



Biomass co-firing, a choice for environment and economy

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Outline

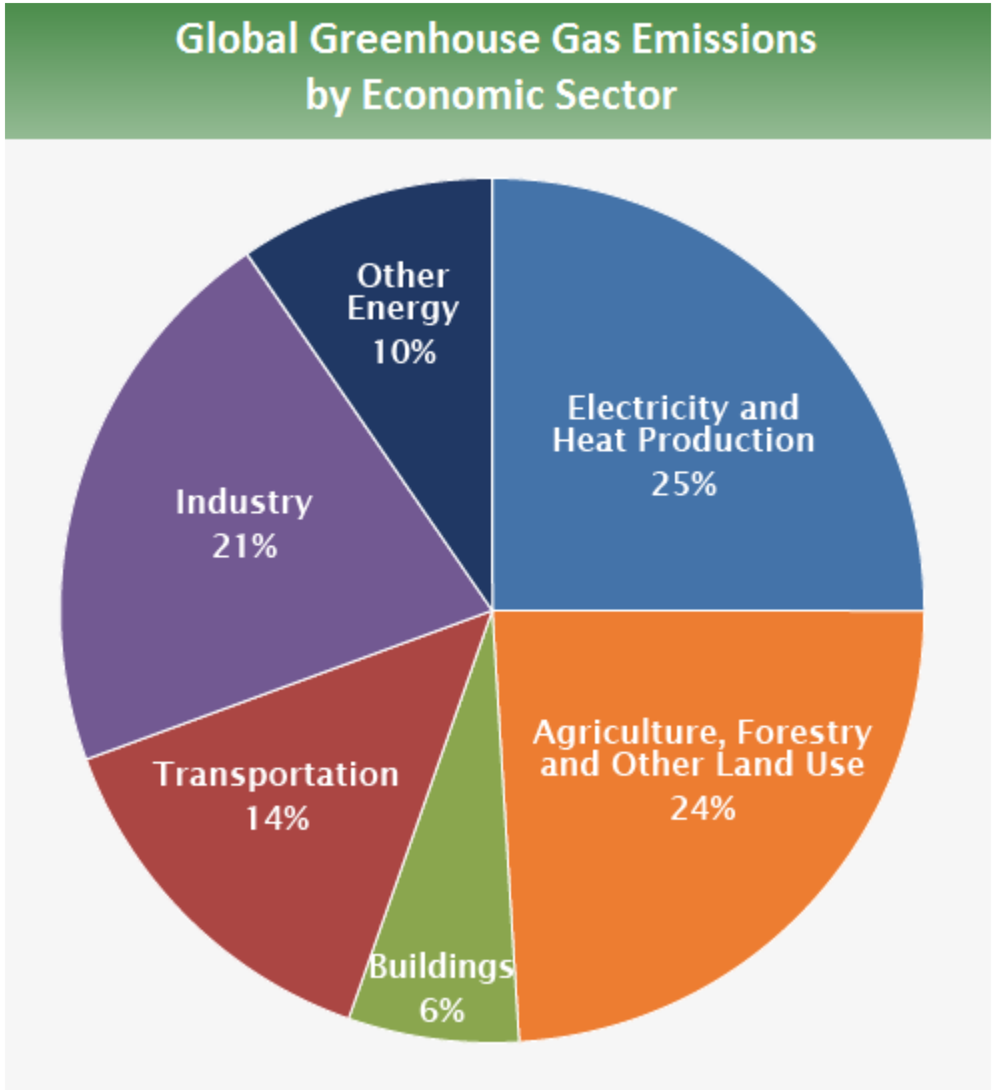
- Green House Gas (GHG) and other emissions
- Comparison with other green energy options
- Reduction potential with biomass fuel
- Other Low GHG options and comparison with biomass fuel
- Economic and environmental benifits
- Test firing and extent of biomass fuel use possible
- Ways to increase co-firing proportion- Torrefaction and fuel processing/ treatment
- State of the technology in India and the way ahead
- Reduction of SOX, NOX, GHG, particulate and radio-active emissions
- Conclusion

Disclaimer

Ideas expressed here are author’s own views and may not represent the views of the affiliated institutions

Introduction

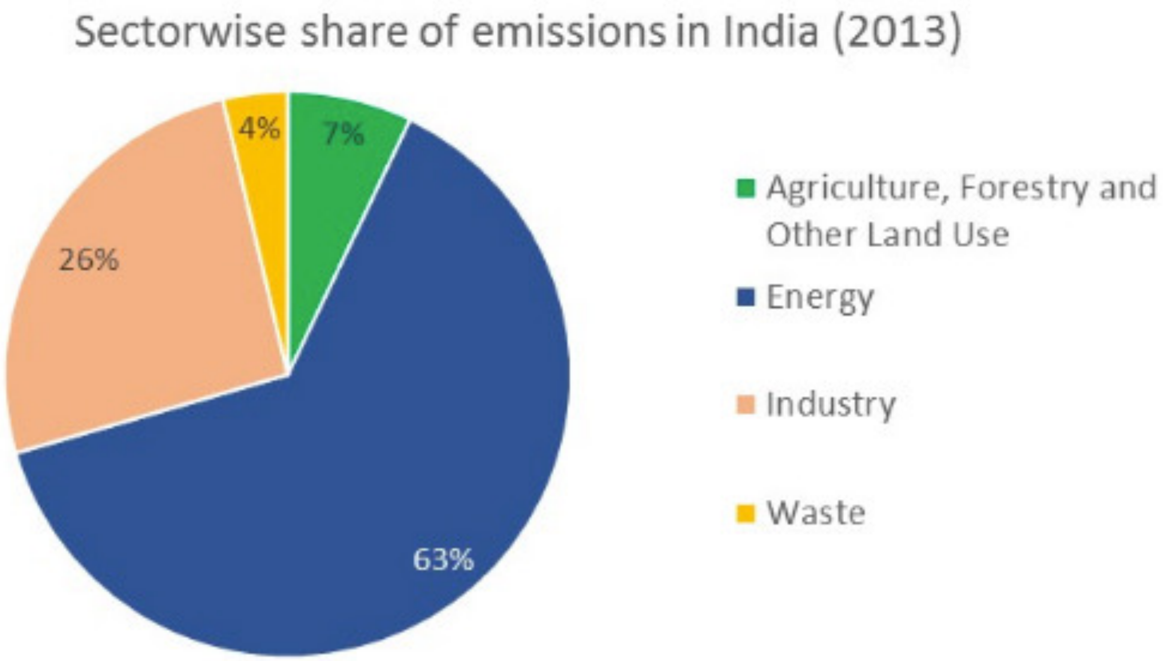
GHG Emissions: Sector Wise



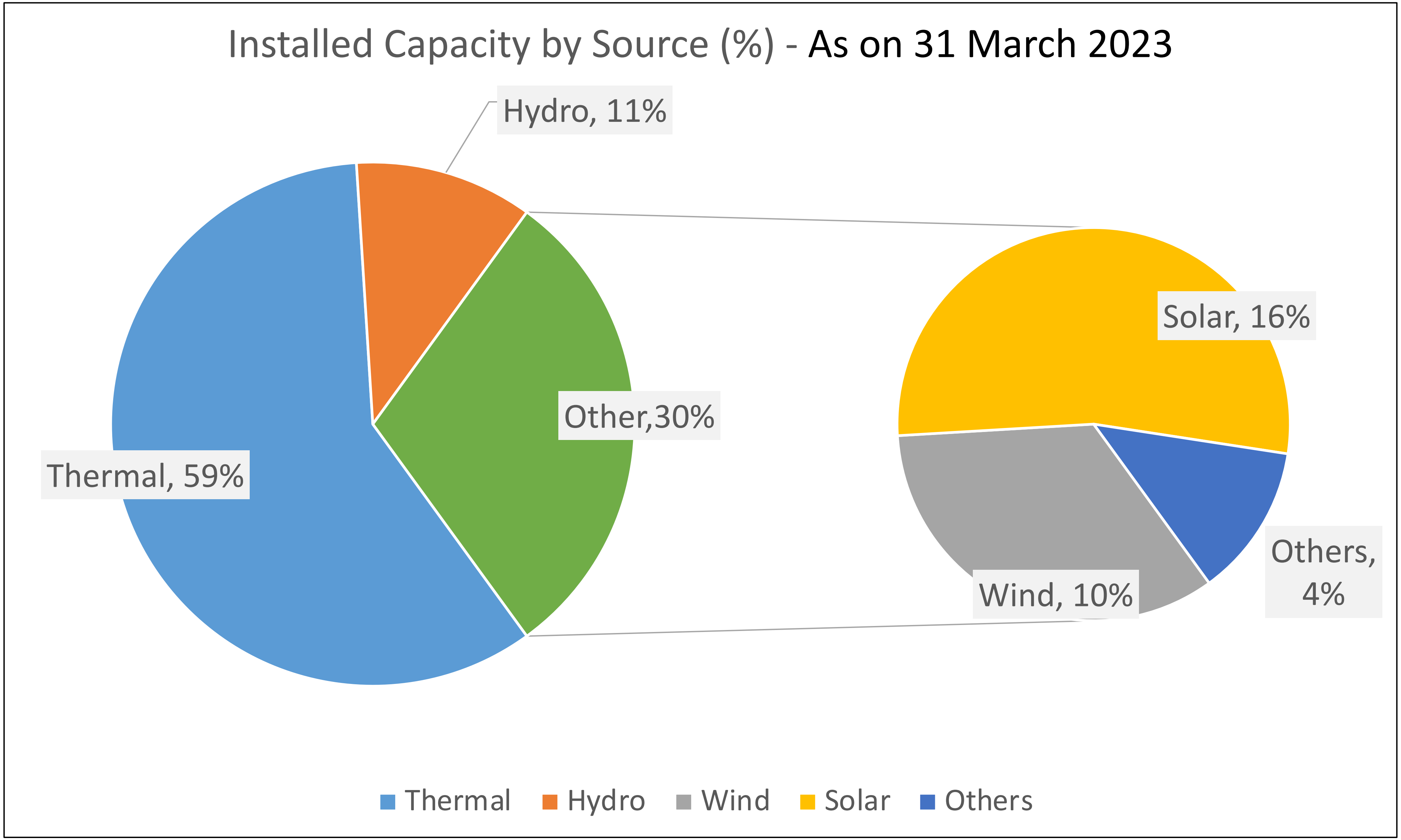
Source: IPCC 2014

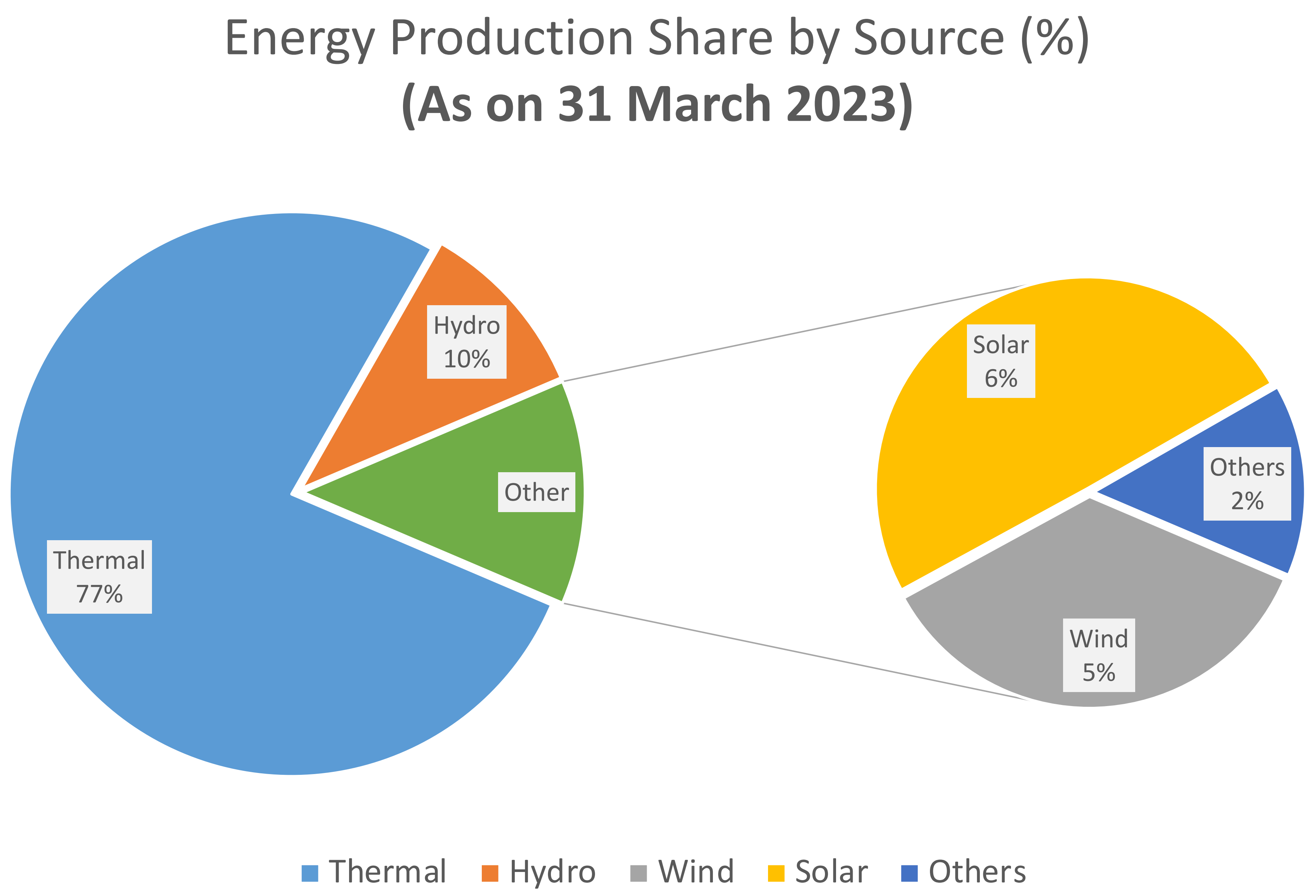
- Electricity and heat production is the largest source of green house gas emissions (25%)
- Next highest source is Agriculture and Forestry (24%). However, about 20% these emissions are sequestered back into the atmosphere by biomass, dead organic matter, and soil.
- Industry and transport sector are the next major sources of green house gas emissions globally.
- In the US, Transport is the number 1 emitter followed by electricity sector

Sector-wise Share of GHG Emissions in India



- Focusing on energy sector is essential to have an impact on GHG emission reduction efforts.
- Coal based power plants consume huge amount of coal- 15000 tonnes per day for each 1000 MW capacity (approx. 5 MTPA per 1000 MW)
- India has about 2 Lakh MW of installed capacity of coal based plants
- Potential to consume approximately 1000 MTPA (800 MTPA with 80% utilization)


Installed Capacity by Source (%) - As on 31 March 2023
Hydro, 11%
Other,30%
Thermal, 59%
Solar, 16%
Wind, 10%
Others, 4%
Thermal
Hydro
Wind
Solar
Others


Energy Production Share by Source (%)
(As on 31 March 2023)
Hydro
10%
Other
Thermal
77%
Solar
6%
Others
2%
Wind
5%
Thermal
Hydro
Wind
Solar
Others

Emissions from pulverized fuel power plants:

Annual emissions for a typical coal having GCV of 4275 kcal/kg and C=44%; S=0.5%, Ash 33% . All India average PLF 69%

Fuel	Quantity (MMTPA)	CO_2 (MMTPA)	SO_X (KTPA)	Particulate Mg/NM ^{3}	Ash MMTPA
Coal/ 1000 MW	4.46	7.195	44.6	50	1.47
Coal for the entire fleet (205000 MW)	630	1018	6308	50	207

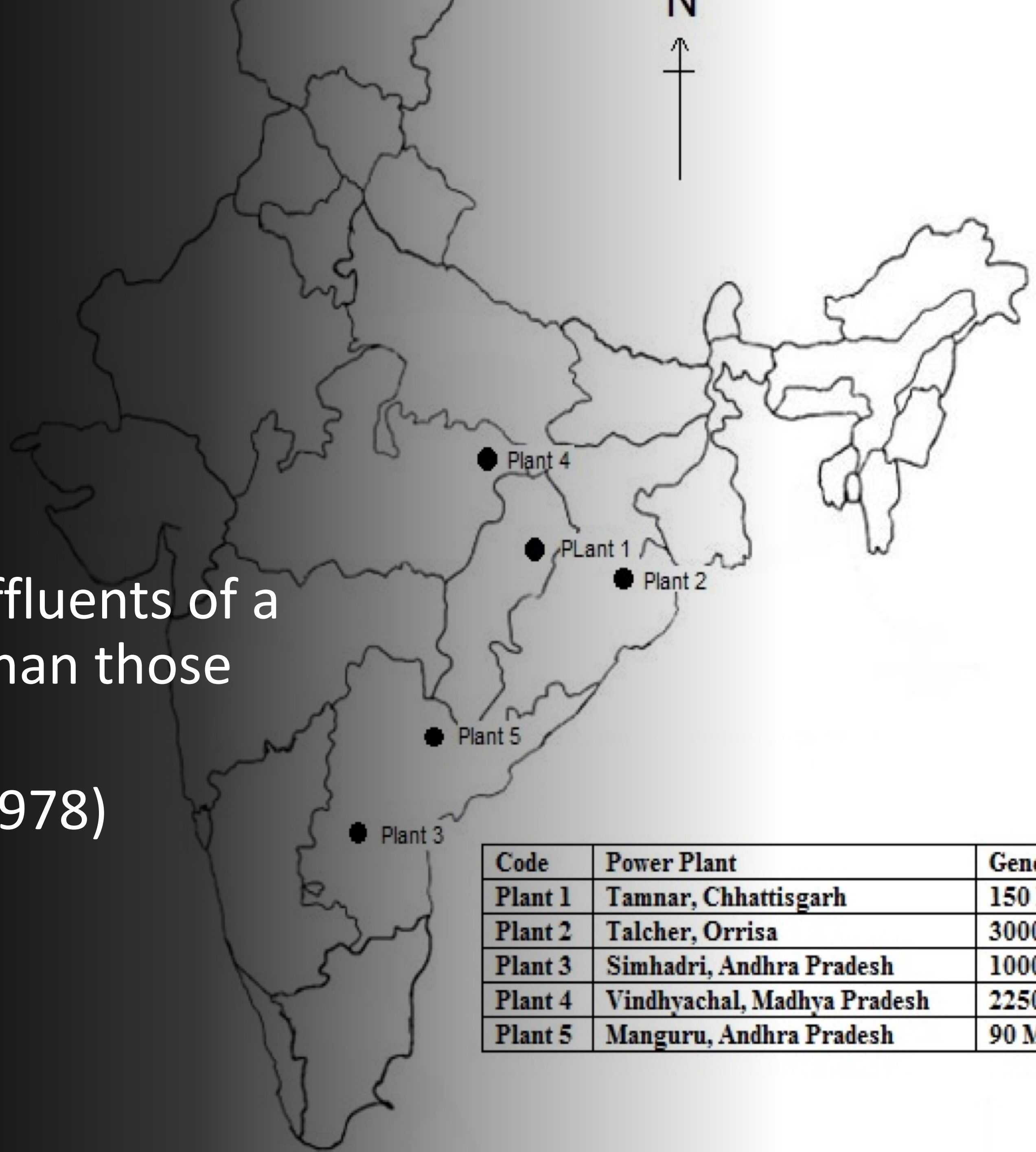
Carbon Emissions Reduction from Coal plants Through biomass route in India

	Coal plant	Coal plant with Biomass fuel switching	Annual Reduction in CO2.
EMISSION FACTOR	970 gm/kWh	230 gm/kWh	740 gm/kWh
ENERGY GENERATION (ANNUAL)	1050 BU	1050 BU	1050 BU
TOTAL CO2 EMISSIONS	1018.5 million tons	241.5 million tons	777 million tons

Radioactivity from Thermal Power plants

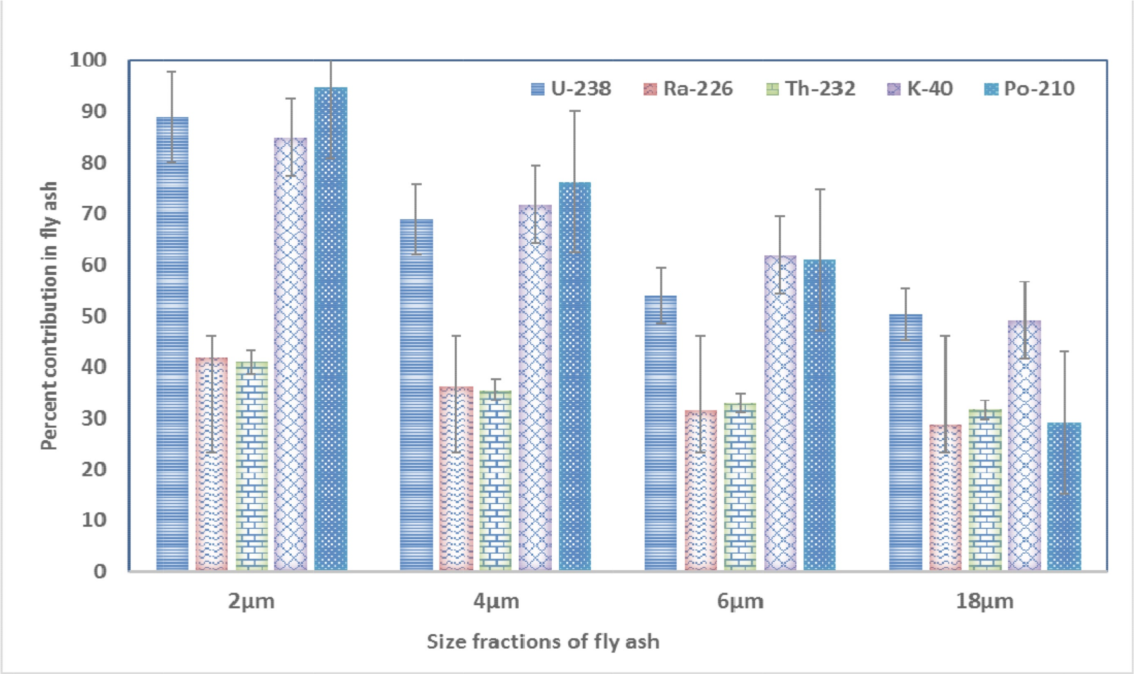
Radiation doses from airborne effluents of a coal-fired plant may be greater than those from a nuclear plant.

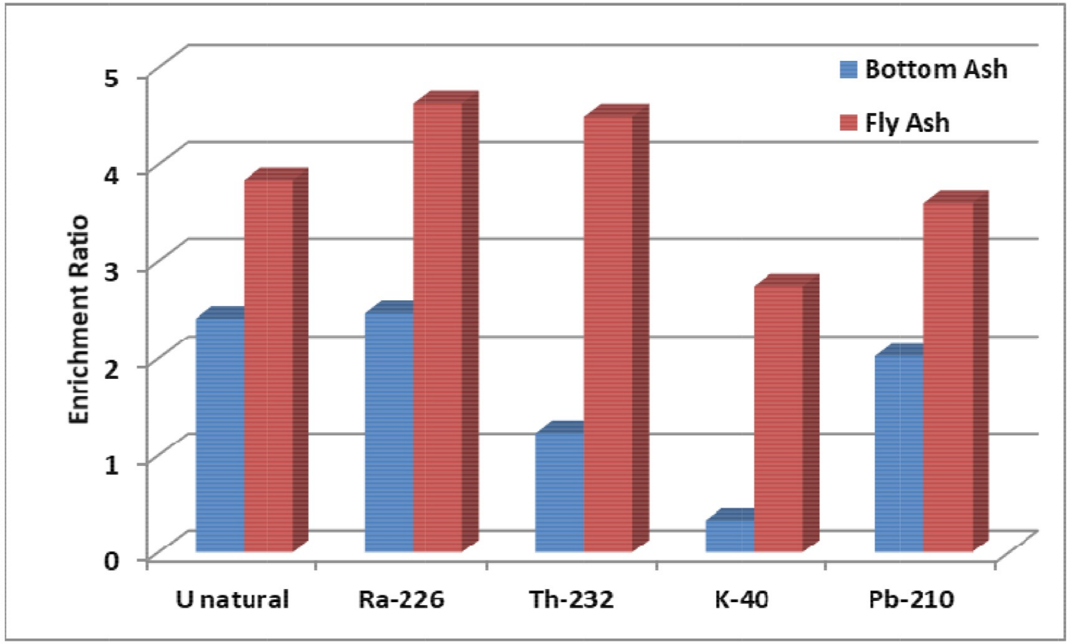
J .P . McBride, et al in Science (1978)



Code	Power Plant	Generation Capacit
Plant 1	Tamnar, Chhattisgarh	150 MW
Plant 2	Talcher, Orrisa	3000 MW
Plant 3	Simhadri, Andhra Pradesh	1000 MW
Plant 4	Vindhyachal, Madhya Pradesh	2250 MW
Plant 5	Manguru, Andhra Pradesh	90 MW

Finer particles have higher radioactivity and fly ash is 4-5 times more radioactive than coal





RADIOLOGICAL AND CHEMICAL POLLUTANTS CHARACTERIZATION OF FLY ASH FROM FEW INDIAN THERMAL POWER PLANTS (Bhabha Anatomic Research Centre Report)

S. K. Sahu, M. Tiwari, R. C. Bhangare, P. Y. Ajmal, T. D. Rathod and A. Vinod Kumar

Radioactivity as per BARC Report

^{210} Po Activity

- In coal the ^{210}Po activity ->12-43 Bq/kg,
- Bottom Ash -> 14-49 Bq/kg.
- Fly ash samples 25-70 Bq/kg with a mean value of 40 Bq/kg.
- ^{238}U, ^{226}Ra, ^{232}Th, ^{40}K in fly ash were 67-116(91), 60-105(78), 19-125(61) and 43-200 (99) Bq/kg, respectively.
- All the studied radionuclides were observed in all the samples of coal, bottom ash and fly ash.

Low Carbon Energy Options

- Fossil fuel
  - Coal with CCS
  - Gas with CCS
- Hydro
- Renewable
  - Solar with storage
  - Wind with storage
  - Biomass
- Nuclear
  - Conventional
  - Small modular Reactor (SME

Thermal coal with CCS

S — STRENGTHS

Thermal Technology is widely deployed and mature

W — WEAKNESSES

(1) 14% output penalty; 29% efficiency penalty
(2) 350% increase in power tariff
(3) High Capex ₹ 300 million/MW
(4) Noncyclic-> infinite storage
(5) Transport Infra

O — OPPORTUNITIES

Large Target Fleet

T — THREATS

1. Use of solvents may pose health hazard and environmental restrictions
2. Long term stability of geological storage
3. In most utilizations CO_2 is eventually released to atmosphere

INTERNAL

EXTERNAL

Thermal plants may may continue to operate with CCS However, high tariff, noncyclic process, High Capex and environmental and health hazards of the chemicals used in the process are the main deterrent.

Solar/ wind with storage

	STORAGE TECHNOLOGIES		
	Pumped Storage	Lithium Ion Battery	Hydrogen
MAX POWER RATING (MW)	3000	100	100
DISCHARGE TIME	4-16 hours	1 min to 8 hours	min to weeks
LIFE OR DISCHARGE CYCLES	40-60 years	3000 cycles	5-30 years

Solar with battery storage

Strength

Mature generation technology

Mature battery storage technology

Cost

Weakness

High NPV of CAPEX

Environmental hazards

Explosion/ safety risks

400-650 gm CO_2 /kWh

Opportunity

Falling prices with advances

Easy installation modular design

Threat

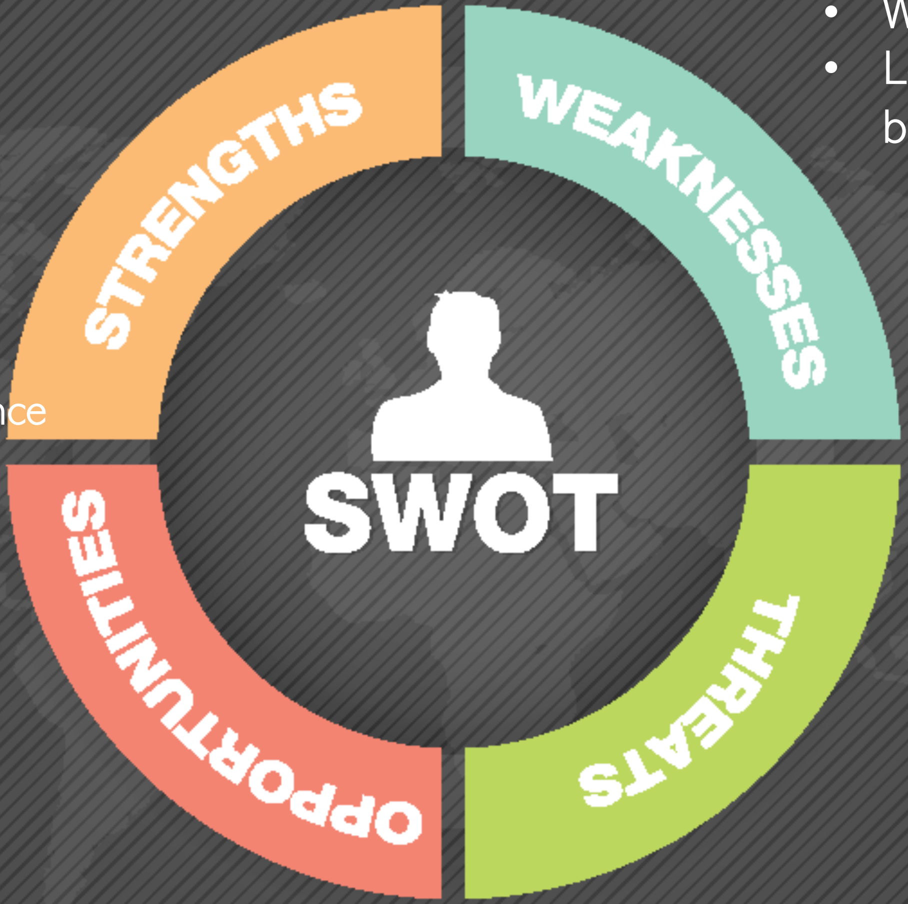
Recycling and Disposal

Import dependence

Thermal with biomass fuel

- Ample availability >1000 MMT
- Competitive ECR 5 to 5.5 per kWh with other options
- Power cost 6.5 to 7 kWh.
- Indian technology tested by NTPC at Varanasi
- Lower SOx and GHG emissions, ash
- Evenly distributed hence reduced transport

- Unorganized suppliers
- Higher collection cost
- Weak supply chain
- Low density of raw biomass



- Waste deposal
- AQI improvement
- Controls Invasive Alien Species
- Clean land water
- Improves farmers income
- Positively impacts most SDG goals
- Improved health

- Falling prices of solar and storage
- Needs policy support to take off

Torrefied biomass can replace upto 100% coal in thermal power plants

Non torrefied biomass pellets are being used in cofiring mode

They deliver competitive tariff with opportunities for several associated benefits

Small Modular Reactor

S

- Minimal life cycle carbon emission
- Low gestation period (3 years)
- Modular and standard designs
- Non intermittent

W

- Minimal life cycle carbon emission (09-111 gm/kWh
- Cost 23- 50 Cr /MW v/s 12 Cr/MW for full scale nuclear under Indian program

O

- Rapid base load capacity addition with minimal GHG emissions

T

- High neutron leakage leading to higher radioactive waste then traditional nuclear
- Higher tariffs
- Lower public acceptance
- Energy security issues due to import dependence for technology and fuel

Environmental and financial attributes of various low-GHG technologies

	Solar with storage	Nuclear (SMR)	Biomass firing	CCUS
Emission Factor (gm/kWh)	500	Less than 111	230	Greater than 240#
Capex per MW over 25 years	₹167 million	₹ 230 million – ₹ 500 million	₹18-₹ 150 million	₹309 million
Tariff (non-solar hours)	₹9/kWh	Above ₹ 8.8 /kWh	₹ 6-₹7/kWh	₹ 12/kWh
Potential for negative emissions	No	No	Yes	Yes/ with biomass

#assuming 75% capture

Economic advantages of biomass fuel

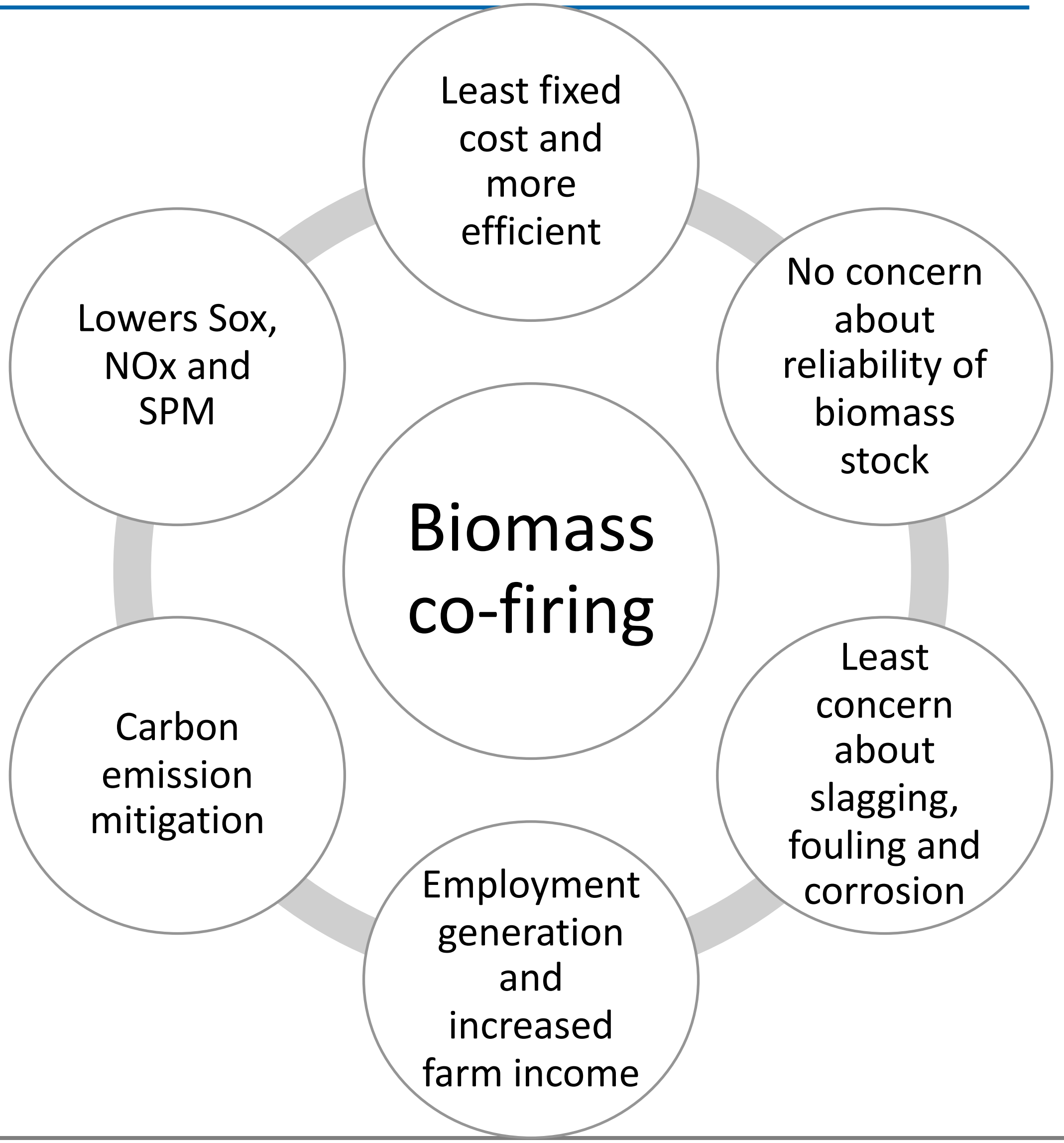
- India loses about 300 million dollars annually due to health effects of biomass burning in Punjab and Haryana alone*
- Total quantity of rice straw in Punjab and Haryana is 23 million tons annually
- Each ton of biomass is causing a loss 13 dollars (1 rupees per kg) only due to health hazard.
- It can avoid loss of visibility, accidents, Traffic jams, Flight delays or curtailment and similar other losses.
- Avoids loss of land fertility
- Cost of extreme cycling of thermal units can be reduced due to dispatchable nature of this renewable resource. (impact on consumer tariff)
- Additional cost of storage is not required for biomass-based power
- Same power infrastructure is used for generation. Additional cost is only for biomass processing.
- Additional low skill job creation in the villages and additional income to farmers.
- Global warming reduction resulting in associated economic advantages.
- Perfect case of supporting the drive from public money

- Source: Suman Chakrabarti and others, Risk of acute respiratory infection from crop burning in India: estimating disease burden and economic welfare from satellite and national health survey data for 250 000 persons, *International Journal of Epidemiology*, Volume 48, Issue 4, August 2019, Pages 1113–1124,)

Brief about Biomass to Energy in India

Environmental and social gains

Biomass co-firing based on residues and wastes has been recognised by the United Nations Framework Convention on Climate Change (UNFCCC) as a technology to mitigate GHG emissions so that countries can sell carbon credits associated with their co-firing projects. 10% co-firing means, 10% cut in GHG emission.

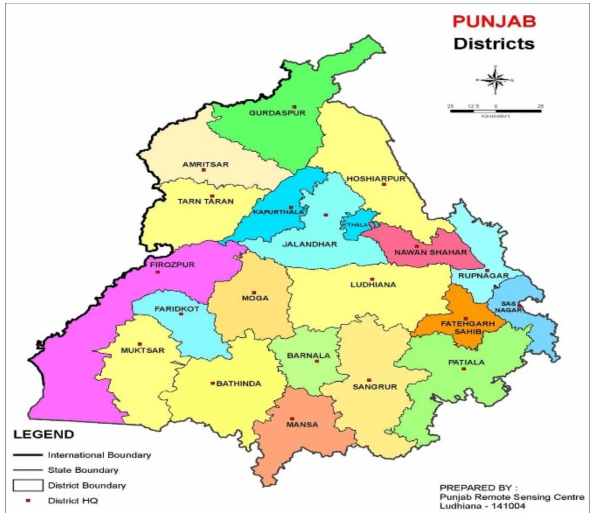


Biomass Generation in India and Power Potential

BIOMASS	GROSS AVAILABILITY (MILLION TONS PER YEAR)	FOR ENERGY USE (MILLION TONS PER YEAR)	GROSS CALORIFIC VALUE (KCAL/KG)
AGRO- RESIDUE	750	230	3000-4000
MSW	58	40	2200-2800
LANTANA	616	492	4300-4600
PINE NEEDLES	4.19	2.93	4800-5500
CATTLE DUNG	1322	168	3800-4000
OTHERS	300	200	3000-4000
TOTAL		1132	

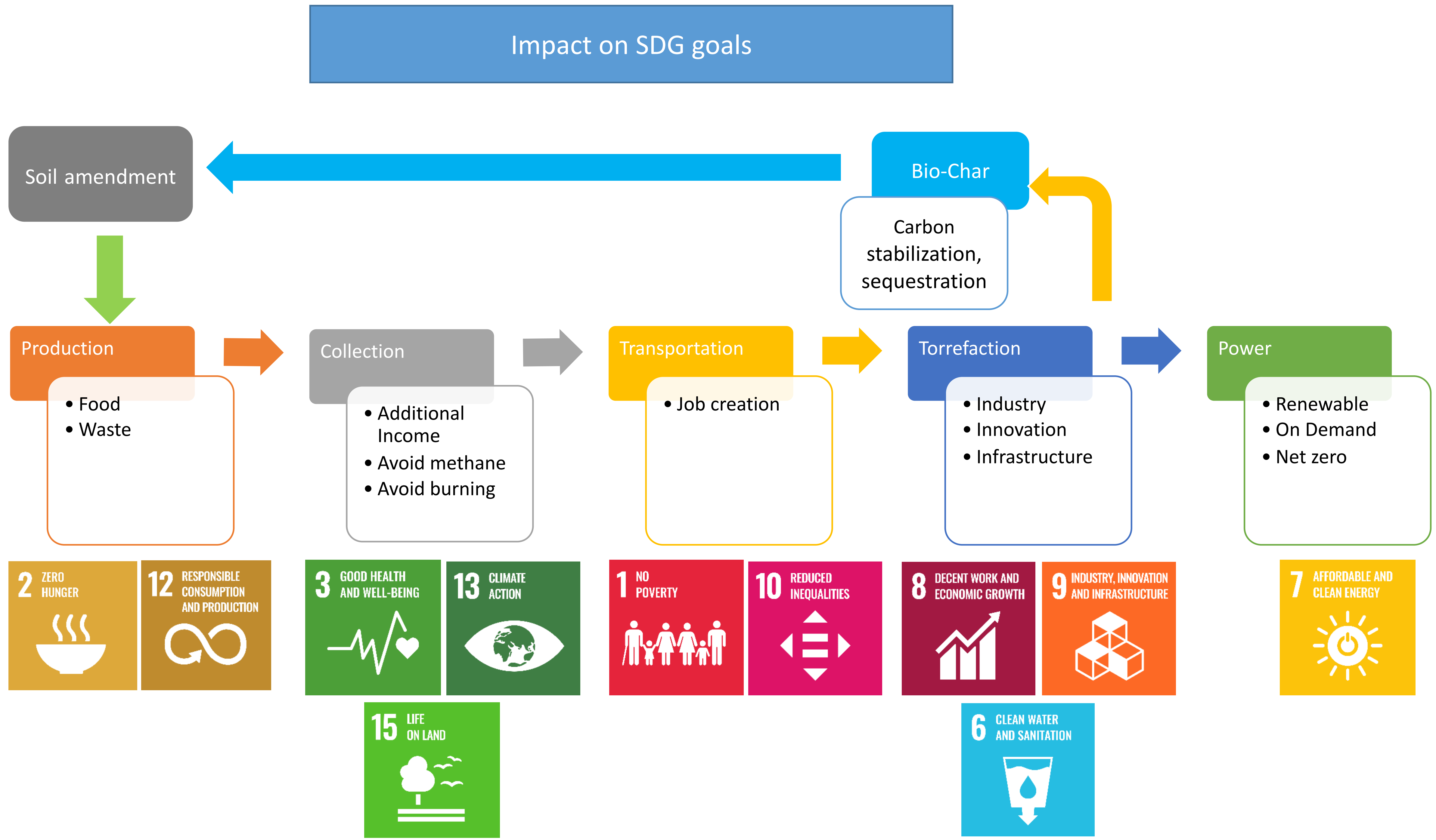
At 100% PLF, 1000 MW plant requires daily 1600 MT biomass @10% co-firing ratio, it is sufficient to replace energy from all the coal used in thermal power plants.

Punjab/Haryana - Paddy Straw Availability and Biomass Power



Rice straw production in Punjab	12.4 Million Ton
Rice straw production in Haryana	10.9 Million Ton
Total Rice straw generation	23.4 Million Ton
Capacity required for 10% Co firing	~47,000 MW
Thermal Plants in Punjab & Haryana	~10,780 MW
NTPC Dadri 1820 MW + Harduaganj 610 MW	2430 MW
Total Thermal power plant capacity	~13000 MW
Co-firing potential	**28% (6.6 million ton at 70% PLF)**

Balance bio mass pellets can be transported by trains to other power plants.



Impact on SDG goals
Soil amendment
Bio-Char
Carbon stabilization, sequestration
Production
• Food
• Waste
Collection
• Additional Income
• Avoid methane
• Avoid burning
Transportation
• Job creation
Torrefaction
• Industry
• Innovation
• Infrastructure
Power
• Renewable
• On Demand
• Net zero
2 ZERO HUNGER
12 RESPONSIBLE CONSUMPTION AND PRODUCTION
3 GOOD HEALTH AND WELL-BEING
13 CLIMATE ACTION
15 LIFE ON LAND
1 NO POVERTY
10 REDUCED INEQUALITIES
8 DECENT WORK AND ECONOMIC GROWTH
9 INDUSTRY, INNOVATION AND INFRASTRUCTURE
6 CLEAN WATER AND SANITATION
7 AFFORDABLE AND CLEAN ENERGY

Economic advantages should be factored in to socialize the cost and promote biomass fuel for energy

- Biomass power meets most social and environmental goals
- Abates carbon footprint
- Reduces many expenses like health, and transport sector losses
- Improves air quality and environmental pollution.

Various phases of Test firing

- **First phase:-** Objective of this phase was to establish biomass pellets blending procedure and to establish procedure for safe and reliable co-milling operation and to examine the **mill performance** by pulverising lean blend **(2.5%) of biomass pellets with coal in one mill** which was successfully achieved.

- **Second Phase:-** Objective of this phase was to examine the **mill performance** with increased proportion of biomass **blend (5%) in one mill** and fine tuning of the blending process which was successfully achieved.

- **Third phase:-** Objective of this phase was to examine the effect of biomass co-firing on **boiler performance** such as efficiency loss, increase in auxiliary power consumption, ash characteristics, NOx, SOx and particulate emission at higher **blend ratio (7%) in all four mills at full load** which was successfully achieved.

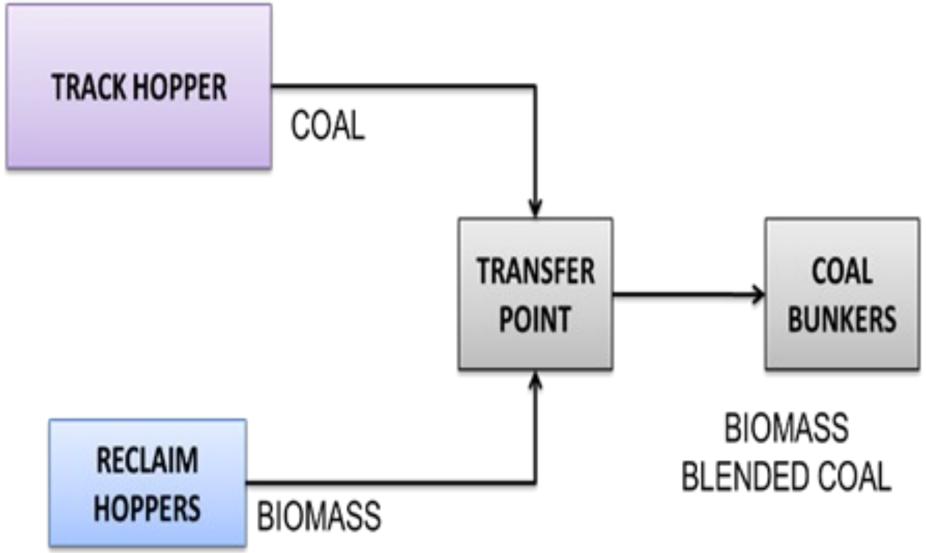
- **Fourth Phase:-** Objective of this phase was to examine **mill performance at higher blend ratio (10%) in all four mills** which was successfully achieved.

Analysis of biomass pellets used for co-firing

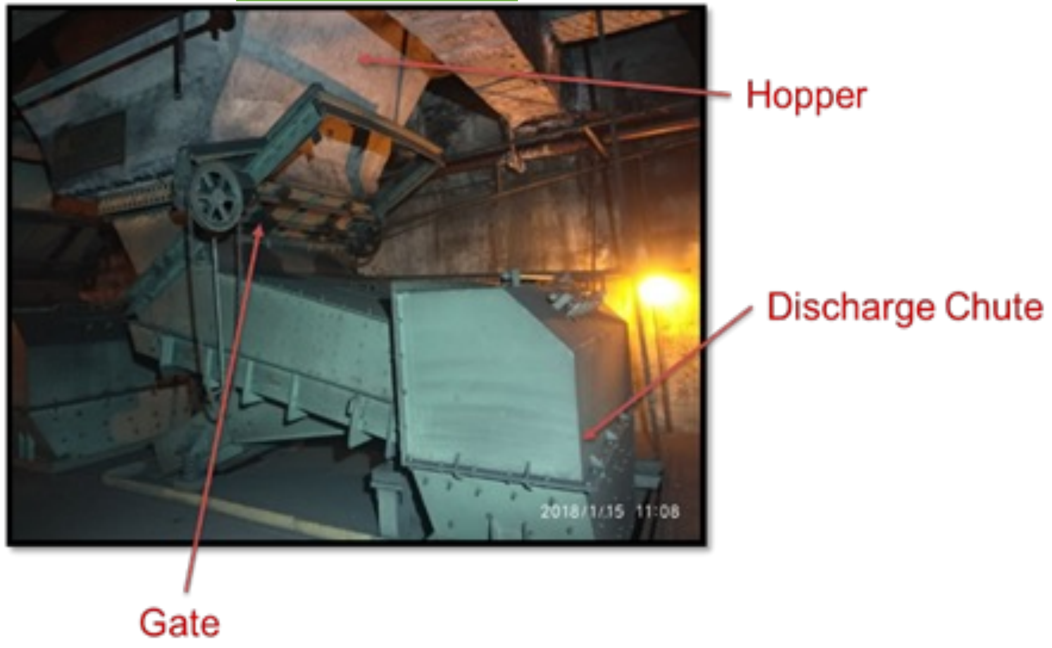
- Test firing was conducted with saw dust pellets.
- Firing saw dust pellets hardly makes any difference as far as test firing objectives are concerned.
- Constituent particle size distribution of pellets was in range of 75-80% through 1 mm sieve.

Parameter	Coal	Paddy straw
Carbon content	34-35%	10-15%
Volatile content	20-21%	60-66%
Ash content	38%	15%
Moisture	12-18%	8%
GCV	3500 Kcal/Kg	3750 Kcal/kg
Alkali content (K, Na)	-	6-8%
Chlorine content	0.05-0.08%	0.8-1.5%
Density	833 kg/m3	700 Kg/m3
Ignition temperature	454 C	240 C
Grind ability index	70-80	Fibrous
Particle type	Brittle	
Ash Fusion Temp.	1150 C	850-900 C
Ash resistivity	moderate	High

Biomass pellets blending with coal



Reclaim hopper



Biomass pellets feeding was done through vibrating emergency feeder (also called as reclaim hopper) located in coal yard in controlled manner by manually adjusting balancing weights for regulating vibration of feeder and manually adjusting rack and pinion gate of feeder. The pellets were blended in desired proportion with coal coming from track hopper at TP-3.

Reclaim Hopper and Conveyor

Biomass pellets feeding through reclaim hopper located in coal yard. Biomass pellets is being conveyed from reclaim hopper to TP-3 for blending with coal coming from track hopper.

Test Results : Mill Internal Inspection

No settling of biomass was observed within mill during internal inspection.

It was deduced that size of biomass particles might be reduced to some extent due to its attrition with coal. Further, due to lower density of biomass particles, it might be passed through classifier even with higher particle size in comparison to coal.

Biomass Co-firing Experience at NTPC Dadri (Pilot tests)

Objective

- To establish the procedure for blending of biomass pellets with coal in predetermined ratio
- To establish procedure for safe and efficient method of co-firing of biomass pellets by co-milling.
- Studying impact of biomass co-firing on mill operation, boiler efficiency, Aux. Power Consumption, emission level (Sox, Nox, SPM), bottom and fly ash characteristics etc.
- Studying commercial implication

Various types of biomass pellets

Can We Entirely Switch to biomass fuel in the Existing Plants?

Technology and Research Gaps

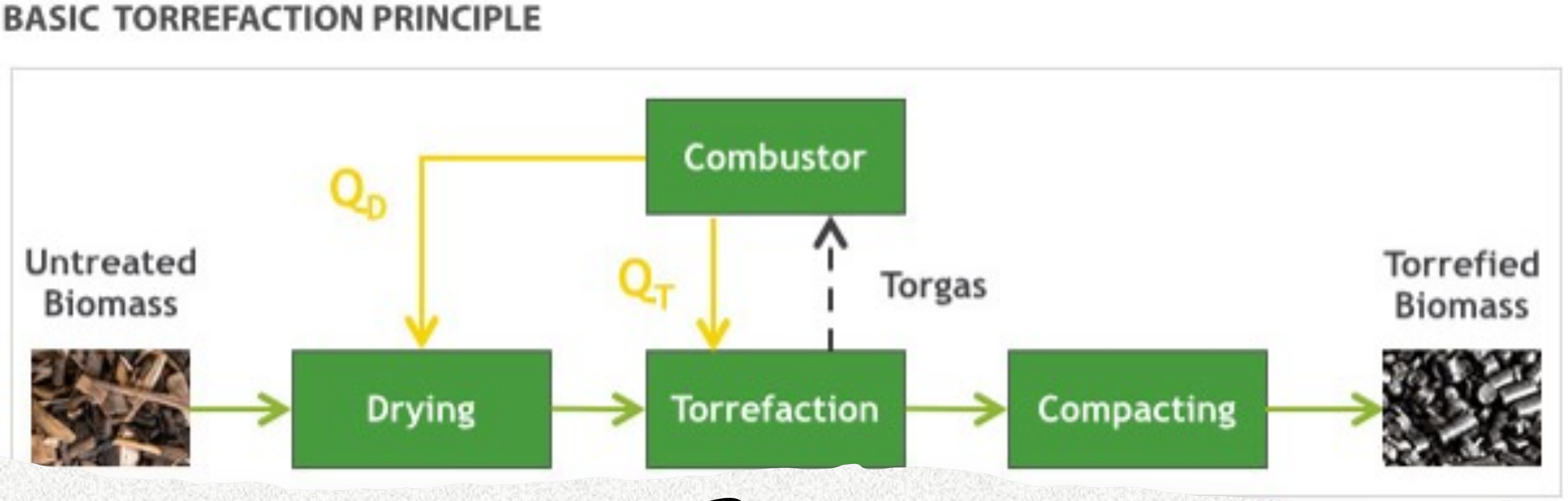
- In my leadership, demonstrated successfully up to 10% co-firing of biomass in NTPC Dadri
- Now, NTPC is co-firing biomass pellets in 14 NTPC plants. More than 1 Lakh tons already fired
- Higher percentage can not be fired due to certain limitations
  - Milling constraints: Mills are designed to grind non fibrous high HGI coal, however biomass is fibrous (limits to 10%)
  - Boiler constraints: (limits to approx. 20%)
    - Biomass has high chlorine, may result in fire side corrosion of high temperature alloys used in heat exchangers.
    - Alkali present in the fuel reduces ash melting point and can cause slagging and fouling problem in the boiler
  - High volatile content in biomass (about 65- 80% v/s less than 30% in coal) presents fire and safety risk.
  - Ash utilization constraints: Higher alkali in ash may present challenges in its utilization in certain applications (Limits to approximately 40% for Indian coal)

Torrefaction: the way ahead

How can we increase the proportion?

The Way Ahead:

- Torrefaction improves the fuel characteristics by
  - Improving grindability and other physical properties similar to coal, reducing volatile content, and improving GCV
  - Reducing alkali and chlorine during torrefaction process
  - Still residual chlorine and alkali will not permit 100% replacement of coal
  - If alkali, chlorine and other unwanted elements can be reduced, the fuel may be suitable for replacement of coal.
  - Design and investigation of torrefaction methods, and/ or processing of torrefied charcoal to reduce unwanted elements is of interest.
  - We at amity have achieved it successfully and economically, large scale replacement of coal with biomass derived fuel is possible now, thus solving two challenges--environmentally safe waste disposal and GHG emission reduction.



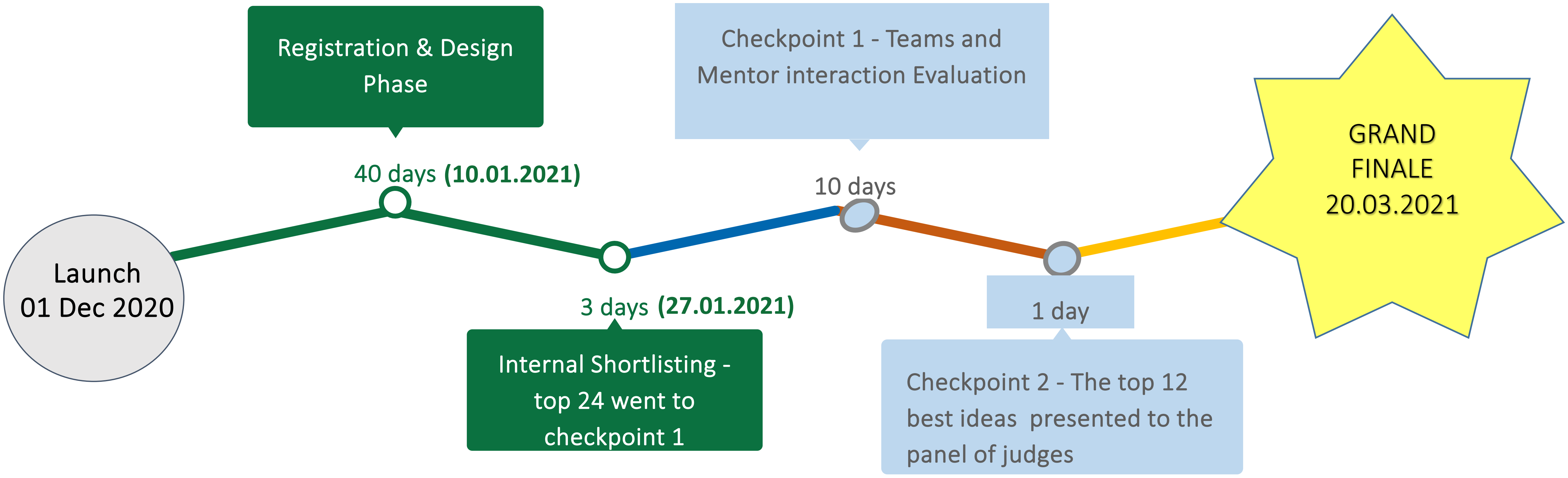
Torrefaction process

Torrefaction is a thermochemical process typically **at 200-350 °C in the absence of oxygen**. The process causes biomass to partly decompose, creating torrefied biomass, a charcoal like substance, with improved fuel characteristics. Torrefied pellets are more suitable for co-firing in thermal power plants in replacing higher percentage of coal.

Waste to Coal Initiative

- Torrefaction principle applied on carbonaceous waste (excluding stones, concrete, glass and metal)
- Material is heated in the absence of oxygen at up to 300 °C . Material is carbonized and the volatile matter released are used for producing heat for torrefaction
- Pilot plant installed at NTPC Dadri (capacity 10 TPD)
- Planning to install a plant for managing the waste at Varanasi
- Advantages are:
    - As the heating is done in the absence of oxygen no dioxin and furan formation
    - High calorie charcoal is formed which can be used in power plants
    - Smaller plants can be used for distributed applications even for villages.

Green Charcoal Hackathon



Increasing the percentage of Biomass firing

- Challenges:
  - Milling System challenges due to fibrous nature of biomass fuel
  - Challenges in Boiler due to slagging, Fouling and corrosion
  - Challenges in DNOx System
  - Challenges in Ash Utilization
- Remedial measures:
  - Pellets made of finer pre-milled material or using Separate Milling system
  - Still co-firing is limited by boiler constraints (Approx. 20%)
  - Use of Torrefied Biomass (20-30%)
  - Use of processed torrefied biomass (% can be further increased)
  - Using gasifier and firing syngas in the boiler (% can be further increased)

MSW to Fuel

एनटीपीसी
NTPC
विद्युत व्यापार
Vidyut Vyapar



600 TPD VARANASI HARIT KOYALA PARIYOJANA



Major Highlight of Varanasi Harit Koyla Pariyojna

1. **Swatchh Bharat Abhiyan (SBM) :-** Torrefaction process is a very clean technology ensures no harmful emissions
2. **Make in India:-** Complete Plant's Equipment(s) will be manufactured in India
3. **Aatma Nirbhar Bharat Abhiyan :-** 1st kind of WTE Facility making India a self-reliant nation in waste management.
4. **Innovation:-** This plant is an example of Innovation in waste management.

Location	**Near Ramana Village of Harahua Block**
Emaciated Area	25 Acre
Nearest Highway	NH 19 (about 2 KM)
Nearest Commercial Airport	Lal Bahadur Shastri International Airport, Babatpur, Varanasi (about 40 km)
Nearest Railway Station	Varanasi Cantt (about 15 km)
Other Railway Station	Banaras (about 14 km)

PROJECT DETAILS

PROJECT NAME

Varanasi Harit Koyala Pariyojana

वाराणसी हरित कोयला परियोजना

PROJECT CAPACITY

600 Tons input MSW per day

COMPLETED PROJECT COST

Approx. 200 Cr. till the end of project

LOA DATE

12th November 2021

COMPLETION 11th December 2023

Advantages of Torrefaction Technology

- Generation of High Calorific Value Fuel similar to the nature of Mineral Coal
- Can be used for both organic and non-organic waste
- No emissions of Dioxins and Furans due to Lower process temperature
- Lower Capital cost in comparison to Mass Incinerators, Pyrolysis and Gasification Plants and Lower Operational Costs
- Torrefied coal can be cofired with Existing burners of Boilers
- Diversion of Municipal waste from Landfill, only non-reactive inert goes to Scientific Landfill.
- Green Project thus eligible for Carbon Credit

KEY FEATURES OF PLANT

- The plant is designed in modular/unit wise fashion to allow for assembly, testing, maintenance, and replacement of individual sub-assemblies.
- The Complete plant will be odorless and applicable emission norm compliant.
- The plant will have an aesthetic environment with noise level in permissible limits.
- The plant involves adequate automation to prevent human exposure to messy areas during operation and maintenance (O&M) of plant and to save the human resource requirement.
- The plant is designed for 25 years of life.

Torrefaction Plant at Varanasi: 3x200 TPD

where it can be used?

COAL PRODUCED IN PLANT CAN BE SUPPLIED IN NEARBY NTPC PLANTS:				
Sl. No.	**Thermal Power Station**	**Owned By**	**Location**	**Distance from Varanasi (kms)**
1	Meja thermal Power Station	NTPC Limited	Meja, UP	130
2	Obra Thermal Power Station	UP Rajya Vidyut Utpadan Nigam Limited	Obra Village, Sonbhadra Dist., UP	135
3	Tanda Super thermal Power Station	NTPC Limited	Tanda, UP	177
4	Singrauli Super thermal Power Station	NTPC Limited	Shaktinagar, UP	200
5	Unchahar Super thermal Power Station	NTPC Limited	Unchahar, UP	210
6	Rihand Super thermal Power Station	NTPC Limited	Rihand, UP	220

Emission reduction with fuel switching

Emissions from 1000 MW pulverized fuel power plant: Effects of fuel switching

- Annual emissions for a typical coal having GCV of 4275 kcal/kg and C=44%; S=0.5%, Ash 33%

Fuel	Quantity (MMTPA)	CO_2 (MMTPA)	SO_X (KTPA)	Particulate Mg/NM^3	Ash MMTPA
Coal	4.46	7.195	44.6	50	1.47
Torrefied rice straw	4.46	1.712	17.8	50	1.45
Torrefied Lantana	3.23	900	-	30	0.725

NOX Emissions reduction through biomass co-firing (US-NREL study)

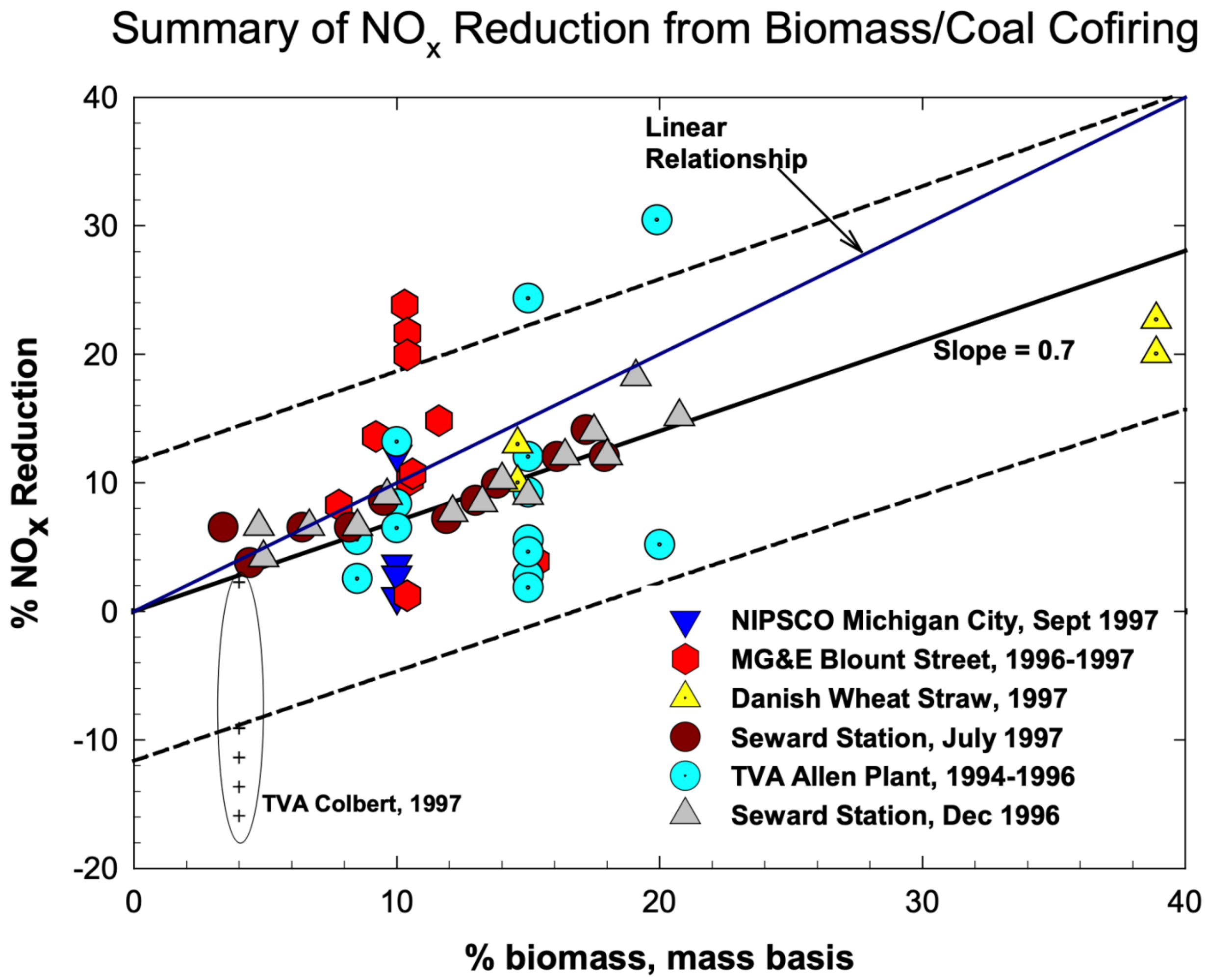


Figure 1: A summary of NOx reduction from a number of biomass/coal cofiring full-scale and pilot-scale demonstration tests, based on the mass input of biomass. Dashed lines are 95% prediction limits that encompass the range of variability in the measured data.

ESP Issues: A word of caution

- No experience is available about the behaviour of biomass ash in electrostatic precipitators (EP), which is critical as biomass ash may have vastly different types of ash particles.
- The literature points out that biomass ash may contain particles of sub-1-micron size whose charging mechanism may not be adequate to precipitate them in the EP.
- The efficiency of the EP in terms of the number of particles may decrease, while it may not be affected in terms of mass.
- Fortunately, however, the ash content in most of the biomass is less than that of domestic coal, and the issue, if observed during field tests, can be tackled with bag filters or a combination of EP and bag filters.

Abatement of radioactivity through fuel switching

- Wood and biomass are one of the least radioactive substances
- Fuel switching to biomass can considerably reduce population exposure to harmful radiations through airborne ash particles.
- Biomass co-firing may also reduce radioactive exposure to some extent. However, studies needs to be done to quantify it.

Conclusion

- The author has demonstrated biomass co-firing up to 10%in NTPC plants successfully and it is well proven.
- Technologies are available to use higher percentage of biomass fuels using torrefaction.
- Author's research demonstrate that 100% use of torrefied fuel is also possible with some fuel processing
- Fuel switching may result in 777 MMT of CO2 reduction annually.
- All emissions including GHG, SO_X, NO_X, particulate and radioactivity can be reduced to a large extent.

Thank You

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