about 92.78 tonnes of gold from its lease hold areas and has a employee strength of 3605.

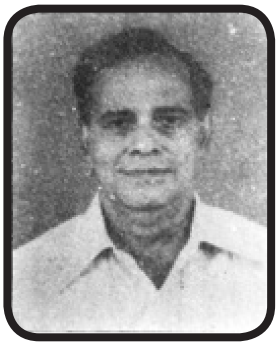
"Nature is precious than Gold" is the belief that has made M/s HGML one of the most eco-friendly companies of the country. Many actions of M/s. HGML such as large scale multi-species plantations, bio-fuel initiatives, establishment of a Bio-fuel Park, creation of a Clonal Orchard for bio-fuel development, biogas and bio-diesel plants, introduction of non-polluting electric vehicles in the campus demonstrates HGML commitment towards reducing global warming. It is evident that these green initiatives of M/s HGML would soon transform Hutti Gold Mines into Hutti Gold's Green Mines.

The Corporate Social Responsibility (CSR) initiatives are not limited to its M/s. HGML's operational areas alone but extended to all corners of the state. The state and national economics have benefited from HGML operations, in addition to direct and indirect employment provided in the backward districts.

Since inception M/s. HGML has continued to combine outstanding production performance with low operating cost. The HGML has built up vast gold ore reserves and established large scale production potential. Its net income, cash-flow position, track record of making profit continuously, continued growth in its existing leases, entry into hot-spot areas for which applications for prospecting licenses (PL)/mining licenses (ML) have already been made in Karnataka, will ensure the HGML position as the Premier Gold Mining Company in the country. HGML is adopting the new technologies in exploration, mining and metallurgy immediately to keep pace with the rest of the gold industries across the globe and is in the midst of implementing an ambitious expansion plan to enhance its gold production capacity.

HGML is built upon a long term vision and with a clear mission. It is one of the most vibrant, self-reliant, a financially viable, growth oriented and humane organization.

OBITUARY



Dr. Shyamal Chakraborty

Late Dr. Shyamal Chakraborty (MMGI, LM – 6090, 1992 - 93) passed away on 20th June 2022. With heartfelt grief MGMI members wishes his soul to Rest in Peace in his heavenly abode. May God give strength to his surviving family members and friends to bear the loss.

Born in 1938 Dr Chakrabarty obtained his first class Masters' Degree in Geology in 1959 from Presidency College (now Presidency University), Kolkata and Ph.D. in 1963 from University of Calcutta. He joined Geological Survey of India in 1962 as Assistant Geologist being posted at the then Coal Division and was promoted as Geologist in 1964, Geologist (Sr) in 1971. His major contribution was unravelling huge resources of coking and non-coking coal in North Karanpura Coalfield. He also carried out exploration in South Karanpura, Daltonganj, Bokaro, Auranga, Talcher coalfields.

He had been a faculty member of GSI Training Institute at Chainpur and Kuju centers. Becoming Director in 1985 he took charge of the Training Institute at Hyderabad where he did planning and management of the training programmes till 1989. Subsequently he was transferred back to Coal Wing and supervised exploration activities in Godavari coalfield and lignite in Tamil Nadu. He retired in 1996 as Director, Basin Analysis Division, Coal Wing of GSI.

Late Dr. Chakraboty was closely associated with MGMI since 1992. He was Chairman, Scrutineers Committee of MGMI Council Election from 2004 to 2010. He was a man of kind disposition and pleasing manners and was loved by all.

R. H. Sawkar

R. H. Sawkar, Life Member of MGMI (LM-6166, 1992-93) breathed his last peacefully on the morning of June 1, 2022 at the age of 87 in his home at Bengaluru. Late R.H. Sawkar is survived by his Wife, Son, Daughter and Grand - Children and their families and settled in Bengaluru.

Born on March 29, 1935, he is from Karnataka. He graduated in B.Sc (Hons) in Geology in 1959 and M.Sc in Geology in 1961 from Mysore University followed by Diploma in Aerial Photo Interpretation and training in I.T.C (Australia) Mineral Exploration and Mine Development Programme under Colombo Plan. He was a sportsman, swimmer and wrestler. He retired from HGML on 31.3.1995 as Executive Director and subsequently, he worked in HGML as Technical Advisor up to 1.6.1997. He was Secretary General of the Geological Society of India. Late R.H. Sawkar will remain in the hearts of many. He will be missed deeply by his family and colleagues.

DOWN THE MEMORY LANE

THROUGH DOWN PIT TO MARRIAGE : HOW I FINALLY GOT MARRIED!

Sheo Shankar Mishra

The term 'getting married' invariably sends pulsating sensations down the spine of almost everyone but my journey to that milestone was somehow filled with thrilling uncertainties fueled by some personal ambitions. This brief memoir is a humble attempt to capture those events and circumstances for a captivating sojourn for the reader.

In the Indian context, numerous social and cultural traditions and practices define the landscape of marriage. This institution is a pre-destined union of two wandering souls who pledge to tread the rest of their journey together through the tumultuous weathers of their mortal life. Having born and brought up in a remote village in Bihar, I was the fourth child in my family of six siblings; two brothers and four sisters. A culture in which marriages were solemnized at an early age, my parents also had similar expectations from me as early as I was just 13 years old and studying in the eighth standard. My eldest brother got married at the age of 15 years in 1957; the year I was born. He already had three kids when I was trying to elude from marriage. Though quite difficult to safely sail through, I tried to convince my parents to set aside the proposal in pursuit of my higher goals in life. Thankfully, I kept crossing some professional milestones like, the admission into the prestigious the then Indian School of Mines (ISM), Dhanbad in 1975, passing out of ISM in 1980 with flying colors and getting employed with the Coal India Limited immediately thereafter. The pressure of getting married kept growing exponentially with time. I had so far been seeking refuge behind the protective veil of my simple mother's deep affection and love for me.

I was posted at the Birsinghpur Colliery of the then Sohagpur Area of the Western Coalfields Ltd; (now Johilla Area of SECL, a subsidiary of the Coal India Limited). My next professional challenge was to obtain the First Class Mine Manager's Certificate of Competency; a significant milestone which many of the mining engineers in those days wished to cross before crossing over to the envisaged green pastures of a married world. However, the pressure to get married had been building up to the extent that I exhausted all my weaponry to defend myself. Till that time, all my siblings, elder and younger, including my eldest niece had been married. I was thus the last wicket in my family waiting to fall. On the other hand, my married colleagues were also fueling the fire to jump over the fence.

On the work front, the recovery of old West Rise Area of my Colliery, which had been sealed off due to a major fire way back in 1950 was planned. Recovery of this area was a big challenge as several earlier attempts to recover this area went futile. After previous failed attempts, the recovery this time was planned through a pair of vertical shafts sunk subsequently. I was assigned with this responsibility along with a competent team of supervisors. The area was successfully recovered in 1982. This accomplishment spread my reputation like a fire in the woods. Since I had obtained my Second Class Mine Manager's Certificate of

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Competency by then, I was assigned the shift duty as Under Manager with higher responsibilities. While it was an elevation for me, it was also a new challenge which I was able to successfully win over with the full support of my dedicated colleagues.

Soon arrived the year 1983, my sole chance before marriage to appear in the First Class Mine Manager's examination. I had little time to prepare due to my night duty which used to exhaust me to the core. As if it was not enough, I had also chosen to teach legislation to the final year students of the Government Polytechnic, Shahdol. Thursday being my weekly day of rest, I used to take three to four classes in that single day. Being a win-win situation, it created the urge within me to leave no stone unturned in preparation for my lectures while it also generated an equal interest and engagement on the part of students who absorbed the subject to full taste.

As ill luck would have it, I fell sick just two weeks before the examination, and was completely bed ridden. I stand forever indebted to my well-wishers like Mr Ashok Kumar; my close colleague, Dr. Mrs Chakroborty, wife of my the then Manager; late Deepak Chakroborty who not only visited me regularly to know my wellbeing but also helped me in revising the course content for the examination.

Fortunately, with efforts of my peers I was lucky enough to crack the written examination. The excitement of my close friends and family filled my heart with joy that can't be described in words. I was determined to crack the verbal round as well. During this time, back shifts proved to be a boon as they were quite calm and peaceful for studies. Helpless in the hands of my commitment towards my duty, I continued to go for underground inspection but my caring supervisors and workers always insisted on to concentrate on my studies. It was no less than a blessing to have such understanding and supportive colleagues.

At personal front, the pressure for getting married had built up to the extent that soon after declaration of my First Class results in 1984, the much awaited event was locked in the same year itself. Though all seemed clear for the final take off, my dear father left for heavenly abode leaving no option for us but to defer the wedding to the next year.

In my professional world, my new competency certificate enabled my elevation to the level of Assistant Manager with bigger responsibilities. As the big event was nearing, travel plans were worked out and advance train reservation was secured to reach my village one week before the date of marriage, so that some pre-wedding ceremonies could be performed.

As the excitement was building up to park the life into the next orbit, devils were also on work to derail the much awaited launch. As luck would have it, the regular Mine Manager had gone on leave authorizing me to hold charge of the mine with the commitment to return on the day of my departure which he could not. Furthermore, a fatal accident also took place in the previous night shift which required my personal presence to manage the whole incident. This situation brutally hung me between my personal aspirations on one hand and my professional obligations on the other. It was quite late on that day when my regular Manager suddenly appeared on the scene but by that time, I was left with no option but to drop my travel plans with no means to inform my parents about the deferral. Statutory inquiry into occurrence of the accident by DGMS commenced three days later where I was required to record my statement before the Inspector. These were the times when I felt helpless in the hands of my destiny that had inked such a rough and bumpy trajectory for me.

After my statement, I was finally permitted to leave. I hurriedly packed my belongings and soon left for the Katni Railway Station, about 90 km away by road to catch any train available. Due to marriage season in India, all trains were running full to their capacity and I had no reservation in any of them. The sheer excitement of getting back home for the so special event dwarfed the difficulties that I had to face by undertaking an extremely arduous journey. I took trains to Banaras, took an auto from Banaras to Mughal Sarai, and jumped on another train to Arrah. The final leg of my journey from the Arrah Bus Stand to my village was by travelling with a marriage party to my neighboring village as I had missed the last bus.

The last half a kilometer of walk to the doorsteps of my sweet home raised the dust of hope that brightened my face. My sudden appearance in our courtyard at 9 pm on 27th May, 1985 made everyone burst into excitement and hugs with tears in the eyes of my helplessly waiting mother, family members and the relatives whose happiness knew no bounds. The bride side also took a sigh of relief who had lost all hopes of my arrival for my Tilak ceremony on that very day itself. For me, it was no less than winning the whole world to get to the stage which my mother had been decorating with her little dreams all these years for me.

Thus ended the countdown for the final take off with full celebrations and excitement filling the air all around. With rising of the Sun on 29th May, 1985, my wife entered my life and her presence filled our lives with happiness. We wrote many interesting chapters together all these years, and she still continues to be a formidable support for the entire family.

In this journey, I learnt that we simply cannot abandon the ship every time we encounter a storm. As they say "It's your reaction to the adversity and not the adversity itself that determines how your life's story will develop". I am happy to declare I wrote my life's story without abandoning the ship!

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