Blue Coal Power Plants for India's Net Zero Targets - A Solution for Affordable, Reliable and Sustainable Power

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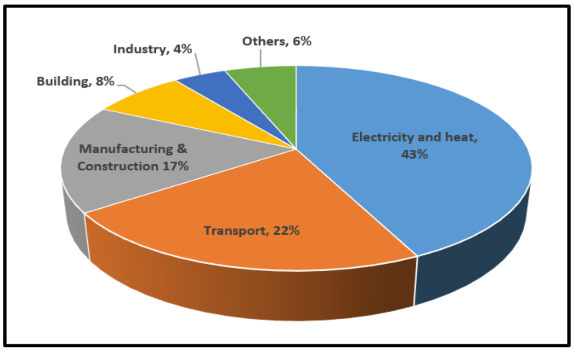
Abstract: ***In India, fossil fuels have been providing most of the energy requirements of all the sectors till now. With the COP26 commitments, there is a wide assumption that there must be an end to the use of coal to achieve the Net Zero Emission (NZE) targets. Some countries have already committed to phase out coal-based power plants for achieving the net zero commitments. These are mostly developed countries with slow growing economies and potential of relatively cheaper renewable energy. However, in comparison, India is a fast-growing economy and has a huge dependence on coal for energy security. Coal remains the dominant source of energy in India as it is relatively cheap and readily available. The greatest challenge for India in such a scenario is to meet the country's demand in an affordable, reliable and environmentally acceptable way. The demand for electricity is set to increase manifold in India as a result of significant GDP growth expected over the next two decades. The paper discusses the challenges for achieving the NZE targets in Indian scenario and suggests a future roadmap for coal-based plants in India for achieving these targets while ensuring reliable, sustainable and affordable power for all. Power sector, which presently contributes around 35% of total CO2 emissions in India, is going to play a key role in achieving India's COP26 commitments. India is a coal rich country and generation from coal-based power plants dominates the total electricity generation in the country. Although, the share of thermal power in generation mix shall reduce by 2030, the generation from coal-based sources is expected to still dominate due to multiple factors such as growing energy demand, challenges associated with installation of non-fossil-based sources, intermittency of renewables, non-availability of commercially viable storage solutions, grid stability issues, availability of large coal reserves in India etc. Therefore, decarbonizing coal-based power plants is equally essential for achieving the NZE targets. There is a lot India can do to approach NZE, starting with the deployment of low emission coal technologies, high efficiency and low emission (HELE) ultra-super critical technology, co-firing low emission fuels, use of carbon capture & utilization (CCU) technologies, augmentation of Small Module Reactors (advanced nuclear reactors) at CRH steam interface etc. CCU is a necessary part of India's transition to NZE as fossil fuels are expected to remain the major source of baseline power generation and will continue their presence in the industrial processes that are hard to abate such as steel and cement industry as well as play an important role in the new industries such as Hydrogen, Ammonia, Dimethyl Ether (DME) etc. Energy transition and decarbonisation is the need of hour to meet the global climate targets. However, for a country like India, where per capita energy consumption is a fraction of the global average, ensuring energy security, sustainability and affordability is an equally important aspect. Meeting the energy needs of underserved populations, improving safe and sustainable energy access for the poorest and most vulnerable groups is the first and foremost consideration in India. Therefore, a comprehensive road map is required for achieving country's Net Zero commitments in a graded manner following a transition path.***

Keywords: Thermal Power, Net Zero Emission, Blue Coal, Energy Transition, Future of Coal, Carbon Capture, Biomass cofiring, Ultra-super critical technology, methanol firing, High Efficiency and Low Emission (HELE)

1. Introduction

Fossil fuels have been providing most of the energy needs of the world for past many years. These include the energy required for power, industry, transport sector etc. The economic progress along with rapid expansion of the global population has resulted in dramatic rise of CO2 emissions in the last few decades. Power and transport sector together accounted for over two thirds of the total emissions in 2021 while the remaining one third was mainly associated with industry, buildings, manufacturing and construction. The sector wise CO2 emissions percentage globally and in India (FY-2021-22) is indicated in Figure-1 & 2.



Source: https://ourworldindata.org

Figure 1: Sector-wise CO_2 emissions %age (GlobalScenario FY-2021-22)

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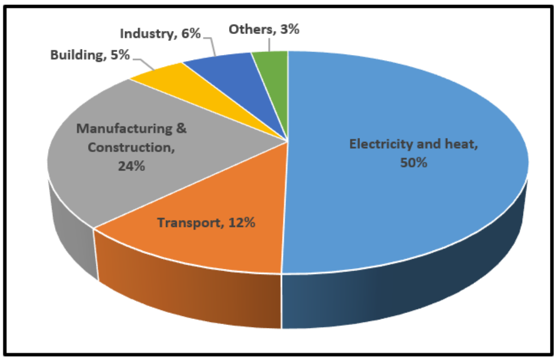

Source: https://ourworldindata.org

Figure 2: Sector-wise CO_2 emissions %age (Indian Scenario FY 2021-22)

For achieving the Net Zero Emission targets, countries are looking at new building blocks that can get the world on a more sustainable low carbon pathway in future. There is a general assumption that achieving Net Zero means the end of using coal. However, for developing countries with relatively fast-growing economies and having large coal reserves such as India, there is a need to accelerate the deployment of low emission coal technologies, co-firing of low carbon fuels, high efficiency and low emission (HELE) ultra-super critical technologies, use of carbon capture & utilization (CCU), augmentation of Small Module Reactors (advanced nuclear reactors) at CRH steam interface etc. for achieving the NZE targets.

Presently, the coal-based power plants are the largest source of electricity generation in India and the trend is likely to continue beyond 2050 considering the growing energy demand, challenges associated with installation of non-fossil-based based sources, intermittency of renewables, non-availability of commercially viable storage solutions, grid stability issue etc. Further, India has the fifth largest coal reserves in the world and a major employment in India is in the mining industry and coal-based power plants. Completely phasing out coal plants in such a scenario also poses many other challenges such as economic and social hardships due to loss of employment, power affordability etc. These challenges need to be properly identified and a comprehensive approach/road map for a graded transition needs to be adopted.

2. Power Sector Scenario in India

India's Power sector is the most diversified in the world with power generation from various conventional sources such as coal, natural gas, hydro, nuclear power with a mix of non-conventional sources such as wind, solar, biomass etc. Figure-3 indicates the generation mix of India (as on May-2023).

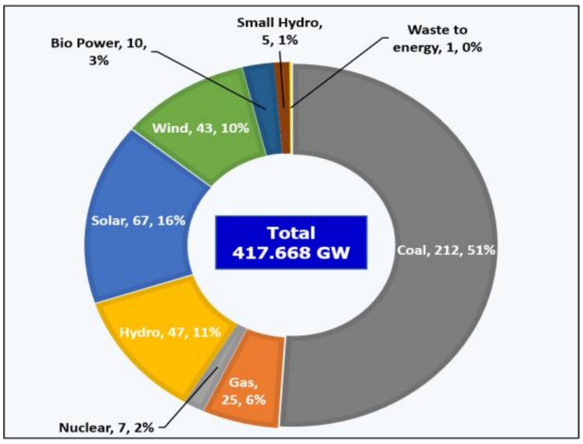

Figure 3: Installed Capacity of India in GW (as on May'23) Source: powermin.gov.in

India is the third largest producer of electricity in the world having coal-based installed capacity of 212 GW out of total installed capacity of 418 GW (as on May' 2023) and annual generation of 1180 BU from coal-based plants out of total generation of 1624 BU in FY 2022-23 (Figure-4).

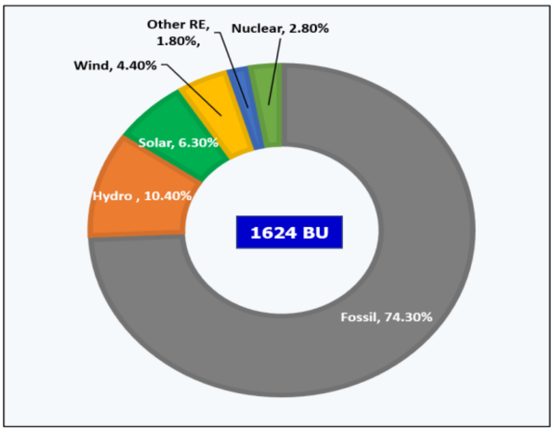

Figure 4: Details of Generation in India for FY-2022-23 Source: CEA 2023 report

However, the per capita consumption of electricity in FY 2022-23 was 1297 KWh which is only a fraction of the per capita consumption of the developed countries.**Figure-5** gives a comparison of per capita consumption of electricity in India and developed countries for FY 2022-23.

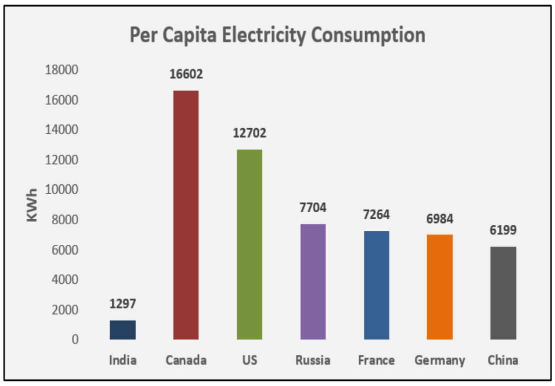

Figure 5: Per Capita Electricity Consumption (FY2022-23) Source: *https://ourworldindata.org*

India's power generation is expected to increase manifold considering the expected GDP growth over the next two decades. Both peak load demand and energy requirement are expected to grow at a very rapid pace. Figure-6 & 7 provide details about the expected generation mix of India and generation from various sources in 2030.

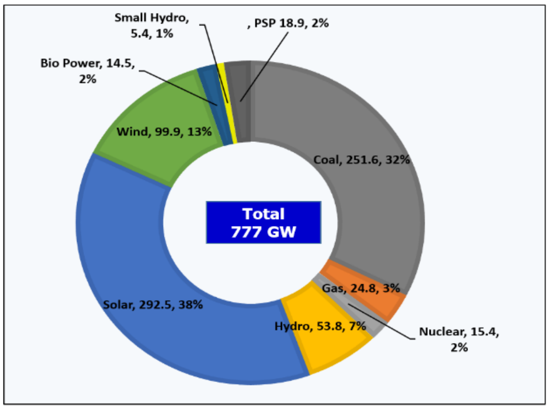

Figure 6: Likely Installed Capacityof India in 2029-30
Source: CEA report on Optimal Generation Mix for 2029-30 Ver2.0

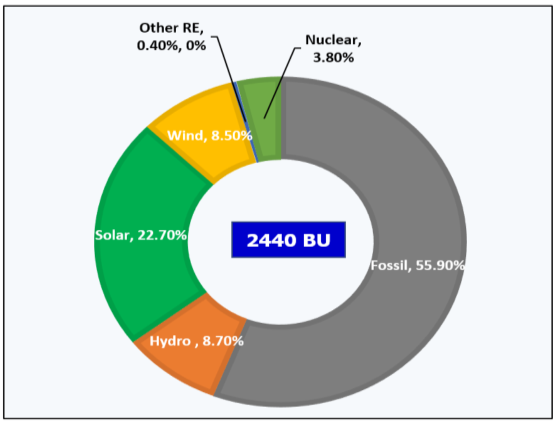

Figure 7: Project gross generation of India in 2029-30
Source: CEA report on Optimal Generation Mix for 2029-30 Ver2.0

Further,**Table-1**provides details about the power sector scenario in FY-2022-23and expected scenario in FY 2029-30.

Table 1: India's Power Sector Scenario (FY22-23 and 29-30)

	FY- 2022-23	FY- 2029-30
Installed Capacity (GW)	415	777
Generation (in BUs)	1624	2440
Peak Load Demand (GW)	215	340
Non- Fossil Capacity (GW)	129.6	500

Source: MOP, CEA

The installed capacity of coal-based power plants (as on May'2023) is around 51% and renewables is 41% of total installed capacity. However, the share of generation from thermal plants is 74.3% and renewable is 22.9% of the total annual generation. With GoI target of 500 GW of non-fossil fuel capacity by 2030, the generation mix is expected to undergo a significant change. The changing generation mix poses serious challenges for achieving affordable, reliable and sustainable power considering the intermittency of renewables, non-availability of commercially viable large scale storage solutions, grid stability issues etc. Also, the electricity requirement in India is expected to grow in tandem with its GDP growth and the per capita consumption is expected to rise to 3000 KWh by 2040.

In view of the above and considering the challenges associated with installation and integration ofsuch huge renewable capacity, decarbonizing the coal-based power plants becomes an equally important aspect for achieving the COP26 commitments. Therefore, huge induction of renewables as well as decarbonizing coal-based power plants needs to be taken up on priority.

3. Challenges for COP26 Commitments

The target for decarbonization of Indianeconomy has been well and truly set by our Hon'ble PM in COP26. As per the updated NDC, India stands committed to achieve 50% cumulative electric power installed capacity from non-fossil fuel-based sources by 2030 and reduce Emission Intensity of its GDP by 45% by 2030, from 2005 level.Some of the challenges for achieving COP26 commitments have been summarized below:

- Expected exponential rise in power demand
- Reducing emissions from power sector
- Ensuring reliable, sustainable and affordable power
- Land requirement and manufacturing facilities for renewables
- Intermittency of renewables
- Non-availability of commercially viable large scale storage solutions
- Grid stability/reliability issues with the addition of RE (requirement of fast ramp up/down, flexible operation, reduction in inertia, short circuit power etc.)
- Difficulty in implementation of nuclear power as per plan
- Infrastructure for carbon reduction from industry and transport sector

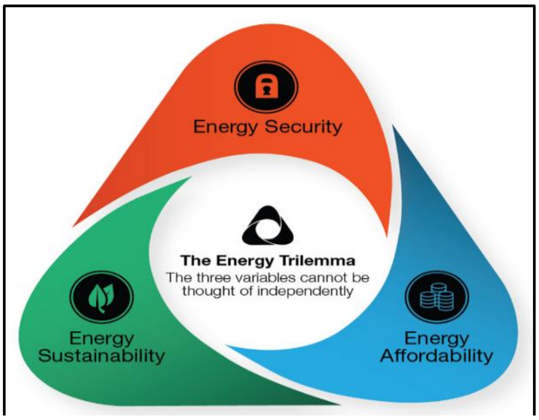

Figure 8: Solving the Energy Trilemma: Key to a Sustainable Future

Considering the above challenges and availability of abundant coal reserves in India, coal-based power plants shall have an important role for providing reliable, sustainable, affordable power and meeting Indian electricity demand in future. Hence, there is a need for decarbonizing the coal-based plants apart from addition of renewables in the grid for achieving the COP26 commitments.

Therefore, a comprehensive roadmap is required for achieving country's NZE targets in a graded manner following a transition path with a focus on ensuring energy security, sustainability, and affordability.

4. Roadmap for COP26 Commitments

The current trends of CO2 emissions from various sectors are environmentally unsustainable. The existing energy path requires a drastic change and for this energy revolution, a combination of various solutions shall be required. These include large scale deployment of energy efficient technologies, implementation of various type of renewable energy sources, energy storage systems, carbon capture and utilization (CCU), nuclear power, new technologies for reducing emissions from industry, transport sector etc.

Fossil fuels are an important source of energy for India, especially for power generation. The anticipated GDP growth over the next two decades and challenges associated with non-fossil fuel-based sources are likely to extend the dependence on coal. Therefore, there is a need to progressively focus on low emission coal technologies, co-firing of low carbon fuels, development and deployment of high efficiency, low emissions (HELE) technologies, carbon capture & utilization, explore various innovative solutions such as possibility of augmentation of Small Module Reactors (advanced nuclear reactors) at CRH steam interface etc. for power generation from coal.

A suggestive road map for blue coal power plant in India which can be adopted alongside addition of renewable energy for achieving India's COP26 commitments is given below:

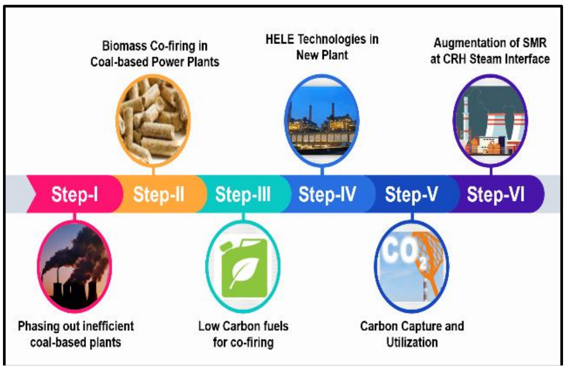

Figure 9: Suggestive Roadmap for blue coal power plant

Step-I: Phasing out inefficient coal-based power plants
All subcritical coal-based power plants which do not havespace for installation of FGD (Flue Gas Desulphurization) system to curb SOx emissions shall be phased out. This shall require shutting down of 10 GW of thermal plants which is around 5% of overall coal-fired installed capacity in India. Studies shall be carried out before retiring these plants for ensuring that there is no impact of phasing out on the overall grid stability or economics of the system. A holistic approach shall be adopted to strategically utilise the resources of old units. This includes utilizing these plants for flexible operation, repurposing as synchronous condenser etc.

Step-II: Biomass Co-firing in Coal-based Power Plants
There is substantial biomass resource available in the country. In India, the biomass waste is generally burnt on the field, thereby causing serious harm to the environment. Utilizing this biomass for co-firing can not only address the environmental hazards due to direct burning but can also be an effective method to decarbonize the existing coal fleets. Also, burning of agricultural residue destroys micro-organisms and moisture in soil which reduces land fertility. Therefore, biomass co-firing in power plants can help in replacing some percentage of coal, reducing CO2 emissions and also help in preserving the soil fertility.

Figure 10: Paddy Straw burning on field

NTPC has recently successfully demonstrated biomass co-firing (up to 10%) at NTPC Dadri thermal plant without impacting the safety concerns and mechanical performance of the existing milling and firing system.

As agro residue is a carbon neutral fuel, 10% co-firing will reduce the net carbon emission by 10%, bringing the sub-critical power plants (with biomass co-firing) at par with super-critical plants in terms of carbon emissions. Also, the sulphur content in the agro residue is far less than coal, therebyreducing the SO2 emissions. Further, the alkali present in biomass absorbs SO2 generated (due to sulphur in the coal) which further reduces the overall SO2 emissions.

Next phase in this step shall be to increase the percentage of biomass co-firing to 20% which shall help in utilizing higher quantity of biomass, increasing the efficiency and further reducing the emissions.

Figure 11: Different forms of Biomass

Step-III: Low carbon fuels for co-firing

Another option for reducing CO2 emissions in coal-based power plants can be co-firing of ammonia, methanol etc. R&D works are being carried out for studying the techno-commercial viability of co-firing these fuels in coal-based power plants. The possibility of firing ammonia, methanol etc. can provide an additional tool for decarbonizing the power sector and help in grid stability by providing the flexible operation of the plants. These low carbon fuels have the potential of replacing HFO/LDO being used in power plants and can significantly help in reducing the imports.

Step-IV: HELE Technologies in New Plants

All new power plants shall be equipped with High efficiency and low emission (HELE) technologies i.e Ultra-Super Critical technologies having Main Steam Pressure of 270 Bar, Main Steam Temperature of 600 deg C and Reheat Temperature of 600 deg C. The improved efficiency with above technologies reduces CO2 emissions and other pollutants. Each percentage increase in efficiency reduces CO2 emissions by approx. 2-3%. Also, installation of FGD systems helps in reducing the SOx emissions from the power plants.

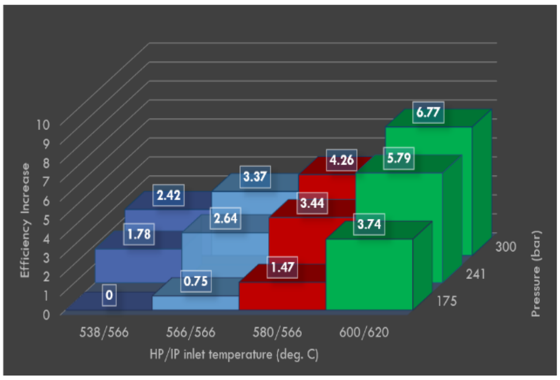

Figure 12: Improvement if efficiency of Rankine cycle with increase in Main Steam Temp. and Pressure

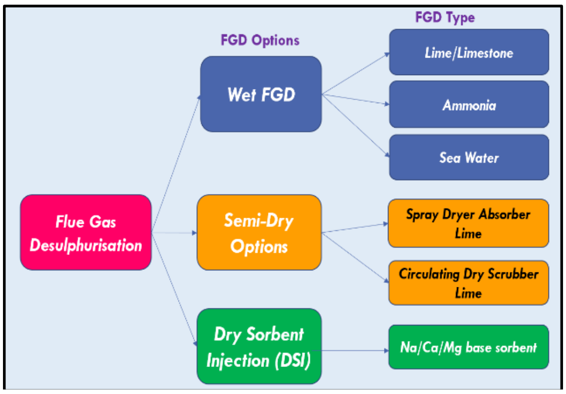

Figure 13: Major SOx Reduction (FGD) Technologies

Step-V Carbon Capture and Utilization: Carbon capture and utilization (CCU) from flue gas can be the next step in decarbonizing the coal-based plants. The use of carbon capture in high efficiency plants (Super- Critical and Ultra-Super Critical) can be more economically viable as it reduces the volume of CO2 to be captured, thereby reducing the capital and operational costs for carbon capture.

The captured CO2 can be utilized for production of green chemicals. For example, the captured CO2 can be catalytically hydrogenated (using green hydrogen) to synthesize methanol. The methanol can be used as an alternate fuel in transport and aviation sector for reducing the emissions and can significantly help in reducing the imports. Another example for use of captured CO2 is production of green ammonia and urea. Capturing CO2, nitrogen from flue gases and mixing them with green hydrogen can produce ammonia and urea for use as a fertilizer (green prilled urea). The production of urea using CO2 captured from flue gases can help inreducing CO2 emissions and narrowing the gap between urea demand and supply. Further, methanol and ammonia produced can also be fired directly in the boilers for reducing the input coal and CO2 emissions. Presently, space provision for CCU is being kept in all new thermal plants being planned by NTPC.

After successful implementation of CCU technology in new plants, the technology may be extended to existing coal-based power plants for reducing the emissions after consideration of techno-economic viability of the proposed installation and any site-specific issues such as space for installation etc.

However, strong policies and regulations are required for installation of these technologies in the existing plants.

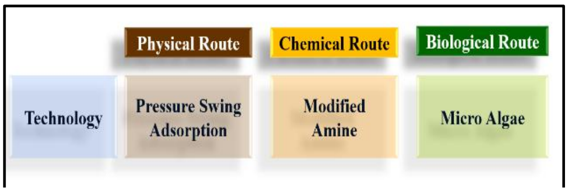

Figure 14: Pilots for different Carbon Capture Technologies by NTPC

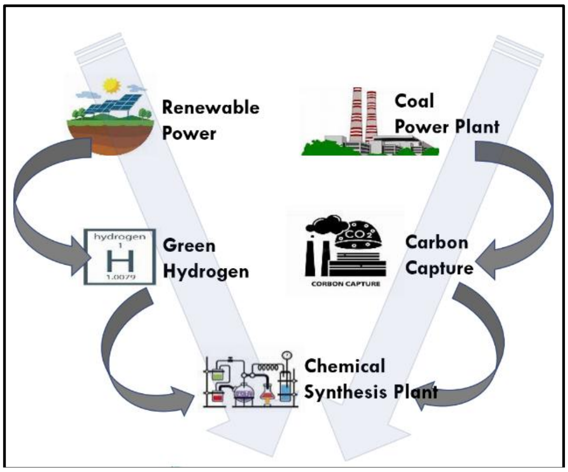

Figure 15: Chemical Synthesis from Coal Power Plant using Green Hydrogen

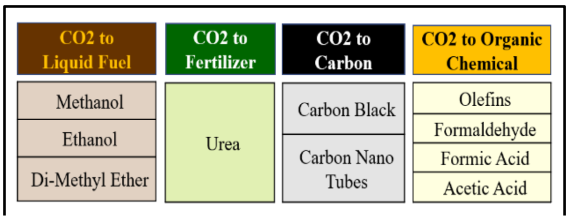

Figure 16: Utilizing CO2 for synthesis of high value products (with use of hydrogen)

The economic feasibility of CO_2 utilization routes is crucial for its industrial application. Presently, green methanol and4G ethanol costs (produced from CO2 capture and green hydrogen) are comparatively higher than production from conventional methods. However, the cost of green chemicals shall significantly reduce when green hydrogen (which contributes approximately 75-85% of the overall green chemical cost) becomes available at a cost-competitive price. Further, incentives in the form of carbon credits etc. can help in developing a sustainable value chain for green chemicals. The green chemicals produced using carbon capture can be used in the transport sector (replacement of petrol/diesel), energy sector (DG sets, boilers, fuel for gas turbines, heater modules etc.), blending with LPG etc. and can reduce CO2 emissions, particulate matter etc., thereby providing an accelerated path towards a circular economy.

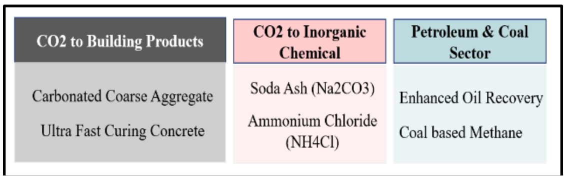

Figure 17: Utilization of CO2 alone in a process or product

Step-VI: Augmentation of SMR at CRH Steam Interface: R&D works are being carried out for integration of SMRs i.e. Small Module Reactors (advanced nuclear reactors) with coal-based power plants. In this case, the SMRs shall be interfaced with CRH steam and after heat addition in SMRs, the steam shall be added in the main cycle at Reheater inlet. Addition of SMR in coal-based power plants has the potential to reduce coal firing by approximately 20%, thereby reducing the CO2 emissions.

Potential CO2 Reduction with suggested roadmap
The use of combination of these technologies (Ultra-Super Critical Technology, Biomass co-firing, Carbon capture and Augmentation of SMR) can reduce CO2 emissions from coal-based power plant to the level of emissions from gas-based plant or even lower. **Figure-18** illustrates the CO2 reductions with use of different technologies.

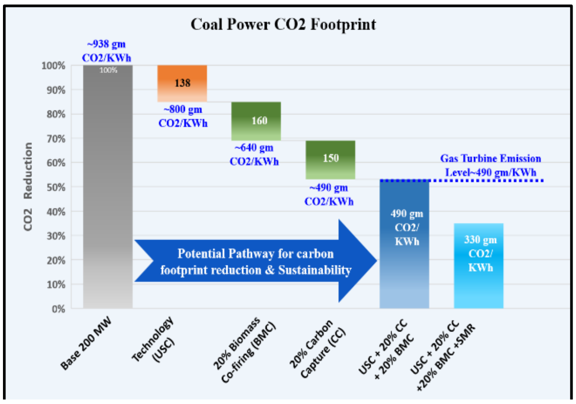

Figure-18: CO2 reduction with different technologies

India has one of the youngest coal fleets in the world, with more than 60% of the capacity less than a decade old. Maintaining efficiency and reducing emissions from these plants is going to play a key role in India's path towards NZE. The policies of government for implementation of new and advanced technologies for existing and new plants shall play an important role in this regard.

Use of HELE combined with carbon capture has the potential to reduce CO2 emissions to less than 100g/kWh.

Initially, decarbonization with use of high efficiency and low emission (HELE) USC technology, 20% biomass firing and 20 % carbon capture can bring the emissions to the level of a gas power plant, thereby providing a path for future transition to NZE. Increasing the carbon capture above 90% along with use of the above technologies and SMR in coal-based power plants has a potential to result in in net negative CO2 emissions, effectively removing CO2 from the atmosphere. Therefore, with improvement in technologies, fossil-fuel based plants have the potential to remain an integral part of the Indian grid even in the NZE era. A further opportunity area is the development of waste to energy plants. The development of such plants with CO2 capture higher than what is produced from direct burning can result in net negative emissions and can help in contributing for reducing emissions.

5. Role of Fossil Fuel-based Plants for Addressing Challenges for Grid Stability

Ancillary services are required in the power system to maintain the reliability and support the basic function of supplying electricity to the consumers. The ancillary services consist of the services required for:

- Maintaining system frequency (load— generation balance)
- Maintaining voltage and reactive power support
- Maintaining reserve capacity
- Restoring the system after partial or complete blackout

Conventional fossil fuel-based plants can be the most preferable solution for provision of these ancillary services for ensuring the grid stability and reliability in the renewable era.

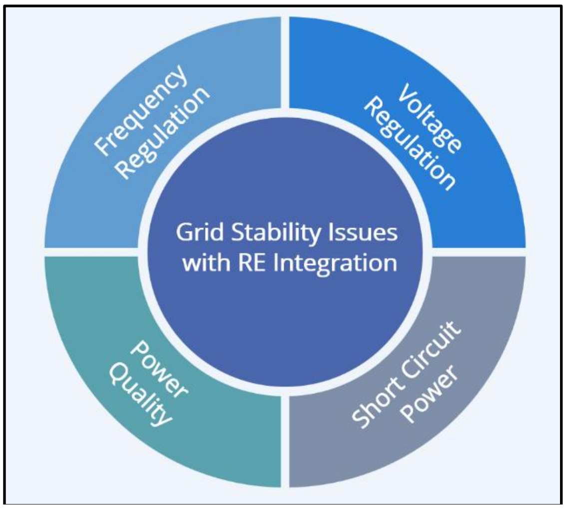

Figure 19: Major Grid Stability Issues with RE Integration

Conventional fossil fuel-based plants can support the integration of variable renewable energy into the grid in the following ways:

Supporting VRE by Flexible Operation:
As the percentage of variable renewable energy (VRE) increases in the grid, dispatchable coal power can play an important role by providing the required flexible operation according to the variation in output of renewables. The flexible operation includes faster ramp rates, start-up, lower minimum load etc. The required flexibilization can also be provided by gas-based plants, hydro plants and other energy storage options. However, for Indian scenario, coal-based plants may be the most suitable option for providing the required flexibility. **Table-2** belowindicates the challenges for other available options for India's case.

Table 2: Challenges of Gas-based plants, Hydro Plants and Energy storage options for flexible operation

OPTIONS	PROS	CONS
Gas Turbines	Fast ramp up/down	Issue in fuel availability, Limited Capacity
Hydro Plants	Fast ramp up/down	Limited potential, easy options already tapped, very low PSP
Energy Storage • Battery • PSP • Thermal / Mechanical	Emerging Technology	Not proven for large scale, High cost, Specialised Materials (Lithium, Vanadium),

Providing Inertia, Short Circuit Power and dynamic reactive power for grid stability
Inertia is required in the system forfrequency control and short circuit power, reactive power is required for voltage supportand regulation.With the increasing penetration of renewables and withdrawal of conventional energy sources from the grid, there is a challenge for grid stability due to lack of inertia, short circuitpower and dynamic reactive power. These services have inherently beenprovided by the conventional generators and hence grid stability has never been an issue in thepre-renewable era. The renewable generators which mostly consist of solar and wind areintegrated to the power system with the use of power electronic devices. This poses serious challenges to the powersystem as renewable generators cannot provide inertia, have limitations of providing short circuit power, dynamic reactivepower and introduce harmonics in the power system.Continuing low emission fossil fuel-based plants shall ensure the required reserves for inertia, short circuit power, dynamic reactive power and required flexibility in the system for smooth integration of renewables as well as maintaining strong and reliable grid.

Therefore, addition of renewable capacity in the grid does not essentially mean closure of coal-based power plants. The coal-based power plants are not competing with renewable generators, instead they are facilitating the integration of variable renewable energy into the grid. Further, studies can also be carried out for continuation of inefficient plants for flexible operation/synchronous condenser operation for optimal utilization of the existing assets in India.

6. Importance of Coal for Indian economy

Coal mining and coal-based power plants are two of the core industries that provide employment to around 3.6 million people directly or indirectly in India. Further, India's railway sector, logistics, iron/steel, aluminium, cement industry are among several industries that depend on India's domestic coal.

With abundant coal reserves in India, coal is considered an important asset for energy security in India and is a key source of revenue for the government. Further, it is estimated that Indian Railways derives more than 46 percent of its freight revenue from coal and uses this income to subsidize passenger fares. Considering the importance of rail transport, particularly for the poorer segments of the population, any reduction in fare subsidies shall impact the under privileged section of the society. In addition, Indian railways employs around 1.3 million people. Any reduction in the transportation of coal, shall also impact such employment opportunities.

Also, India's capacity to manufacture PV cells is only around 3 GW per annum. As a result, more than 90 percent of its cells are imported, which causes concerns related to energy security. Further, India does not currently manufacture lithium-ion batteries, thereby raising similar concerns regarding dependence on imports for battery/storage solutions. Hence, coal plays an important role in Indian economy, not just in terms of energy source but also for the socio-economic security.

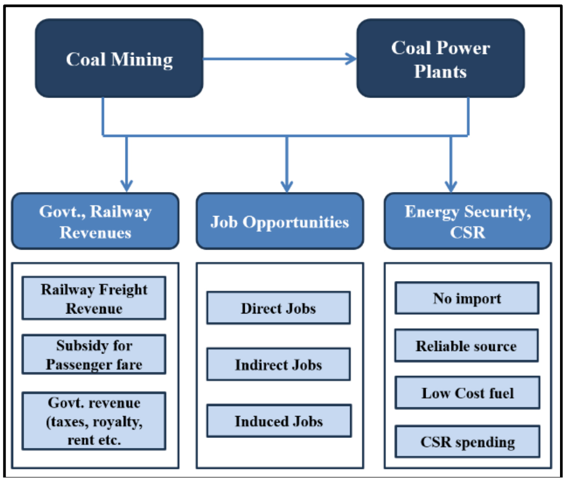

Figure 20: Role of Coal in Indian Economy

7. Comparison with Global Scenario

Per capita consumption of electricity and carbon footprint of India is significantly lower than that of developed countries as well as the world average values.**Figure-21** compares the per capita CO2 emissions/year of India with the developing countries.

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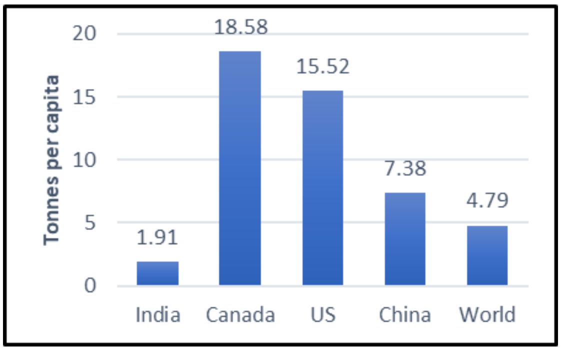

Figure 21: Per Capita CO2 comparison/ year

As per CAIR report of 2021, the approx. CO2 emissions till date for USA is 500 billion tons, China is 280 billion tons and Russia is 180 billion tons. India with its huge population of 135 Cr people has only emitted around 85 billion tons of CO2 so far. Further, as per IEA Report 2021, per capita CO2 emissionsmeasured in terms of Tons/Year/Person is > 15 for USA, Canada & Arab countries, > 10 for Russia & Australia, > 8 for China, Germany & Japan whereas for India is < 2 Tons/Yr. CO2 emissions from developed nations have already utilised the carbon space available for developing nations.

For the Indian scenario, energy transition has to be done smoothly and gradually without any shock to the system both in terms of power availability and affordability. A graded response to environmental considerations needs to be planned. Before achieving fully carbon neutral state, intermediate solutions have to be worked out gradually reducing the carbon footprint and simultaneously investing on cleaner technology development through R&D. Another factor for deciding the road map for NZE in India is the average age of Power Plants which is much lower in comparison to the plants in developed countries. Newer plants have higher efficiency and lower emission intensity in comparison to the old fleet.

India needs to build a 'Business Model' which achieves NZE targets, improves 'Energy Security', cuts down on 'Import Bill' while leveraging the national treasure of 'Coal Reserve' and utilizing 'Coal-based Power Plants' where investment has already been made. A lot of capital is still to be recovered from power plants considering the relatively lower average age of the fleet.

8. Regulatory/Policy Framework

Considering the significant role that low emission coal technologies are expected to play in achieving India's NZE targets, there is an urgent need to develop and implement policies for encouraging the technologies for reducing CO2 emissions from the coal-basedpower plants. The basic considerations while framing the regulations shall be as follows:

- Reduced generation from less efficient plants and repurposing these assets for gird stability
- Reducing emissions from existing plants by co-firing biomass and low carbon fuels
- Defining the role of low carbon coal technologies as a key component for achieving NZE targets
- Encourage deployment of HELE technologies with biomass/ammonia/ methanol co-firing and carbon capture utilization technologies
- Promoting investment to facilitate R&D activities for developing advanced HELE technologies and effective, large-scale CCU technologies.
- Introducing RTC RE framework rather than standalone RE projects with low utilization factors
- Concept of equivalent ECR should be introduced which should factor in the environmental impact of plant in addition to the fuel cost.
  Eq. ECR = ECR + Carbon Emission Penalty
  Dispatch of energy to be based on the above concept of equivalent ECR, giving due preference to cleaner projects having lower emission intensity.
- Strengthening of ancillary system framework and cost recovery mechanisms/tariff model for ancillary services.
- Supporting communities and workforce that shall be affected directly and indirectly due to decarbonization. Reskilling and reemployment of this workforce is essential to mitigate the adverse social effects of energy transition.

9. Conclusion

Energy transition and decarbonisation is the need of hour to meet the global climate targets. However, for a developing country like India, where per capita energy consumption is a fraction of the global average, ensuring energy security, sustainability and affordability is an equally important aspect. Meeting the energy needs of underserved populations, improving safe and sustainable energy access for the poorest and most vulnerable groups is the first and foremost consideration in India. The electricity requirement in India is expected to grow in tandem with its GDP growth and the per capita consumption is expected to rise to 3000 KWh by 2040. In view of the above and considering the challenges of the Indian scenario, renewables capacity addition alone shall not be enough for ensuring reliability, sustainability and affordability in future. Therefore, decarbonizing fossil fuel-based plants becomes an equally important aspect for achieving the COP26 commitments as well as meeting the Indian electricity demand in future.

There is a wide assumption that there must be an end to the use of coal to achieve the net zero emission (NZE) targets. However, addition of renewable capacity in the grid does not essentially mean closure of fossil fuel-based plants. These plants are not competing with renewable generators, instead they are facilitating the integration of variable renewable energy into the grid by providing the required flexible operation and ancillary services for grid stability

A comprehensive roadmap along with strong regulatory/policy framework is required for achieving India's Net Zero Emissions targets in a graded manner following a transition path with a focus on the challenges in the Indian scenario. The roadmap shall include phasing out/ strategically utilizing the inefficient plants, biomass co-firing up to 20% in existing plants, co-firing low carbon fuels, use of high efficiency low emission (HELE) USC technologies with biomass firing and carbon capture utilization technologies in new plants etc. The use of high efficiency and low emission (HELE) USC technology, 20% biomass firing and 20 % carbon capture can bring the emissions to the level of a gas power plant, thereby providing a path for future transition to NZE. Increasing the carbon capture above 90% along with use of the above technologies has a potential to result in net negative CO2 emissions, effectively removing CO2 from the atmosphere.

Therefore, with improvement in technologies, fossil-fuel based plants have the potential to remain an integral part of the Indian grid even in the NZE era. This shall provide a win-win situation i.e. cheapest solution for decarbonisation, facilitating integration of variable renewable energy into the grid and also provide opportunity for utilising coal resources and provide reliable, affordable & sustainable power along with socio-economic security.

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