DECARBONIZING INDIA'S POWER SECTOR THROUGH CO_2 STORAGE IN DEEP UNMINEABLE COAL SEAMS: POTENTIAL AND PATHWAYS

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OUTLINE OF THIS TALK

- Climate change: urgency and impacts
- The genesis of net-zero targets
- Where are we right now?
- Elements of a net-zero energy system
- Role of coal for India's future consistent with net-zero by 2070

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CLIMATE CHANGE IS PRODUCING PRONOUNCED AND WIDESPREAD EXTREMES

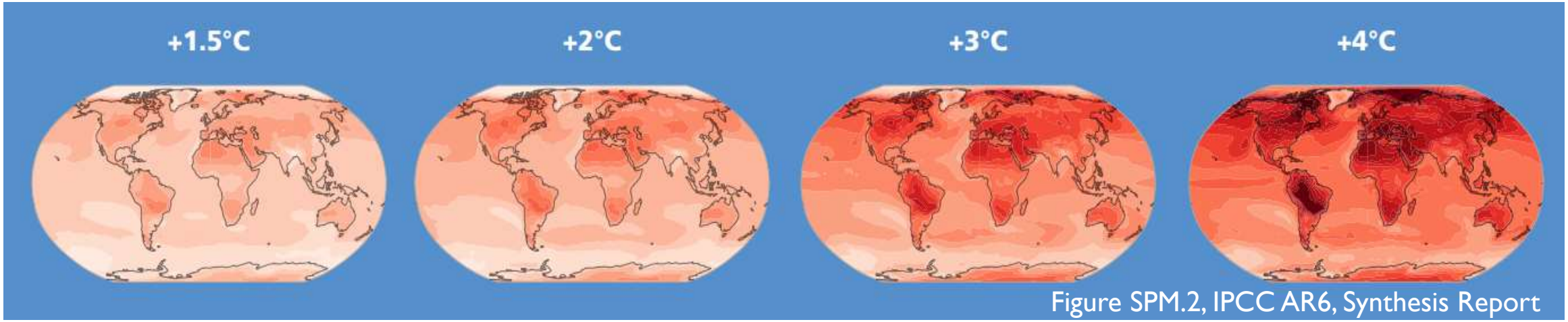

Figure SPM.2, IPCC AR6, Synthesis Report

- Those who contributed the least to climate change are often the most vulnerable to its impacts.
- Millions exposed to acute food insecurity, reduced water security.
- Biggest impacts in parts of Africa, Asia, Central/South America, LDCs, Small Islands, Arctic.
- People in highly vulnerable areas up to 15 times more likely to die in floods, droughts, storms (compared to those in most resilient areas)
- **Fairness is one of the solutions**

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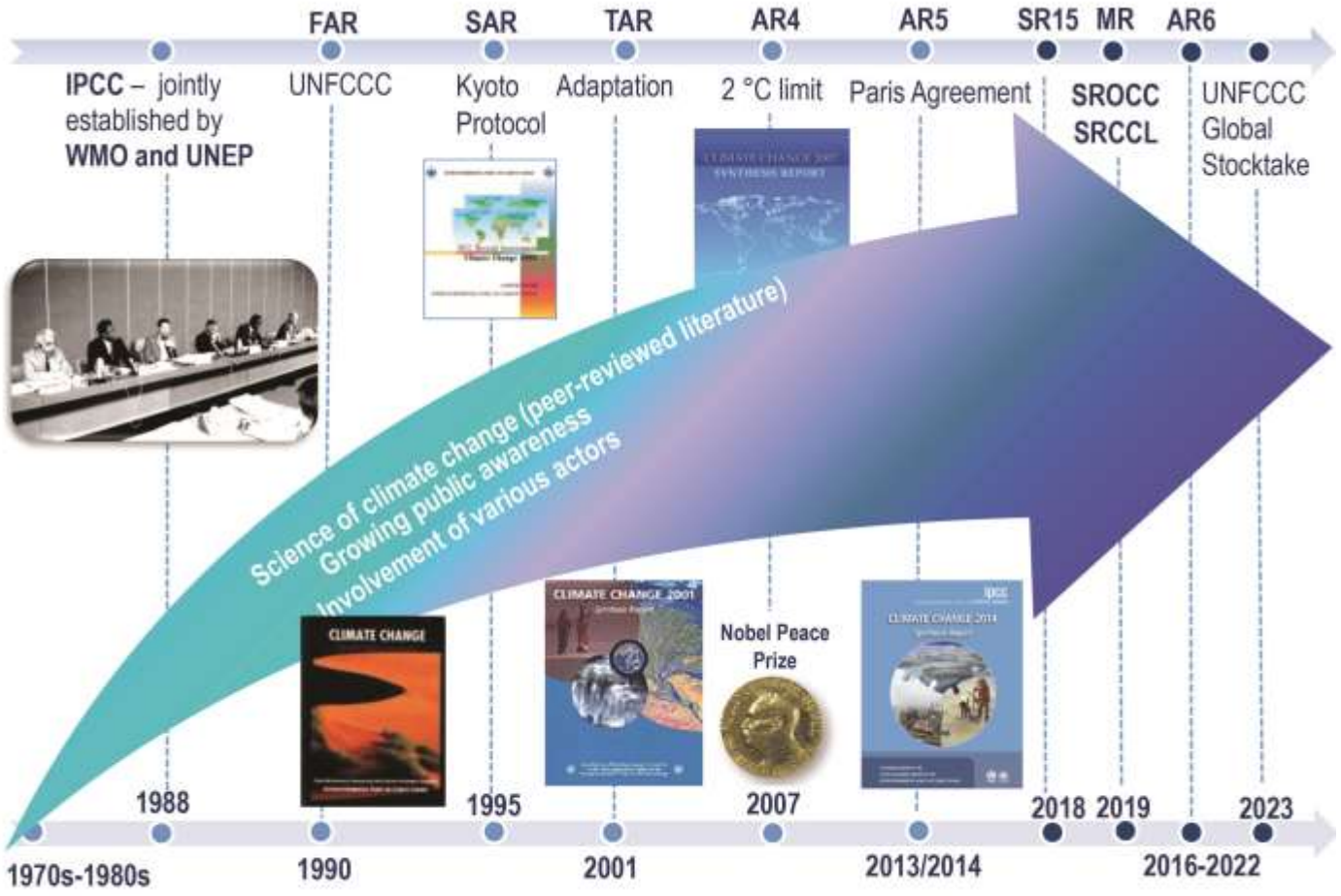
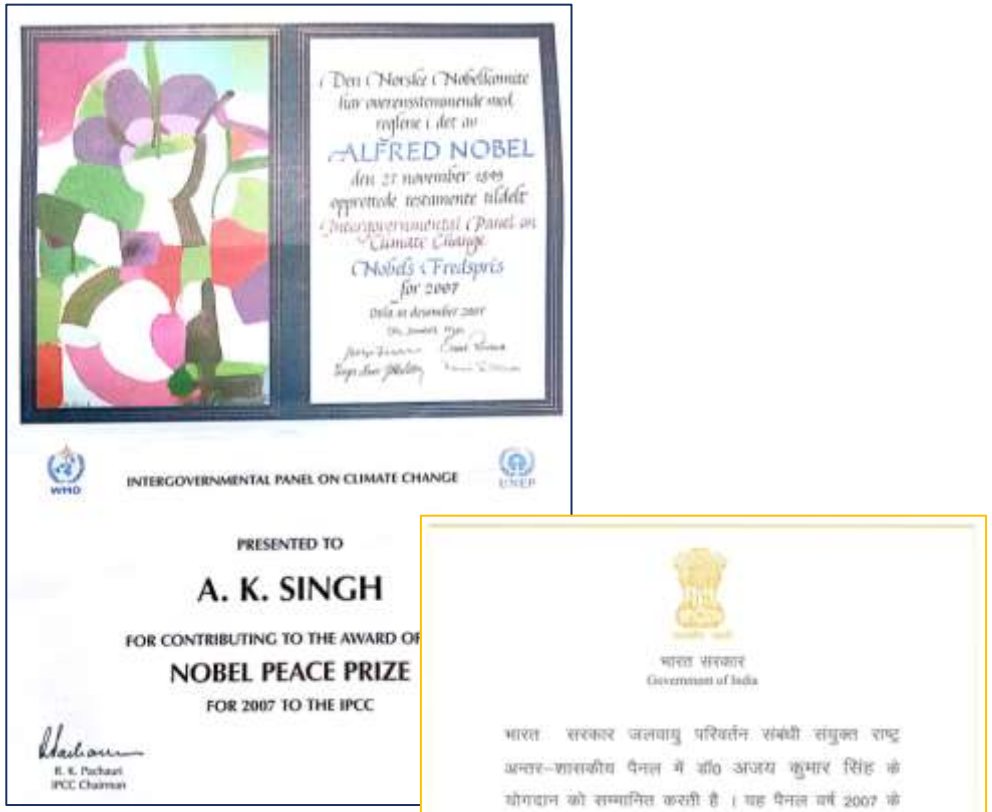
IPCC AND 30+ YEARS OF ASSESSMENT OF CLIMATE CHANGE



https://archive.ipcc.ch/pdf/ar6_material/AC6_brochure_en.pdf

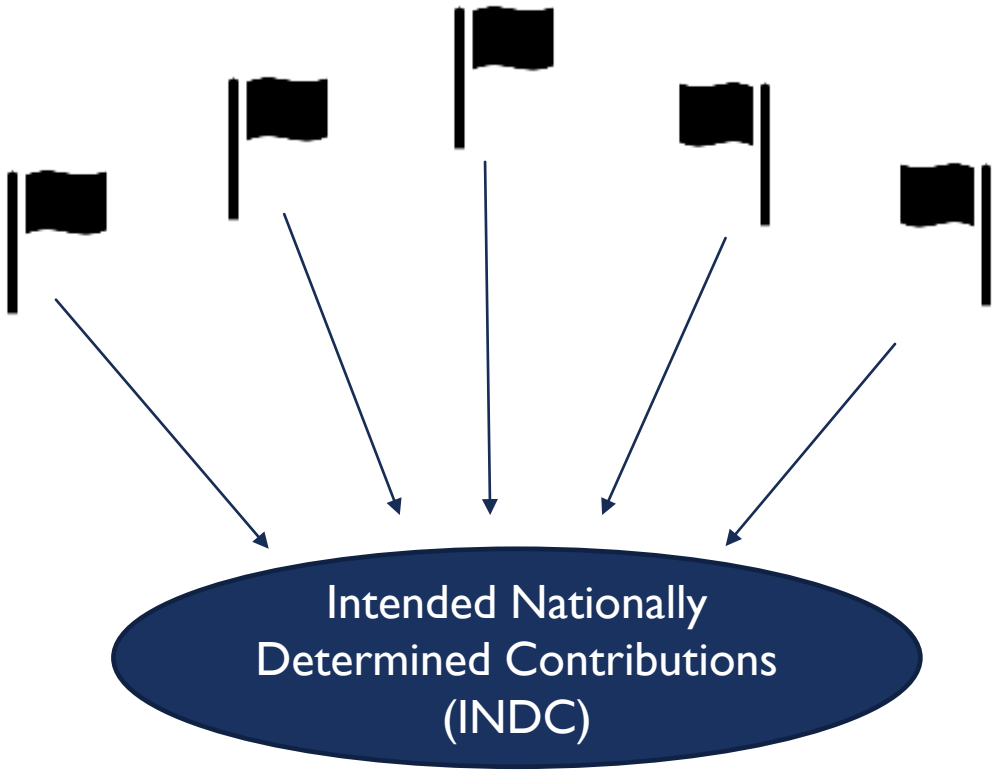
- The Intergovernmental Panel on Climate Change (IPCC) is a panel of experts for bringing out a systematic assessment of climate change primarily to inform the UNFCCC process:
  - Physical science basis of climate change (WG I)
  - Impacts, vulnerability and adaptation to climate change (WG II)
  - Mitigating climate change (WG III)
- In addition, the IPCC also provides methodological guidance on estimating greenhouse gas emissions and sinks
- Thus far, there have been six assessment report cycles of the IPCC and the seventh is now underway

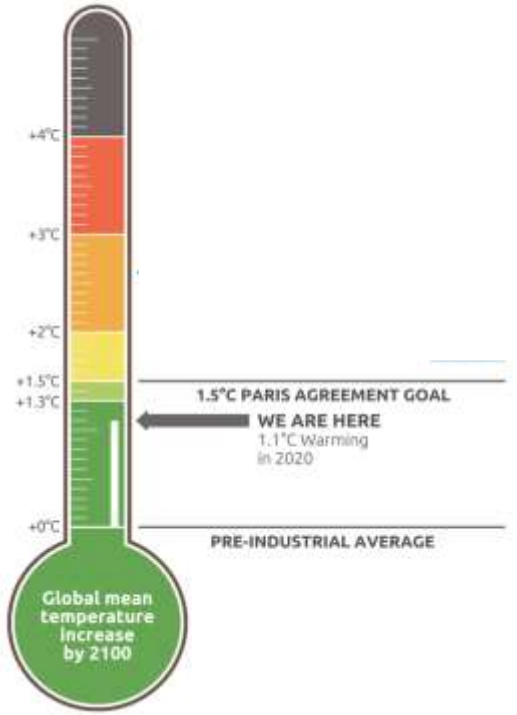


Felicitation ceremony for Indian researchers involved in the IPCC by the then Prime Minister of India at this residence, Nov 2027

PARIS AGREEMENT WAS SIGNED IN 2015 FOLLOWING AR5 PUBLICATION

- Signed on December 12, 2015 at COP21 in Paris
- 190+ Countries; Largest international cooperation of its kind





Scientifically informed target

KEY GOALS OF THE PARIS AGREEMENT

Mitigation: Reducing (or stopping) climate change by limiting the rise (or accelerating decline) of greenhouse gas emissions

Adaptation: Adjusting to existing or anticipated climate change

Both are crucial in their own contexts

Picture Courtesy: Yale Sustainability

INDIA'S NATIONALLY DETERMINED CONTRIBUTIONS (NDCS) 2021-2030

1. To put forward and further propagate a healthy and sustainable way of living based on traditions and values of conservation and moderation.
2. To adopt a climate friendly and a cleaner path than the one followed hitherto by others at corresponding level of economic development.
3. **To reduce the emissions intensity of its GDP by 45 per cent by 2030 from 2005 level.**
4. **To achieve about 40 per cent cumulative electric power installed capacity from non-fossil fuel-based energy resources by 2030 with the help of transfer of technology and low cost international finance including from Green Climate Fund (GCF).**
5. **To create an additional carbon sink of 2.5 to 3 billion tonnes of CO_2 equivalent through additional forest and tree cover by 2030.**

INDIA'S NATIONALLY DETERMINED CONTRIBUTIONS (NDCS) 2021-2030 (CONTINUED)

6. To better adapt to climate change by enhancing investments in development programmes in sectors vulnerable to climate change, particularly agriculture, water resources, Himalayan region, coastal regions, health and disaster management.
7. To mobilize domestic and new and additional funds from developed countries to implement the above mitigation and adaptation actions in view of the resource required and the resource gap.
8. To build capacities, create domestic framework and international architecture for quick diffusion of cutting edge climate technology in India and for joint collaborative R&D for such future technologies.

India's Updated First Nationally Determined Contribution Under Paris Agreement (2021-2030), August 2022 Submission to UNFCCC, Government of India (https://unfccc.int/sites/default/files/NDC/2022-08/India%20Updated%20First%20Nationally%20Determined%20Contrib.pdf)

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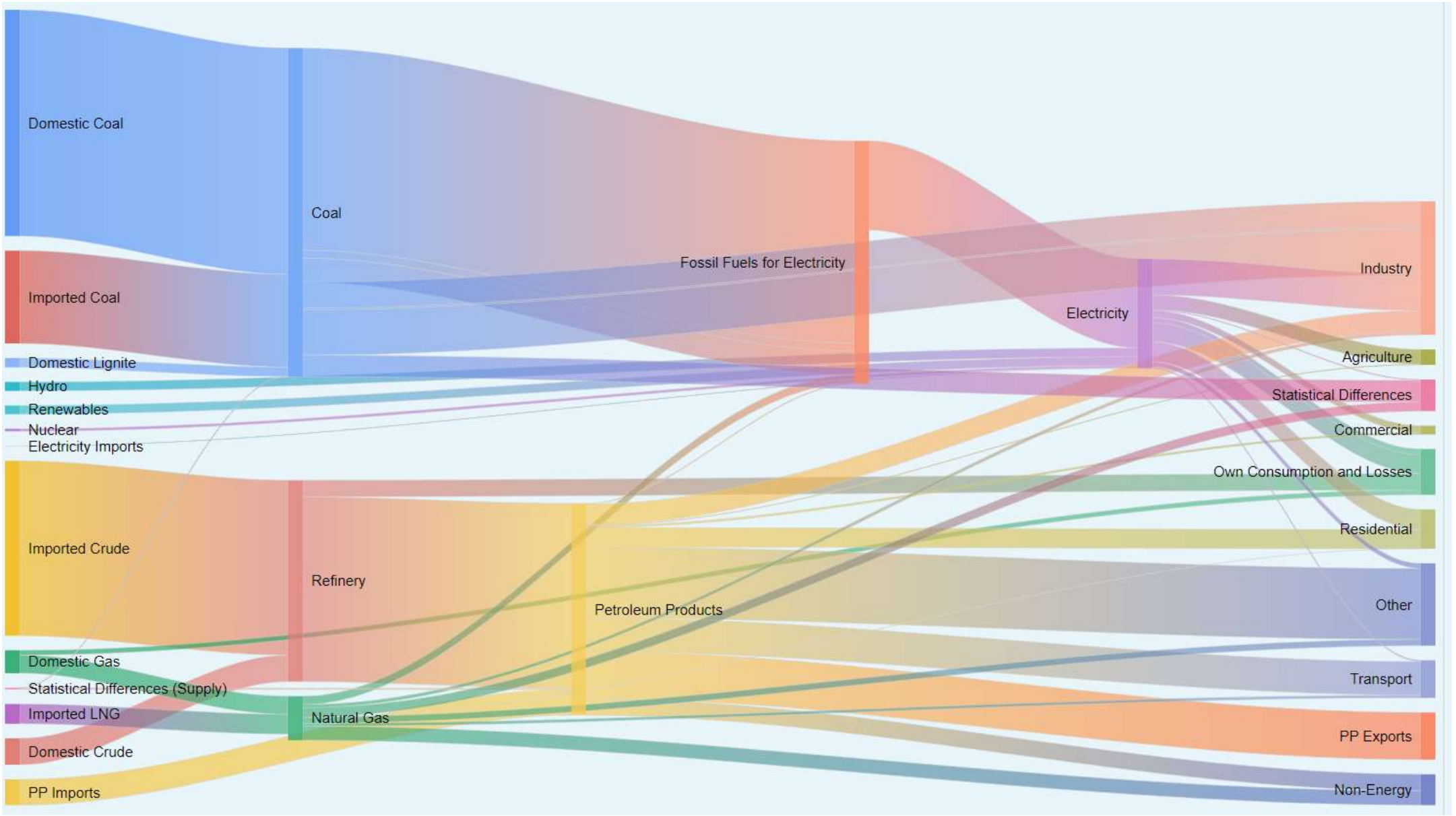
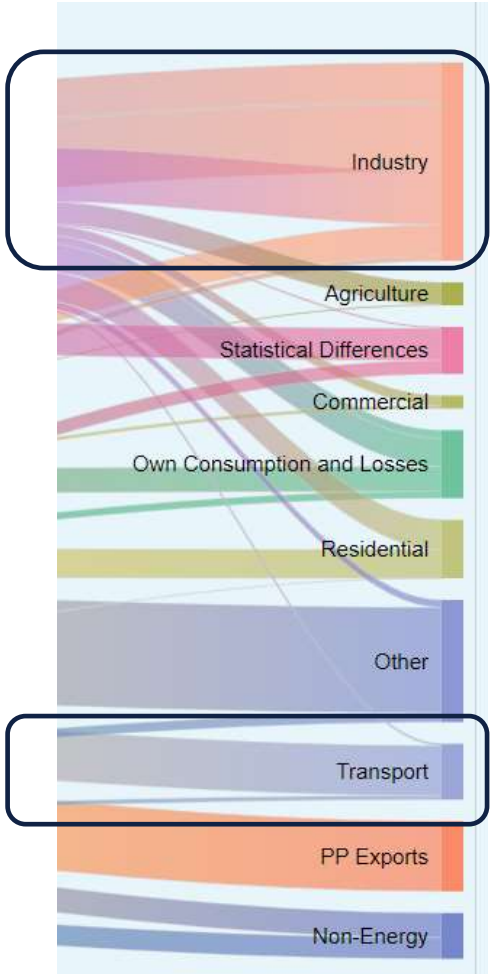


India's energy use Sankey diagram developed by NITI Aayog

HARD-TO-DECARBONIZE SECTORS

- Growth in solar and wind has been supported strongly by the government; however, they may support only electricity
- Heavy duty transport and industry and hard-to-decarbonize sectors
- Transport requires high energy density
  - Even if we see vast progresses in light-duty vehicles, aviation and heavy-duty transport will likely need liquid fuels for a long time
- Industry requires very high temperature, which is difficult to electrify
- Fossil fuels are also sources of carbon and hydrogen, in addition to energy

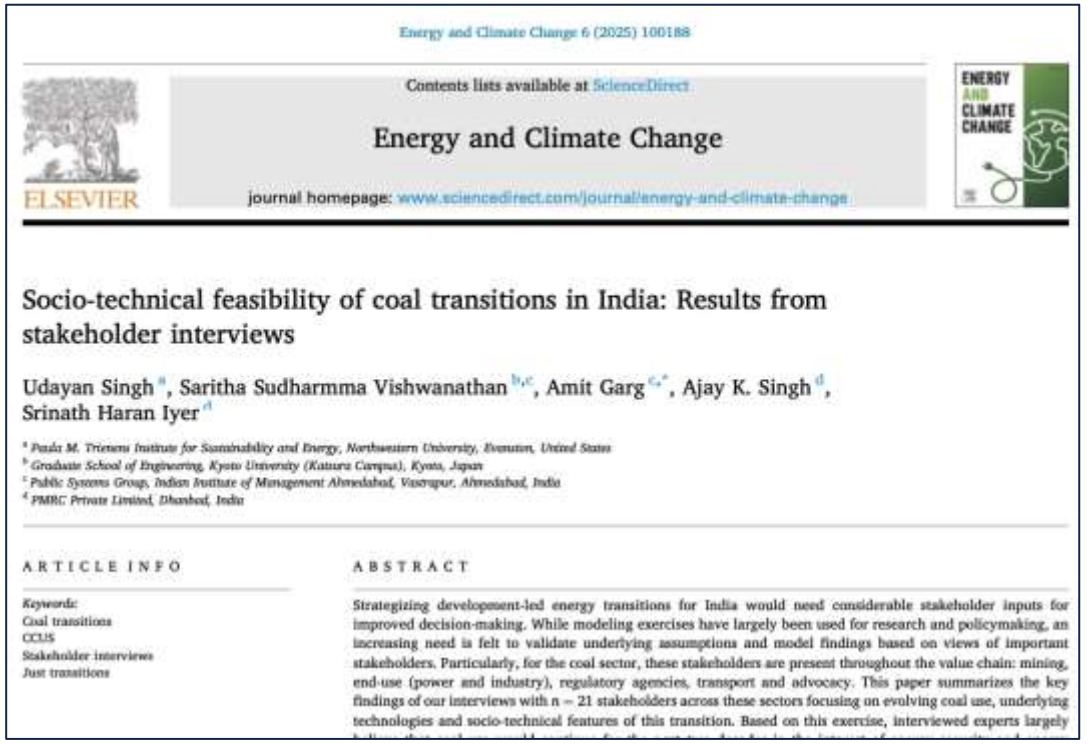


BEYOND MODELING: OUR APPROACH TO HOLISTICALLY UNDERSTAND BETTER CURRENT STATE OF INDIA'S ENERGY MIX

"All models are wrong, some are useful"

Box and Draper (1987)

- Integrated assessment modeling and lately national energy systems modeling have been influential in shaping the policy discourse in climate mitigation – particularly in the IPCC Assessments
- There is a strong need to evaluate these models for realism for technological and societal feasibility
- Our work with IIM Ahmedabad sought to reconcile modeling estimates with views of stakeholders across the coal supply chain – understand the actual rate of growth in technologies along with key challenges in implementation



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ELSEVIER

ENERGY AND CLIMATE CHANGE

Socio-technical feasibility of coal transitions in India: Results from stakeholder interviews

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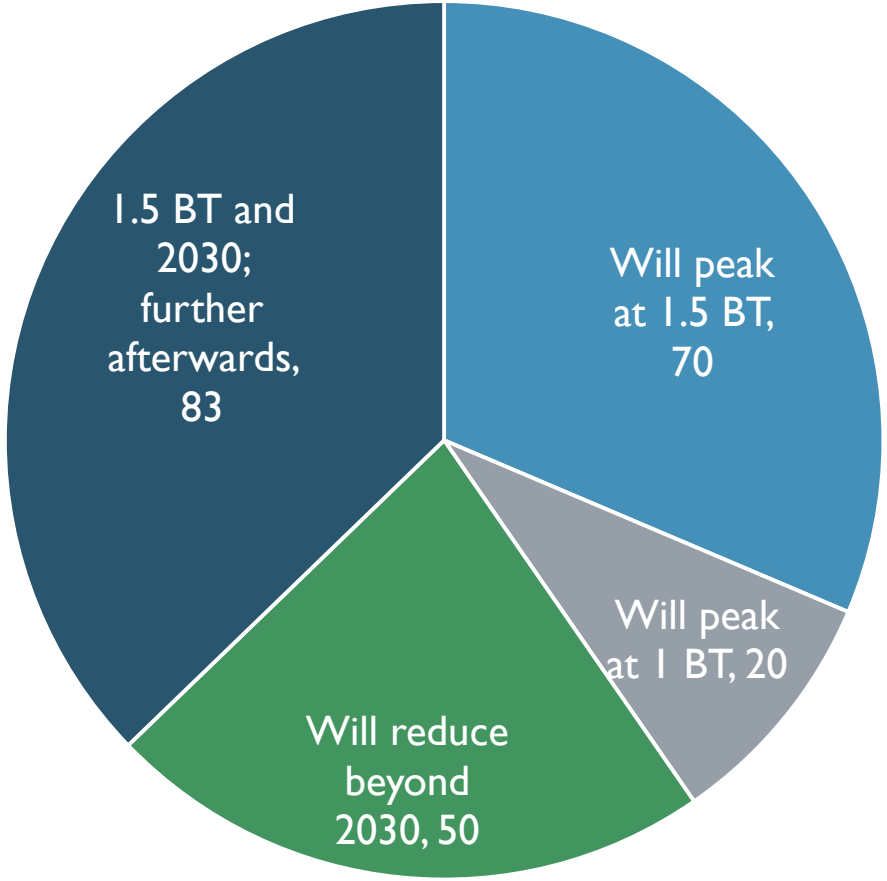
ABSTRACT

Strategizing development-led energy transitions for India would need considerable stakeholder inputs for improved decision-making. While modeling exercises have largely been used for research and policymaking, an increasing need is felt to validate underlying assumptions and model findings based on views of important stakeholders. Particularly, for the coal sector, these stakeholders are present throughout the value chain: mining, end-use (power and industry), regulatory agencies, transport and advocacy. This paper summarizes the key findings of our interviews with n – 21 stakeholders across these sectors focusing on evolving coal use, underlying technologies and socio-technical features of this transition. Based on this exercise, interviewed experts largely

WE CANNOT WISH AWAY COAL IN INDIA

- "Should coal use in India increase or decrease"
  - 74% say yes (one third enthusiastically yes)
  - < 20% believe no
- This increase would come from increased coal capacity (as per recent speculations), increasing PLF for existing power plants and also coal diversification (e.g. methanol)



What future trajectory do you see for coal use?

2024 GLOBAL COAL DEMAND

The retirement of coal-fired power plants in the West has had no impact on global coal demand.

- **Global Demand**: 8.77 Bt in 2024 (+1%)
- **Growth**: +4.7% in 2022, +2.4% in 2023
- **China**: Demand growth 1% to 4.9 Bt in 2024
- **India**: Projected growth of 5% to 1.3 Bt.
- **EU/US**: Demand continues to fall, but at a slower pace
- **Power Sector**: Coal-based generation 10,700 TWh (35% of global electricity generation, 1% growth) in 2024

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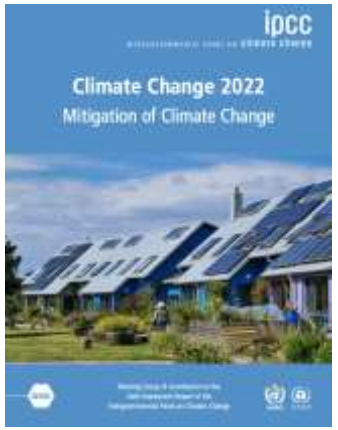
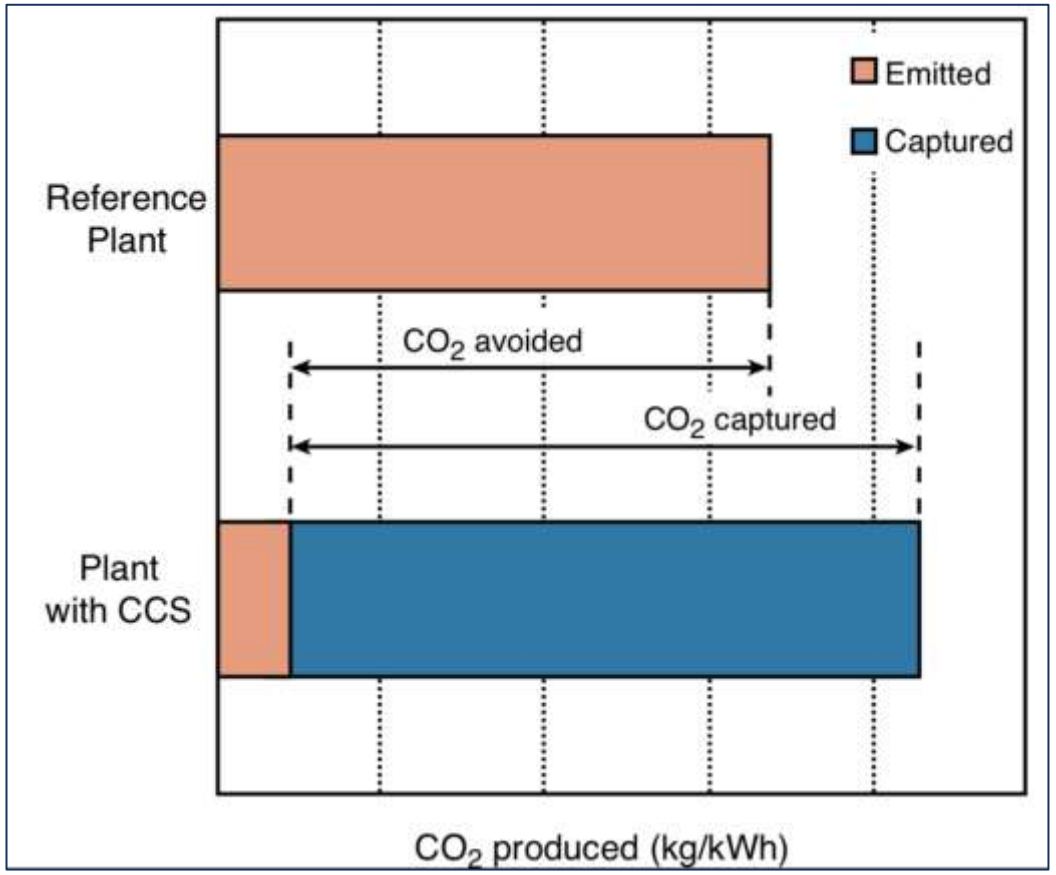
GETTING TO NET-ZERO

- International and Indian literature point to two different ways of getting to net-zero
- Both are important to understand and applicable to India
- Elements of a net-zero energy system as per AR6 in a global context
  - Increased share of wind, solar and other 'carbon-free' energy (e.g., nuclear) in the primary energy
  - Higher share of energy carriers (e.g., electricity, hydrogen, synthetic fuels and ammonia) in final energy
  - Increased share of CDR
  - Fossil fuel use will be mostly with CO_2 capture and storage
- In Indian context, we need development-led transition and not transition-led development
  - Increased energy use
  - Diversified primary energy use that facilitates energy security
  - Energy sector will still emit 0.5-1 BtCO2 in 2070, which will be removed by AFOLU and potentially engineered CDR



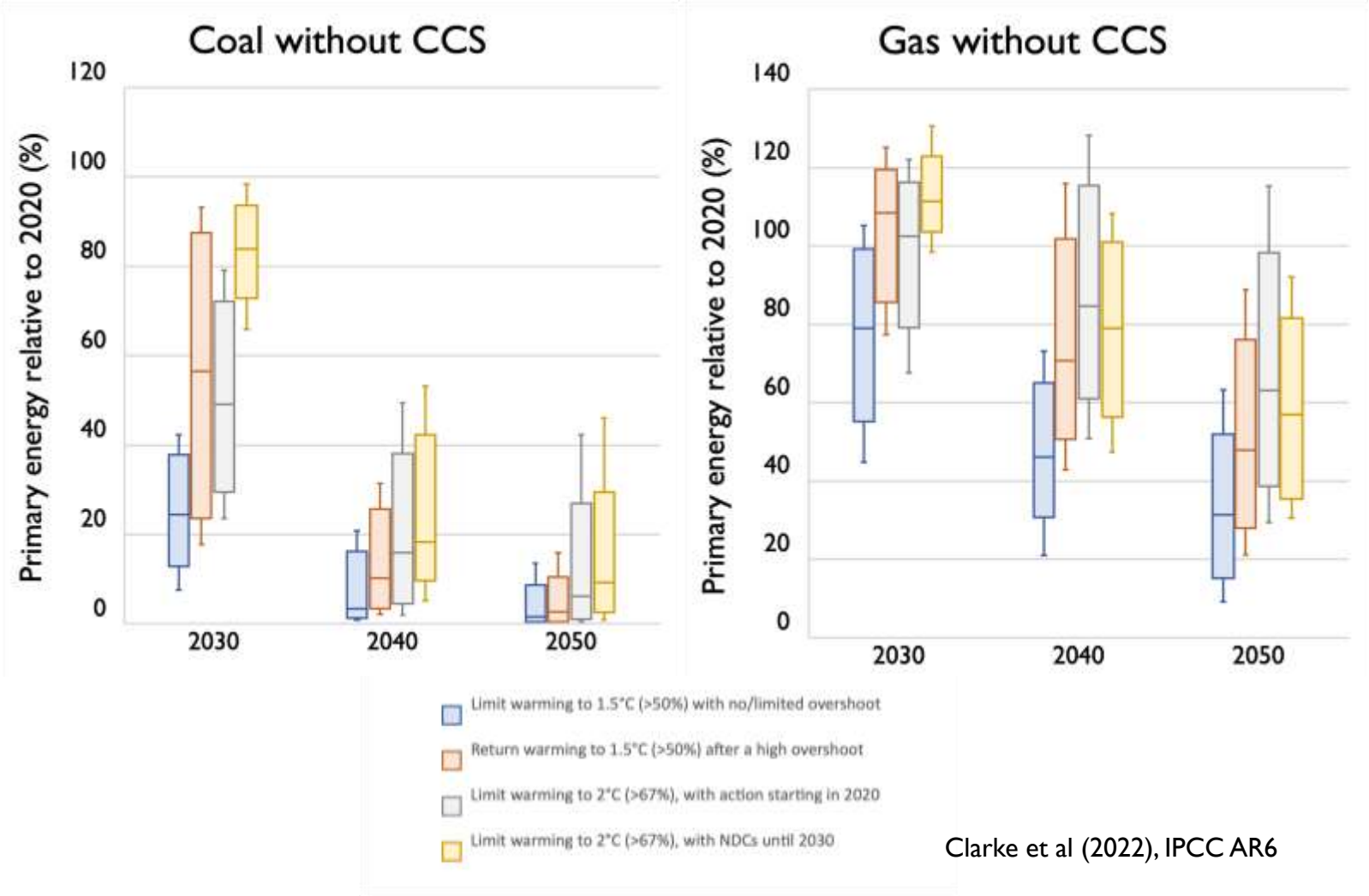
USING CO_2 CAPTURE TO AID DECARBONIZATION OF FOSSIL ELECTRICITY



IPCC, 2005

- CO_2 capture and storage in fossil electricity can help avert ~90% CO_2 emissions
- Major issue: CO_2 capture is expensive in terms of economic and energy costs
- Hasn't commercially taken off

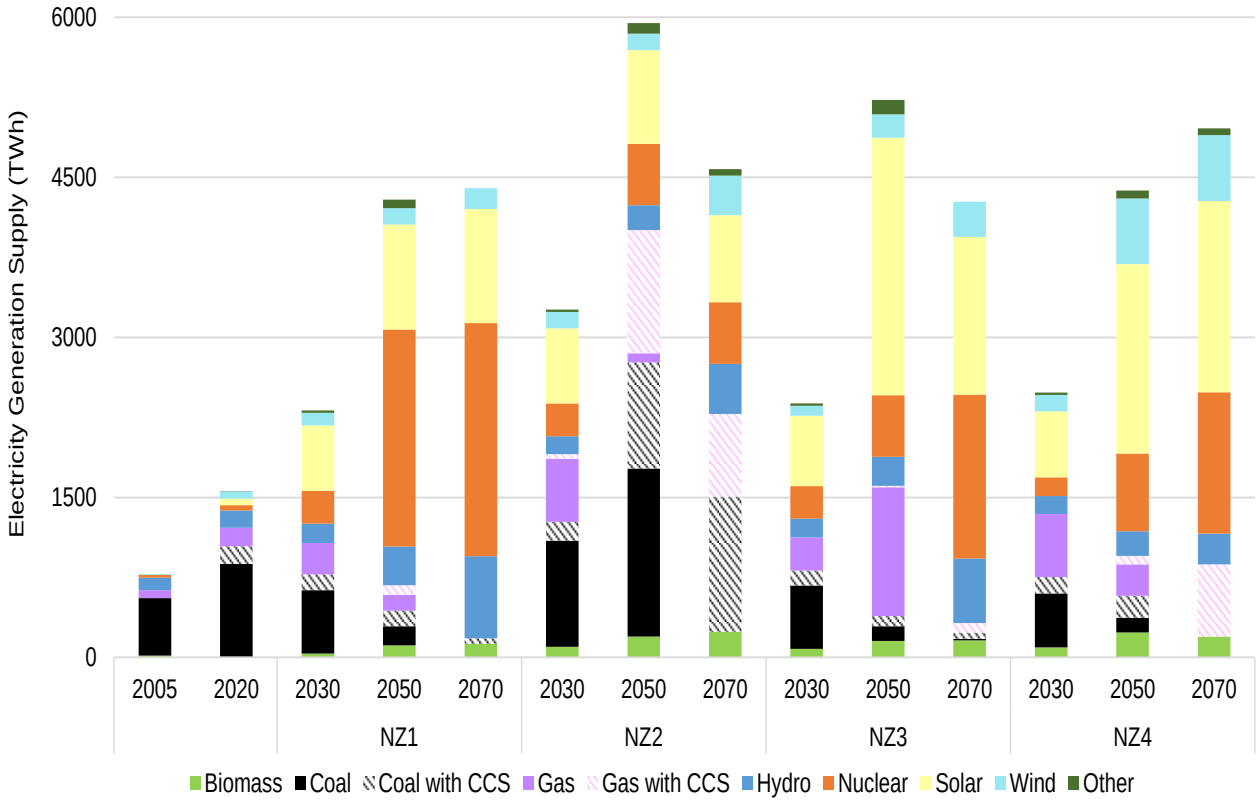
IPCC AR6: UNABATED FOSSIL FUEL USE WOULD NEED TO GO DOWN



Clarke et al (2022), IPCC AR6

- IPCC AR6 consensus:
  - Unabated fossil fuel use (i.e. without CCS) would need to decrease sharply if global temperature rise is to be limited to 1.5°C or 2 °C

HOW CAN INDIA REACH NET ZERO BY 2070?



- NZ1: Policy Thrust on Nuclear, NZ2: on coal with CCS, NZ3: on Renewables, NZ4: All of the above
- **Coal is projected to continue until the next two decades as the backbone of the Indian energy system. However slowly but surely non-fossil energy comes in (renewable and nuclear).**
- Nuclear power would be part of the NZ solution under all future scenarios.

Garg, A., Patange, O., Vishwanathan, S. S., Nag, T., Singh, U., & Avashia, V. (2024). Synchronizing energy transitions toward possible Net Zero for India: Affordable and clean energy for all. A Report Prepared for Office of the Principal Scientific Advisor (PSA) to Government of India and Nuclear Power Corporation of India Limited (NPCIL).

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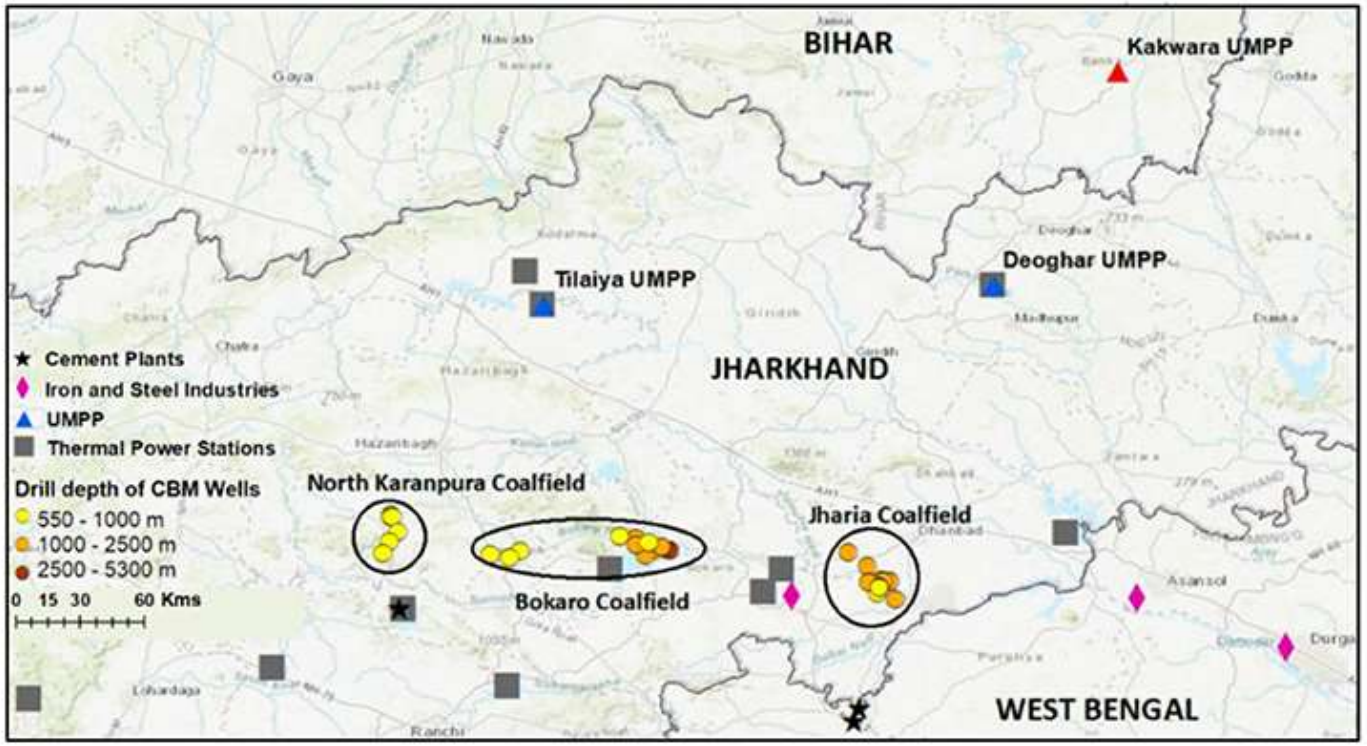
INDIA'S COAL RESERVES & PRODUCTION GROWTH

Abundant resource and accessible at reasonable costs

- Resource: 389.42 BT as on 1st April 2024
  - Gondwana: 387.76 BT (99.57%), Tertiary: 1.66 BT (0.43%)
- Annual production: 893.19 MT in 2022-23
- Annual production: 997.83 MT in 2023-24 (Growth: +11.72%)
- Annual production: 1.047 BT in 2024-25 (Growth: + 4.93%)
- Target: 1150 MT in 2025 – 26

Coal consumption is set to remain at these high levels for 2-3 decades

ENHANCED CBM SUB-CLUSTERS IN EASTERN INDIA?



Source: Singh et al, 2022

- Scope for ECBM recovery as increasing geological pressure with increasing depth holds more CH_4 in place
- Eastern India has 150 Mt-CO_2 emissions in close proximity
- Gassy coalfields (Raniganj, Jharia, East Bokaro, North Karanpura) which could be prospective ECBM subclusters
- There is already active coalbed methane extraction going on in these coalfields by public and private sector companies
- Would be suitable for ECBM from 2030-35 onwards

PROMISING CO_2-ECBM SITES IN INDIA

Damodar Valley, Eastern India, most promising site

- ✓ High gassiness
- ✓ Production of CBM ongoing

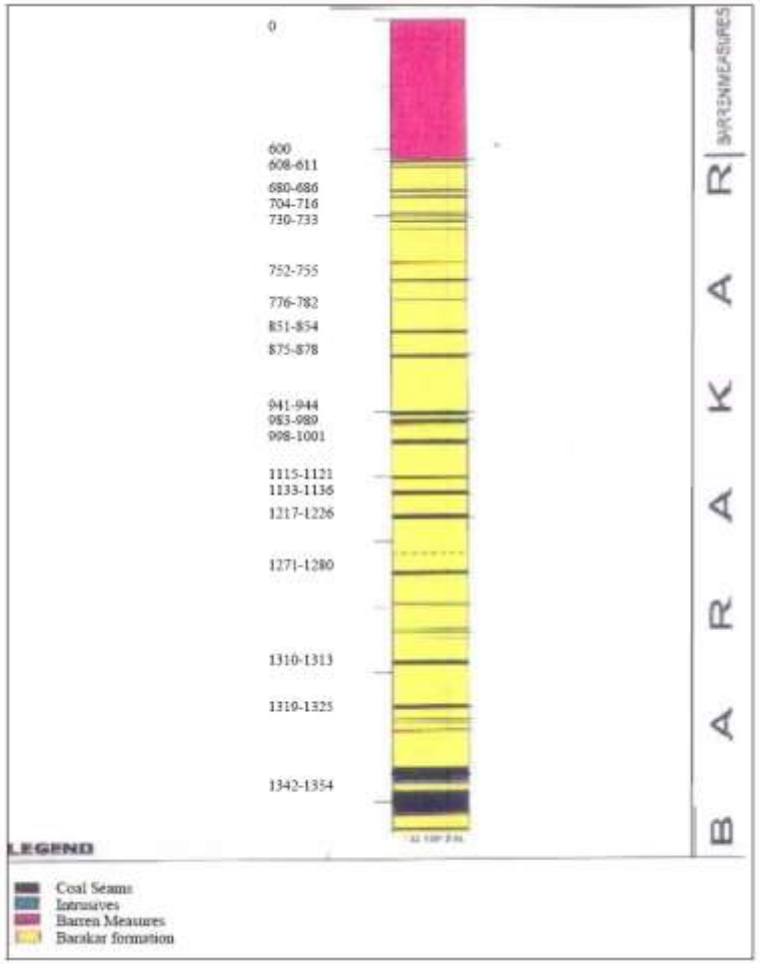
POTENTIAL AREAS

Potential areas for implementation:

- ✓ **Raniganj Coalfield**
- ✓ **Jharia Coalfield**
- ✓ **East & West Bokaro Coalfields**
- ✓ **North & South Karanpura Coalfields**

GEOCHEMICAL CHARACTERISTICS OF COALS IN MOHUDA SUB-BASIN IN JHARIA

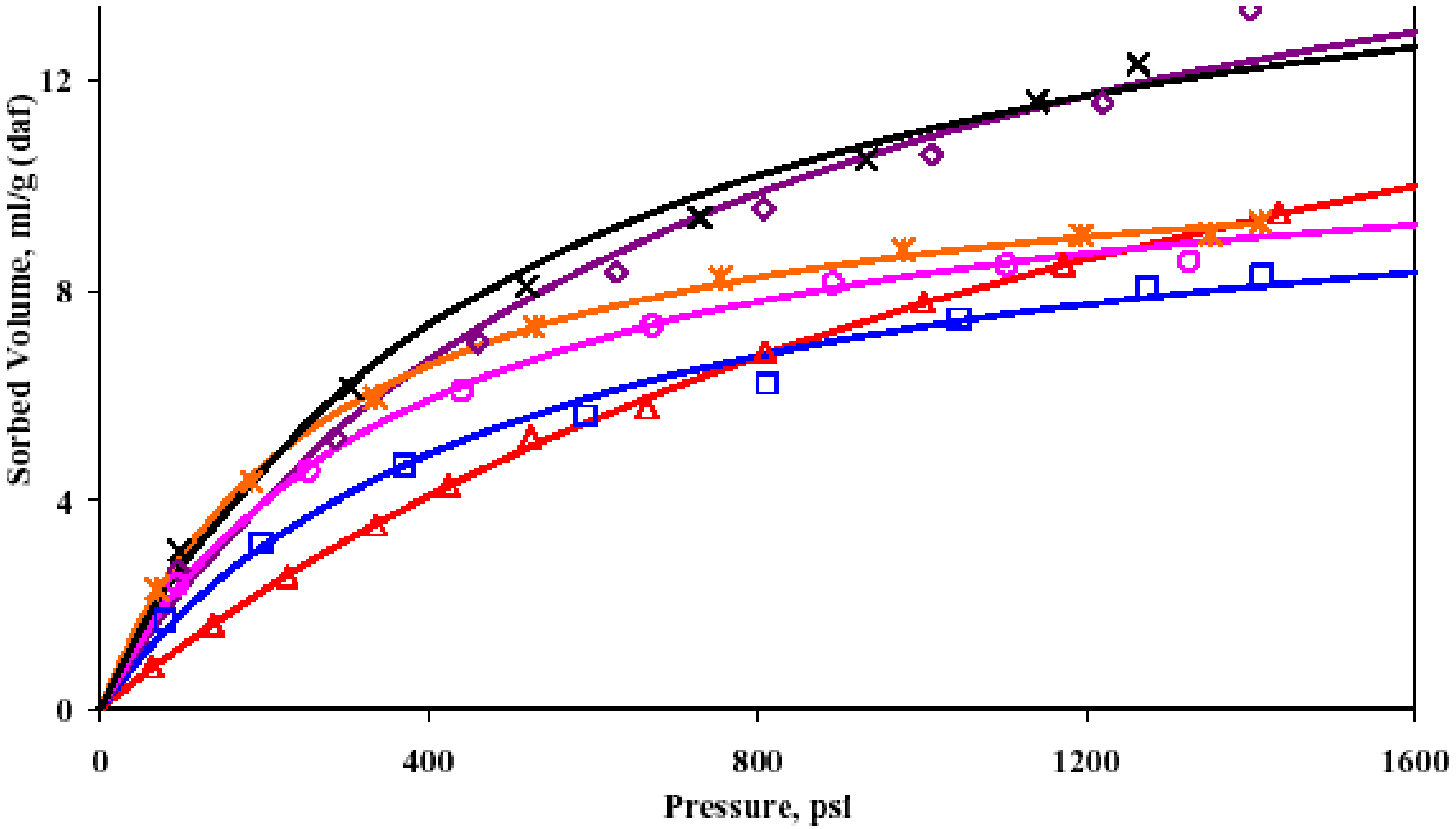
- Two vertical boreholes were drilled in the Mohuda Sub-basin
- Collected subsurface drill cores
- Comprehensive study of in-situ gas content
- Gas content of coal samples was 10 - 35 m^3/t
- *In-situ* gas content of Shale: 0.15 - 3.69 m^3/t
- High paleo-geothermal gradient: 5.57 to 6.19°C per 100 meters of depth
- TOC content: 9 - 17 weight percent, indicates the presence of source rock with excellent organic richness.



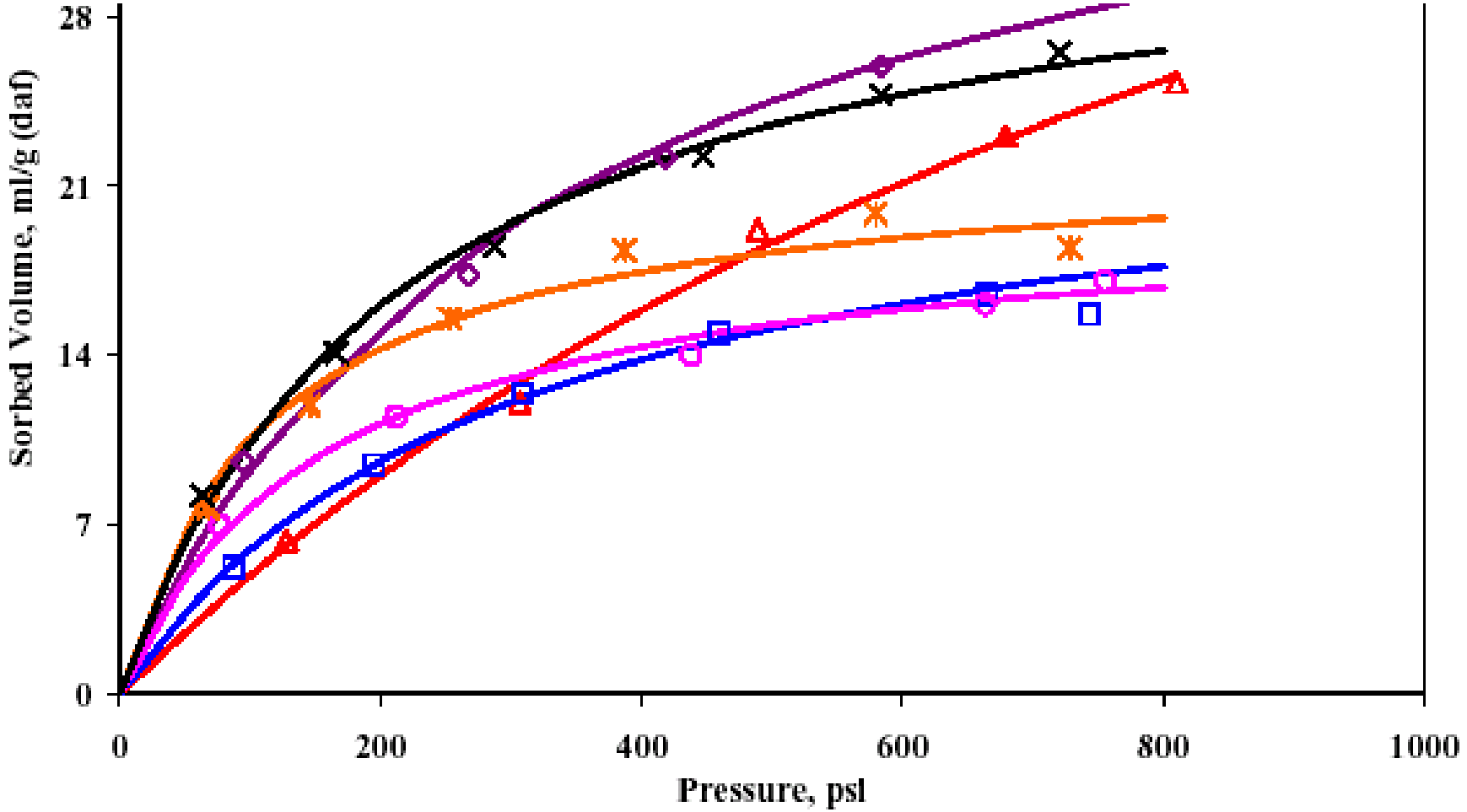
COMPARATIVE ADSORPTION OF CO_2 AND CH_4

- **Studies conducted so far supports stronger affinity of CO_2 to the coal molecule.**
- **2 to 3 molecules of CO_2 may displace one molecule of methane**
- **It means carbon dioxide is preferentially adsorbed onto the coal structure over methane (2:1 ratio).**
- **Methane sorption capacity for Indian coals were investigated.**
- **Understanding controls on CO_2 and CH_4 adsorption in coals is important for the modeling of both CO_2 sequestration and CBM production.**

METHANE SORPTION OF INDIAN COAL



CO_2 SORPTION OF INDIAN COAL



METHANE AND CO_2 ADSORPTION

Methane Adsorption (actually measured)		Estimated CO_2 Adsorption cc/g
Pressure (atm)	Moisture Equilibrated cc/g	
0	0	0
4.91	1.8	3.6
10.99	3.7	7.4
18.08	5.3	10.6
27.91	6.5	13.0
37.62	7.6	15.2
48.04	8.4	16.8
57.14	9.2	18.4
67.69	10.0	20.0
77.20	10.4	20.8
86.98	10.8	21.6
96.57	11.1	22.2

ESTIMATED CO_2 STORAGE CAPACITY

Coalfield	CO_2 storage potential in Mt with 90% saturation level			Total-Mt
	Unmineable beds	Grey areas	Concealed areas	
East Bokaro	x	84.94	x	85
South Karanpura	x	36.33	x	36
Jharia	x	71.20	x	71
Raniganj	x	41.57	x	42
Singrauli	1.32	x	x	1
Sohagpur	x	36.70	x	37
Mand Raigarh	2.67	x	x	3
Talcher	37.06	87.75	x	118
Godavari-Ramgundam	67.75	x	?	68
Cambay Basin	x	x	1885.02	1885
Barmer Sanchor basin	X	x	1667.95	1668
W. Bengal Gangetic Basin	x	x	234.80	235
Birbhum	x	x	151.61	152
Domra Panagarh	x	x	29.20	29
Wardha	x	x	11.80	12
Kamptee Coalfield	x	x	17.48	17
Total				4459

KEY TAKEAWAYS (1)

- Climate change is a pressing challenge and costs of inaction will be much higher than costs of climate action (mitigation + adaptation).
- Multiple cycles of IPCC assessments and international negotiations have given way to net-zero targets, India committed to reaching net-zero emissions by 2070, indicating GoI commitment to climate change.
- Coal dominates Indian energy sector and remains indispensable – not only for power generation but for industrial uses.
- India needs much more energy, so it is not a question of coal or renewables, it has to be coal and renewables.
- Costs of renewables (particularly solar) have come down substantially and this aligns well with GoI *Panchamrit* goal – which includes 500 GW non-fossil capacity by 2030,

KEY TAKEAWAYS (2)

- For a net-zero energy system, elements include increased share of renewables, electricity/hydrogen, energy efficiency and potentially CDR.
- In the Indian case, development must lead and therefore, in addition to above goals, energy access must be prioritized. This will need coal with CCUS and nuclear.
- Currently, India's per-capita energy use is 21 GJ/y. No country has reached HDI of 0.9 < 75 GJ/y. With energy efficiency, India could target 56 GJ/y but unlikely that HDI 0.9 can be reached below this.
- Coal is likely to remain an important player. But technologies need to be explored on both upstream and downstream sides. Most coal use in a net-zero energy system will be with CCS. In addition to power, coal can also play an important role in methanol production.
- At the same time, coal seams can act as a geologic storage site with considerable opportunities in Indian coalfields.

THANK YOU!

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