Council of Enviro Excellence

5th NATIONAL POWER-GEN ENERGY EFFICIENCY AWARDS-2026

5TH NATIONAL POWER-GEN ENERGY EFFICIENCY

SUMMIT AND AWARDS 2025

Enhancing Efficiency in Indian Thermal Power Plants

EFFICIENCY AS STRATEGY - HEAT RATE, EFFICIENCY IMPROVEMENT & THE FUTURE OF INDIA'S THERMAL POWER SECTOR

DR. HIMADRI BANERJI

Council of ENVIRO Excellence

EY

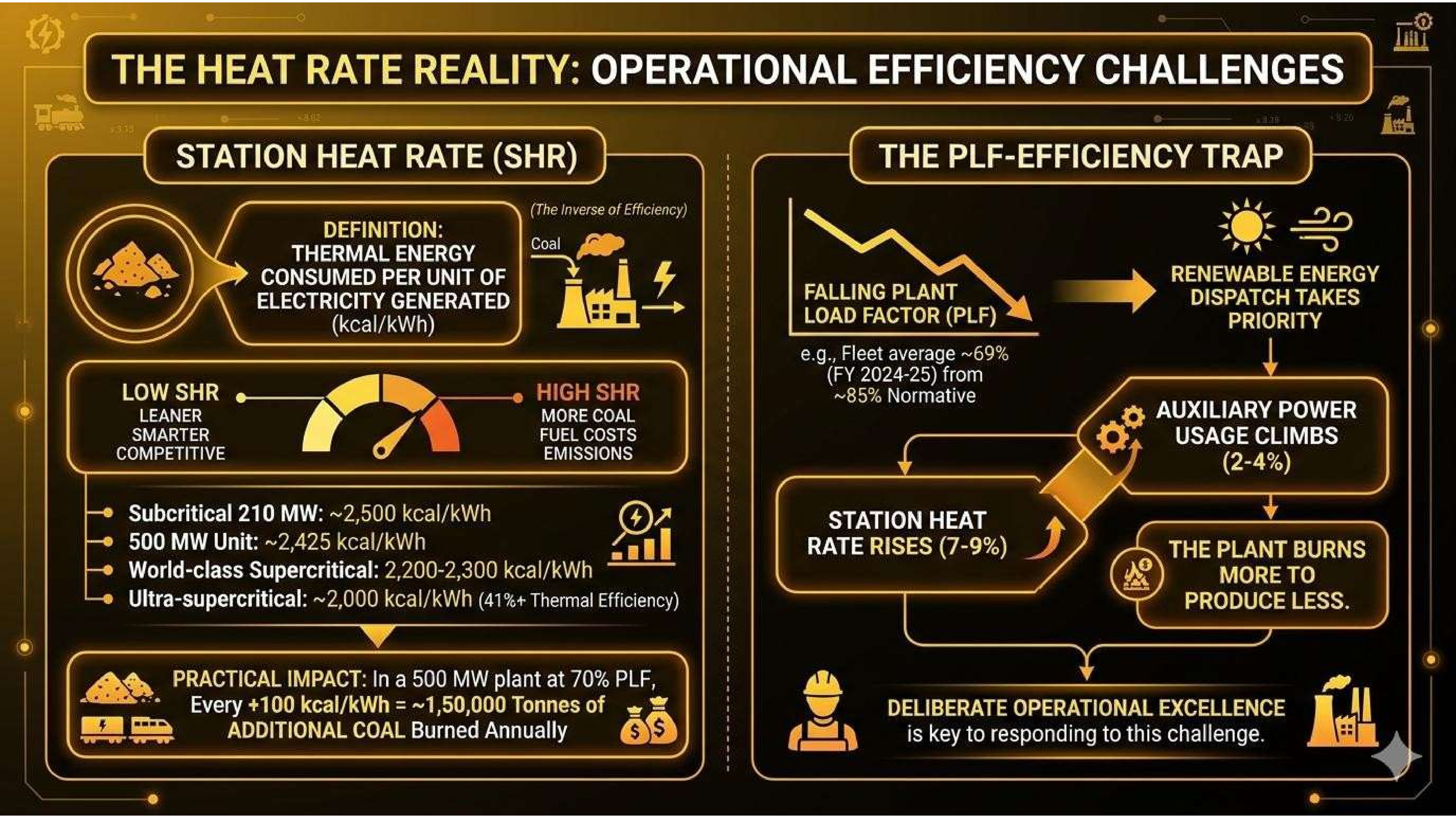
5th National Power-Gen Energy Efficiency Awards-2026

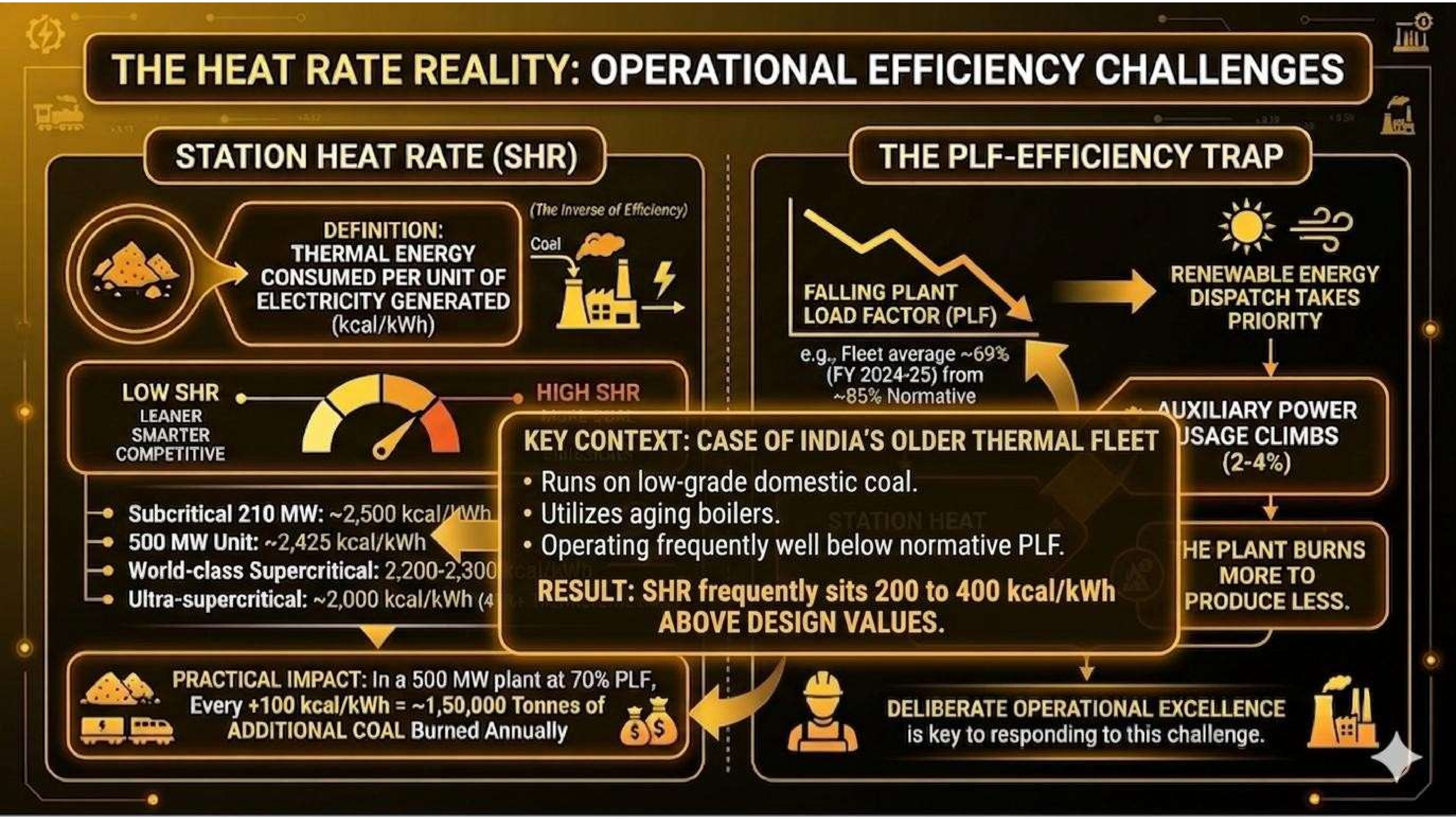
EFFICIENCY AS STRATEGY

Heat Rate, Efficiency Improvement & the Future of India's Thermal Power Sector

Dr Himadri Banerji

International Expert and Advisor Power Sector, E&Y India


THE HEAT RATE REALITY: OPERATIONAL EFFICIENCY CHALLENGES
STATION HEAT RATE (SHR)
DEFINITION: THERMAL ENERGY CONSUMED PER UNIT OF ELECTRICITY GENERATED (kcal/kWh)
(The Inverse of Efficiency)
Coal
LOW SHR
LEANER
SMARTER
COMPETITIVE
HIGH SHR
MORE COAL
FUEL COSTS
EMISSIONS
Subcritical 210 MW: ~2,500 kcal/kWh
500 MW Unit: ~2,425 kcal/kWh
World-class Supercritical: 2,200-2,300 kcal/kWh
Ultra-supercritical: ~2,000 kcal/kWh (41%+ Thermal Efficiency)
PRACTICAL IMPACT: In a 500 MW plant at 70% PLF, Every +100 kcal/kWh = ~1,50,000 Tonnes of ADDITIONAL COAL Burned Annually
THE PLF-EFFICIENCY TRAP
FALLING PLANT LOAD FACTOR (PLF)
e.g., Fleet average ~69% (FY 2024-25) from ~85% Normative
RENEWABLE ENERGY DISPATCH TAKES PRIORITY
AUXILIARY POWER USAGE CLIMBS (2-4%)
STATION HEAT RATE RISES (7-9%)
THE PLANT BURNS MORE TO PRODUCE LESS.
DELIBERATE OPERATIONAL EXCELLENCE is key to responding to this challenge.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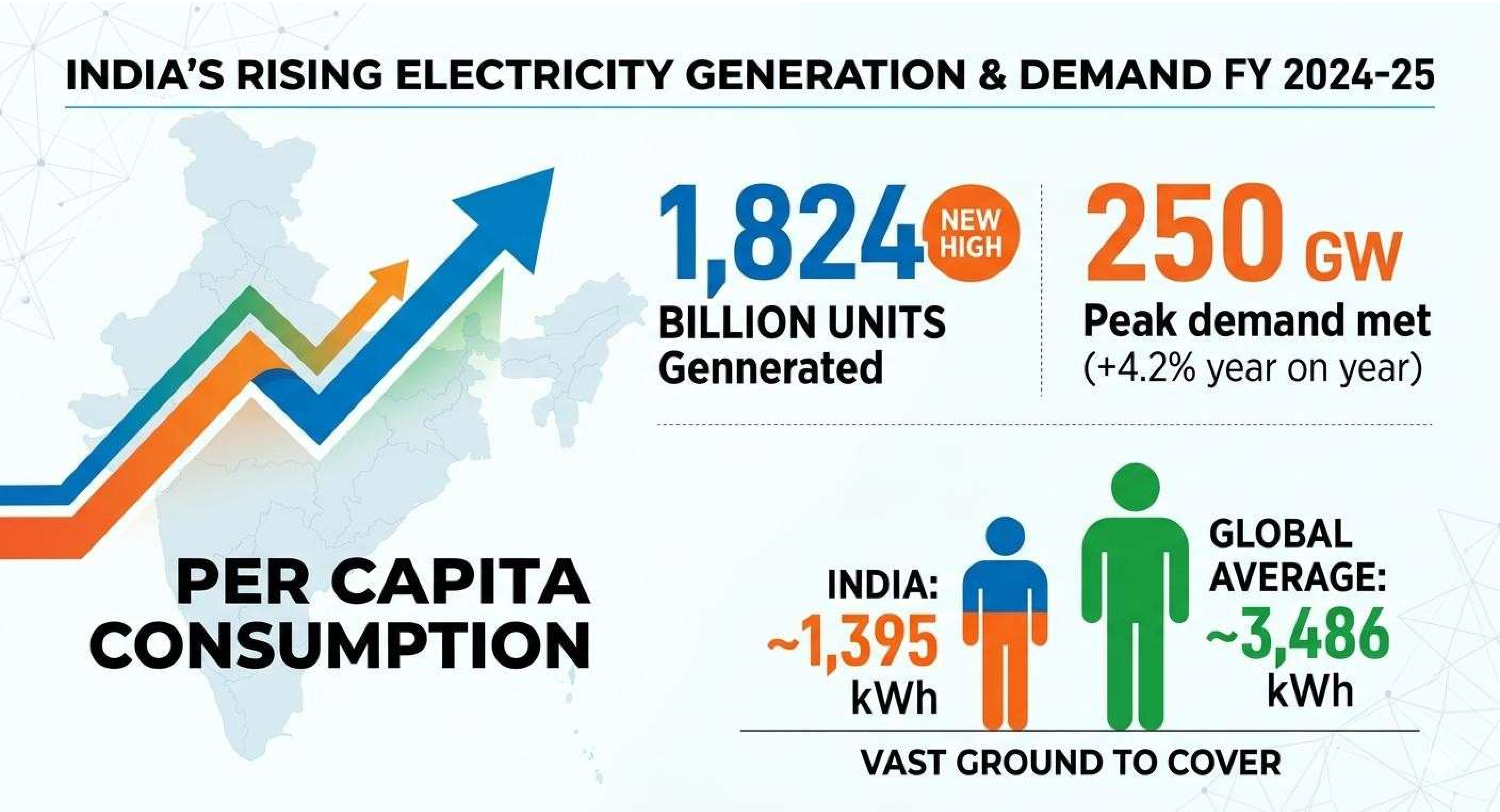
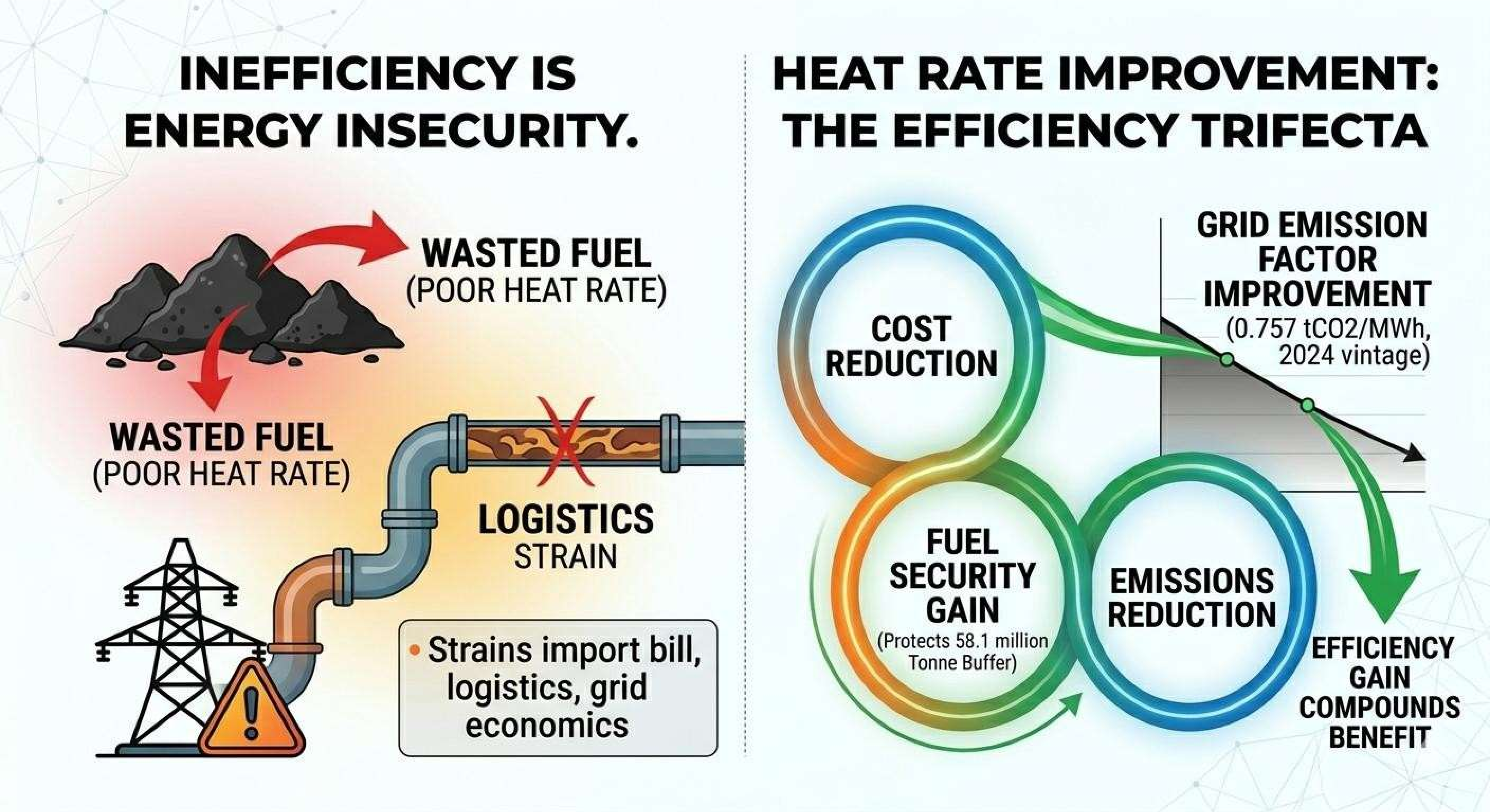
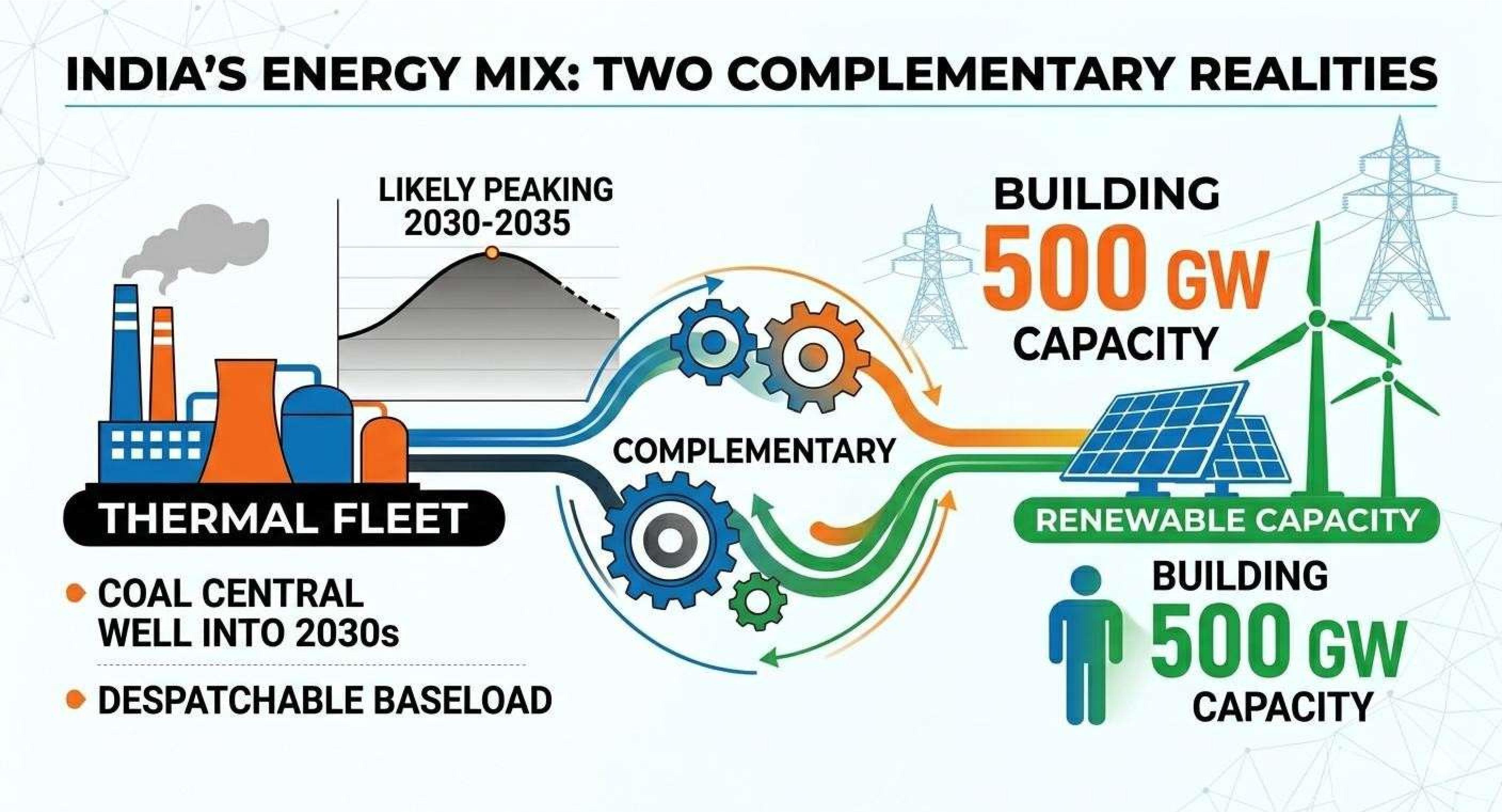
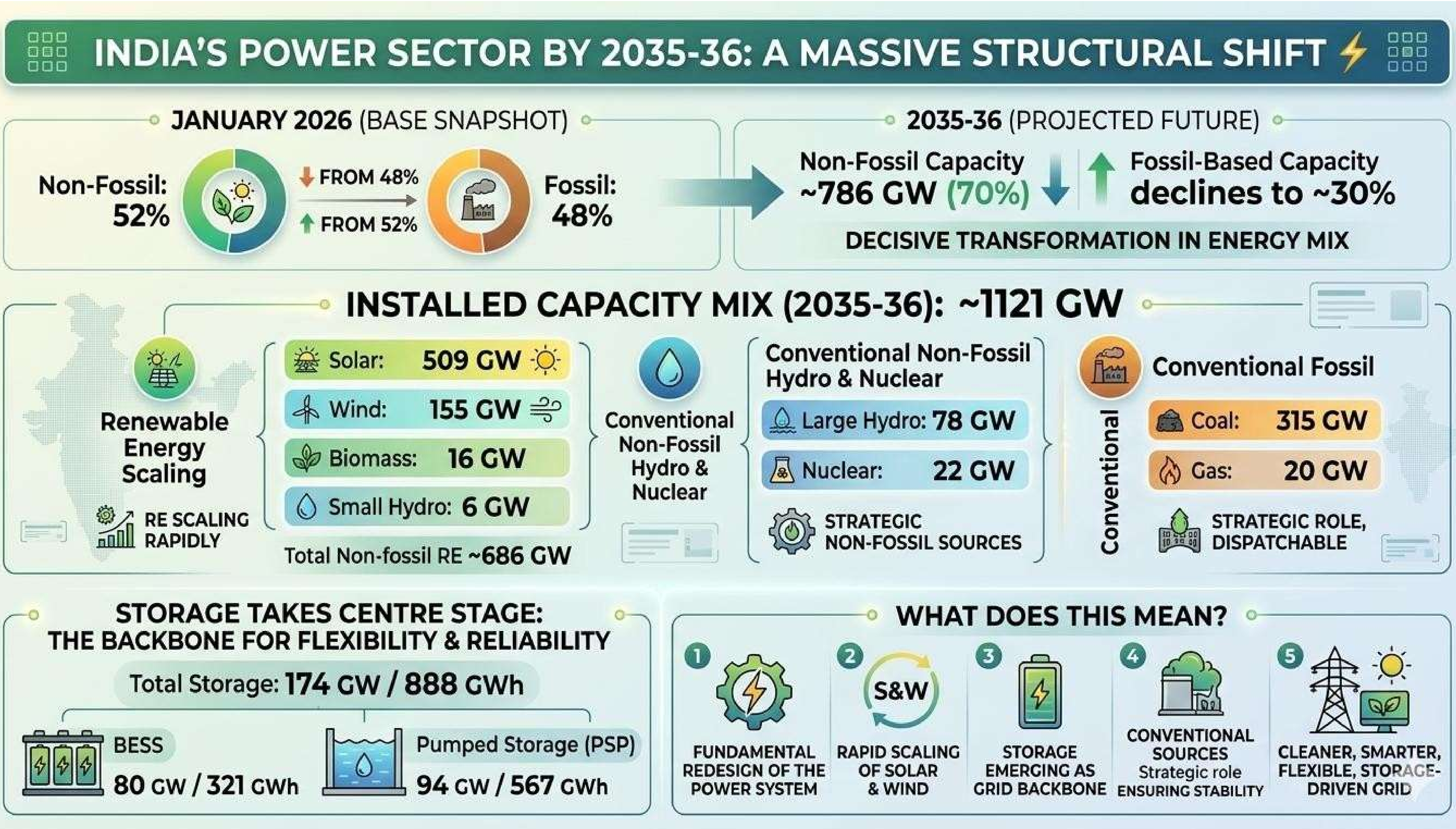
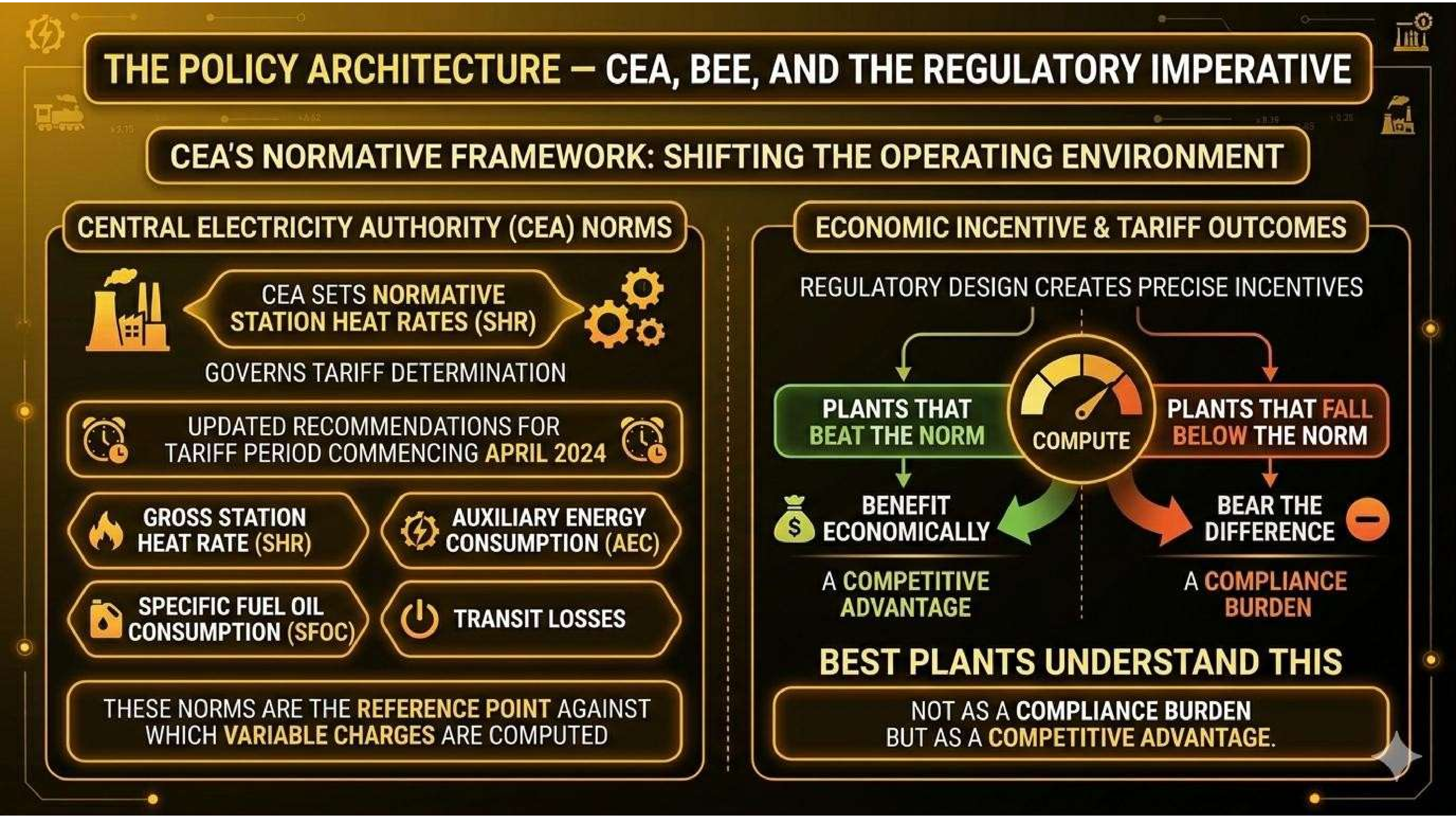
RENEWABLE ENERGY DISPATCH TAKES PRIORITY
AUXILIARY POWER USAGE CLIMBS (2-4%)
THE PLANT BURNS MORE TO PRODUCE LESS.
KEY CONTEXT: CASE OF INDIA'S OLDER THERMAL FLEET
• Runs on low-grade domestic coal.
• Utilizes aging boilers.
• Operating frequently well below normative PLF.
RESULT: SHR frequently sits 200 to 400 kcal/kWh ABOVE DESIGN VALUES.
DELIBERATE OPERATIONAL EXCELLENCE is key to responding to this challenge.

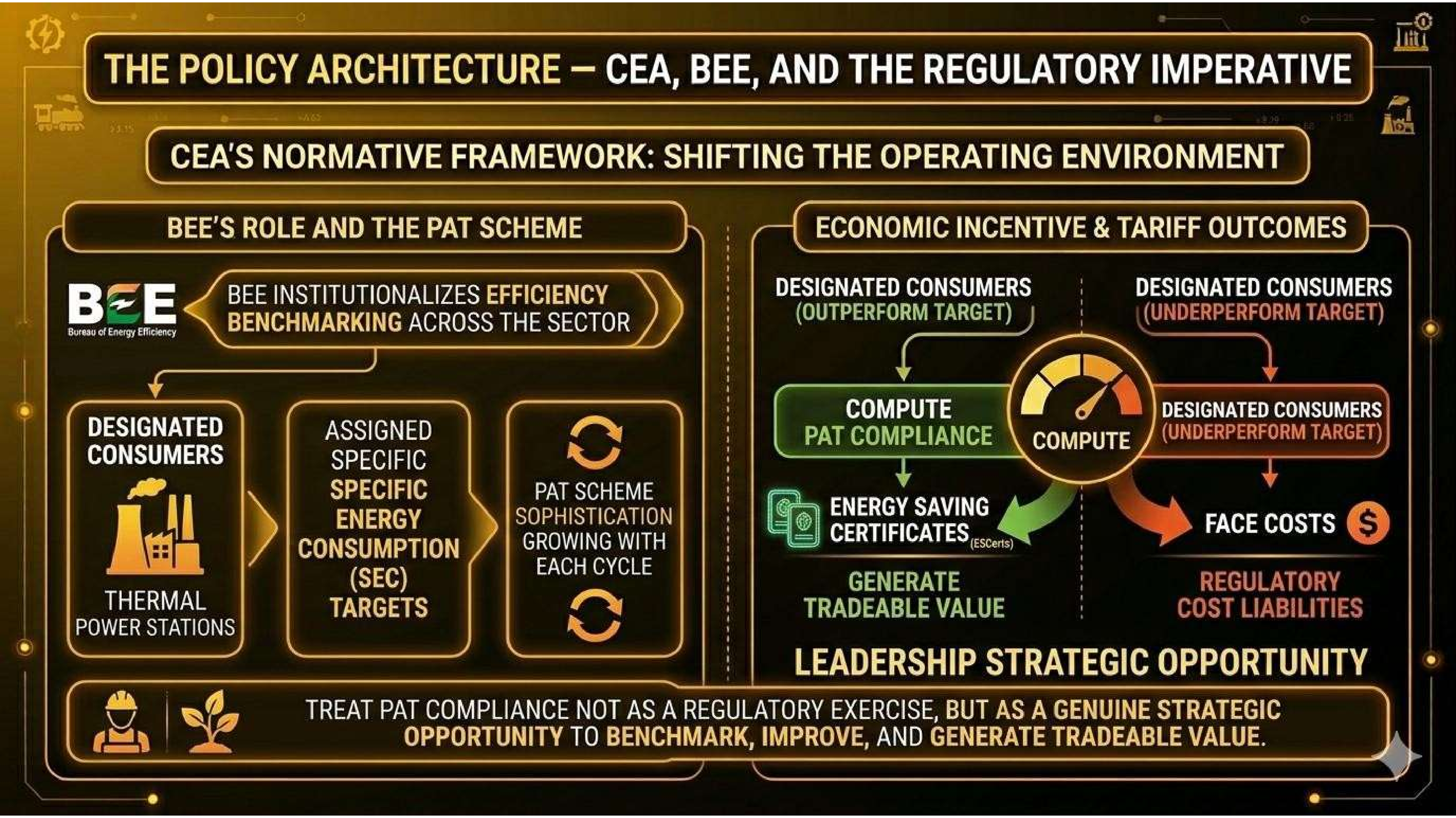

INDIA'S RISING ELECTRICITY GENERATION & DEMAND FY 2024-25
1,824
NEW HIGH
BILLION UNITS
Gennerated
250 GW
Peak demand met
(+4.2% year on year)
PER CAPITA
CONSUMPTION
INDIA:
~1,395
kWh
GLOBAL
AVERAGE:
~3,486
kWh
VAST GROUND TO COVER

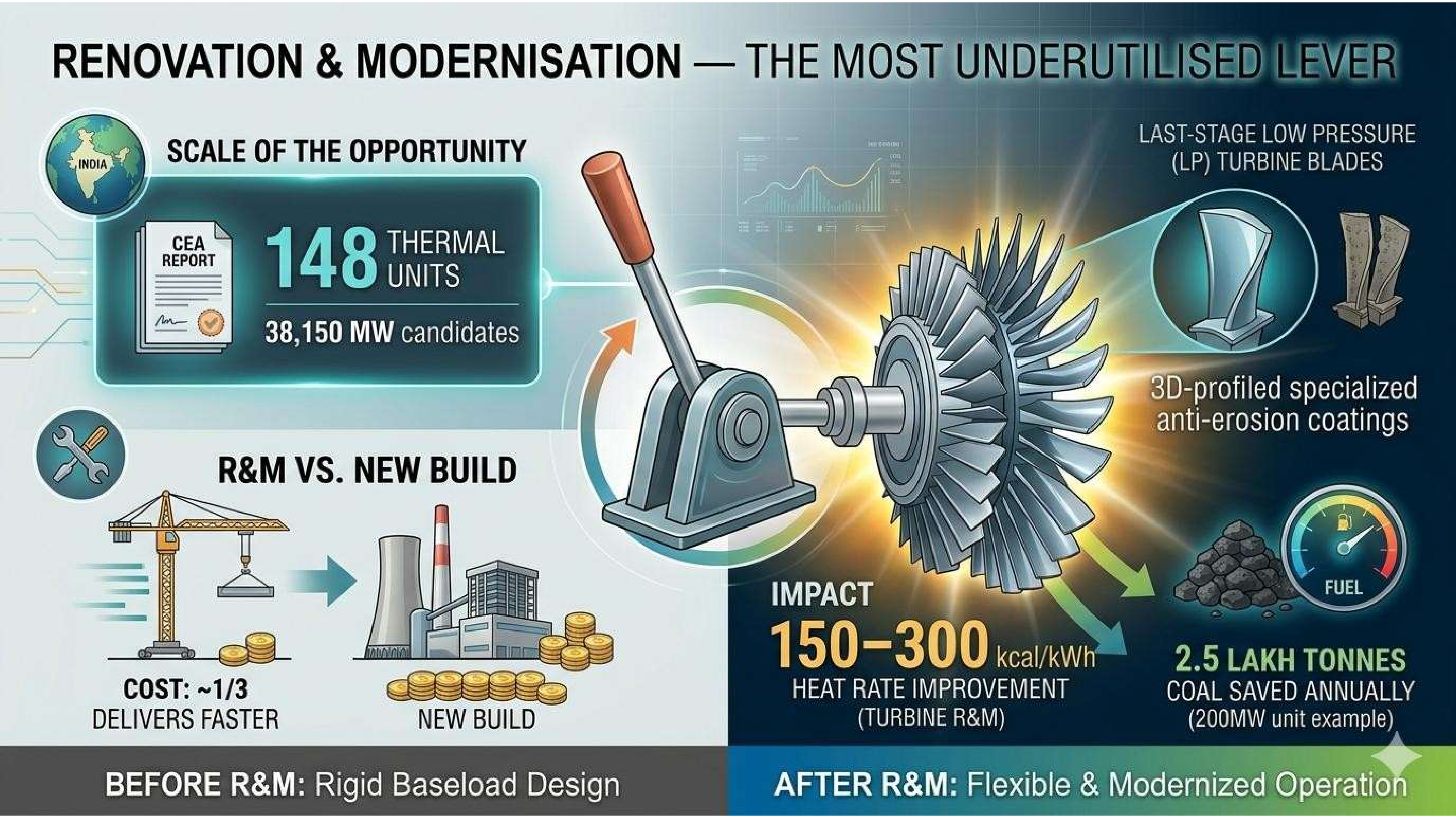

INEFFICIENCY IS ENERGY INSECURITY.
WASTED FUEL
(POOR HEAT RATE)
WASTED FUEL
(POOR HEAT RATE)
LOGISTICS
STRAIN
Strains import bill, logistics, grid economics
HEAT RATE IMPROVEMENT: THE EFFICIENCY TRIFECTA
COST REDUCTION
FUEL SECURITY GAIN
(Protects 58.1 million Tonne Buffer)
EMISSIONS REDUCTION
GRID EMISSION FACTOR IMPROVEMENT
(0.757 tCO2/MWh, 2024 vintage)
EFFICIENCY GAIN COMPOUNDS BENEFIT


INDIA'S ENERGY MIX: TWO COMPLEMENTARY REALITIES
LIKELY PEAKING
2030-2035
THERMAL FLEET
COAL CENTRAL
WELL INTO 2030s
DESPATCHABLE BASELOAD
COMPLEMENTARY
BUILDING
500 GW
CAPACITY
RENEWABLE CAPACITY
BUILDING
500 GW
CAPACITY

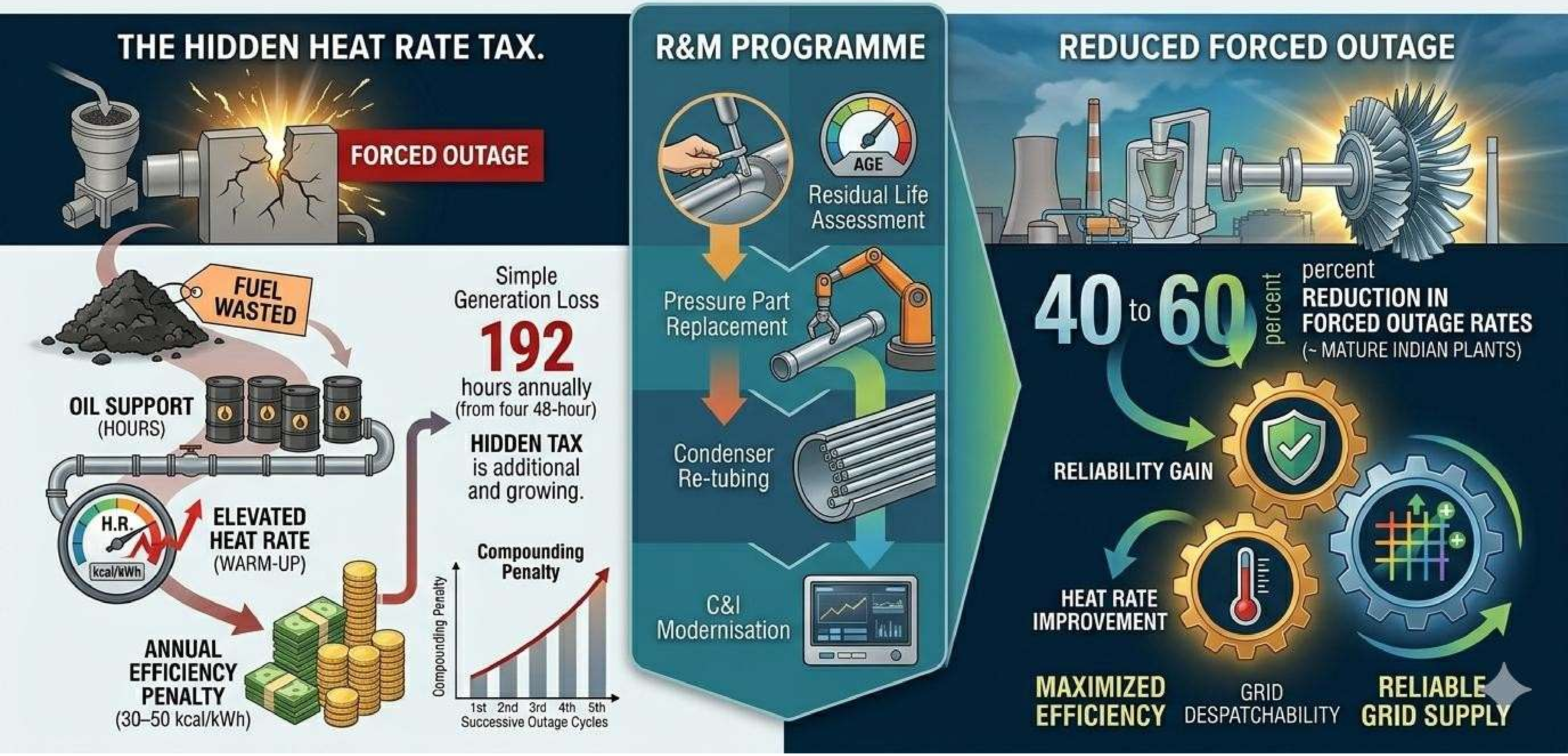

INDIA'S POWER SECTOR BY 2035-36: A MASSIVE STRUCTURAL SHIFT
JANUARY 2026 (BASE SNAPSHOT)
Non-Fossil: 52%
FROM 48%
FROM 52%
Fossil: 48%
2035-36 (PROJECTED FUTURE)
Non-Fossil Capacity ~786 GW (70%)
Fossil-Based Capacity declines to ~30%
DECISIVE TRANSFORMATION IN ENERGY MIX
INSTALLED CAPACITY MIX (2035-36): ~1121 GW
Renewable Energy Scaling
RE SCALING RAPIDLY
Solar: 509 GW
Wind: 155 GW
Biomass: 16 GW
Small Hydro: 6 GW
Total Non-fossil RE ~686 GW
Conventional Non-Fossil Hydro & Nuclear
Conventional Non-Fossil Hydro & Nuclear
Large Hydro: 78 GW
Nuclear: 22 GW
STRATEGIC NON-FOSSIL SOURCES
Conventional
Conventional Fossil
Coal: 315 GW
Gas: 20 GW
STRATEGIC ROLE, DISPATCHABLE
STORAGE TAKES CENTRE STAGE: THE BACKBONE FOR FLEXIBILITY & RELIABILITY
Total Storage: 174 GW / 888 GWh
BESS
80 GW / 321 GWh
Pumped Storage (PSP)
94 GW / 567 GWh
WHAT DOES THIS MEAN?
1 FUNDAMENTAL REDESIGN OF THE POWER SYSTEM
2 S&W RAPID SCALING OF SOLAR & WIND
3 STORAGE EMERGING AS GRID BACKBONE
4 CONVENTIONAL SOURCES Strategic role ENSURING STABILITY
5 CLEANER, SMARTER, FLEXIBLE, STORAGE-DRIVEN GRID

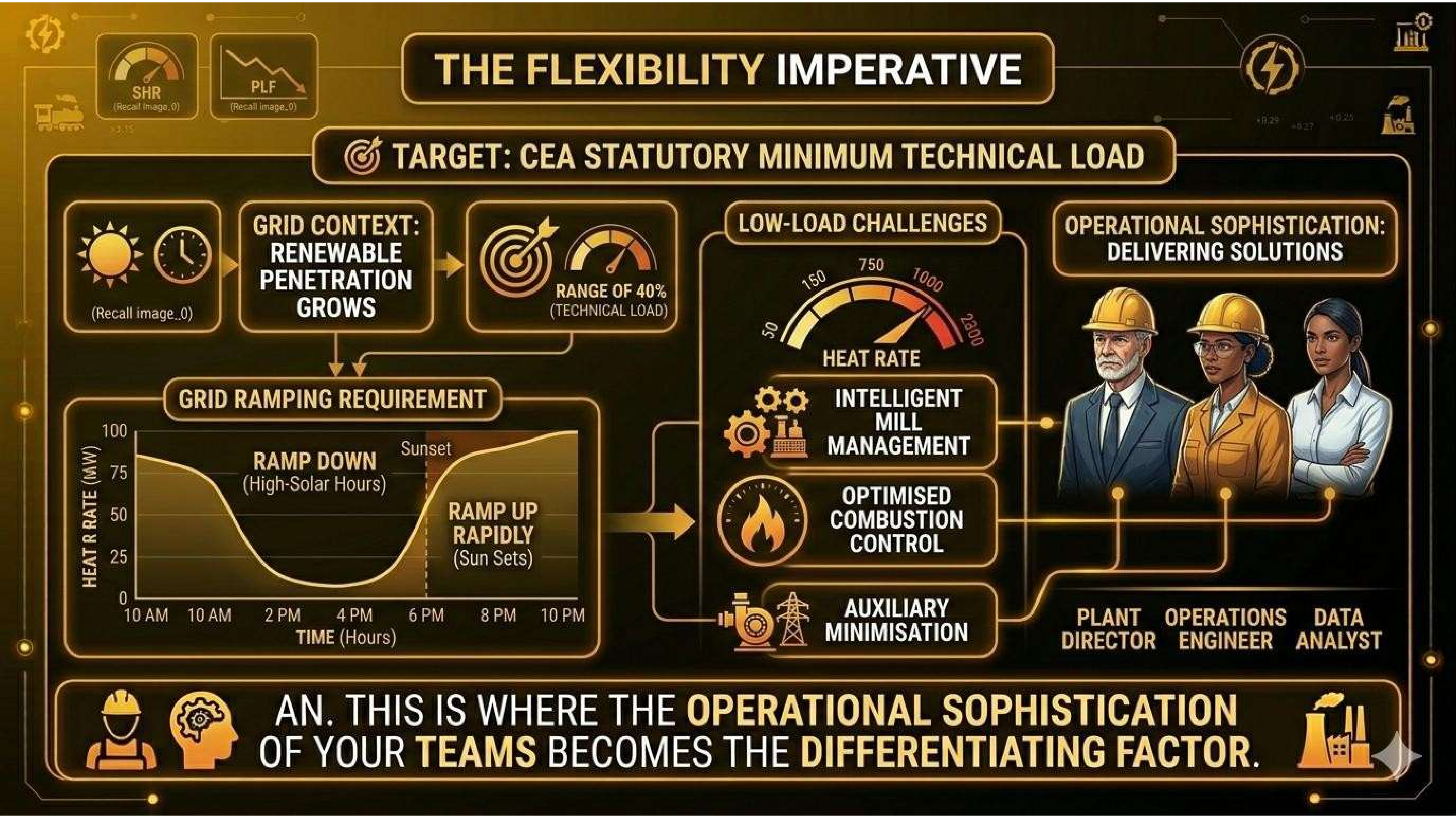

THE POLICY ARCHITECTURE — CEA, BEE, AND THE REGULATORY IMPERATIVE
CEA'S NORMATIVE FRAMEWORK: SHIFTING THE OPERATING ENVIRONMENT
CENTRAL ELECTRICITY AUTHORITY (CEA) NORMS
CEA SETS NORMATIVE STATION HEAT RATES (SHR)
GOVERNS TARIFF DETERMINATION
UPDATED RECOMMENDATIONS FOR TARIFF PERIOD COMMENCING APRIL 2024
GROSS STATION HEAT RATE (SHR)
AUXILIARY ENERGY CONSUMPTION (AEC)
SPECIFIC FUEL OIL CONSUMPTION (SFOC)
TRANSIT LOSSES
THESE NORMS ARE THE REFERENCE POINT AGAINST WHICH VARIABLE CHARGES ARE COMPUTED
ECONOMIC INCENTIVE & TARIFF OUTCOMES
REGULATORY DESIGN CREATES PRECISE INCENTIVES
PLANTS THAT BEAT THE NORM
COMPUTE
PLANTS THAT FALL BELOW THE NORM
BENEFIT ECONOMICALLY
BEAR THE DIFFERENCE
A COMPETITIVE ADVANTAGE
A COMPLIANCE BURDEN
BEST PLANTS UNDERSTAND THIS
NOT AS A COMPLIANCE BURDEN BUT AS A COMPETITIVE ADVANTAGE.


THE POLICY ARCHITECTURE — CEA, BEE, AND THE REGULATORY IMPERATIVE
CEA'S NORMATIVE FRAMEWORK: SHIFTING THE OPERATING ENVIRONMENT
BEE'S ROLE AND THE PAT SCHEME
BEE
Bureau of Energy Efficiency
BEE INSTITUTIONALIZES EFFICIENCY BENCHMARKING ACROSS THE SECTOR
DESIGNATED CONSUMERS
THERMAL POWER STATIONS
ASSIGNED SPECIFIC SPECIFIC ENERGY CONSUMPTION (SEC) TARGETS
PAT SCHEME SOPHISTICATION GROWING WITH EACH CYCLE
ECONOMIC INCENTIVE & TARIFF OUTCOMES
DESIGNATED CONSUMERS (OUTPERFORM TARGET)
DESIGNATED CONSUMERS (UNDERPERFORM TARGET)
COMPUTE PAT COMPLIANCE
COMPUTE
DESIGNATED CONSUMERS (UNDERPERFORM TARGET)
ENERGY SAVING CERTIFICATES (ESCerts)
FACE COSTS
GENERATE TRADEABLE VALUE
REGULATORY COST LIABILITIES
LEADERSHIP STRATEGIC OPPORTUNITY
TREAT PAT COMPLIANCE NOT AS A REGULATORY EXERCISE, BUT AS A GENUINE STRATEGIC OPPORTUNITY TO BENCHMARK, IMPROVE, AND GENERATE TRADEABLE VALUE.

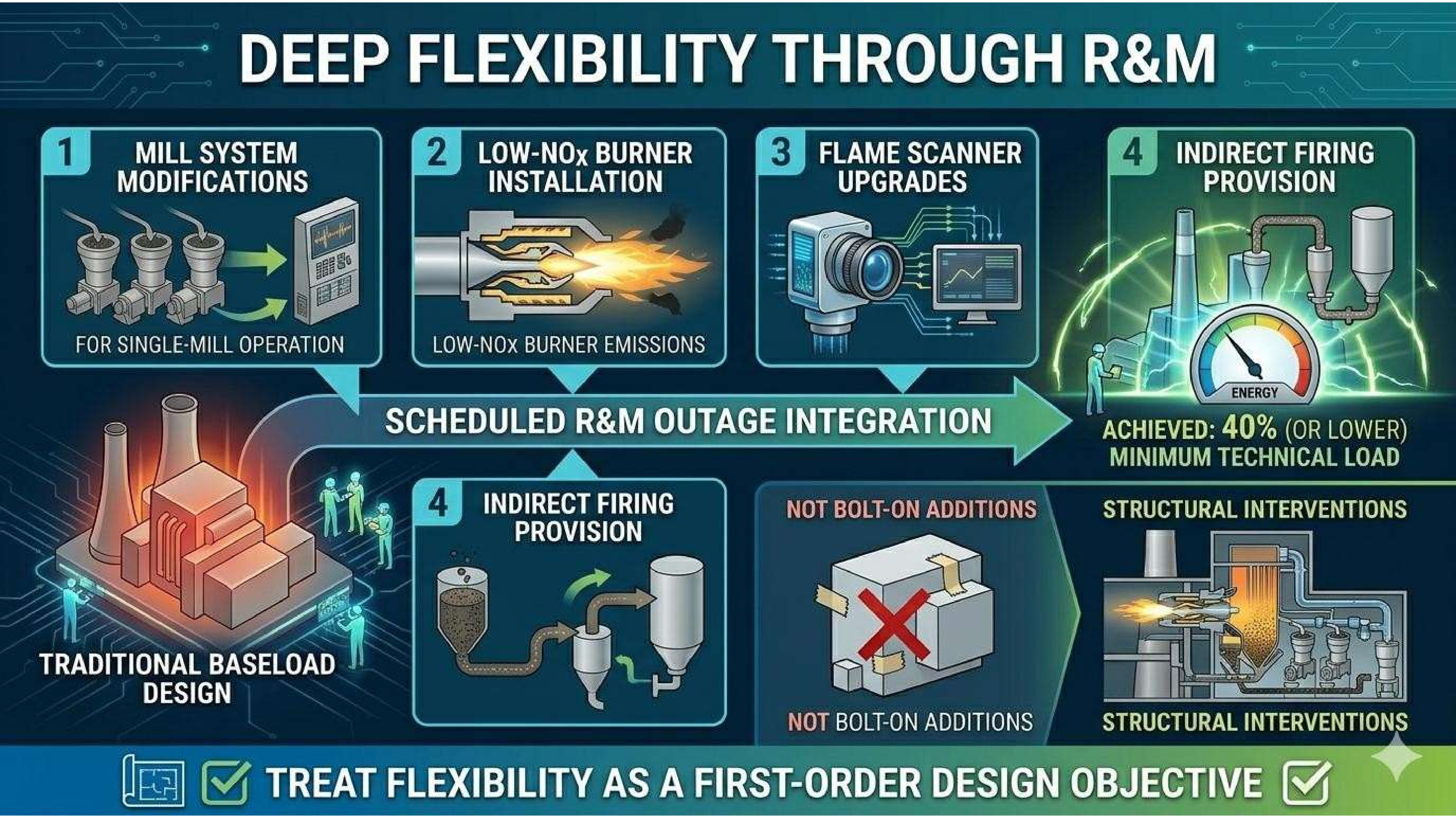

RENOVATION & MODERNISATION — THE MOST UNDERUTILISED LEVER
INDIA
SCALE OF THE OPPORTUNITY
CEA REPORT
148 THERMAL UNITS
38,150 MW candidates
R&M VS. NEW BUILD
COST: ~1/3
DELIVERS FASTER
NEW BUILD
LAST-STAGE LOW PRESSURE (LP) TURBINE BLADES
3D-profiled specialized anti-erosion coatings
FUEL
IMPACT
150–300 kcal/kWh
HEAT RATE IMPROVEMENT
(TURBINE R&M)
2.5 LAKH TONNES
COAL SAVED ANNUALLY
(200MW unit example)
BEFORE R&M: Rigid Baseload Design
AFTER R&M: Flexible & Modernized Operation

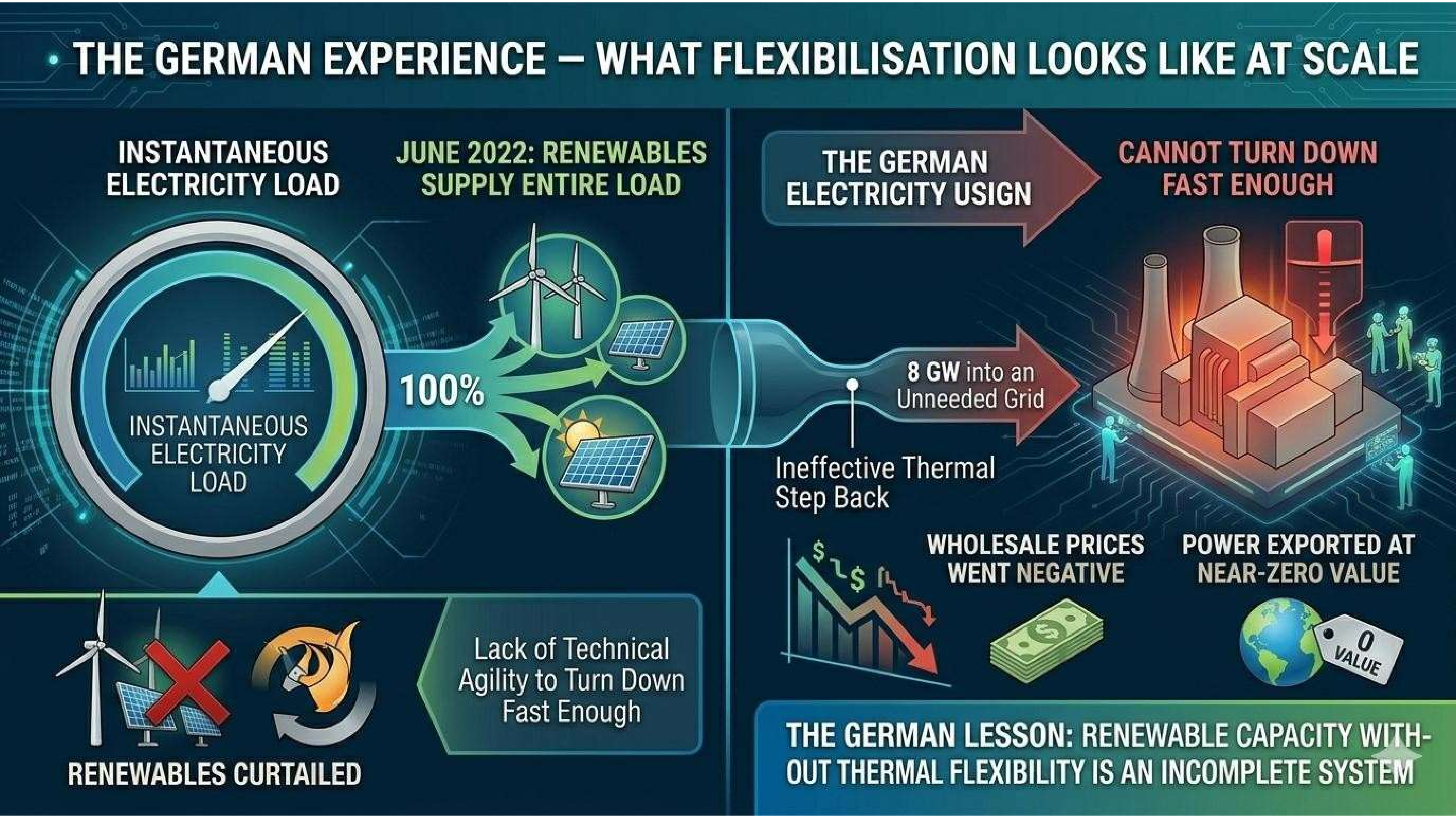
FORCED OUTAGE REDUCTION — THE HIDDEN HEAT RATE TAX

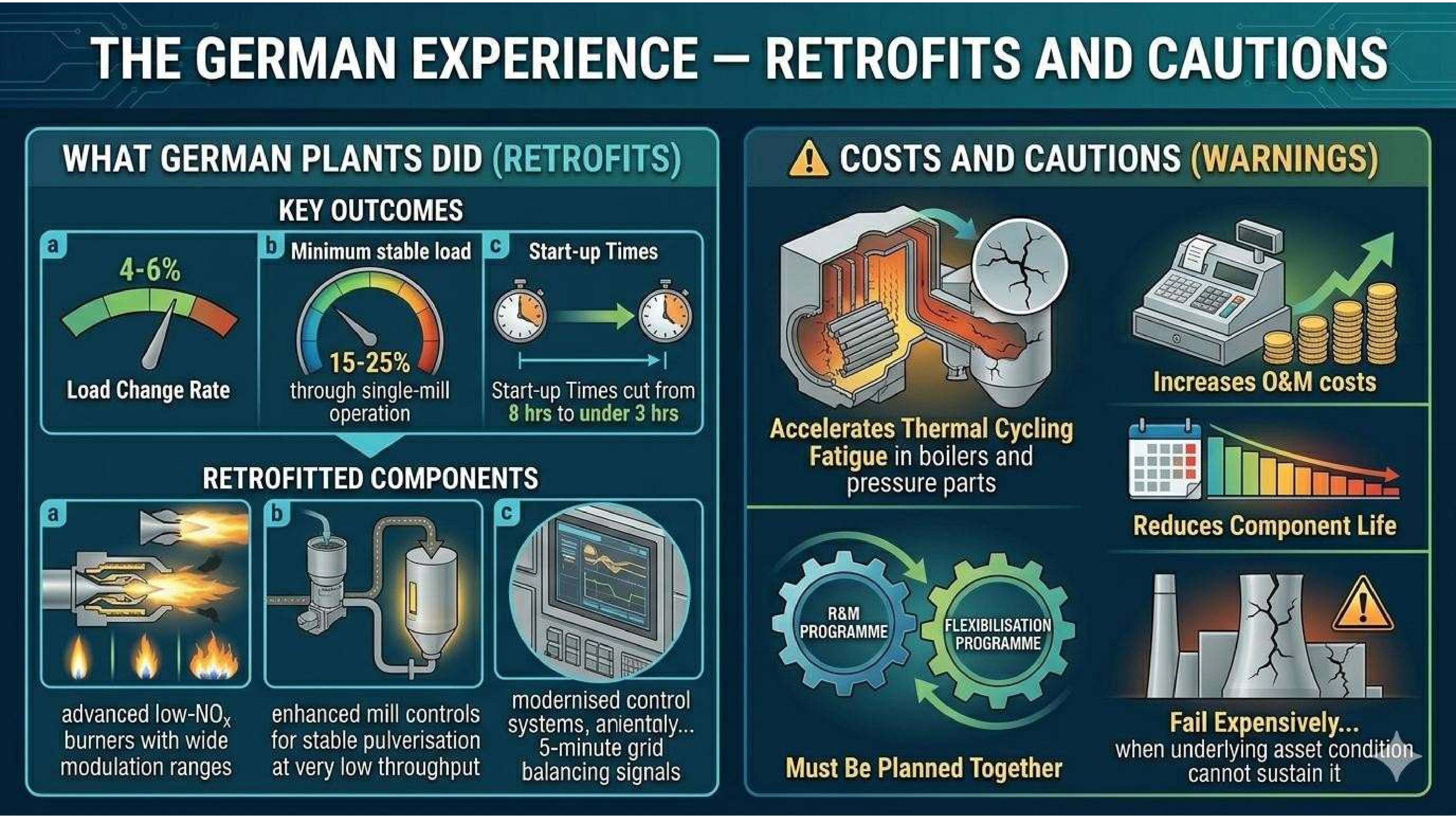




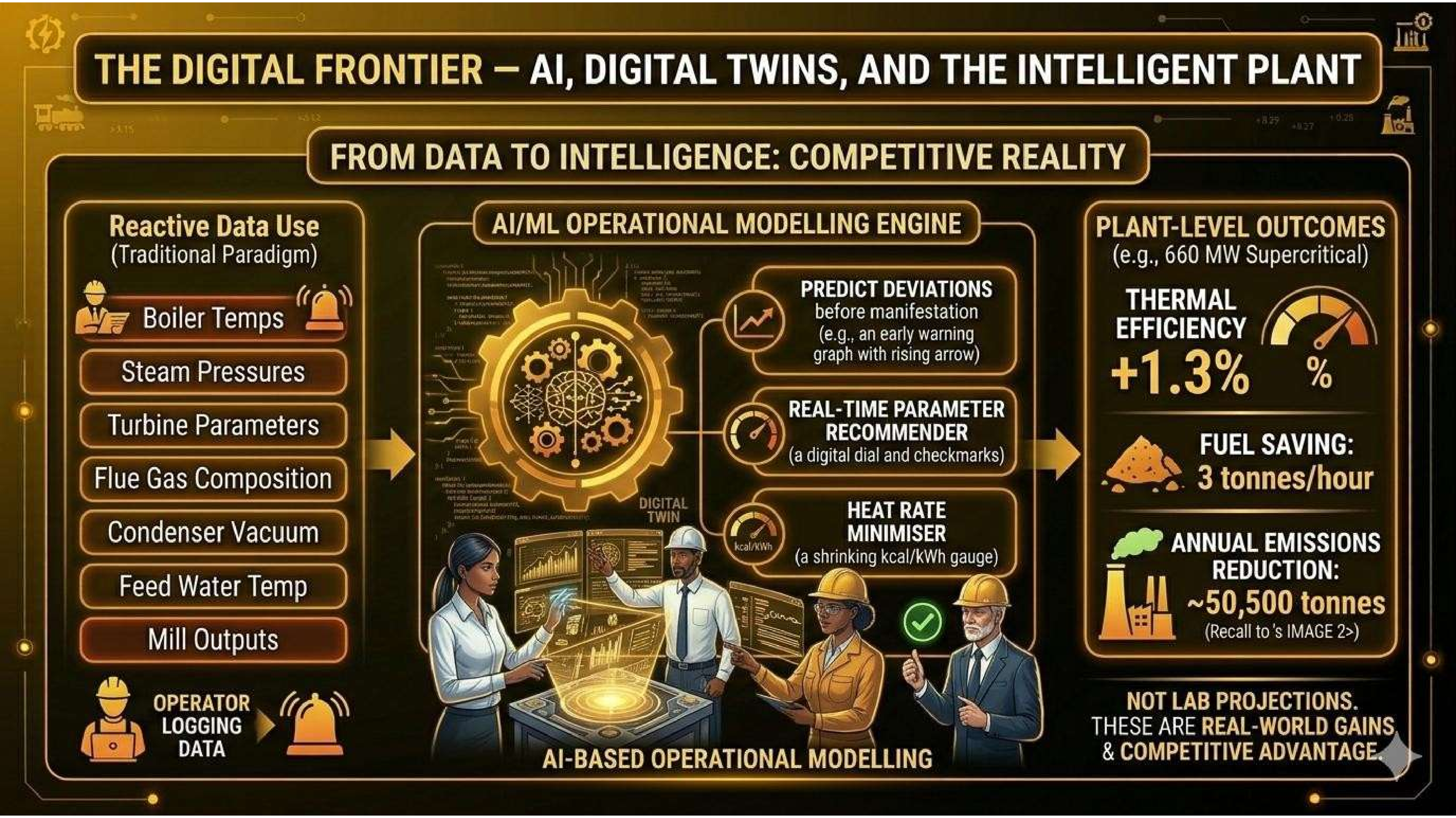
THE FLEXIBILITY IMPERATIVE
SHR
(Recall image_0)
PLF
(Recall image_0)
TARGET: CEA STATUTORY MINIMUM TECHNICAL LOAD
(Recall image_0)
GRID CONTEXT: RENEWABLE PENETRATION GROWS
RANGE OF 40% (TECHNICAL LOAD)
GRID RAMPING REQUIREMENT
100
75
50
25
0
HEAT R RATE (MW)
RAMP DOWN (High-Solar Hours)
Sunset
RAMP UP RAPIDLY (Sun Sets)
10 AM
10 AM
2 PM
4 PM
6 PM
8 PM
10 PM
TIME (Hours)
LOW-LOAD CHALLENGES
50
150
750
1000
2300
HEAT RATE
INTELLIGENT MILL MANAGEMENT
OPTIMISED COMBUSTION CONTROL
AUXILIARY MINIMISATION
OPERATIONAL SOPHISTICATION: DELIVERING SOLUTIONS
PLANT DIRECTOR
OPERATIONS ENGINEER
DATA ANALYST
AN. THIS IS WHERE THE OPERATIONAL SOPHISTICATION OF YOUR TEAMS BECOMES THE DIFFERENTIATING FACTOR.

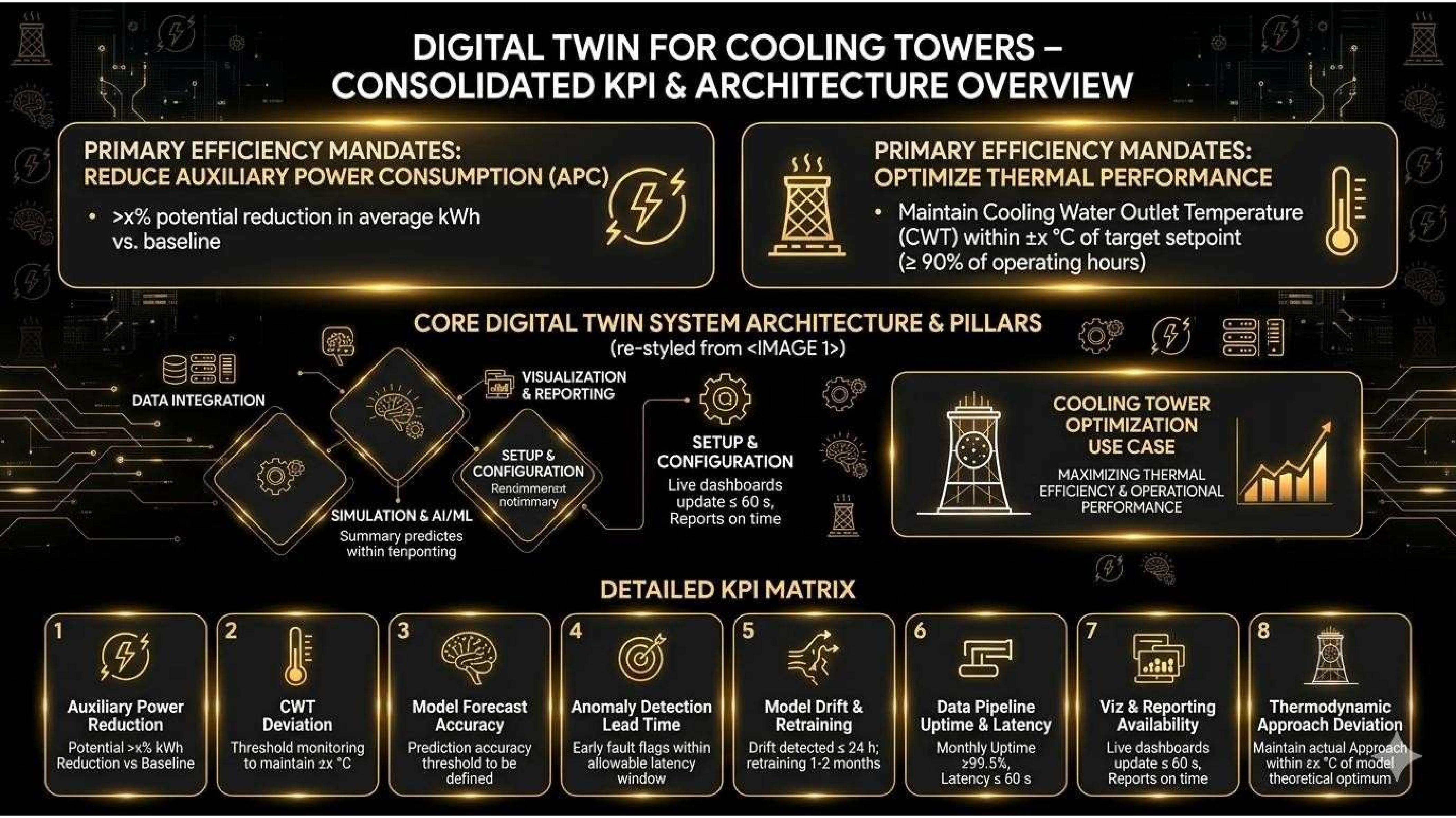

DEEP FLEXIBILITY THROUGH R&M
1 MILL SYSTEM MODIFICATIONS
FOR SINGLE-MILL OPERATION
2 LOW-NOx BURNER INSTALLATION
LOW-NOx BURNER EMISSIONS
3 FLAME SCANNER UPGRADES
4 INDIRECT FIRING PROVISION
ENERGY
ACHIEVED: 40% (OR LOWER) MINIMUM TECHNICAL LOAD
SCHEDULED R&M OUTAGE INTEGRATION
TRADITIONAL BASELOAD DESIGN
4 INDIRECT FIRING PROVISION
NOT BOLT-ON ADDITIONS
NOT BOLT-ON ADDITIONS
STRUCTURAL INTERVENTIONS
STRUCTURAL INTERVENTIONS
TREAT FLEXIBILITY AS A FIRST-ORDER DESIGN OBJECTIVE

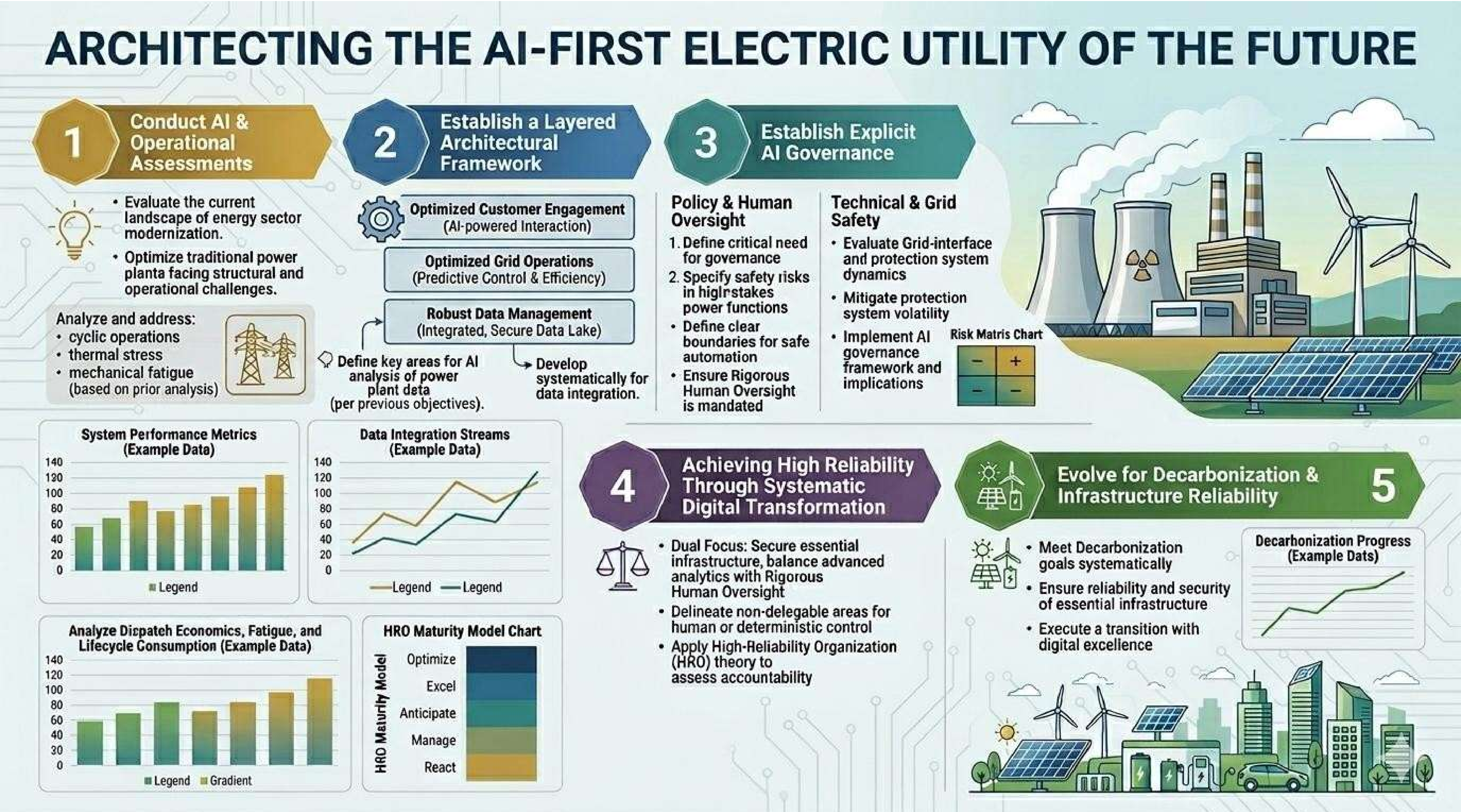

THE GERMAN EXPERIENCE — WHAT FLEXIBILISATION LOOKS LIKE AT SCALE
INSTANTANEOUS ELECTRICITY LOAD
JUNE 2022: RENEWABLES SUPPLY ENTIRE LOAD
INSTANTANEOUS ELECTRICITY LOAD
100%
THE GERMAN ELECTRICITY USIGN
CANNOT TURN DOWN FAST ENOUGH
8 GW into an Unneeded Grid
Ineffective Thermal Step Back
WHOLESALE PRICES WENT NEGATIVE
POWER EXPORTED AT NEAR-ZERO VALUE
0 VALUE
Lack of Technical Agility to Turn Down Fast Enough
RENEWABLES CURTAILED
THE GERMAN LESSON: RENEWABLE CAPACITY WITH-OUT THERMAL FLEXIBILITY IS AN INCOMPLETE SYSTEM


THE GERMAN EXPERIENCE — RETROFITS AND CAUTIONS
WHAT GERMAN PLANTS DID (RETROFITS)
KEY OUTCOMES
a
4-6%
Load Change Rate
b Minimum stable load
15-25%
through single-mill operation
c Start-up Times
Start-up Times cut from 8 hrs to under 3 hrs
RETROFITTED COMPONENTS
a
advanced low-NOx burners with wide modulation ranges
b
enhanced mill controls for stable pulverisation at very low throughput
c
modernised control systems, anientaly... 5-minute grid balancing signals
COSTS AND CAUTIONS (WARNINGS)
Accelerates Thermal Cycling Fatigue in boilers and pressure parts
Increases O&M costs
Reduces Component Life
R&M PROGRAMME
FLEXIBILISATION PROGRAMME
Must Be Planned Together
Fail Expensively...
when underlying asset condition cannot sustain it


THE TAKEAWAY FOR INDIA
THE EMERGING GRID CHALLENGE
INDIA'S RENEWABLE PENETRATION GROWING FASTER THAN GERMANY.
GRID MANAGEMENT CHALLENGE WILL ARRIVE SOONER (by 2028)
2028
THE RISK OF INFLEXIBILITY (THE GERMAN TRAP)
AVOID THE TRAP THAT AFFLICTED GERMANY'S INFLEXIBLE FLEET.
DESPATCHED LAST
LAST CALL
CYCLED MOST
UNABLE TO CAPTURE PEAK VALUE
ROADMAP TO FLEXIBILISATION & CAUTION
INVESTMENT DECISIONS TODAY
एनटीपीसी NTPC
NTPC NETRA: SUCCESSFUL PILOT
ACHIEVED 40% TURNDOWN in 500MW conventional unit
CEA CAUTION: OLD PLANTS (DESIGNED FOR BASE LOAD)
THE WINDOW IS OPEN. THE ENGINEERING IS PROVEN.
THE QUESTION IS ONLY WHETHER THE INVESTMENT DECISIONS ARE BEING MADE TODAY.


THE DIGITAL FRONTIER — AI, DIGITAL TWINS, AND THE INTELLIGENT PLANT
FROM DATA TO INTELLIGENCE: COMPETITIVE REALITY
Reactive Data Use
(Traditional Paradigm)
Boiler Temps
Steam Pressures
Turbine Parameters
Flue Gas Composition
Condenser Vacuum
Feed Water Temp
Mill Outputs
OPERATOR LOGGING DATA
AI/ML OPERATIONAL MODELLING ENGINE
PREDICT DEVIATIONS
before manifestation
(e.g., an early warning graph with rising arrow)
REAL-TIME PARAMETER RECOMMENDER
(a digital dial and checkmarks)
kcal/kWh
HEAT RATE MINIMISER
(a shrinking kcal/kWh gauge)
DIGITAL TWIN
AI-BASED OPERATIONAL MODELLING
PLANT-LEVEL OUTCOMES
(e.g., 660 MW Supercritical)
THERMAL EFFICIENCY
+1.3%
%
FUEL SAVING:
3 tonnes/hour
ANNUAL EMISSIONS REDUCTION:
~50,500 tonnes
(Recall to 's IMAGE 2>)
NOT LAB PROJECTIONS.
THESE ARE REAL-WORLD GAINS & COMPETITIVE ADVANTAGE.


DIGITAL TWIN FOR COOLING TOWERS –
CONSOLIDATED KPI & ARCHITECTURE OVERVIEW
PRIMARY EFFICIENCY MANDATES:
REDUCE AUXILIARY POWER CONSUMPTION (APC)
• >x% potential reduction in average kWh vs. baseline
PRIMARY EFFICIENCY MANDATES:
OPTIMIZE THERMAL PERFORMANCE
• Maintain Cooling Water Outlet Temperature (CWT) within ±x °C of target setpoint (≥ 90% of operating hours)
CORE DIGITAL TWIN SYSTEM ARCHITECTURE & PILLARS
(re-styled from <IMAGE 1>)
DATA INTEGRATION
VISUALIZATION & REPORTING
SETUP & CONFIGURATION
Rendimmenact notimmary
SIMULATION & AI/ML
Summary predictes within tenponting
SETUP & CONFIGURATION
Live dashboards update ≤ 60 s, Reports on time
COOLING TOWER OPTIMIZATION USE CASE
MAXIMIZING THERMAL EFFICIENCY & OPERATIONAL PERFORMANCE
DETAILED KPI MATRIX
1
Auxiliary Power Reduction
Potential >x% kWh Reduction vs Baseline
2
CWT Deviation
Threshold monitoring to maintain ±x °C
3
Model Forecast Accuracy
Prediction accuracy threshold to be defined
4
Anomaly Detection Lead Time
Early fault flags within allowable latency window
5
Model Drift & Retraining
Drift detected ≤ 24 h; retraining 1-2 months
6
Data Pipeline Uptime & Latency
Monthly Uptime ≥99.5%, Latency ≤ 60 s
7
Viz & Reporting Availability
Live dashboards update ≤ 60 s, Reports on time
8
Thermodynamic Approach Deviation
Maintain actual Approach within ±x °C of model theoretical optimum


ARCHITECTING THE AI-FIRST ELECTRIC UTILITY OF THE FUTURE
1 Conduct AI & Operational Assessments
• Evaluate the current landscape of energy sector modernization.
• Optimize traditional power planta facing structural and operational challenges.
Analyze and address:
• cyclic operations
• thermal stress
• mechanical fatigue
(based on prior analysis)
2 Establish a Layered Architectural Framework
Optimized Customer Engagement
(AI-powered Interaction)
Optimized Grid Operations
(Predictive Control & Efficiency)
Robust Data Management
(Integrated, Secure Data Lake)
Define key areas for AI analysis of power plant data (per previous objectives).
Develop systematically for data integration.
3 Establish Explicit AI Governance
Policy & Human Oversight
1. Define critical need for governance
2. Specify safety risks in higlrstakes power functions
• Define clear boundaries for safe automation
• Ensure Rigorous Human Oversight is mandated
Technical & Grid Safety
• Evaluate Grid-interface and protection system dynamics
• Mitigate protection system volatility
• Implement AI governance framework and implications
Risk Matris Chart
System Performance Metrics
(Example Data)
140
120
100
80
60
40
20
0
Legend
Data Integration Streams
(Example Data)
140
120
100
80
60
40
20
0
Legend
Legend
Analyze Dispatch Economics, Fatigue, and Lifecycle Consumption (Example Data)
140
120
100
80
60
40
30
0
Legend
Gradient
HRO Maturity Model Chart
HRO Maturity Model
Optimize
Excel
Anticipate
Manage
React
4 Achieving High Reliability Through Systematic Digital Transformation
• Dual Focus: Secure essential infrastructure, balance advanced analytics with Rigorous Human Oversight
• Delineate non-delegable areas for human or deterministic control
• Apply High-Reliability Organization (HRO) theory to assess accountability
Evolve for Decarbonization & Infrastructure Reliability 5
• Meet Decarbonization goals systematically
• Ensure reliability and security of essential infrastructure
• Execute a transition with digital excellence
Decarbonization Progress
(Example Dats)

THANK YOU

QUESTIONS

SPEAKER CONTACT

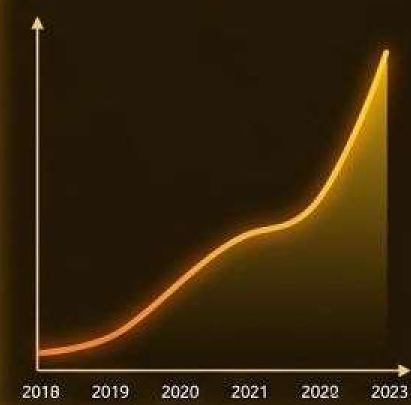
- Dr Himadri Banerji
- EY India
- International Expert and Advisor Power Power Sector

IMPACT & RESULTS

AI DEPLOYMENT

ASSET OPTIMIZATION

MONETIZE EFFICIENCY



EFFICIENCY TRENDS

HOME BACK EXIT