Council of Enviro Excellence

Date: 01 October 2024
Venue: Hyatt Centric, Janakpuri, New Delhi

FLEXIBLE OPERATIONS IN THERMAL POWER PLANT

Adoption of Flexible Operation for Sustainable Energy Transition: Barriers and Challenges

Mr Anjan Kumar Sinha
Intertek

Total Quality. Assured.

Adoption of Flexible Operation for Sustainable Energy Transition

BARRIERS AND CHALLENGES

Anjan Kumar Sinha
October 1st , 2024

PRESENTATION OUTLINE

INTERTEK IS UNIQUELY POSITIONED TO DELIVER ATIC SOLUTIONS

44,000+ EMPLOYEES

GLOBAL MARKET LEADER IN ASSURANCE

12,000+ AUDITORS, INSPECTORS, TECHNICAL PERSONNEL

340,000+ INSPECTIONS AND OTHER TECHNICAL VISITS / YEAR

100+ COUNTRIES

GLOBAL MARKET LEADER IN TIC

1,000+ LABS & OFFICES

80+ LANGUAGES

Systemic approach to Quality and Safety

Our Sectors

Products | Trade | Resources

POWER PLANT FLEXIBILITY
INTERTEK EXPERIENCE

INTERTEK IS A WORLD LEADER IN THE FIELD OF IDENTIFYING AND ESTIMATING THE COSTS OF FOSSIL PLANT CYCLING.

WE ARE ONE OF THE FIRST TO IDENTIFY CYCLING AS A MAJOR COST ISSUE.

- Our staff is highly experienced and well versed with:
  - Power plant component damage mechanisms and failure
  - Component/unit reliability modelling
  - Component aging and impact of fatigue cycling on aging components
  - Capital and O&M accounting and how to associate costs to cycling damage and unit reliability
  - Relevant industry databases
  - Statistical modelling, unit commitment and production cost analysis
- We have extensive experience working on utility projects
- We know how to take sparse data and utilize it effectively
- We advise on design improvements, equipment upgrades/replacement and operating process improvements to ensure your plant operates more efficiently and reliably.
- Asset Life Optimization and assessment of future capital and maintenance costs, stranded costs and dispatch

Strong Commitment to Research & Development

Numerous Patents/ Proprietary Technologies

In-House Metallurgical & Mechanical Test Laboratory

Electric Power Research Institute

Department of Energy

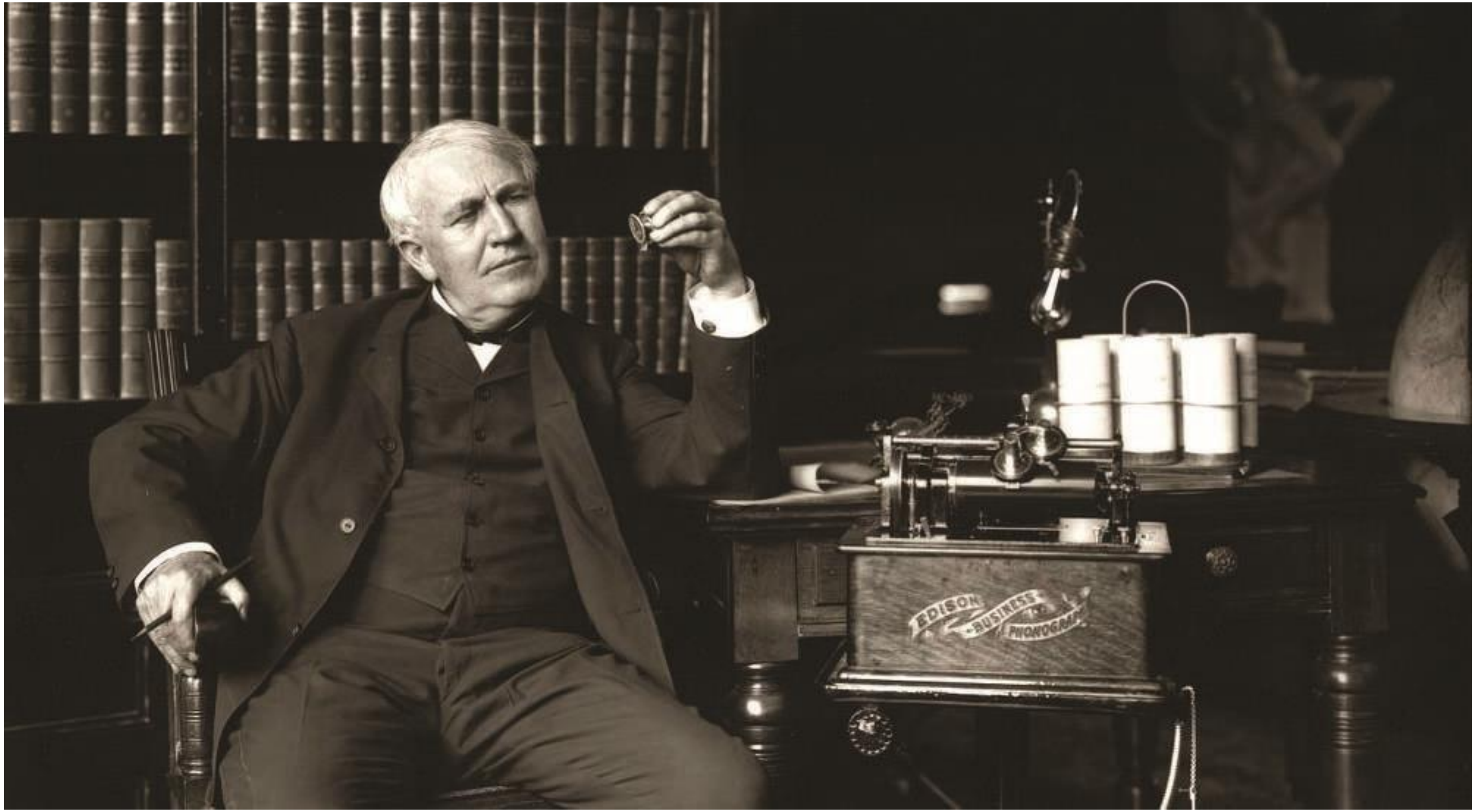
Gas Research Institute

Oil & Gas Companies

Utilities

More than 10,000 Completed Projects

Our Heritage



ETL Testing Laboratories founded by Thomas Edison in 1896.

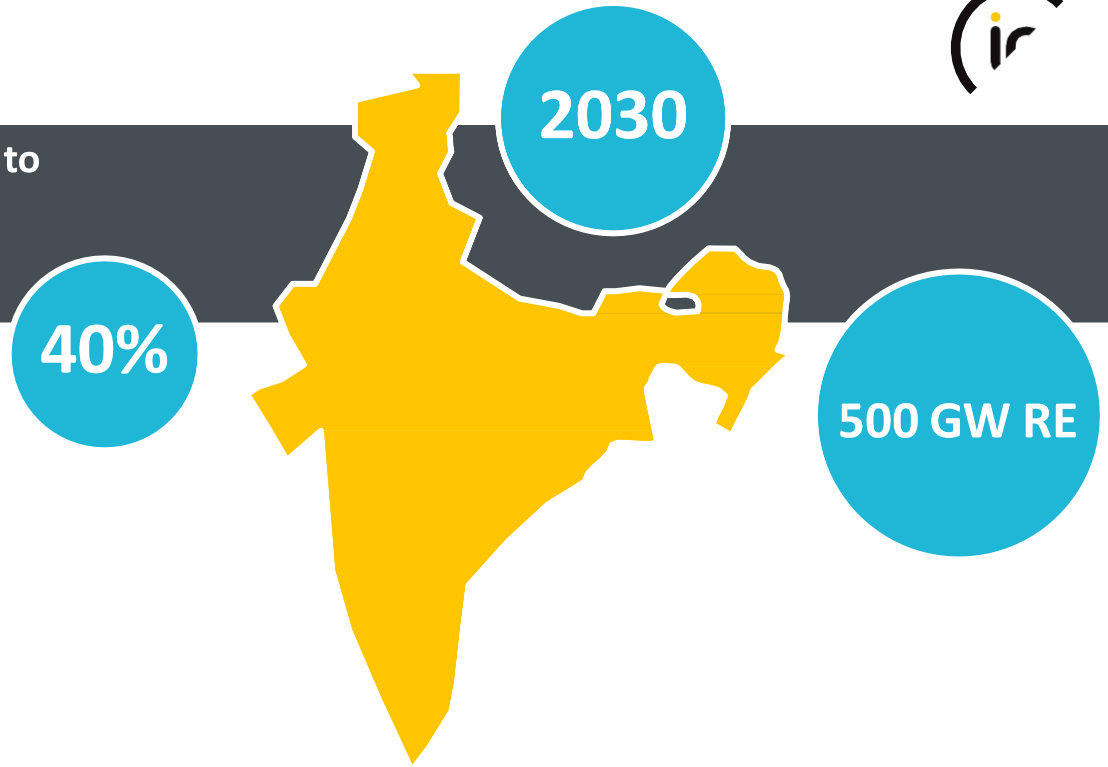
Edison Once Said:

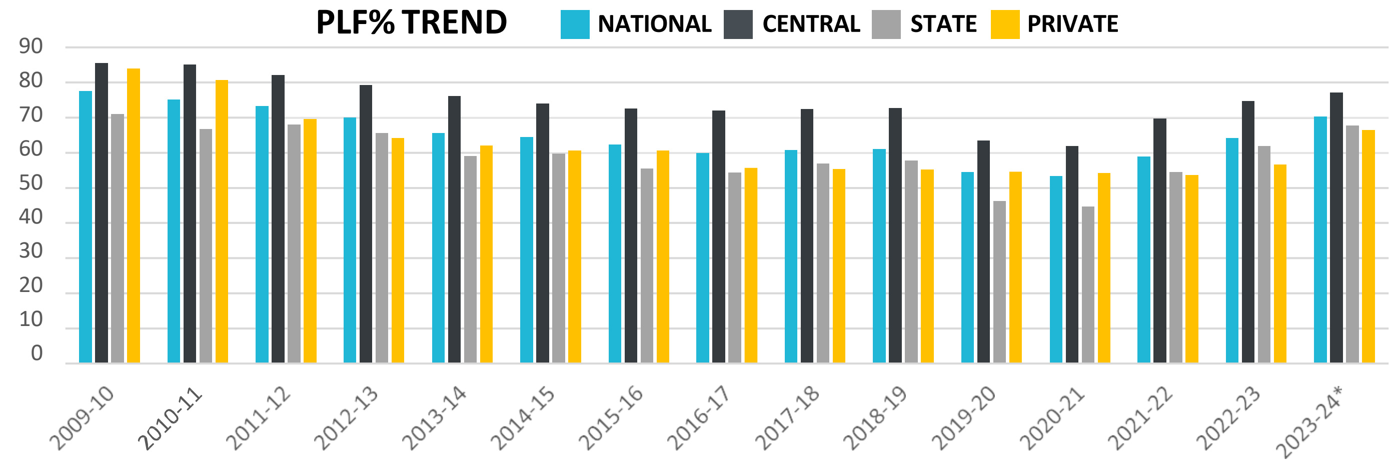
"We are like tenant farmers chopping down the fence around our house for fuel when we should be using natures inexhaustible sources of energy – sun, wind and tide."

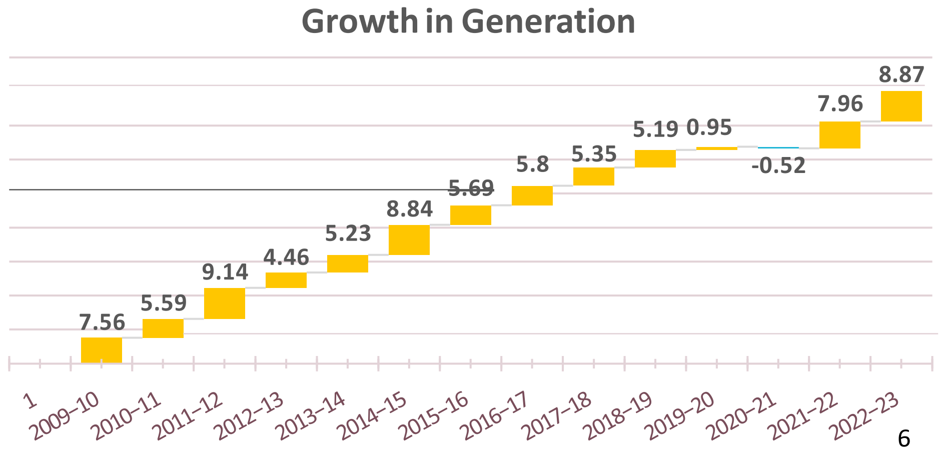
In conversation with Henry Ford and Harvey Firestone (1931); as quoted in Uncommon Friends: Life with Thomas Edison, Henry Ford, Harvey Firestone, Alexis Carrel & Charles Lindbergh (1987) by James Newton, p. 31

BACKGROUND

- India's pledge to increase the share of non-fossil fuels-based electricity to 40 percent by 2030
- 500 GW RE by 2030
- Coal in India is increasingly needed to flexible and play a greener role
- Inadequacy of other balancing resources
- Coal is the mainstay of power generation in India
- Fuel economics-Non-Pit head stations will have costlier fuel
- Tightening environmental legislation
- Transition to electricity market mechanisms – markets will force to operate more efficiently, even during flexible operation

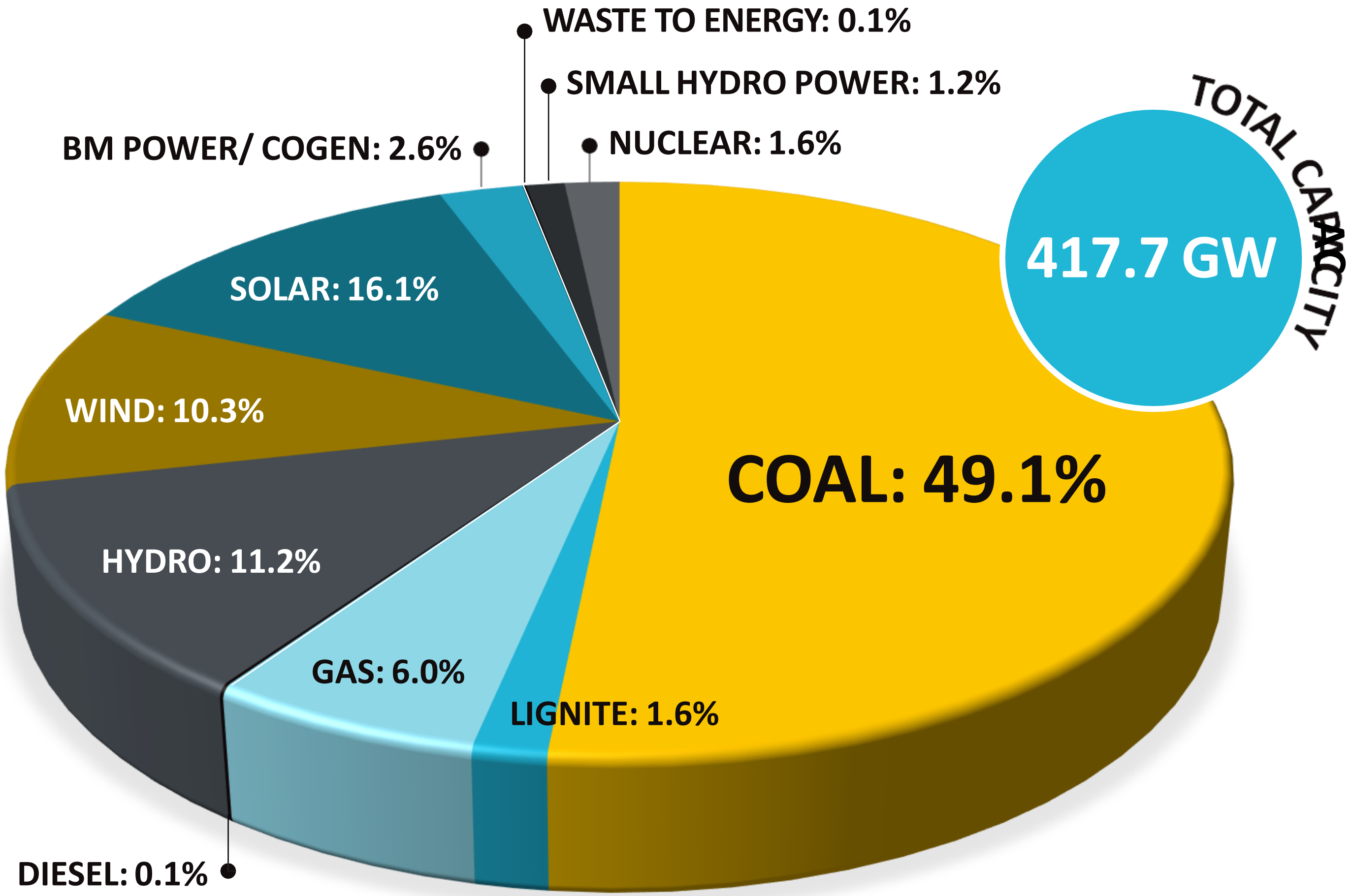


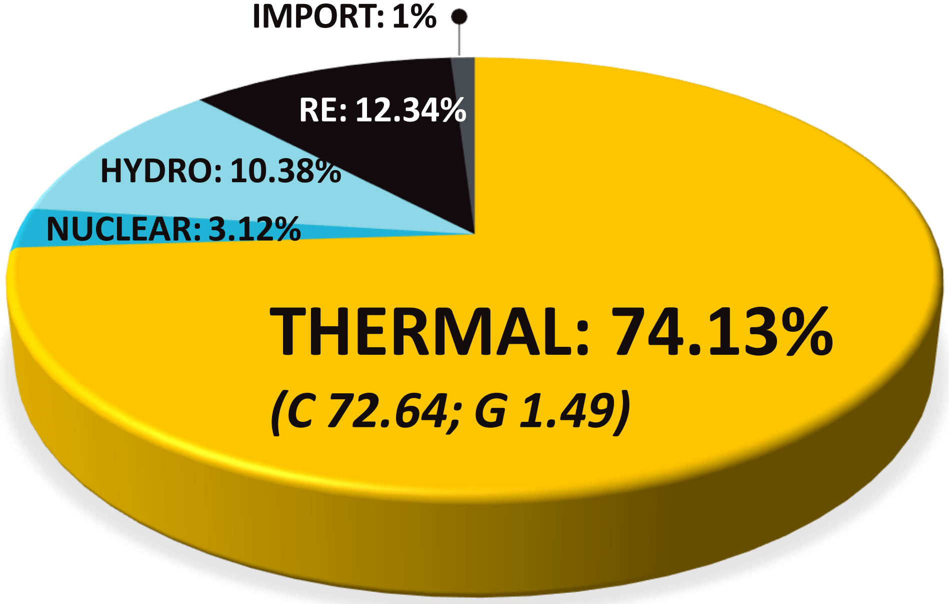




COAL HAS BEEN THE MAINSTAY OF THE POWER GENERATION IN INDIA

GENERATING CAPACITY SOURCE





SOURCEWISE GENERATION

TOTAL CAPACITY as of 31 MAY 2024

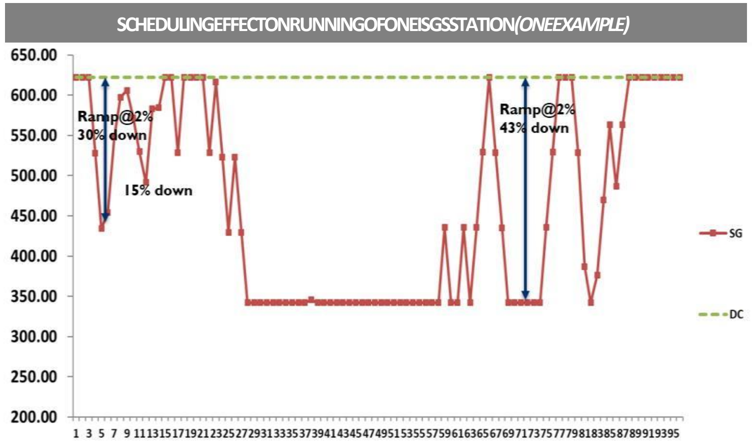
COAL- CRUCIAL FOR SUSTAINABLE ENERGY

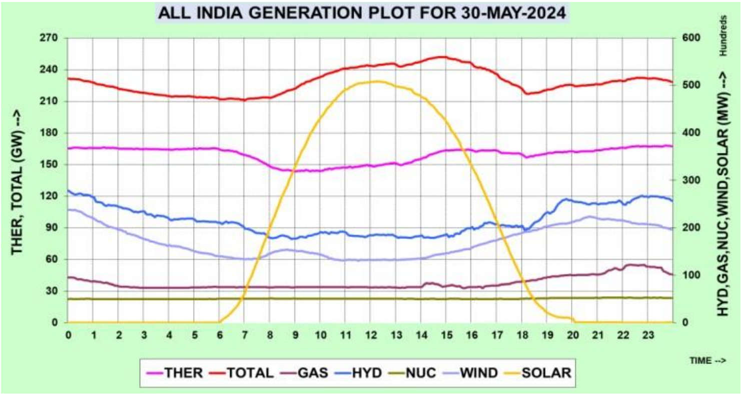
As extreme climate events are witnessed, the electricity demands continue to grow rapidly.

On 29th May,2024 the maximum temperature of 52.9^{0} C was recorded at Delhi's Mungespur

The peak demand scaled at 250 GW on 30th May.

Coal will be a significant resource required for sustainable energy future in India in the scenario of Rapid demand growth and increased VRE additions .





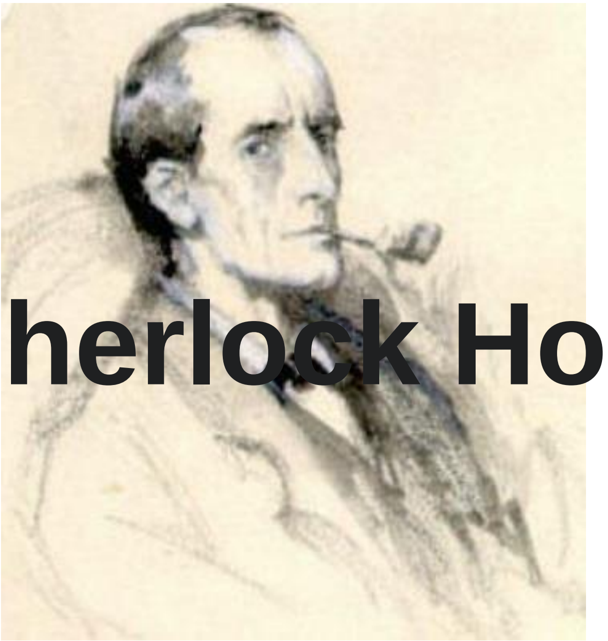
FLEXIBILIZATION AND ENERGY TRANSITION

- The energy transition towards sustainability is massive and two-fold:
  - Rapid growth in demand
  - Rapid deployment of RE (500 GW by 2030)
- Sustainability:
  - Energy Security
  - Affordability
  - Environmental sustainability
- Thermal power plants will be under extreme pressure to deliver all the aspects of the sustainability.
- There will be a shift in the operating regimes- calling for revisions in operating strategies and maintenance practices.
- However, the fundamentals of power generation must not be forgotten at every stage of generation:
  - Combustion optimization at low loads
  - Condensate management
  - Steam parameters
  - Metal temperatures
  - Equipment health monitoring

AWARENESS -FLEXIBLE OPERATION

- Any unit can be Flexed
- Flexing with lack of awareness, can be **DISASTROUS**
- Cycling causes **DAMAGE** and when equipment degrades, performance degrades
- Damage not immediate but **ACCUMULATED** and not easy to quantify
- By the time symptoms of damage is visible it may have become **VERY COSTLY** to correct
- Flexible operation is a difficult mode of operation and even the most conservative approach will increase plant **O&M COSTS** along with per MW variable costs
- Plants that can operate flexibly to meet market conditions while minimizing the financial impact of operating in this environment will continue to be dispatched at least for the near future
- Investments in **RETROFITS** can enhance the flexibility to a large extent
- Revisiting the **O&M PROCEDURES, TRAINING & DIGITALIZATION** support can enhance flexibilization
- **COMPREHENSIVE APPROACH NEEDED INVOLVING PEOPLE, PROCESS & TECHNOLOGY**

Data, data, data……..



Sherlock Holmes

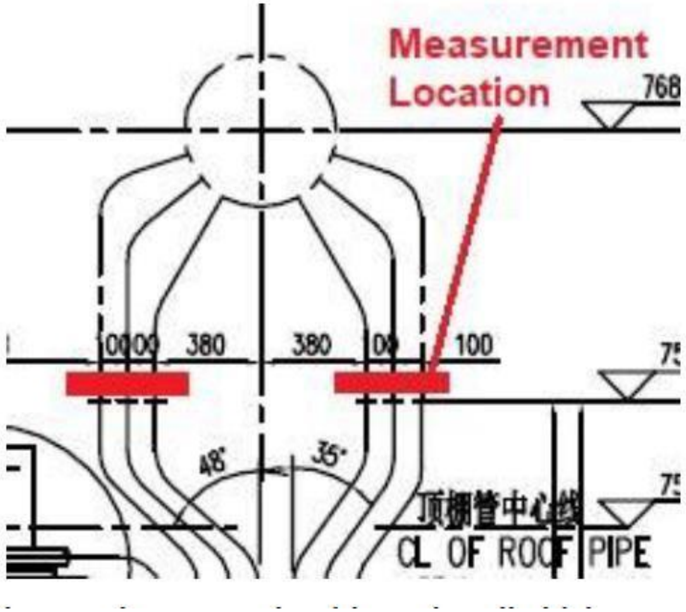
INSTRUMENTATION

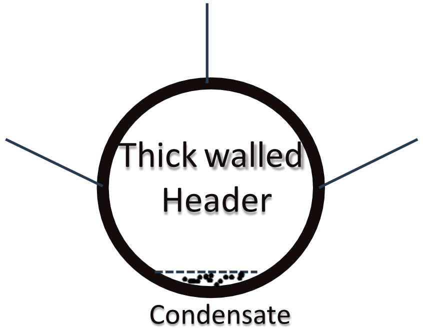
- FEGT
- Coal Pipe temp, velocity, mass flow
- SA Flow(individual burner)
- Drain Flow, temperatures
- Coal Analyser

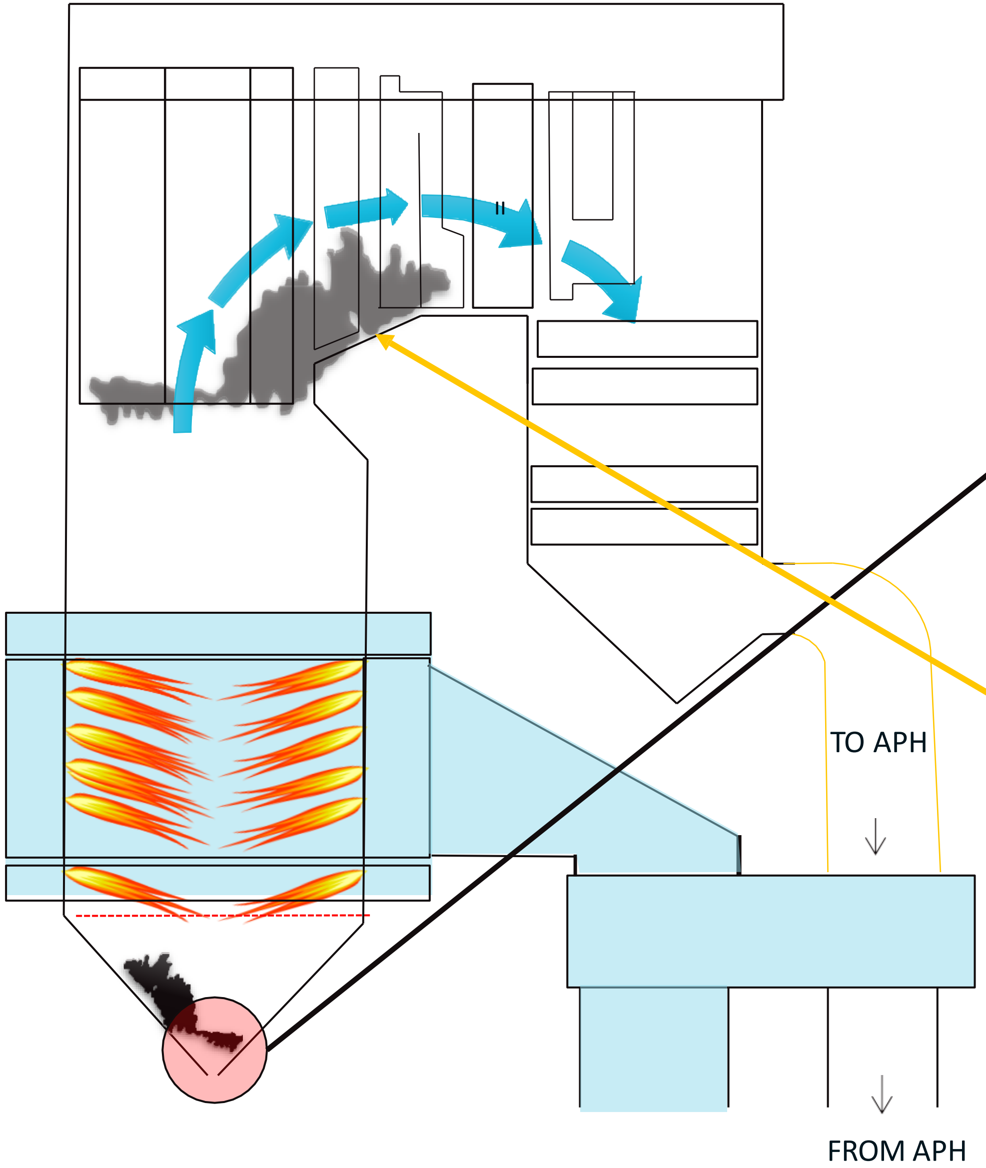
Correct Locations is important

Example- 1.How correct is the excess O2 measurement with air-in-leakages

2. Inadequate thermocouples at proper locations





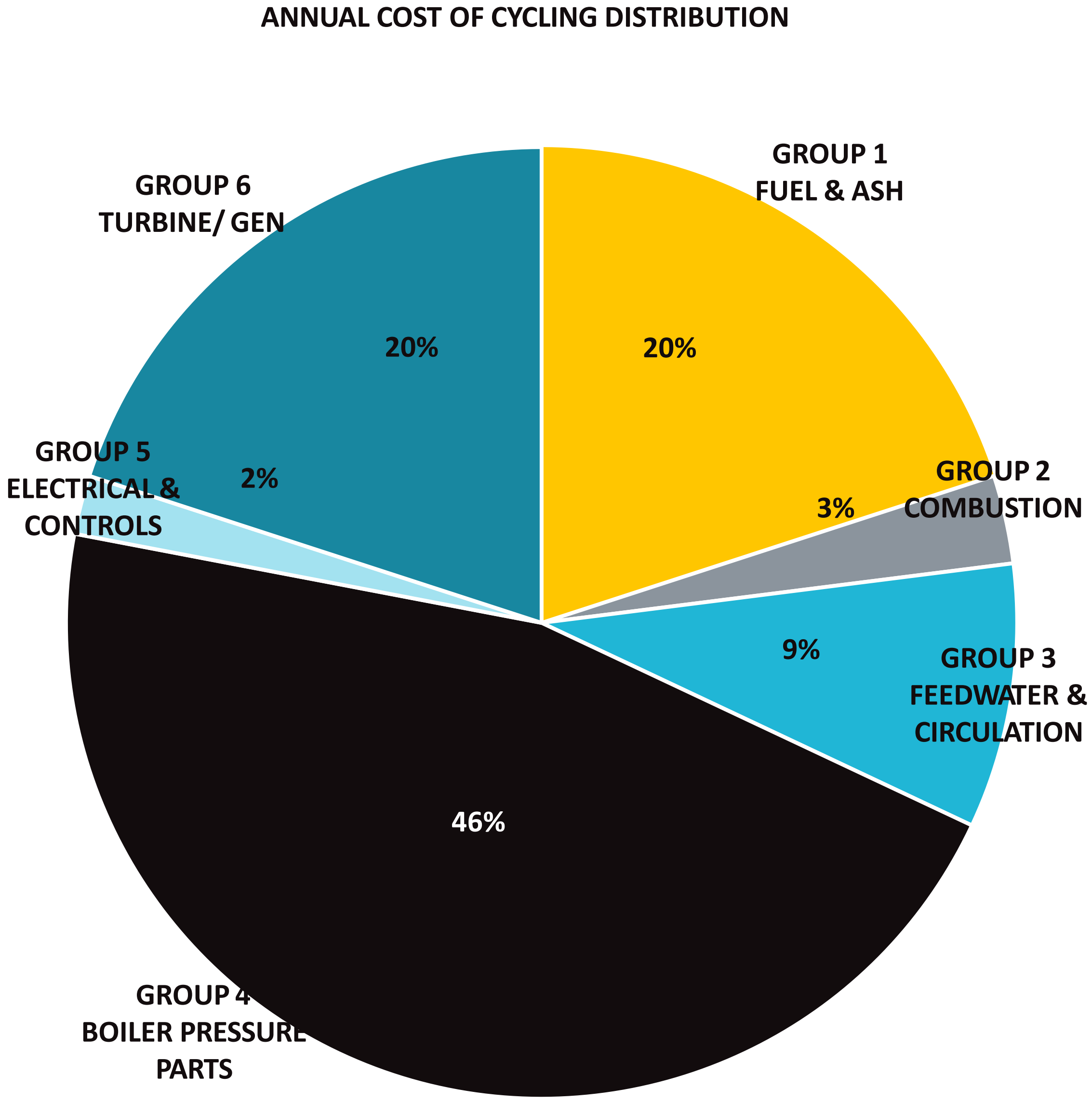


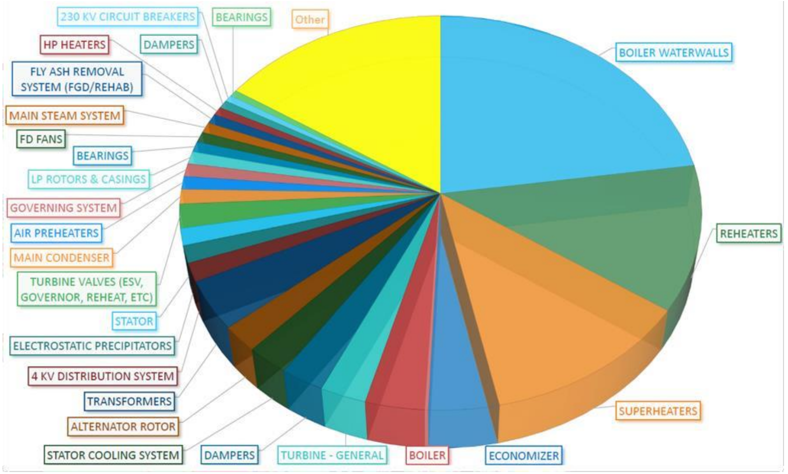
Is the soot Blowing adequate ??????

Do you have measurement??????

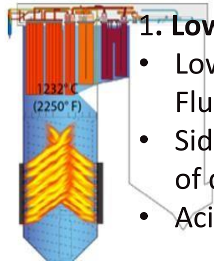
UNDERSTANDING THE DISTRIBUTION OF TOTAL COSTS OF DAMAGE

- **NECESSARY** to tailor the Overhauling & Maintenance Intervals of Units supported by Data
- Analysis of Component-Wise Cost Data is **IMPORTANT**
- Predictive Tools
- Estimated Weekly Damages
- EFOR & Life Management Actions
- Intertek COSTCOM, AWARE, EPRI, GE …

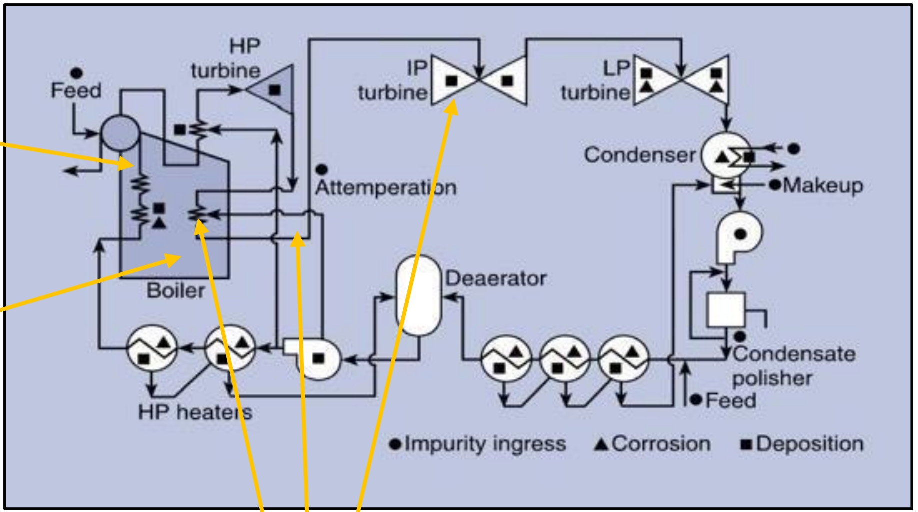




REDUCING MIN LOAD-KEY CHALLENGES



1. Low flue gas temperature
- Low-load operation reduce Flue gas temp
- Side effect: Poor performance of de-NOx eqipm.
- Acid dew point corrosion

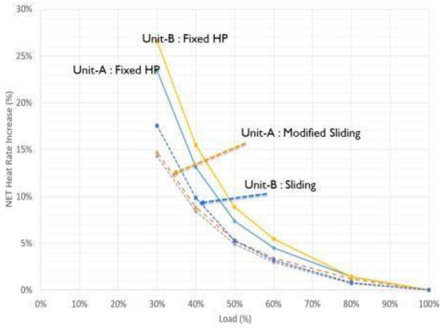


2.Unstable Flame

Maintaining Flame stability is more challenging during low-load operation
- Unbalances A/F distribution
- Deviated A/F ratio
- Coal Quality

3 Thermal stresses

4. Drop in efficiency



Burner Performance	Combustion Issues	Fuel Issues
Furnace Heat Balance	Waterwall Cleanliness	Refractory & Casing Issues
Expansion Joint & Duct Failures	Fan Issues	Burner Damper/ Tilt Issues

5. Reduced load control options
- Reduced steam flow, condensate volume

6. Distorted heat transfer
- Unclean surface
- Slagging

7. Maintaining Chemistry becomes challenging

RAMP ACHIEVED DURING PILOT TESTS

Dadri TPS, (NTPC), Dist. Gautambudh Nagar, UP

Test Date: 21 & 22/06/2018
Unit No.: 6
Unit Capacity: 500MW
Following tests were conducted:

Test	Target	Achieved
a. Minimum Load Test at 40%	200MW	200MW
b. Ramp Up Test	3%/min	~ 1.5%/min
c. Ramp Down Test	3%/min	~ 1.5%/min
d. Ramp Up Test	1%/min	~ 0.86%/min
e. Ramp Down Test	1%/min	~ 0.5%/min

The results are based on IGEF report dated 28/09/2018.

Sagardighi TPS, (WBPDCL), Dist. Musheerabad, West Bengal

Test Date: 27/06/2019
Unit No.: 3
Unit Capacity: 500MW
Following tests were conducted:

Test	Target	Achieved
a. Minimum Load Test at 40%	200MW	200MW
b. Ramp Up Test	3%/min	~ 1.6%/min
c. Ramp Down Test	3%/min	~ 2.6%/min
d. Ramp Up Test	1%/min	~ 1.1%/min
e. Ramp Down Test	1%/min	~ 0.67%/min

Note: No pilot study has been done on a Super-critical Unit In India

Mouda TPS, (NTPC), Dist. Nagpur, Maharashtra

Test	Target	Achieved
a. Ramp up Test (3%)	3%/min	~ 2.04%/min
b. Ramp down Test (3%)	3%/min	~ 2.01%/min
c. Ramp up Test (1%)	1%/min	~ 1.04%/min
d. Ramp down Test (1%)	1%/min	~ 0.92%/min

RBTPS, (Tata Power, DVC JV), DIST. Dhanbad, Jharkhand

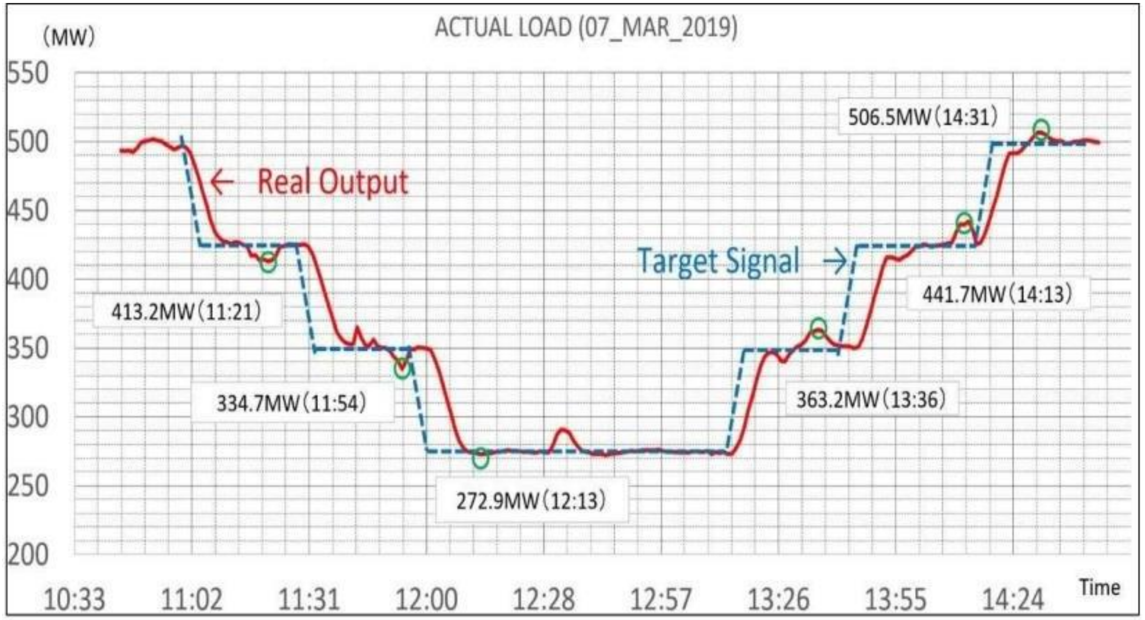
Test Date: 22/07/2021 to 27/07/2021
Unit No: 2
Unit Capacity: 525MW
Following tests were conducted:

Test	Target	Achieved
Minimum Load Test (40%)	210MW	210MW 190MW (36%)* *achieved for short duration of 10min.
Ramp Up/Down Test	1%/min	

The ramp rates achieved were as follows:

	Upward direction	Downward direction
290 MW – 525 MW	0.95%/min	1.52%/min
MW – 290 MW	do	0.95%/min
210 MW – 225 MW	do	0.38%/min

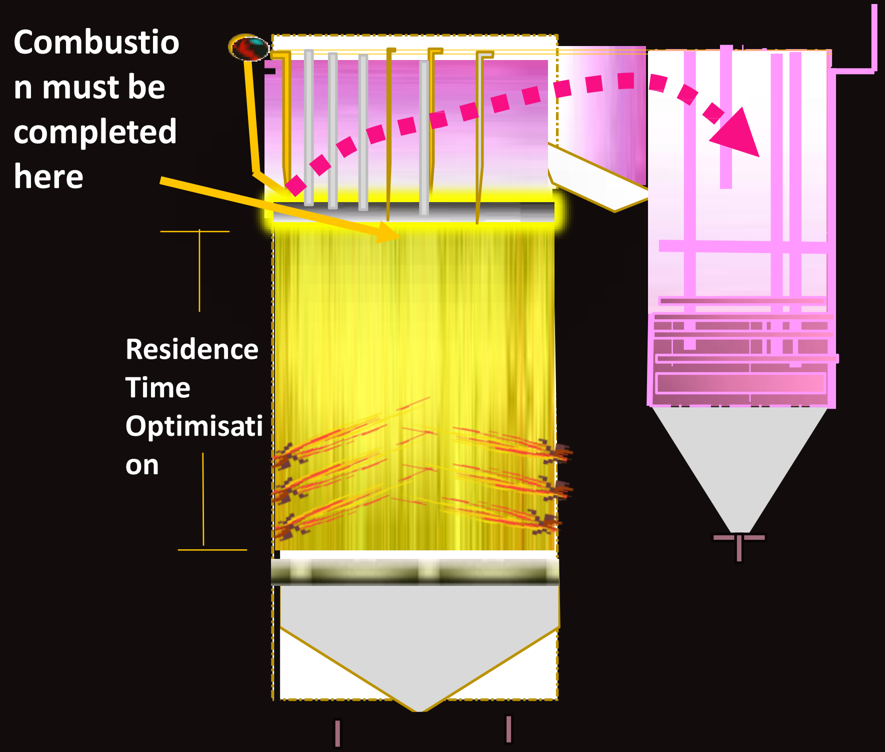
PILOT RESULTS



CEA:
70-100% Load - 3% ramp
55-70% load - 2% Ramp
Below 55% load - 1% Ramp

Ramp rate does not include the time to take mills
Or else partly loaded mills need to be kept in service
Any mill must not be loaded below 50%

COMBUSTION OPTIMISATION



- **Dynamic Combustion Tuning**
- Is anybody doing it?
- Does the skill exist today?
- Is there any vendor/agency in India to do dynamic combustion tuning?

Coal fineness

Balancing of Coal flow across the coal pipes

Fuel/Air ratio, Combustion air

Furnace exit gas temperature

Bottom Ash & Fly Ash Unburnt

Flue gas temperature and excess air stratification

Flue gas oxygen /Excess air level

Coal mill inlet/outlet temperature

Primary Air header pressure

Pulverized coal flow velocity /Temperature of coal pipes

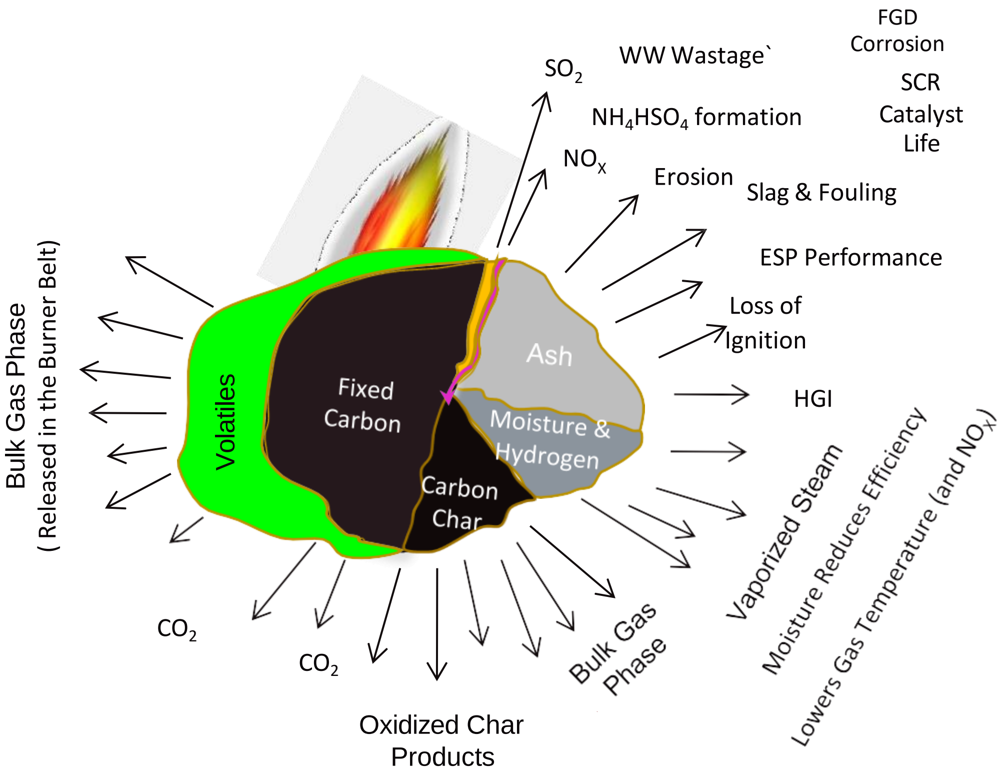
Windbox pressure

Burner Tilt

Flame scanners

Selection of burner

COAL QUALITY IMPACT ON PERFORMANCE



Source: EPRI

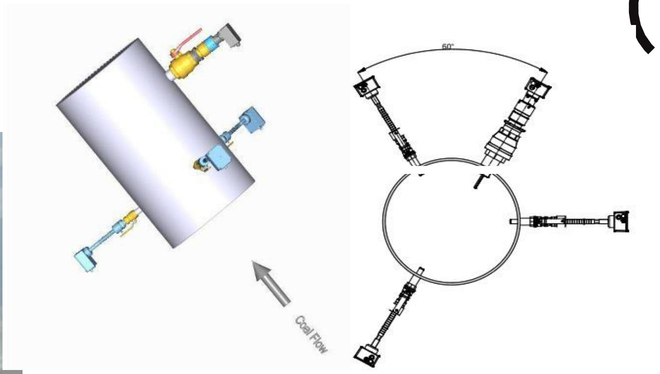
Table No: Samples collected from Coal Stations

Sample	Moist (%)	VM (%)	Ash (%)	FC (%)	HGI	GCV
1	7.2	25.3	36.36	31.14	68.54	3795
2	6.05	25.25	29.92	38.78	59.22	4058
3	8.24	18.34	45.5	27.92	65.2	2869
4	11.45	26.06	38.92	23.57	62.5	3264
5	4.86	31.82	30.02	33.3	58.62	4623
6	6.99	27.79	35.21	30.01	76.09	3871
7	7.41	29.96	32.49	30.14	61.23	4821
8	13.28	20.54	34.46	31.72	48.69	4014
9	9.81	23.45	38.38	28.36	65.93	4268
10	12.96	22.74	46.51	17.79	57.49	2636
11	4.04	28.97	24.26	42.73	60.37	5003
12	6.08	24.01	43.85	26.06	76.65	3692
13	6.58	27.01	38.6	27.81	70.32	3962
14	2.66	22.75	53.22	21.37	57.28	3645
15	7.39	31.05	32.28	29.28	52.33	4538
16	13.6	18.71	46.97	20.72	59.22	2683
17	8.91	20.89	44.67	25.53	63.57	3066
18	4.79	22.11	41.77	31.33	62	3937

- Stations get supplies from multiple sources
- Wide variations on daily basis
- Rarely the design coal is available
- Depletion of stocks
- High Ash content
- Seasonal variation
- Wet coal
- High GCV_Imported coal
- Coal blending
- Insufficient stock
- Coal yard management
- Logistics Issue
- Grade slippage
- Overheads
- Non-pithead – high cost – puts it low on merit order

Coal Variation during a test run

DYNAMIC COAL FLOW MONITORING AND MANIPULATION SYSTEM



Trending and manipulation Based on Real time measurements

- Coal Mass Flow in each pipe
- Coal Roping Area identification
- Coal Temperature in each pipe
- Coal Velocity in each pipe
- Coal Flow Balancing
- DP across Variable Orifice
- Automatic Coal Pipe Balancing by Variable Orifice (Future proposal)

- 3 Mass Flow sensors (microwave based) placed at 120^0 apart)
  - Measures mass flow & indicates coal roping.
- Velocity sensors(Electrostatic based) placed 500mm above the mass flow sensors.
  - Measures coal particle velocity and temperature.
- Monitoring software integrated with system

STUDIES & PILOT TESTS
FOR FLEXIBLE OPERATION

To prepare **units for flexible operation**, test runs were conducted under the directions of MOP and supported by USAID, IGEF, and Jcoal. Important stakeholders included: OEMs *(GE, Siemens, BHEL),* Intertek, VGB , Engie Lab, NTPC, GSECL, KPCL, DVC, Tata Power, WBPDCL & UPPDCL.

PILOT LOCATIONS

- **NTPC Jhajjar Power Plant (500 MW)**
  Jhajjar District, Haryana, India at 28.4892° N & 76.3557° E
- **NTPC Ramagundam Power Plant (200MW)**
  Peddapalli District, Telangana, India at 18.7589° N & 79.4555° E
- **NTPC Dadri (200 & 500MW)**
  UP. India at 28.5985° N & 77.6087° E
- **NTPC Simhadr (500 MW)**
  Visakhapatnam, Andhra Pradesh, India at 17.5961° N & 83.0875° E

Recent Studies(2024) - 4 Units(3 super-critical)

Unit A1 | 685 MW Supercritical Coal Unit | Commissioned in 2014
Unit A2 | 685 MW Supercritical Coal Unit | Commissioned in 2016
Unit V1 | 660 MW Supercritical Coal Unit | Commissioned in 2013
Unit D3 | 210 MW Subcritical Coal Unit | Commissioned in 1999

- **GSECL Ukai TPP (200 & 500 MW)**
  Vagda, Gujarat at 21.2121 ° N & 73.5606° E
- **Anpara A (500MW)**
  Sonbhadra District, Uttar Pradesh, India at 24.2049° N & 82.7832° E
- **Bellary (500MW)**
  Karnataka, India at 15° 11’ 31.5” N & 76° 43’ 03.8” E
- **Tata Maithon (500MW)**
  Jharkhand, India at 23° 49’ 13” N & 86° 45’ 36” E
- **DVC, Andal (500MW)**
  WB at 23° 34’ 55.61“ N & 87° 11’ 8.62“ E

CASE STUDIES
SCOPE

SCOPE

EQUIPMENT HEALTH ASSESSMENT

- Is there any damage?
- What are the damage mechanisms?
- How fast is the damage progressing?
- When will the damage cause failures?
- Are there any low probability but high impact risks?
- Cost of cycling

OPERATIONS AUDIT

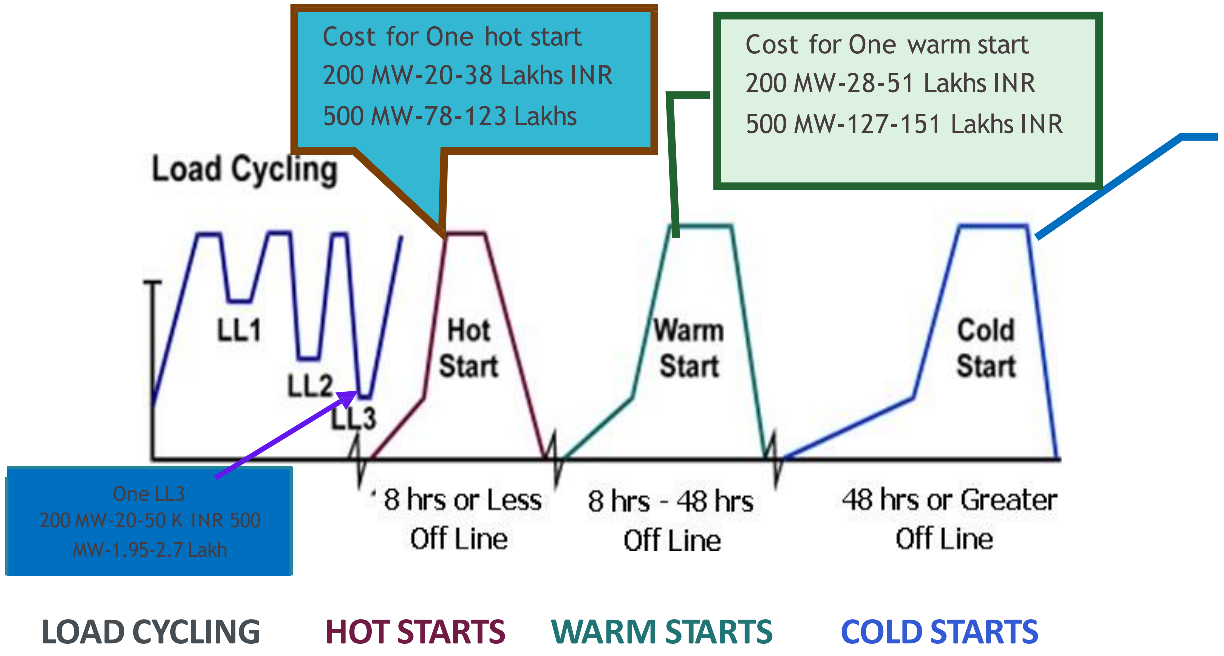
- Operating Procedures Review
- Startup & Shutdown, Min Load, Ramps
- Protocols (Standing Orders)
- Generation Deficiencies & Incidents Documentation/ Reporting
- Training
- Performance Tests vs Design
- Review of Generation Statistics (FOR, EFOR, Availability, etc.)
- Maintenance & Inspection Schedules, Predictive Maintenance Tools, Spare Usage, SOW
- Digitalization Maturity
- Usage of Predictive & Condition Assessment Tools
- Design Review & Requirement of Retrofits

RECOMMENDATIONS FOR OPERATIONS IMPROVEMENTS

- Recommendations for Capital Projects To Reduce Cyclic Damage
- Review & Critique Cycling Cost Methods Used By Utility
- Development of Improved Cost Estimates
- Recommendations on use of Improved Cycling Cost Information in System Operations & Planning

TEST RUNS-
COMMON ISSUES

- **Unoptimized Combustion** at low loads
- In all the test runs conducted, it was observed that **CONTROL LOOPS** were not tuned for low loads
- Burner tilts were on **MANUAL** – key variable having significant influence on steam temperature parameter control
- More number of mills than required were kept in service to take care of the exigencies of **MILL TRIPPING**
- **PRIMARY AIR FLOW** maintained higher than anticipated values as mills were operated at full mill air flow irrespective of the mill loading
- **SECONDARY AIR FLOW** is very much less than the desired level resulting in no or low windbox dP at part loads
- **WB PRESSURE** was improved by closing the secondary air dampers of the mills that were not in service & optimising the primary air flow
- **STEAM COIL APH** was not available/not used regularly
- **SLIDING PRESSURE** was in service – needed modification
- The **PARTIAL STEAMING OF ECO** occurred at low load which can be allowed only for a short time
- Increase in **SH TEMPERATURE** during load ramping & **High SH SPRAY**
- Jerky operation of **FEED WATER FLOW** on opening of the recirculation valves at low load
- The analysis of **DIRTY AIR FLOW** results reveals that there is a good degree of imbalance in coal flow across the pipes at low load



WHY

DO YOU NEED TO PREPARE FOR REDUCING THE LEVEL OF MINIMUM LOAD?

UNIT SIZE	200-250 MW	500 MW
Load Following Cost (US$)	260-650	2500-3500
Hot Start Cost (US$)	26k-50k	100k-159k
Warm Start Cost (US$)	36k-66k	165k-200k
Cold Start Cost (US$)	54k-118k	225k-340k

ECONOMIC BARRIER

COMPENSATION FOR 40% LOAD...

MARKET PRODUCTS ...

1. Capital Expenditure(One time) to be recovered in 5 years (through tariff)

2. O&M Costs

For low load operation for 85% days

Capacity (MW)	Loading (%)	Increase in O&M (%)	Proposed increase in O&M cost (Rs Cr.)
200	<55 to 50	9.00	6.58
	<50 to 45	14.00	10.23
	<45 to 40	20.00	14.62
500	<55 to 50	9.00	11.23
	<50 to 45	14.00	17.47
	<45 to 40	20.00	24.97
660	<55 to 50	9.00	13.34
	<50 to 45	14.00	20.76
	<45 to 40	20.00	29.66
800	<55 to 50	9.00	14.55
	<50 to 45	14.00	22.64
	<45 to 40	20.00	32.35

3.Variable Charges

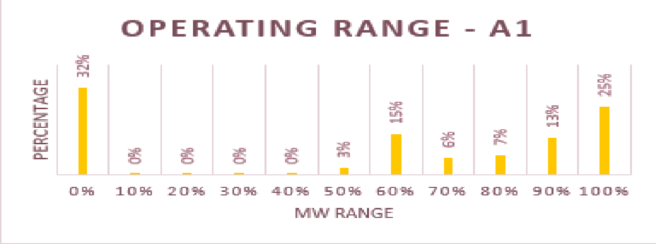
Capacity (MW)	Loading (%)	Net Heat Rate increase (%)	Variable Tariff increase (%) at coal price Rs 2000/ton	Variable Tariff increase (%) at coal price Rs 3300/ton	Proposed variable Tariff increase (%)
200	<55-50	10.00	9.88	9.94	9.91
	<50-45	13.00	12.84	12.92	12.88
	<45-40	16.00	15.81	15.90	15.86
500	<55-50	10.90	10.76	10.83	10.80
	<50-45	13.60	13.44	13.51	13.48
	<45-40	16.00	15.81	15.90	15.86
660	<55-50	8.70	8.59	8.64	8.62
	<50-45	11.90	11.75	11.82	11.79
	<45-40	14.60	14.42	14.50	14.46
800	<55-50	8.60	8.49	8.54	8.52
	<50-45	12.00	11.84	11.92	11.88
	<45-40	15.00	14.81	14.90	14.86

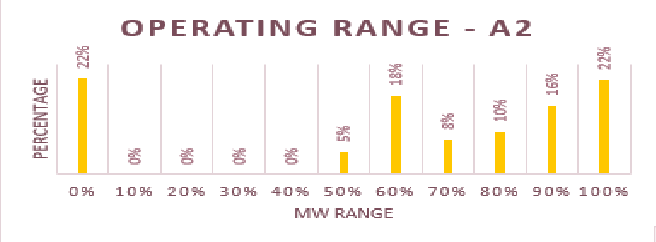
4 Others (Oil & EFOR)

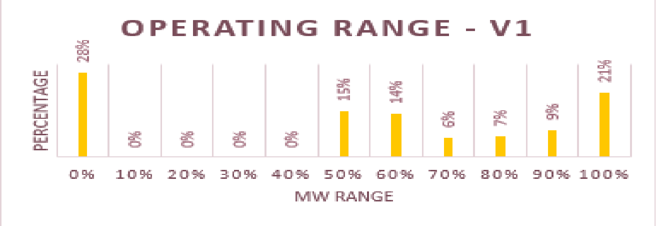
QUESTIONS?- to Utilities, Policy makers, regulators, OEMs

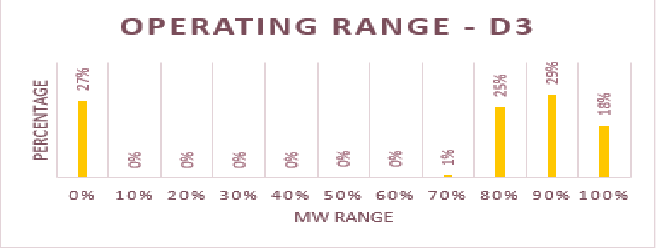
- Is the compensation adequate or overcompensated?
- Two-shifting & start-up?
- Do you understand the costs?
- Do you see any risk?
- Can you see the hidden opportunities?
- Have you formulated any business strategy for flexible operation?. Do you have an institutional mechanism to deal with flexible operation?
- Does this mechanism help in reduction of overall system level costs and risks?
- What will be the business model (for flexing) for the market participants(operating in energy markets) and Non- ISGS units?
- Can we reduce the burden of the consumers through a better policy based on analysis or simply pass on the burden and all inefficiencies on them?

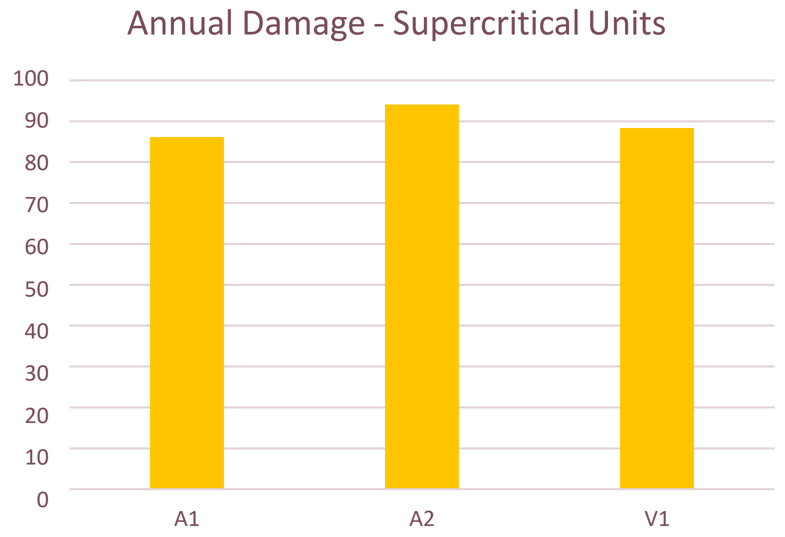
OPERATING MODE/ANNUAL DAMAGE

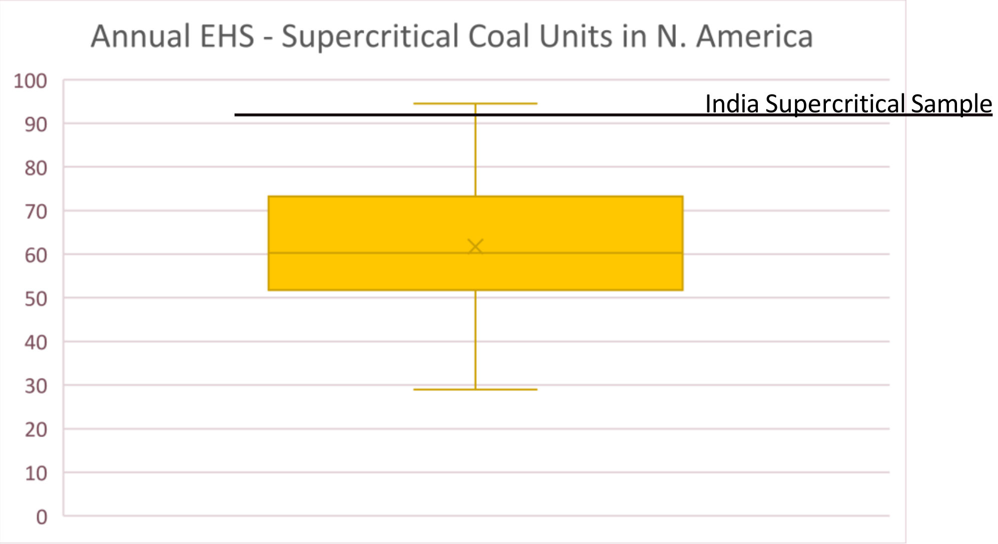




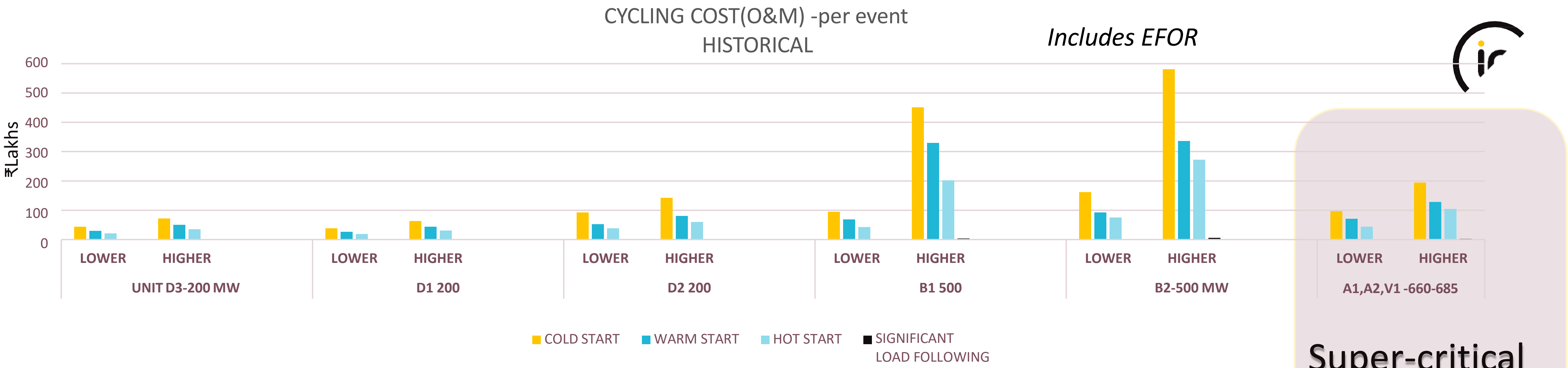


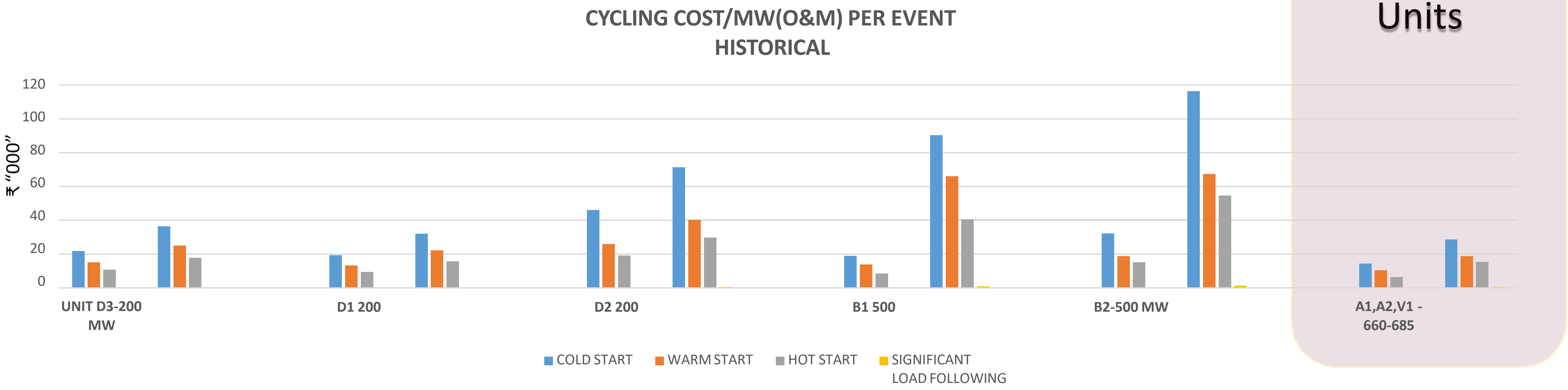




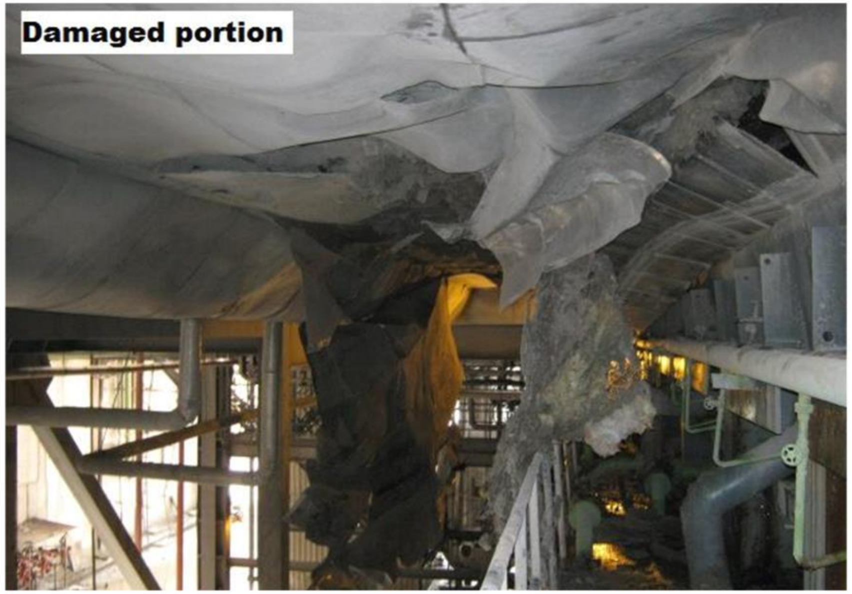


- High exhaust hood temperatures
- High steam seal temperatures
- Rate of change of metal temperatures
- Solid particle erosion
- Main steam and reheat steam temperature differential.
- Internal corrosion and oxygen pitting of waterwall tubes.
- Higher rates of internal corrosion of steam tubing due to increased exfoliation
- Accelerated creep damage of steam (superheater and reheater) tubing.
- Chemistry upsets/excursions resulting in hydrogen damage.
- Fatigue corrosion due to cycling stresses on waterwall tubes.
- Furnace subcooling resulting in external tube failures.
- Overheating during low load operation by improper burner configuration
- Steam line quenching
- Higher risk of furnace explosion due to low turn down of fuel capabilities
- Economizer inlet header thermal fatigue cracking
- Combustion Issues/ Air/Fuel distribution issues


CYCLING COST(O&M) -per event
HISTORICAL
Includes EFOR
₹Lakhs
600
500
400
300
200
100
0
LOWER
HIGHER
UNIT D3-200 MW
D1 200
D2 200
B1 500
B2-500 MW
A1,A2,V1 -660-685
COLD START
WARM START
HOT START
SIGNIFICANT LOAD FOLLOWING
Super-critical Units


CYCLING COST/MW(O&M) PER EVENT
HISTORICAL
₹ "000"
120
100
80
60
40
20
0
UNIT D3-200 MW
D1 200
D2 200
B1 500
B2-500 MW
A1,A2,V1 - 660-685
COLD START
WARM START
HOT START
SIGNIFICANT LOAD FOLLOWING

SAFETY



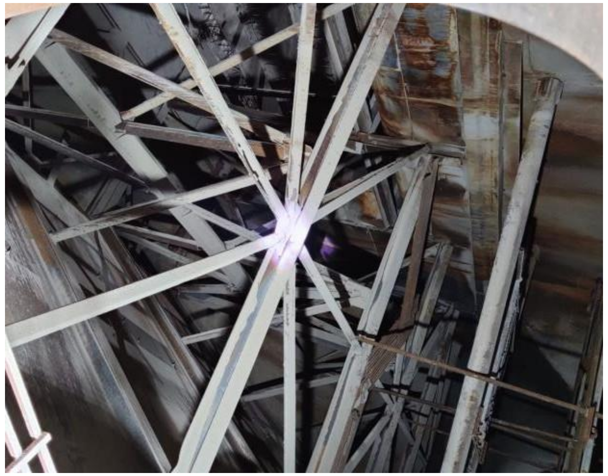
Damages to the "S" panel.

Bow in horizontal tubes of front S panel.

Location of failed tubes

UNIT A2

Ash Accumulation in the Windbox



Erosion/Corrosion in APH Supports/Structural Beams at Unit A1

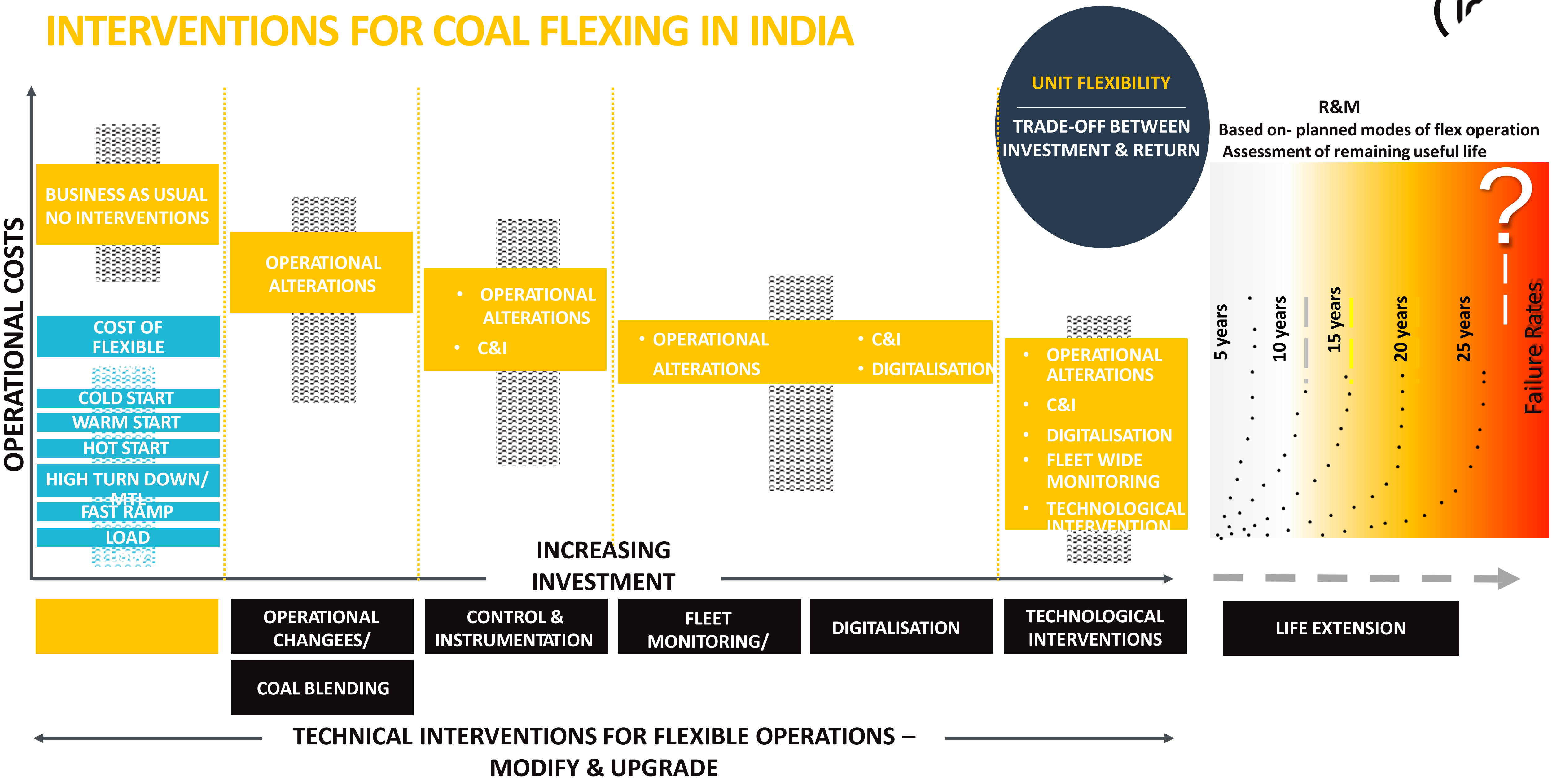
Ash Accumulation in the LTSH

APH Corrosion

Burner Damage

OPTIONS VS COSTS

INTERVENTIONS FOR COAL FLEXING IN INDIA



Total Quality. Assured.

QUESTIONS?

WHAT IS STOPPING YOU FROM BEING FLEXIBLE?

ARE YOU SURE……….? RETHINK, IT IS FOR THE GREEN CAUSE……

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Total Quality. Assured.

THANKING YOU!
ON BEHALF OF

Council of Enviro Excellence