Potential for CCS in India: Opportunities and Barriers

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Outline

- Overview of India's Energy Sector
- GHG mitigation potential – Scenario Analysis
- Cost implications
- CCS potential
- Barriers to CCS
- Conclusions

Domestic coal availability

Fuels	2001	2036
Coking coal (million tonnes)	27	50
Non-coking coal (million tonnes)	299	550
Lignite (million tonnes)	25	50

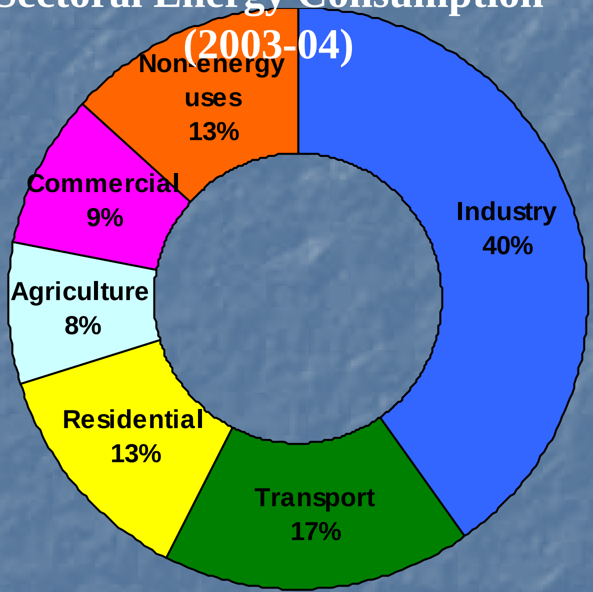
Natural gas availability

Natural Gas availability (MMSCMD)

	2006	**2011**	**2016**	**2021**	**2026**
Domestic availability	*84*	*123*	*125*	*125*	*125*
LNG import	*25*	*65*	*95*	*125*	*135*
Transnational Pipelines					
Iran-Pakistan-India	*0*	*30*	*90*	*90*	*90*
Myanmar-India	*0*	*0*	*30*	*30*	*30*
Total imports	25	95	215	245	255
Total	**109**	**218**	**340**	**370**	**380**

End-Use Consumption

Sectoral Energy Consumption (2003-04)



- **Industry sector contributes about 25 % of India's GDP for the year 2002-03**
- **Industry sector is the largest consumer of commercial energy in Indian economy (40% share of commercial energy during 2003-04)**
- **Seven energy intensive industries: Iron and Steel, Cement, Aluminium, Fertilizer, Pulp and Paper, Fertilizers, Cotton textile, Chlor-alkali are analyzed in details**
  - **Accounts of more than 60% of commercial energy consumption of industry sector.**

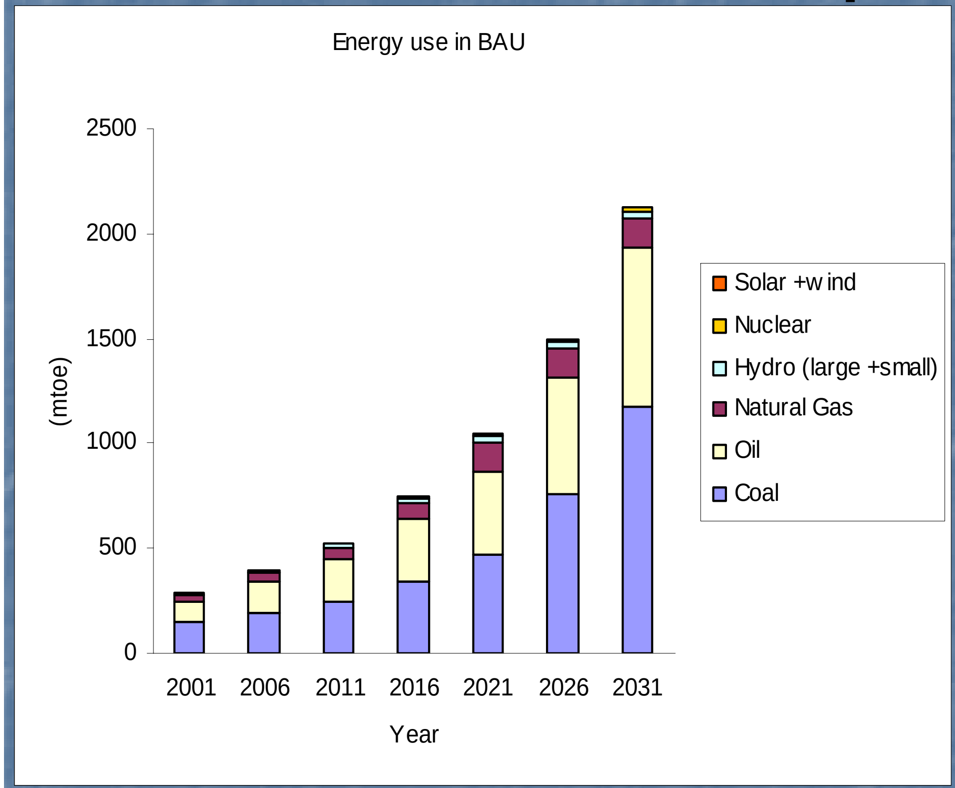
❖**Major industries are already moving towards energy efficiency path**

➢**Iron and steel: Average SEC of integrated steel plants is reduced from 9.29 Gcal/tsc in 1990-91 to 7.28 Gcal/tcs in 2004-05 (22% reduction)**

➢**Cement: Specific heat consumption of clinker production is reduced from 1300-1600 kcal/kg in 1950-60s to 665-800 kcal/kg of clinker at present**

➢**Average SEC of ammonia production is reduced from 13.7 Gcal/tonne in 1985-86 to 9.30 Gcal/tonnes in 2002-03 (32% reduction)**

Total Primary Commercial Energy Requirement



❖Total primary commercial energy increases 7.5 times 2001 to 2031(285 mtoe to 2123 mtoe) (CAGR: 6.9%)

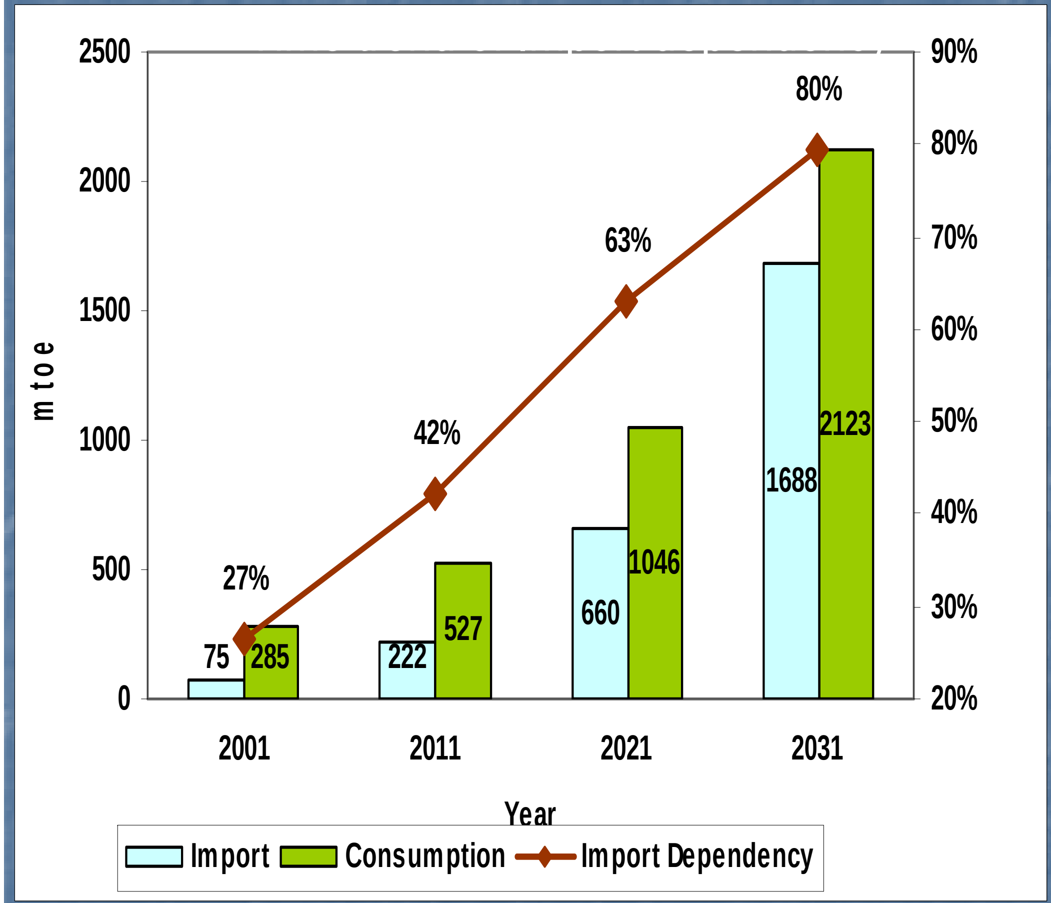
❖ Share of traditional fuels to total primary energy consumption decreases by 35% to 4% (in year 2001 to 2031)

❖Coal and Oil remains the dominant fuels

- ➢Share of Coal: 55% in 2031
- ➢Share of Oil: 36% in 2031

❖Share of hydro in total commercial supply is only 2% in 2031

Energy Security: High Import Dependency

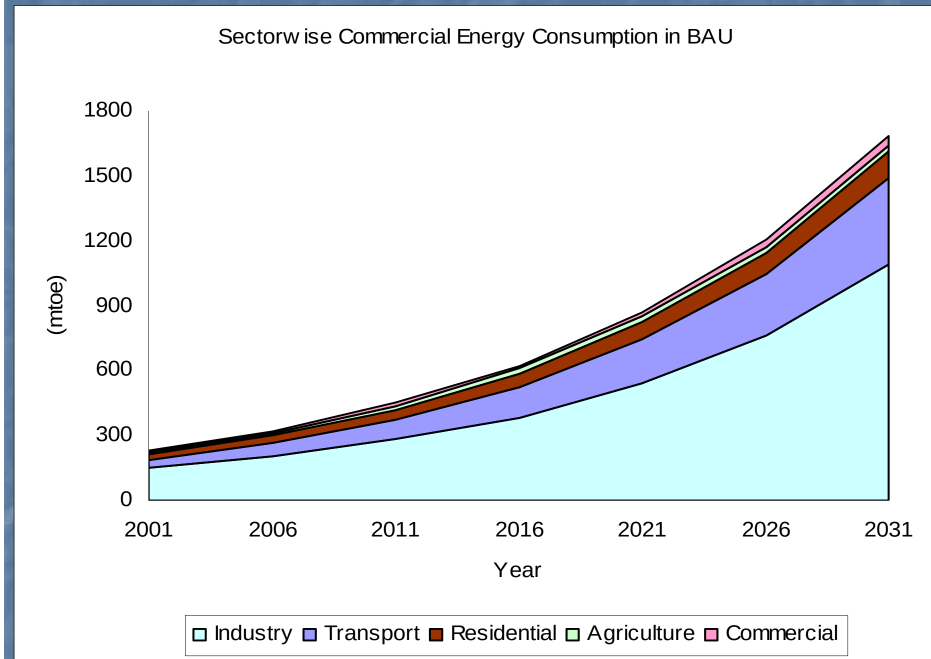


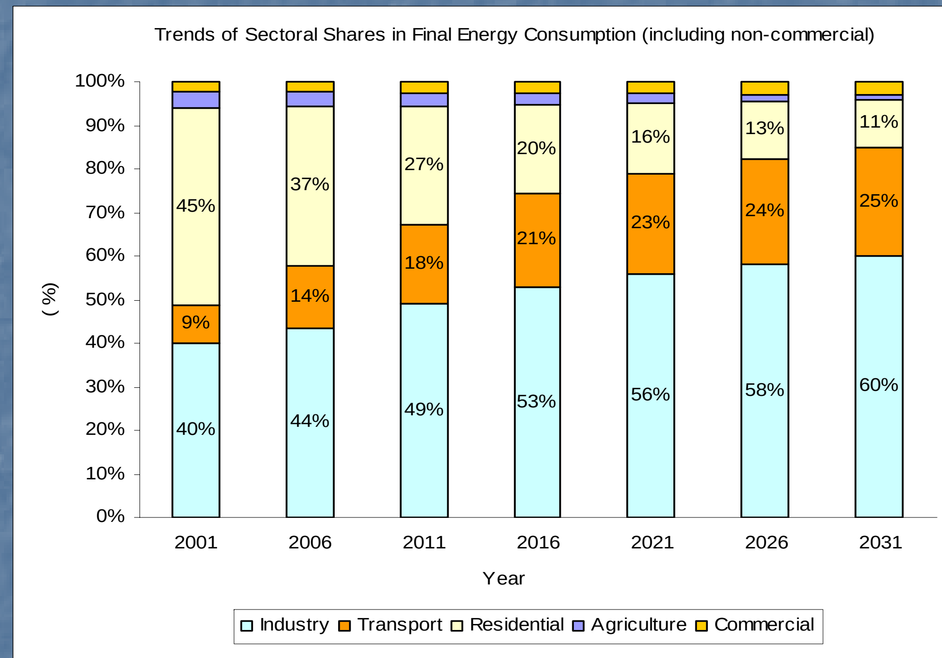
Fuel Import in 2031

- ❖Coal import: 1438 MT
  - ➢~4 times of consumption in 2001
  - ➢Import dependency: 78%
- ❖Oil import: 680 MT
  - ➢Import dependency: 93%
- ❖Gas import: 93 BCM
  - ➢Import dependency: 67%

❖Maximum indigenous production levels for all fuels is achieved by the year 2016

Sectoral Commercial Energy Consumption





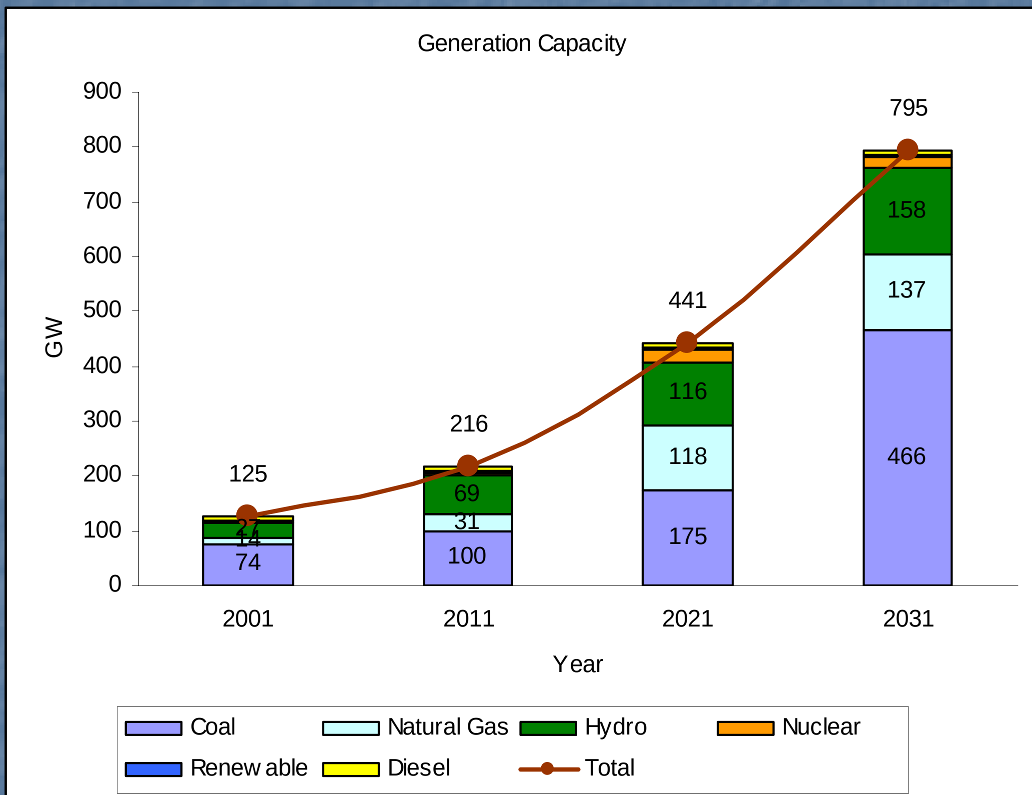
❖Commercial energy consumption from the end-use side increases 7.5 times (in 2001-2031) (CAGR: 7%)

❖Share of residential sector in total final energy (including non-commercial energy) consumption decreases due to shift towards more efficient commercial fuels

❖The highest growth rate in oil consumption in the transport sector increases by 13.6 times (CAGR: 9%)

- ➢Shift towards more energy intensive modes of transportations both for passenger and freight movement

Electricity Generation Capacity



❖Total installed capacity increases by 6.34 times (CGAR: 6.3%)

❖Coal based capacity will remain dominant (59% in 2031) followed by hydro (20%)

❖Decentralized capacity will contribute 19% of the total generation capacity by 2031

❖ Total installed capacity in 2031: 795 GW (Draft Integrated Energy Policy: 778 GW, Ministry of Power: 962 GW)

Scenarios Analysis

Economy-Wide Scenarios

Socio-Economic

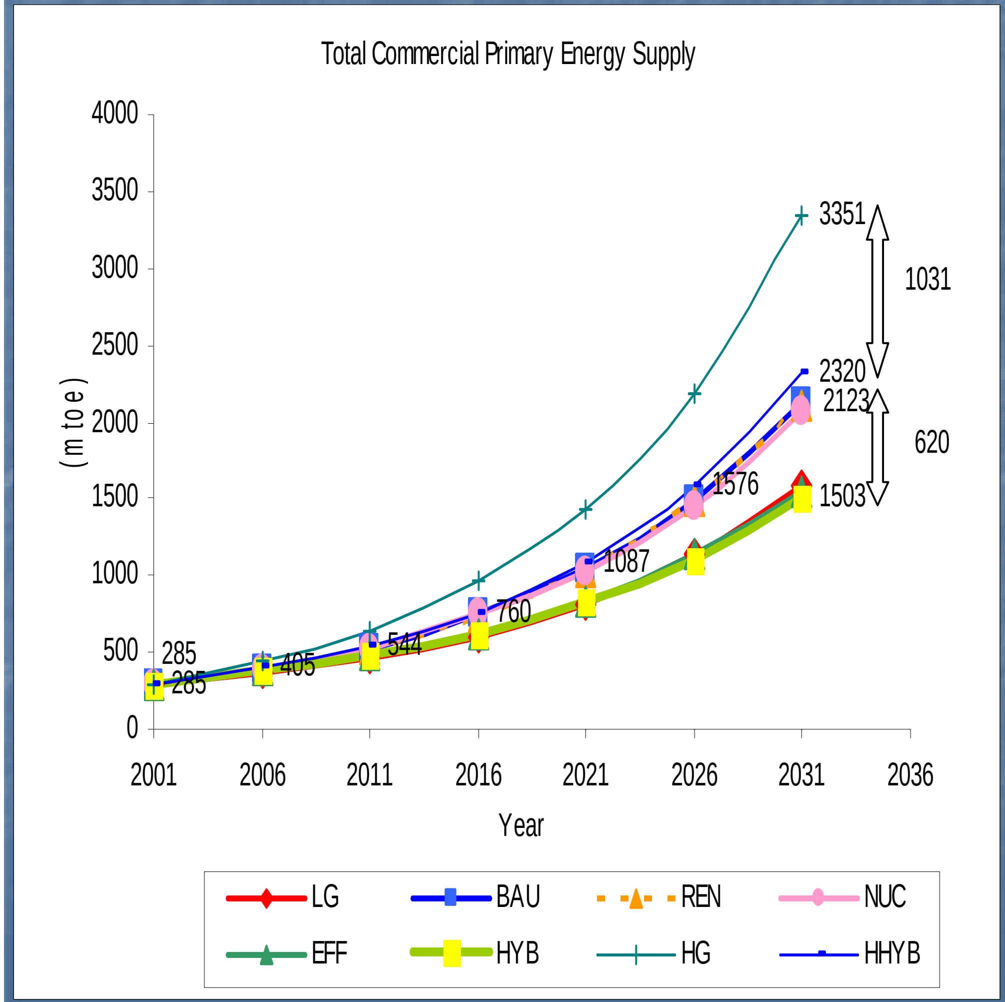
- **BAU scenario -** 8% GDP growth rate (BAU)
- **Low-growth scenario-** 6.7% GDP growth rate (LG)
- **High-growth scenario-**10% GDP growth rate (HG)

Technology-Deployment

BAU scenario (BAU)

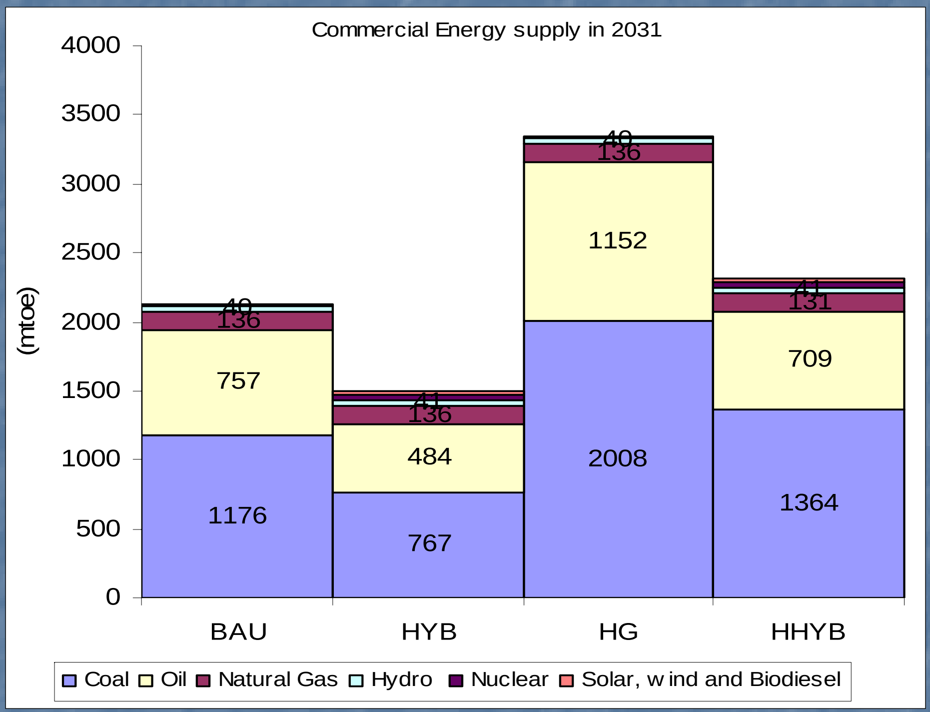
- **High-nuclear capacity (NUC)**
- **Aggressive renewable energy (REN)**
- **High-Efficiency scenario (EFF)**
- **Hybrid scenario (8% GDP) (HYB)**
- **High hybrid scenario (10% GDP) (HHYB)**

Total Primary Commercial Energy Requirement



- ❖ Increase in primary energy by 2031
  - ➢ 7.5 times (BAU)
  - ➢ 5.3 times (Hybrid)
  - ➢ 11.8 times (High growth)
  - ➢ 8.2 times (High growth hybrid)
- ❖ Energy consumption in hybrid scenario (8% GDP) is even less than that in low growth scenario (6.7% GDP)
- ❖ Difference in commercial energy consumption
  - ➢ Between BAU and Hybrid in 2031 is double the total commercial energy consumption in 2001
  - ➢ Between High-growth and High-growth hybrid in 2031 is 3.6 times the total commercial energy consumption in 2001

Fuel wise Total Commercial Energy Supply



❖Difference in commercial energy consumption by 2031 in hybrid scenario vis-à-vis BAU: 620 mtoe, high growth vis-à-vis

➢Difference in coal consumption 409 mtoe (1.4 times of total commercial energy consumption in 2001)

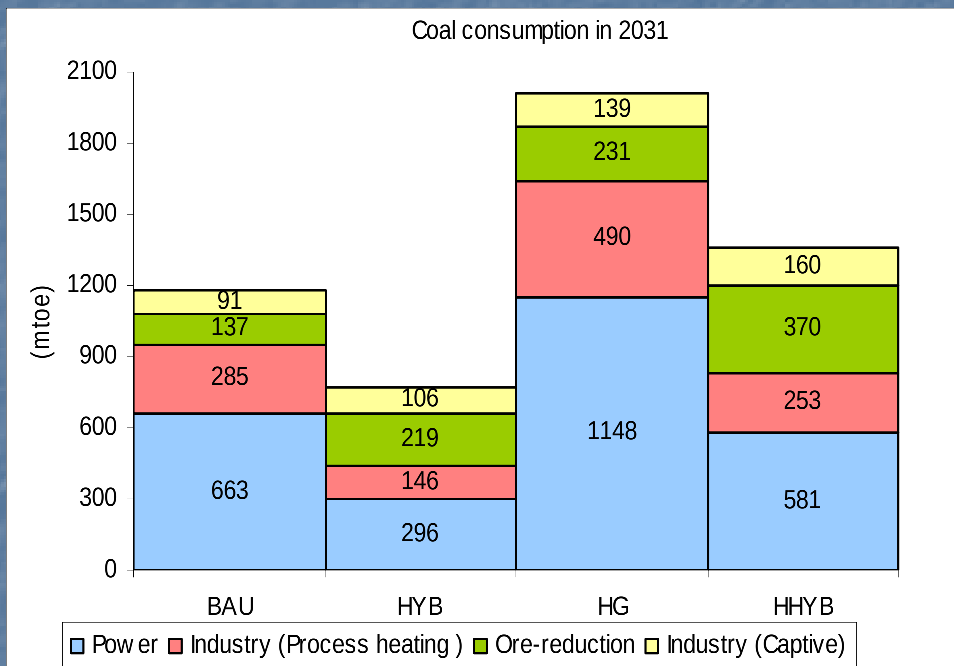
➢Difference in Oil consumption 273 mtoe (96% of total commercial energy consumption in 2001)

❖Difference in commercial energy consumption by 2031 in hybrid scenario vis-à-vis BAU: 1031 mtoe

❖Difference in coal consumption 645 mtoe (2.3 times of total commercial energy consumption in 2001)

❖Difference in Oil consumption 444 mtoe (1.6 times of total commercial energy consumption in 2001)

Sectoral Coal Consumption



❖Maximum share of power sector in coal consumption across all scenarios followed by the industrial sector for process heating and captive power generation

❖Coking coal consumption is the highest in the hybrid scenario due to increased iron making through the blast furnace route

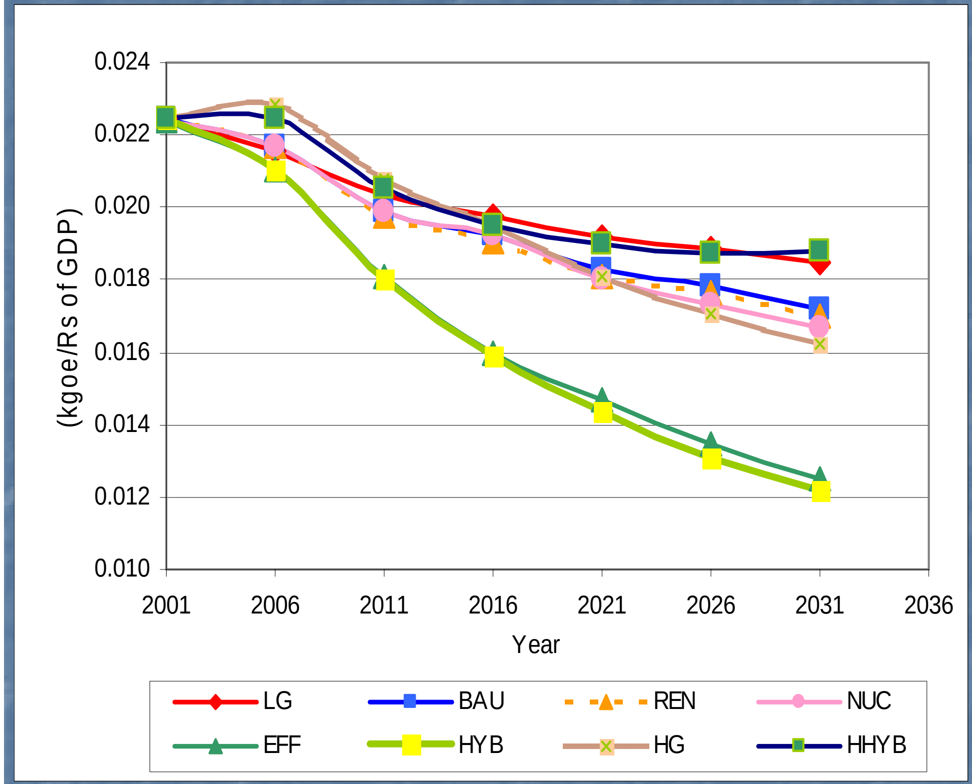
❖ Power sector exhibits highest reduction potential, followed by process heating in industry

❖Difference in coal consumption in the power sector in 2031

➢Hybrid vis-à-vis BAU: 367 mtoe (55% reduction)

➢High growth hybrid vis-à-vis high growth scenario: 568 mtoe (49% reduction)

Energy Intensity



❖ BAU: Decline in energy-intensity from 0.022 kgoe/Rs. of GDP in 2001 to 0.017 kgoe/Rs. of GDP by 2031

- ❖ Decrease of 23%
- ❖Even in BAU scenario Indian economy is progressing along an energy-efficient path

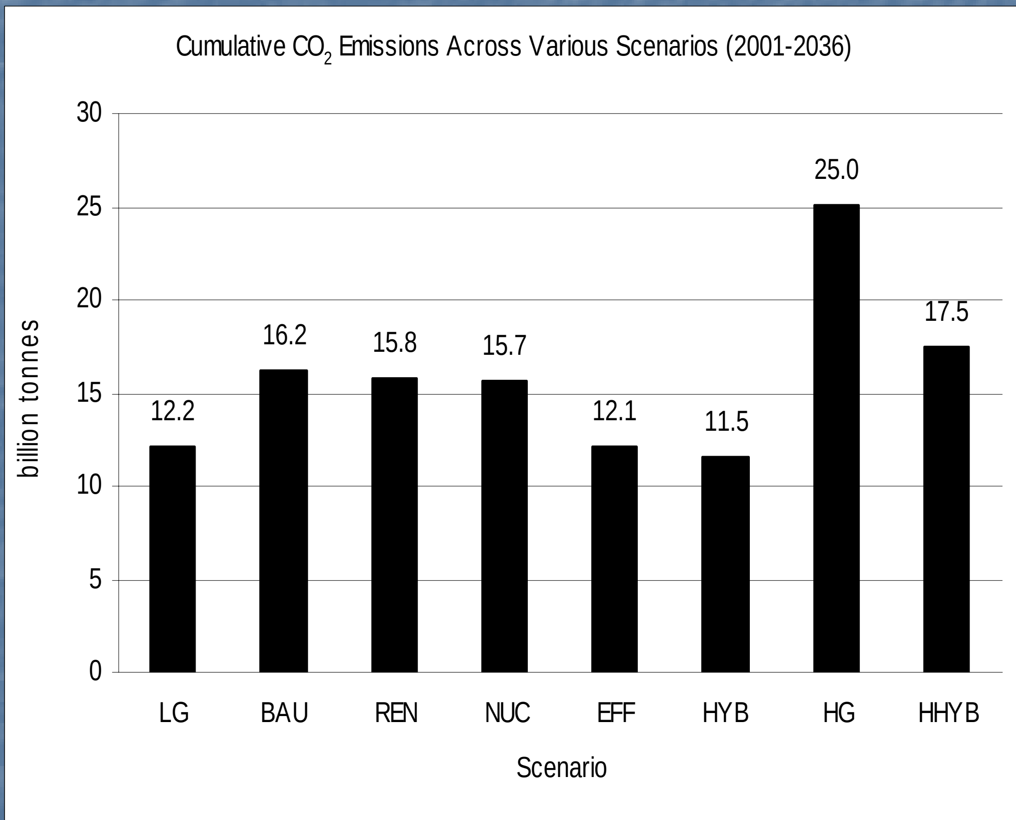
❖Hybrid scenario : Decline in energy-intensity to 0.012 kgoe/Rs. of GDP in 2031 (extent of 29% vis-à-vis BAU in 2031)

❖High-growth hybrid scenario: Decline in energy-intensity to 0.011 kgoe/Rs. of GDP by 2031 (50% reduction from 2001)

❖Progression of economy along a declining energy-intensity path if energy-efficiency measures are pursued aggressively even with a high optimistic growth rate of 10% GDP

Analysis of CO_2 Emissions

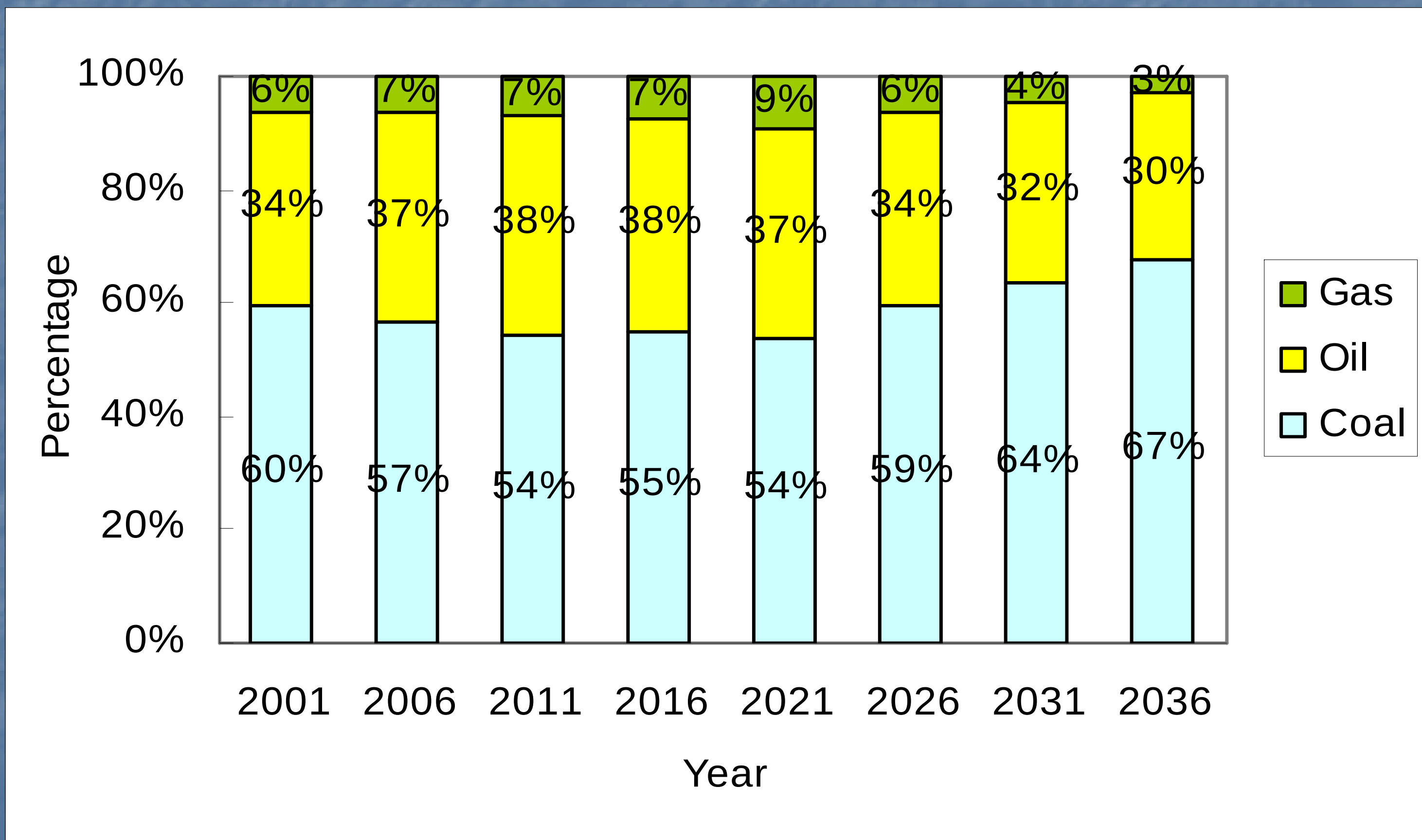
Cumulative CO_2 Emissions



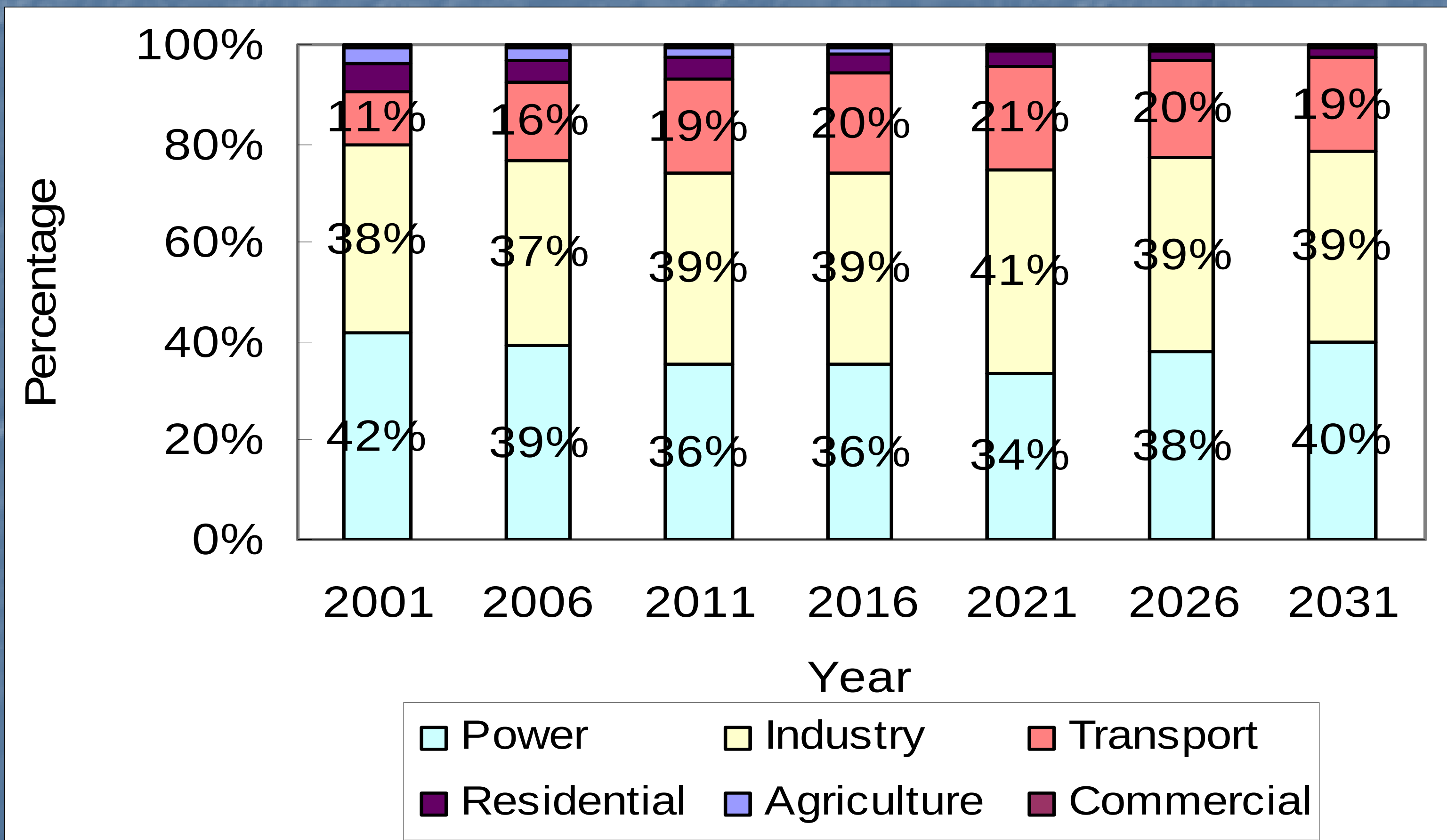
- Cumulative CO_2 emissions lower to the extent of 25% and 29% in the high efficiency and hybrid scenarios respectively vis-à-vis the BAU scenario

- Cumulative CO_2 emissions higher by only 8% in the high-growth hybrid scenario vis-a-vis BAU scenario

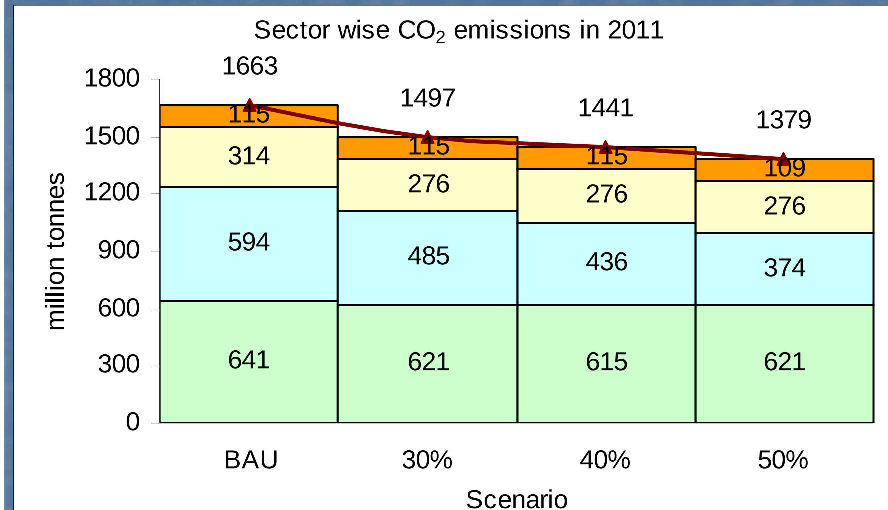
CO2 Emissions by Fuels (BAU)

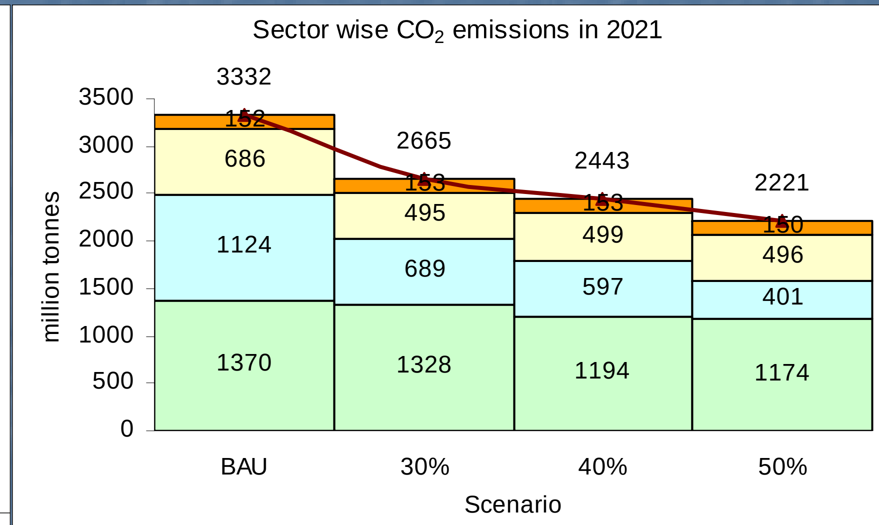


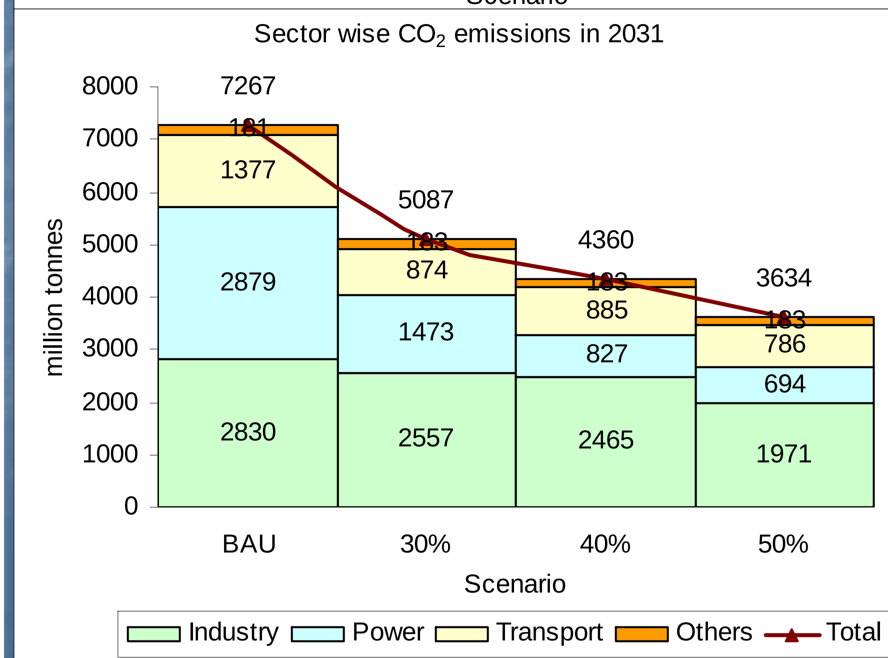
CO2 Emissions by Sectors



CO2 Emissions Reduction Scenarios- Without CCS



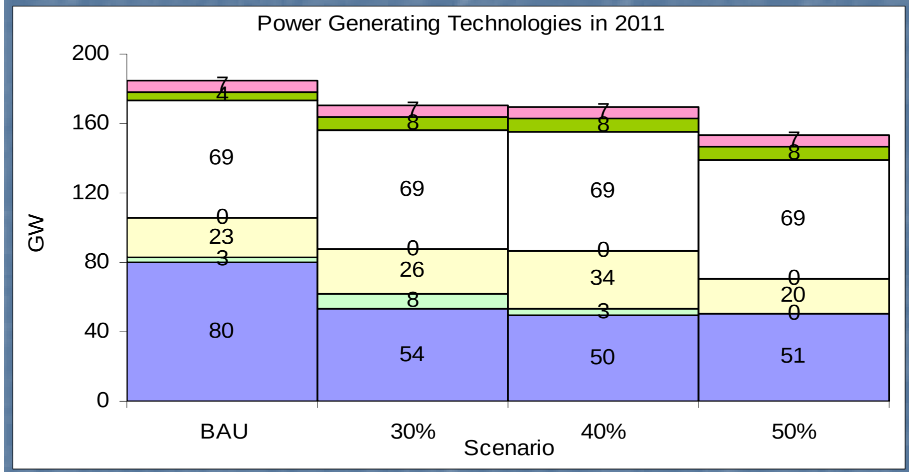


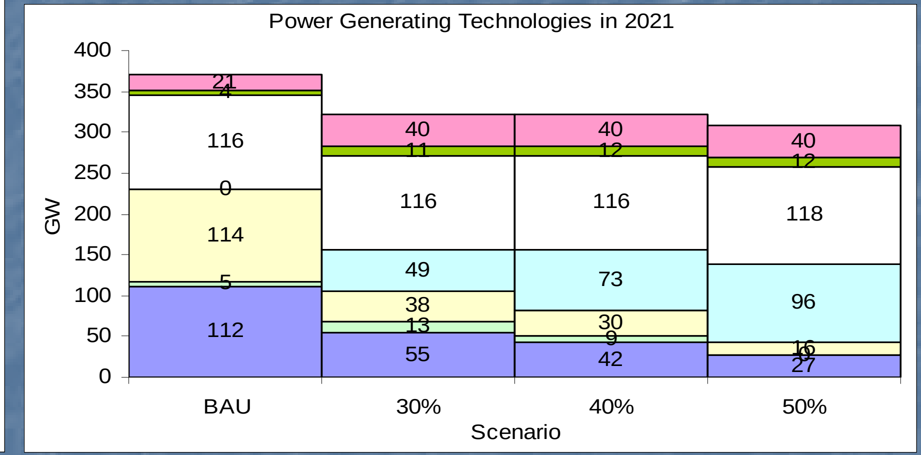


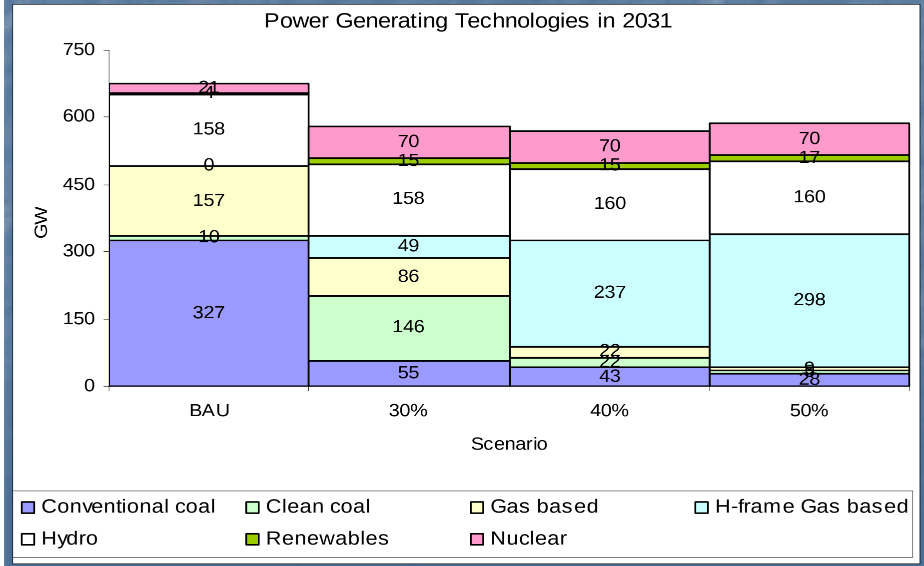
Time Series CO2 emissions (cumulative) reduction targets of 30%, 40% and 50% from the BAU by 2031.

Maximum reduction occurs in the power sector by deployment of clean coal technologies. (70% reduction ~ 2185 million mt.)

Uptake of Power Generating Technologies at Various CO2 mitigation scenarios: Without CCS







Power sector presents the greatest opportunity to implement CCS. With the increase of clean coal technology uptake from 10 GW in the BAU Scenario to 146 GW in the 30% reduction scenario.

GHG mitigation scenarios at various CO2 Prices (without CCS)

Scenario	2001	2011	2021	2031
BAU	917	1663	3332	7267
$ 5/tonne	917	1457	2495	5061
$ 10/tonne	917	1400	2472	4989
$ 20/tonne	917	1383	2412	4972

Units of CO_2 mitigated are in million tonnes

Geological CO2 Storage Potential

- Estimated CO_2 storage potential in
  - deep saline reservoirs (on and off shore) estimates ~ 360 $GtCO_2$
  - Depleted oil and gas wells estimates ~ 7 $GtCO_2$
  - Un-mineable coal seams 5 $GtCO_2$
  - Volcanic rock 200 $GtCO_2$

Source: Singh, A.K., Mendhe, V., Garg, A., 2006, “CO2 sequestration potential of geological formations in India”, 8th International conference on Greenhouse Gas Control Technologies, GHGT-8, Trondheim, Norway, June 19-22, 2006.

Current CCS Activities in India

- India is a member of CSLF & IEA GHG R&D Programme
- It is participating in the Future Gen Programme
- The Government of India has plans to invest in CCS related activities in the XI & XII Five Plan (report of the working group on R&D for the energy sector)
- Institute of Reservoir Studies is carrying out CO2 capture and EOR field studies in Gujarat
- NGRI is testing the feasibility of storing CO2 in basalt formations

Cost Range of CCS components

CCS component	Cost range
Capture from power plant	15 – 75 US $/ mt. CO_2 net captured
Capture from gas processing or NH_3 production	5 – 55 US $/ mt. CO_2 net captured
Capture from industrial sources	25 – 55 US $/ mt. CO_2 net captured
Transportation	1 – 8 US $/mt.$CO_2$(250 km transported)
Geological storage	0.5 – 8 US $/mt. (injected)
Ocean storage	5 – 30 US $/mt. (injected)
Mineral carbonation	50 – 100 US $/mt. (net mitigated)

Source: IEA-GHG R&D programme (Report 2007/9)

Barriers to Adoption of CCS

- Financial Barriers:
  - High capital costs
    - (30 to 40% increase)
  - Higher Energy penalty
    - (O&M)
- Institutional barrier
  - Does not fit in the overall goal of meeting the millennium development goals
  - Non-productive expenditure
    - Does not contribute to sustainable development

- Technical Barriers:
  - Yet to be commercially demonstrated in large point sources of CO2
  - Capture technologies are not standard for all large point sources (ex: power plant & cement plant)
  - Sinks and their capacities to yet be identified
  - Many parts of India are seismically active – issue of permanenance
  - EOR/ECBM/EGR potential yet to be established in India
  - Potential & cost for sequestering in depleted oil & gas wells yet to be determined (off-shore and on-shore)
  - Mapping and matching of sinks and sources for optimization of cost to be done

Other Barriers

- Storage (leakage – safety; leakage-carbon accounting)
- Acceptance – general public is unaware of CCS
- Regulatory: no international standards as yet
  - EC established national standards to allow CCS for European Trading
- Financial: Lack of business architecture; Storage business does not exist

Conclusions

- Climate change is a global problem
  - India needs international cooperation
- Establishment of CCS technologies require major investments in a country like India, which cannot be handled even by OECD countries
- CCS options will vary from region to region and country to country
  - Entire value chain needs vigorous analysis
- International cooperation in CCS is a must for successful deployment of this technology.

Thank you