POWER PLANT ENGINEERING

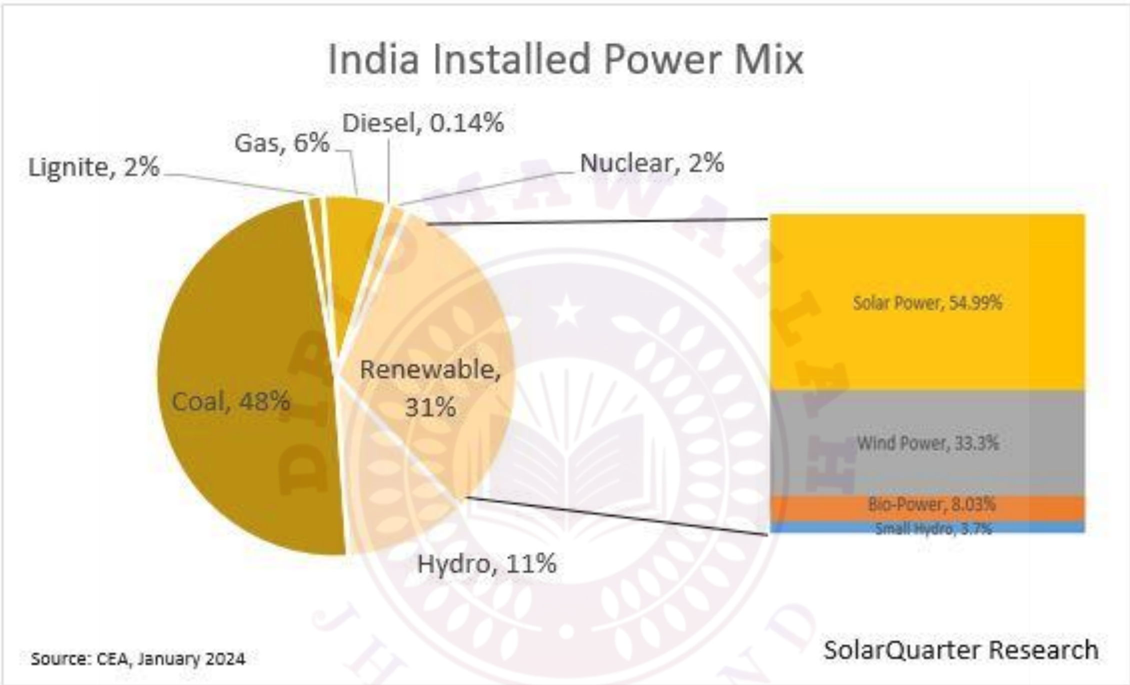
DIPLOMA WALLAH

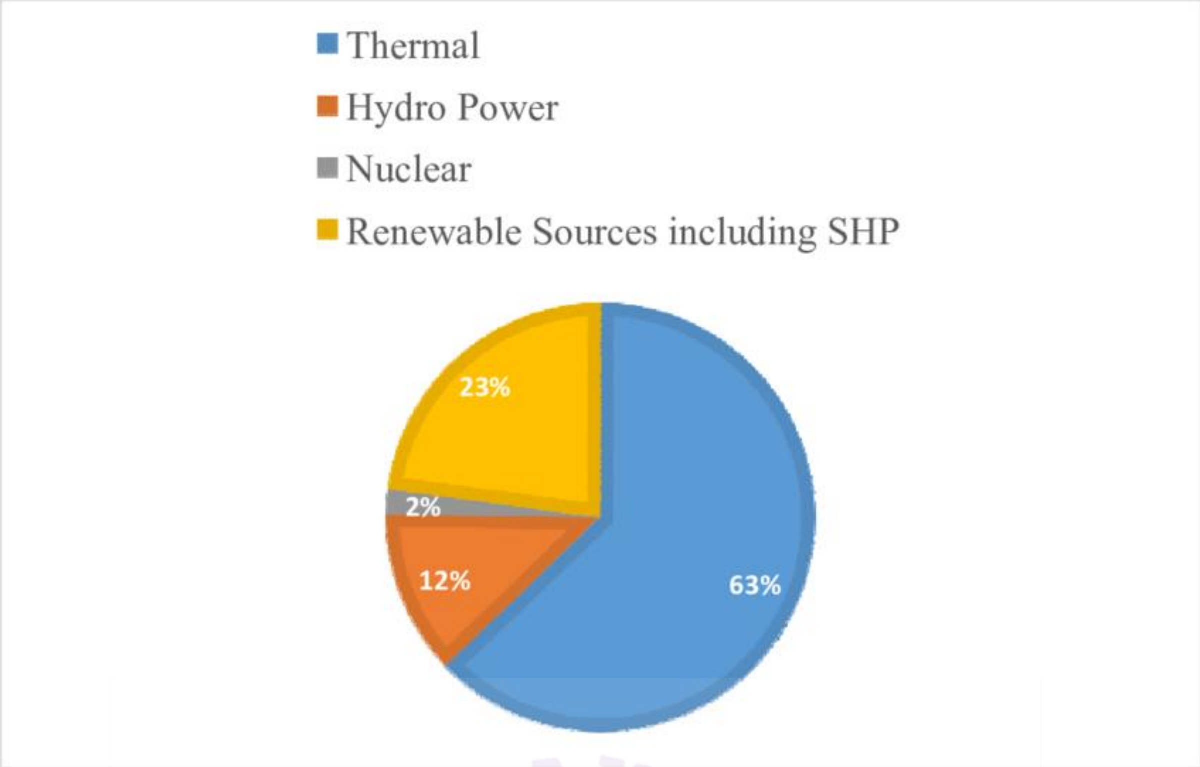
MECHANICAL

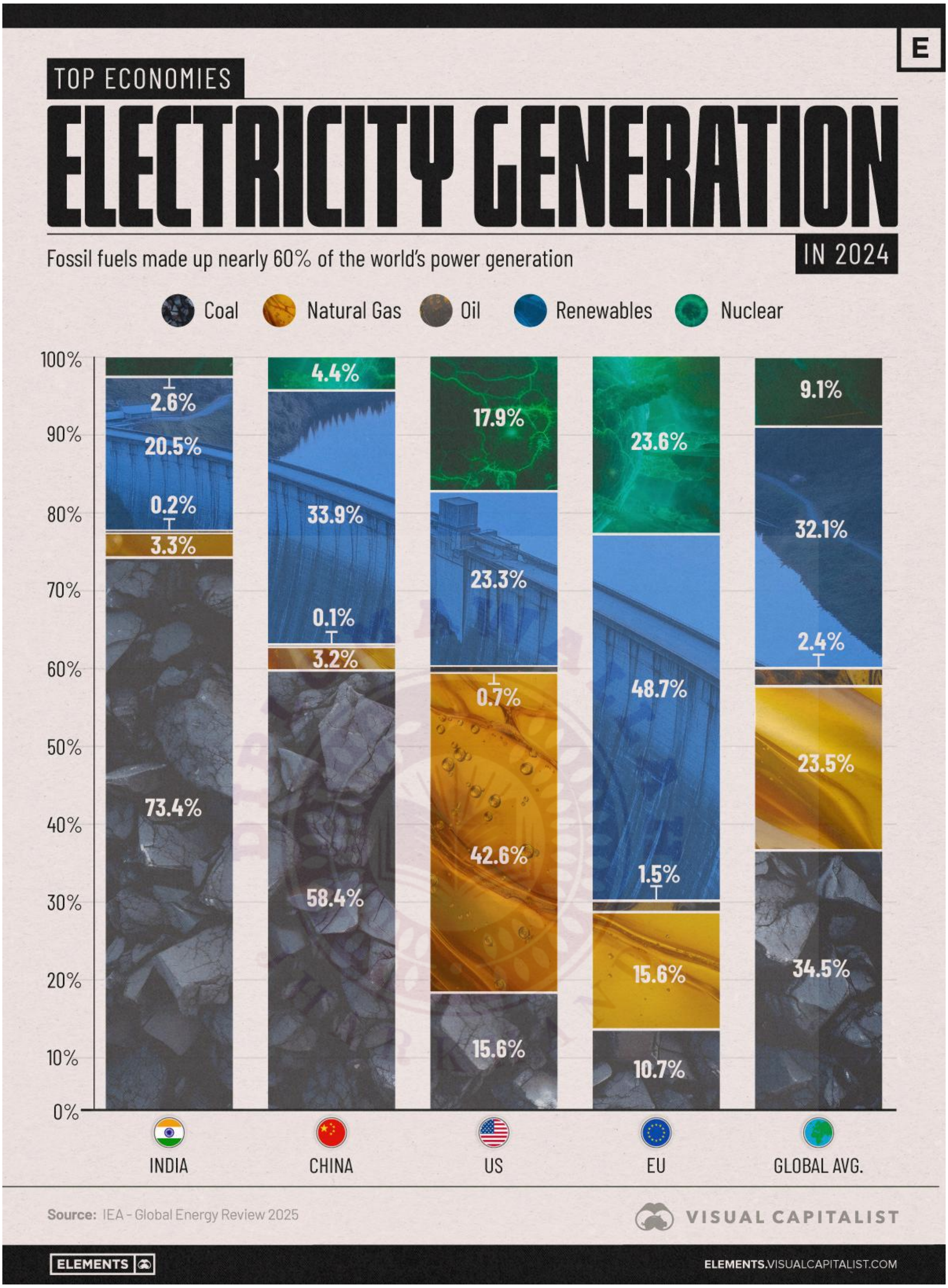
Jharkhand University Of Technology (JUT)

Unit - II Modern Steam Power Plant

1.1 Present Indian & Global Scenario of Demand and Supply of Conventional Power Plants




Thermal
Hydro Power
Nuclear
Renewable Sources including SHP
23%
2%
12%
63%



Definition & Context

- A **power plant** is a facility that converts a primary energy resource (like coal, gas, uranium, or water) into electrical energy via turbines/generators.
- "Conventional power plants" refers typically to thermal (coal, oil, gas), hydro (large), and nuclear plants — in contrast to purely non-conventional/renewable ones like small hydro, solar PV, wind.
- Understanding the global and national supply-demand of conventional power is essential for designing, operating and maintaining modern power plants (relevant to your course).

Indian Scenario

- As of June 2025, India's **total installed power generation capacity** reached about **476 GW**. (Press Information Bureau)
- Of this, thermal (coal, gas, oil) capacity was ~ **240 GW** — about **50.5%** of total installed capacity. (Press Information Bureau)
- Non-fossil fuel (i.e., renewables + nuclear) capacity stood at ~ **236 GW**, ~49% of total. (Press Information Bureau)
- In terms of actual electricity generation, fossil fuels still dominate: about **73%** of electricity generated in recent 12 months was from fossil sources, with coal alone ~71%. (Low-Carbon Power)
- From FY2015-16 (1,168 billion units) to 2024-25 (estimated ~1,824 billion units) generation increased significantly. (Press Information Bureau)
- The **plant-load factor (PLF)** of coal-based plants improved: for first nine months of FY23, PLF ~73.7% versus ~68.5% in FY22. (IBEF)

Global Scenario & Trends

- Globally, many power systems still rely heavily on conventional plants (coal, oil, gas, nuclear) especially in developing countries. (IEA)
- The mix is shifting: more renewables are being integrated, but conventional plants remain essential for baseload and grid stability, especially where demand is rising fast.

- For instance, in India, despite fast renewable additions, coal remains a critical backbone — illustrating the hybrid nature of transition.

Challenges & Engineering Implications

- **Fuel supply & quality**: For coal-based plants, domestic coal often has high ash, low calorific value → plant efficiency and maintenance are impacted.
- **Demand growth & peak loads**: With rising industrialisation, digitalisation, electrification, demand growth puts pressure on supply side — plants must be reliable, efficient, and have good **availability factor**.
- **Environmental/regulatory pressure**: Conventional plants face stricter emission norms, ash-handling rules, and need retrofits or upgrades (which affect cost, downtime).
- **Integration with renewables**: As renewables (variable) increase, conventional plants must provide flexibility (ramping up/down) which affects design and operation.
- **Economic viability**: Heat rate, fuel cost, O&M cost, emission compliance cost all combine to determine cost per kWh. For conventional plants, being efficient and well-maintained is essential to competitiveness.

Key Metrics & Terminology

Term	**Definition**	**Why important**
Installed Capacity	The total maximum output a plant or set of plants can produce under ideal conditions (in GW)	Indicates supply potential
Generation (Units / TWh)	Actual electricity produced over time	Shows utilisation and demand vs supply
Plant Load Factor (PLF)	Ratio of actual generation over a period to the maximum possible generation at full capacity	Higher PLF = better utilisation

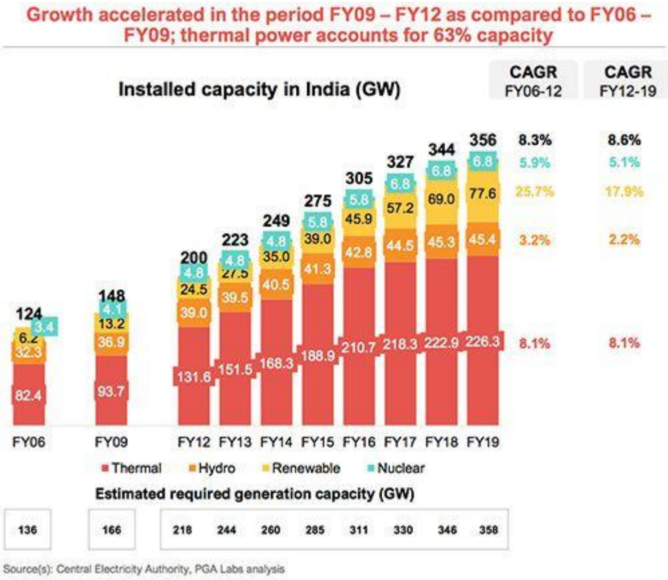
Availability Factor	Fraction of time the plant is available to generate power	Affects reliability
Heat Rate	Heat energy input per unit electrical output (e.g., kcal/kWh)	Lower heat rate = higher efficiency = lower fuel cost
Fuel Mix / Generation Mix	Proportion of electricity from different sources (coal, gas, hydro, nuclear, renewables)	Affects emissions, cost, strategy

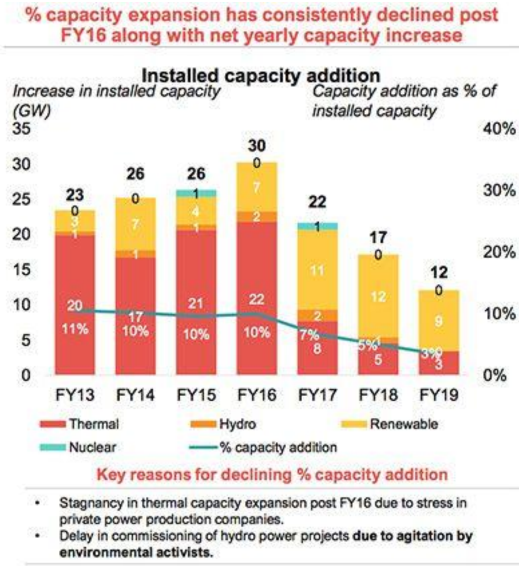
Summary

- India's power sector is rapidly expanding; installed capacity and generation have grown significantly in the past decade.
- Conventional (especially coal) plants still form a large part of both capacity and generation, though renewables are growing fast.
- For mechanical/power engineering students, this means designing, operating, and maintaining conventional plants is still highly relevant — understanding fuel, plant efficiency, regulatory compliance, and integration with newer technologies is key.
- In your course context: For **CO1** (choose appropriate fuel) and even **CO2** (maintain steam power plant), the supply-demand backdrop (fuel availability, cost, generation share) must be kept in mind.

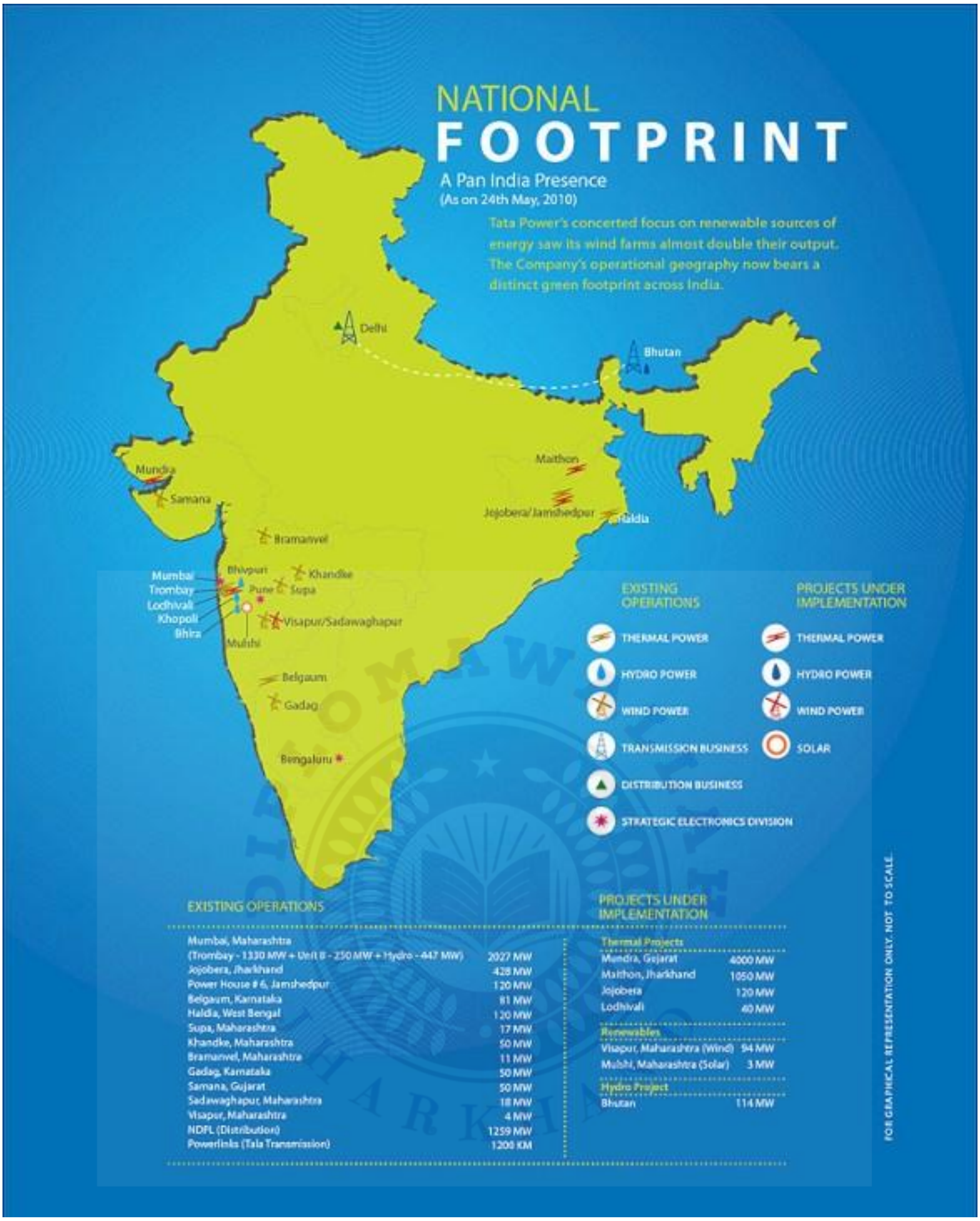
1.2 Overview of Power Generating Plants – Govt. & Private Corporations in India


INDIA
Thermal Power Plants
TAJIKISTAN
AFGHANISTAN
PAKISTAN
CHINA (TIBET)
NEPAL
BHUTAN
BANGLADESH
MYANMAR (BURMA)
SRI LANKA
ARABIAN SEA
BAY OF BENGAL
INDIAN OCEAN
Rupnagar
Bathinda
Yamuna Nagar
Panipat
Suratgarh
Badarpur
Dadri
Faridabad
Harduaganj
Rosa
Gurha
Dibiyapur
Panki
Vidyutnagar
Kanti
Thumbli
Unchahar
Kahalgaon
Barauni
Parichha
Kota
Baran
Obra
Farakka
Sidhi
Rihand
Anpara
Murshidabad
Bongaigaon
Suri
Durgapur
Kutch
Gandhinagar
Birsinghpur
Chachai
Purulia
Hooghly
Kheda
Jamnipali
Mecheda
Jamnagar
Sipat
Jhanor
Sarni
Tamnar
Jharsuguda
Nani Naroli
Adityanagar
Deepnagar
Vidyutnagar
Khaperkheda
Kaniha
Talcher
Nashik
Chandrapur
Parli Vaijnath
Ramagundam
Jyothi Nagar
Chelpur
Palwancha
Simhadri
Ibrahimpatnam
Dondapadu
Raichur
Kudatini
Cuddapah
Athipatttu
Ennore
Metturdam
Neyveli
Kayamkulam
Thoothukudi
LEGEND
Thermal Power Plant
Map not to Scale
Copyright © 2021 www.mapsofindia.com





Energy Source	As on 31 Dec 2024	As on 31 Mar 2025	Change (MW)	% of New Capacity Added*
Wind Power	48,163	50,038	1,875	13.9
Solar Power*	97,865	105,646	7,782	57.7
Small Hydro	5,101	5,101	-	0.0
Biomass	10,728	10,743	15	0.1
Waste to Energy*	620	840	220	1.6
Large Hydro	46,968	47,728	760	5.6
Nuclear	8,180	8,180	0	0.0
Coal (+ Lignite)	218,970	221,813	2,843	21.1
Gas	24,818	24,533	-285	-2.1
Diesel	589	589	0	0.0
Total	462,002	475,212	13,210 (Net capacity added)	-



1.2.1 Ownership & Corporate Structure

- The Indian power generation sector comprises major **public sector** companies (central/state) and **private sector/independent power producers (IPPs)**.
- **Public sector examples**: NTPC Ltd. – among the largest owners of power plants in India. (IBEF) Also, NHPC Ltd. (hydro power)

and Nuclear Power Corporation of India Ltd. (NPCIL) for nuclear. (Wikipedia)

- **Private sector examples**: Adani Power Ltd. and Tata Power Company Ltd.. According to data as of March 31, 2022, the top 10 plant-owners in India (public & private) held ~137,807 MW combined capacity; NTPC alone ~60,906 MW. (GlobalData)
- **Captive power plants**: Many industries (steel, cement, chemical) have their own generation to secure supply—this segment also contributes significantly to the generation mix. (Wikipedia)

1.2.2 Capacity, Technology & Sector Trends

- As of June 2025, India's **total installed power generation capacity** reached ~ 476 GW. (Press Information Bureau) Thermal (coal/gas/oil) still accounts for ~240 GW (~50.5%) of this capacity. (Press Information Bureau)
- Private sector plants often feature newer technologies (supercritical/ultra-supercritical boilers, combined-cycle gas turbines), to achieve higher efficiency, lower emissions and better PLFs.
- Public sector plants may include older units with legacy equipment; maintenance regimes, fuel logistics, plant load factor (PLF) and auxiliary consumption differ compared to newer private plants.
- Example: A large private coal plant (e.g., operated by Adani Power) may be near imported coal port, use advanced boilers, whereas an older government-owned plant may rely on domestic high-ash coal, older design, higher maintenance.
- The choice of corporation type (public vs private) influences funding, upgrade cycle, retrofitting for pollution control (e.g., flue gas desulphurisation), instrumentation/SCADA systems, manpower training.

1.2.3 Engineering & Operational Implications

For a mechanical engineering student studying power plant engineering, the differences between corporations have real implications:

- **Maintenance strategy**: Private plants often aim for maximised uptime and PLF (to meet Power Purchase Agreements – PPAs). Therefore preventive maintenance, condition-monitoring, predictive analytics may be more prevalent. Public plants sometimes have longer-term life-cycle maintenance schedules, heavier reliance on planned outages.
- **Fuel & resource logistics**: Private plants might have contractual fuel supply (imported coal or LNG) and storage optimized; public plants may depend on domestic mines/quality which influences boiler design (ash handling), wear of turbines/pipes, maintenance intervals.
- **Economics & cost control**: Private plants often sensitive to cost per kWh (fuel cost, auxiliary consumption, downtime penalties), so design margins, efficiency improvements, auxiliary power consumption reduction become critical. Public plants may have different cost focus (state subsidies, inflation-indexed tariffs) but still must address efficiency.
- **Technology adoption**: In newer plants—especially private ones—the mechanical systems (boiler drums, reheaters, superheaters, steam turbines, condensers, cooling systems) often use newer materials, tighter tolerances, automated instrumentation; this influences design, operation, and maintenance learning for you.
- **Regulatory compliance & emissions**: Corporations must comply with emission norms (discussed later). Private plants may budget for retrofits (ESP, FGD) early; public plants might have legacy issues; mechanical engineers must factor in space, auxiliary loads, integration of pollution control equipment in plant layout.

1.2.4 Example Data & Tables

Here is a sample summarization of major plant-owners and their active capacity (as of March 31 2022):

Company	Sector (Public/Private)	Active Capacity (MW)	Comment

NTPC Ltd.	Public	~60,906 MW	India's largest power plant owner. (GlobalData)
Adani Power Ltd.	Private	~12,450 MW	One of top private thermal players. (GlobalData)
(others in top 10)	Mixed	Combined ~137,807 MW	Represents the scale of major operators. (GlobalData)

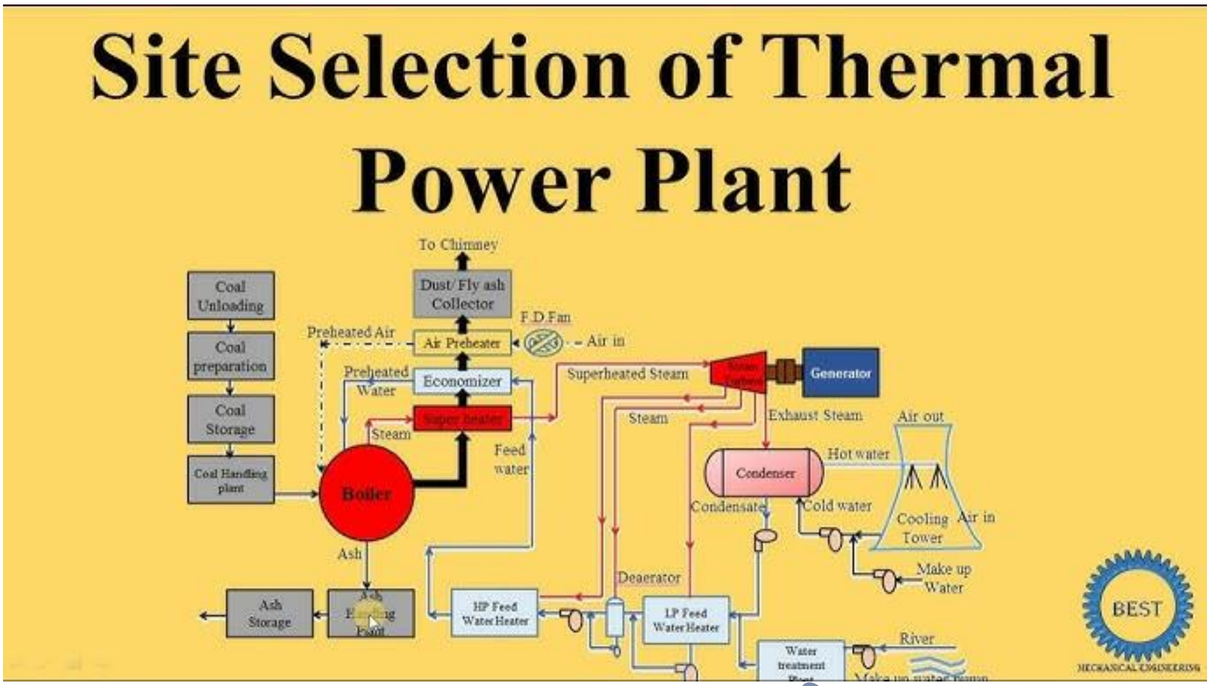
Additional metrics:

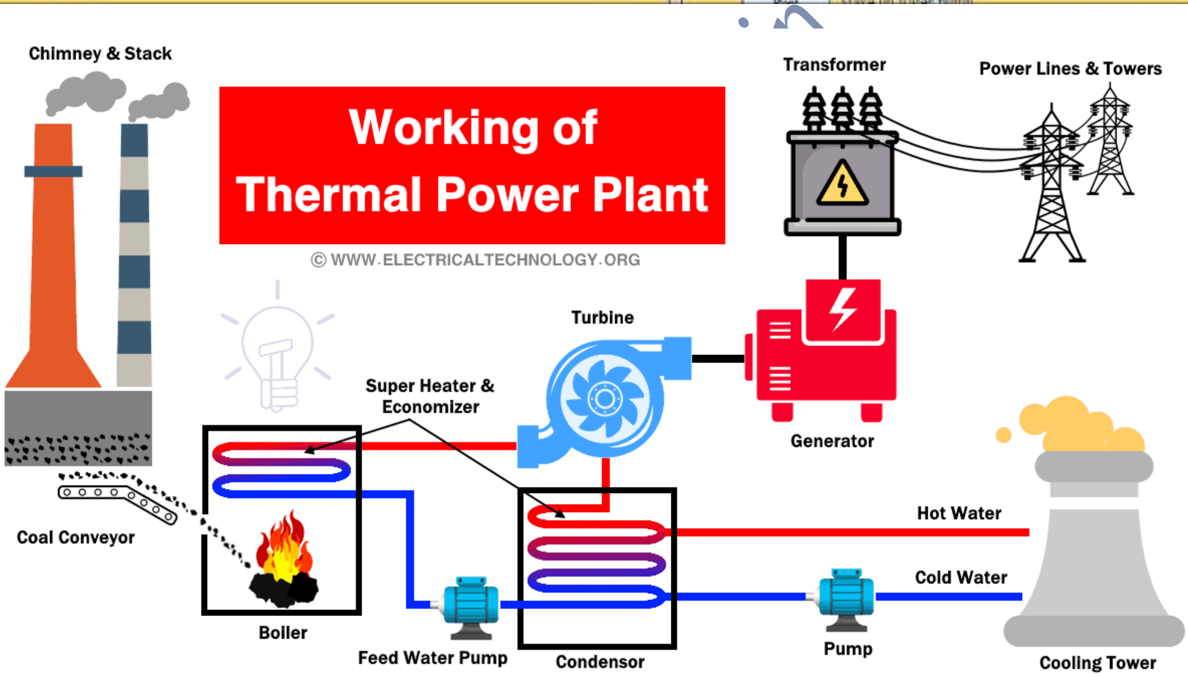
- Plant Load Factor (PLF): This ratio (Actual Generation / Maximum Possible Generation) differs across corporations; private plants may target higher PLF.
- Auxiliary Power Consumption & Forced Outage Rate: Lower auxiliary consumption and lower forced outage rate are signs of good mechanical/plant engineering, often seen in newer plants under private sector.

1.2.5 Summary Points

- Ownership type (public vs private) in power generation impacts technology, cost, maintenance, operation, fuel logistics and corporate strategy.
- For your syllabus and for CO2, CO3, CO5 outcomes (maintenance, gas/waste heat recovery, economic parameters), understanding the plant's corporate background helps you address realistic scenarios: e.g., a private gas combined-cycle plant needing quick turnaround vs a public coal plant doing baseload operation.
- When selecting fuels (CO1) or analysing plant economics (CO5), the corporate nature and capacity of the plant influence availability of fuel, funding for upgrades, cost structures, and thus your engineering decisions.

In-depth Notes for 1.3 Site Selection Criteria for Steam (Thermal) Power Plant


Site Selection of Thermal Power Plant
To Chimney
Coal Unloading
Coal preparation
Coal Storage
Coal Handling plant
Dust/ Fly ash Collector
F.D.Fan
Air in
Preheated Air
Air Preheater
Preheated Water
Economizer
Super heater
Steam
Feed water
Boiler
Superheated Steam
Generator
Steam
Exhaust Steam
Air out
Condenser
Hot water
Condensate
Cold water
Cooling Tower
Air in
Make up Water
Ash
Ash Storage
HP Feed Water Heater
Deaerator
LP Feed Water Heater
Water treatment
River
BEST


Chimney & Stack
Working of Thermal Power Plant
© WWW.ELECTRICALTECHNOLOGY.ORG
Transformer
Power Lines & Towers
Turbine
Super Heater & Economizer
Generator
Coal Conveyor
Hot Water
Cold Water
Boiler
Feed Water Pump
Condensor
Pump
Cooling Tower

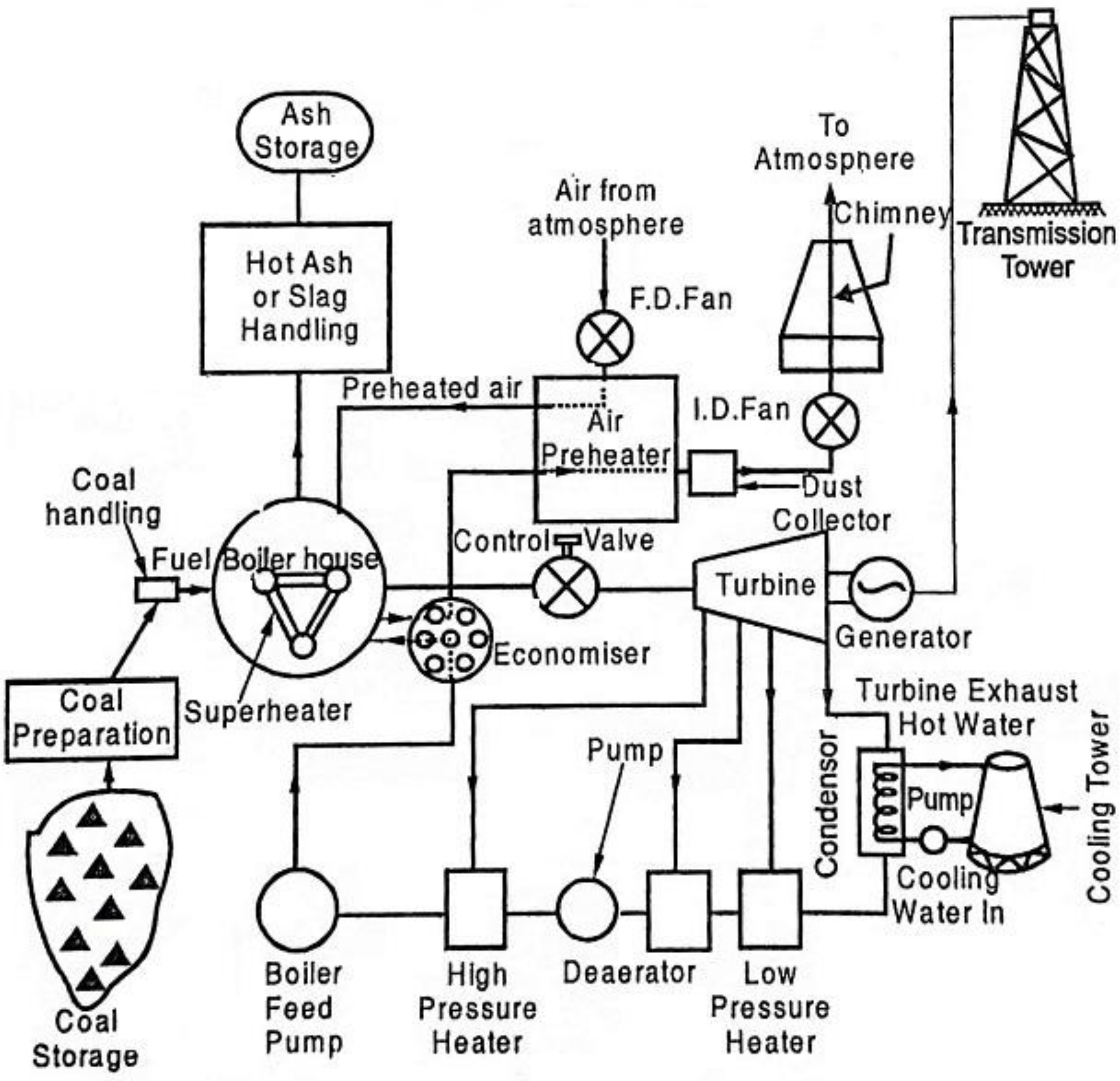


Fig: 1.26 Steam Power Plant or Thermal Power Plant

1.3.1 Why Site Selection Matters

Site selection for a steam (thermal) power plant is **critical** because the location influences many of the major cost drivers and operational constraints: fuel transport cost, water supply and cooling, land cost and terrain, ash disposal, transmission losses, environmental compliance, and future expansion possibilities. Poor site choice can increase capital cost, reduce efficiency, raise operating cost, shorten life-span or cause regulatory issues.

As one source puts it: “While erecting a steam power plant, site selection is an important part because the site life of the plant depends.” (Mundus 2035)

1.3.2 Detailed Criteria & Their Engineering Implications

Below is a detailed list of the major criteria, with engineering and operational implications:

Criterion	Why it matters / Engineering Implication	Key Checks / Considerations
Fuel availability & transportation	Steam plants consume large quantities of fuel (e.g., coal). Transport cost and logistics of fuel stock affect overall generation cost and reliability. (Engineering Notes India)	Proximity to coal mine or port (for imported coal); adequate stockpile capacity; rail/road/sea connectivity; quality of fuel (ash content, moisture)
Water supply & cooling	Steam-cycle plants need water for steam generation, feedwater, condenser cooling, ash handling. Inadequate or expensive water supply can lower efficiency or increase cost. (TutorialsPoint)	Nearby river, lake or sea water; seasonal variability; cooling system type (once-through, cooling tower); make-up water needs; environmental discharge constraints
Land area, terrain & soil bearing capacity	A steam plant has heavy equipment (boilers, turbines, condensers, cooling towers), coal yards, ash ponds, etc. Land cost and geotechnical conditions affect civil works cost and plant foundation design. (Electricalje)	Flat terrain preferred; good soil bearing capacity; site free from flood/plains or high seismic risk; space for future expansion;

		land cost and availability
Transport infrastructure	Plant construction (heavy equipment), fuel transport (coal), ash disposal require robust transport links. Delays or transport bottlenecks raise cost. (Mundus 2035)	Rail siding, road connectivity, port if importing fuel, access for heavy equipment transportation, permitting
Proximity to load centre & grid connection	Locating near demand centres reduces transmission losses and cost. Yet high-voltage transmission enables more remote sites if other conditions are favourable. (electricalengineeringinfo.com)	Transmission line availability, substation proximity, voltage level; trade-off between fuel transport cost vs transmission cost
Ash disposal & waste handling	Coal combustion generates large amounts of fly ash and bottom ash; disposal or utilisation must be accommodated. (ELECTRICAL TECHNOLOGY)	Nearby ash pond or dump area, disposal by road/rail, proximity to ash users (cement/brick industries), environmental clearance for ash handling

Distance from populated areas & environment	Coal plants emit flue gases, dust, noise; site must avoid health/environment risks. (Electricalje)	Buffer zones, compliance with environmental regulation, local community impact, noise/dust mitigation
Future expansion and flexibility	Plants often operate for decades; site must accommodate future capacity addition, changing fuel types, technology upgrades. (Scribd)	Reserve land, infrastructure access, possibility of adding units or converting fuel, modularity
Cost and type of land	Land cost is part of capital cost; cheaper land reduces investment. Also, ease of land acquisition, topography matters. (TutorialsPoint)	Land acquisition cost, flat vs sloped land, existing infrastructure, associated costs for site-preparation

---

1.3.3 Engineering Examples & Numeric Insights

- According to one source, water requirement for condenser cooling in a direct river-cooled plant is ~120 m³ per MW per hour; for cooling tower systems, make-up water may be ~2.4 m³ per MW per hour plus losses. (Engineering Notes India)
- For a large plant (e.g., 400 MW), the land required may be in the order of "3-5 acres per MW" for full layout including coal yard, ash pond, cooling towers. (www.slideshare.net)
- Soil bearing requirement: The land chosen should have sufficiently high bearing capacity (e.g., >10 N/mm²) to support heavy equipment and reduce foundation cost. (Thermodyne Boilers)

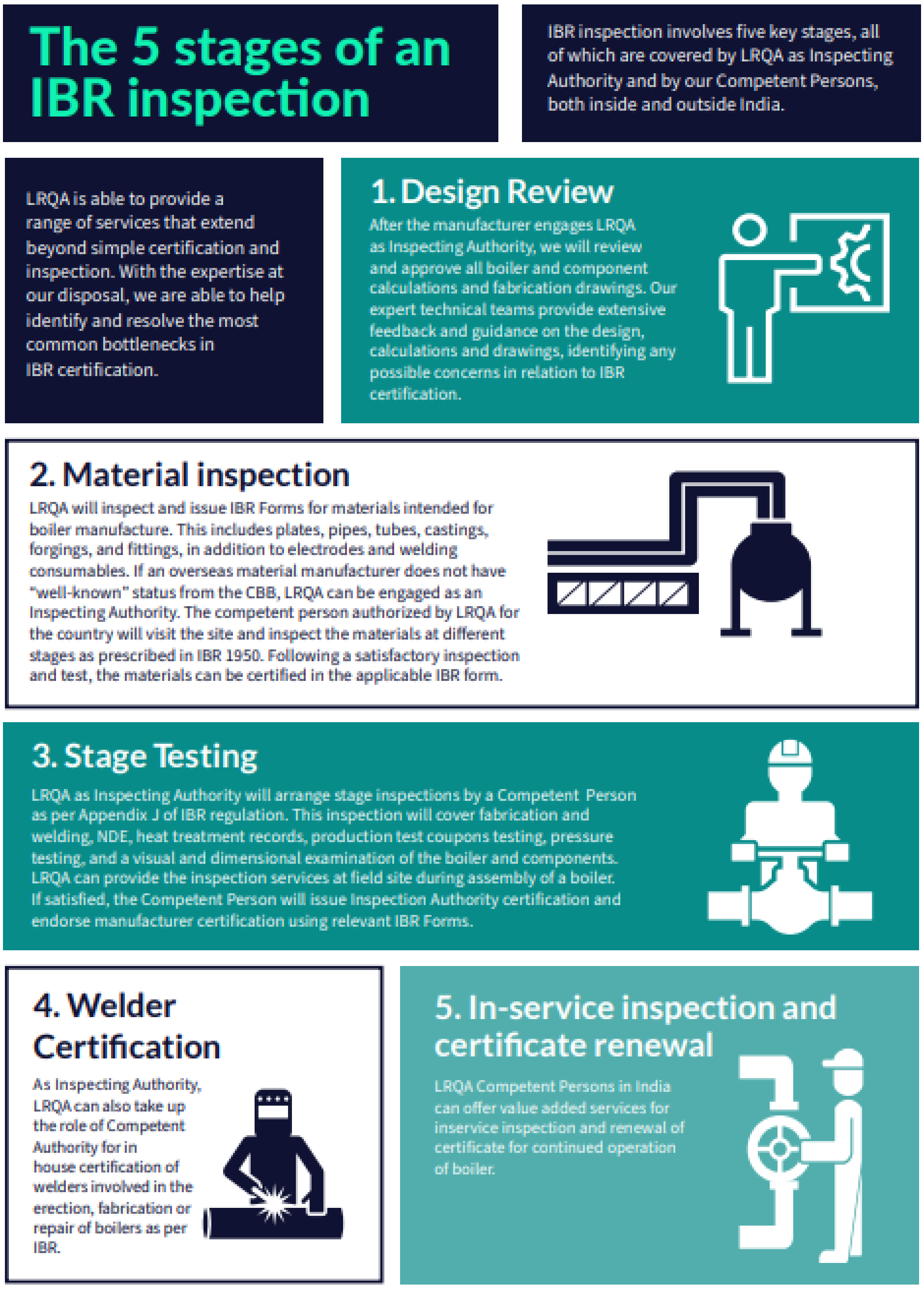
1.3.4 Application to Indian Context & Practical Notes

- In India, many coal-based plants are sited near coalfields (e.g., in Chhattisgarh, Jharkhand) to reduce fuel transport cost and handle high-ash domestic coal.
- However, sometimes sites choose imported coal via ports (Gujarat, Maharashtra) to access better quality fuel — but then transport to plants becomes a factor.
- Water availability is crucial; e.g., plants in dry regions may require cooling towers or seawater cooling, which has cost/efficiency trade-offs.
- Ash disposal is particularly important in India due to use of high-ash coal; proximity to ash-utilisation industries (cement, bricks) can save transport/disposal cost.
- The trade-off between being **near fuel** vs **near load** vs **near water** is often complex; for example, being very near a coal mine but far from load centre increases transmission cost and losses. Site study must weigh these trade-offs.

1.3.5 Summary & Key Takeaways

- Site selection isn't merely choosing a plot of land — it's a **multi-criteria decision** that integrates fuel logistics, water/cooling needs, land & terrain, transport & infrastructure, environmental/regulatory constraints, and future flexibility.
- For your course (Power Plant Engineering), when you later deal with design, operation & maintenance, remember that the site affects almost every subsystem (coal transport system, boiler feedwater system, cooling system, ash disposal, transmission).
- From a student/engineer viewpoint: when conducting a site selection or evaluation, you should list all criteria, assign relative importance (depending on fuel, region, technology), and evaluate trade-offs.
- Key points to emphasise: **Fuel & water** are often the two largest site-driving factors; **land, transport, ash disposal** significantly influence cost; **distance from load** and **environmental constraints** shape site viability in modern context.

1.4 Indian Boiler Regulations, 1950 (IBR) Norms for Steam Power Plant




THERMTECH
4
3
5
2
6
7
1
1 BLOW DOWN
2 ECONOMIZER
3 SMOKE OUT LET
4 BURNER ASSEMBLY
5 CONTROL PANNEL
6 FEED PUMP WITH MOTOR
7 BLOWER WITH LOD PUMP
Coil Type IBR Steam Boiler

FORM XVI-D

[Regulation 4C (2)]

Serial No. FOUNDRY/09/056 F.NO. 8(31)/2012-BOILERS

Central Boilers Board

Certificate of Approval for Well Known Foundry

This is to certify that the Inspection and Quality Management System of:

M/s. KEOKUK STEEL CASTINGS
3972 MAIN STREET
KEOKUK, IOWA
USA - 52632

has been evaluated by the Central Boilers Board and has been granted recognition under regulation 4C (2) of the Indian Boiler Regulations, 1950, as a WELL KNOWN FOUNDRY. FOR MANUFACTURE OF CASTINGS UPTO A MAXIMUM OF 1600 KGS./PIECE

This Certificate is valid for five years, i.e. upto 29th SEPT., 2017

Validity is subject to the adherence to the quality control prescribed under the provisions of the Indian Boiler Regulations, 1950.

1st FEB., 2013
Date of Issue

Approval
Certificate No. 296

Secretary

CBB
CENTRAL BOILERS BOARD

1.4.1 What is IBR?

- The Indian Boiler Regulations (IBR) were constituted under the Indian Boilers Act, 1923 and came into effect on 15 September 1950 (with subsequent amendments). (Thermodyne Boilers Blog)

- IBR sets technical and safety standards for the **design, construction, inspection, testing, certification** and use of boilers, steam piping, pressure parts, and related equipment in India. (Munich Re)
- For a steam power plant (especially coal or nuclear steam cycles), compliance with IBR is a **legal requirement**, and failure to comply can lead to penalties, shutdowns, or unsafe operations. (Twi Global)

1.4.2 Scope & Applicability of IBR

What equipment falls under IBR?

- A "boiler" under IBR is defined as a closed vessel in which steam is generated for external use; it includes fittings and attachments that are under pressure. (Munich Re)
- Steam piping and connected fittings are included when:
  - The steam pressure exceeds certain thresholds (e.g., 3.5 kg/cm² gauge) or
  - The pipe internal diameter exceeds certain limits (e.g., 254 mm) and it carries steam at pressure. (Thermodyne Boilers Blog)
- Also covers: steam receivers, separators, accumulators, superheaters, economisers, feed-piping from pump discharge to boiler, etc. (LRQA)

Why it matters for steam power plants

- In a large thermal power station, numerous components — for example the boiler pressure-vessel, steam drum, superheater tubes, main steam piping, feed water piping, safety valves, stack economiser — fall under IBR jurisdiction.
- Compliance ensures integrity under high pressure/temperature, reliability, safe operation, and standardised maintenance.
- For your subject, this means when you study design & maintenance of steam power plants (related to CO2), knowing which parts require IBR certification is essential.

1.4.3 Key Requirements & Engineering Implications

Design & fabrication

- Design calculations (thickness, stresses, pressure–temperature ratings) must adhere to IBR rules (for example D/t ratios, material stresses). (sgboilerinspector.blogspot.com)
- Materials used: plates, tubes, pipes, fittings must meet specified standards; manufacturers must produce certificates. (Scribd)
- Welding and fabrication: Welders must be certified under IBR; welding procedures must be approved. (www.slideshare.net)

Inspection & Certification

- Manufacturing and erection must be witnessed/approved by an "Inspecting Authority" recognised by the Central Boilers Board (CBB) and state Chief Inspector of Boilers. (TÜV SÜD)
- Key stages include: design review, material inspection, pressure-parts inspection, welder qualification. (www.slideshare.net)
- Equipment must carry relevant certificates (Forms II, III, IV etc) specified under IBR. (mahaboiler.in)

Registration, Operation & Maintenance

- Boilers must be registered with state boiler inspector, examined and re-certified at defined intervals. (cib.assam.gov.in)
- Operation and maintenance of IBR-registered boilers require upkeep of safety valves, gauges, controls, inspection of pressure parts, record keeping of blow-downs, tests, etc.
- Non-compliance can lead to accidents (explosions, pressure failures), and heavy legal/financial consequences. (Twi Global)

1.4.4 Relevance to Power Plant Engineering & Maintenance

- For a steam power plant (coal, nuclear, waste-heat steam cycles) where high pressures (>100 bar) and high temperatures (>500 °C) are used, pressure components and piping are critically stressed. Ensuring these meet IBR norms is foundational for safe, efficient operation.
- Maintenance planning (CO2): You must schedule audits/in-service inspections of IBR components (drums, headers, main steam piping) to maintain integrity and avoid failure.

- During retrofits, upgrades or expansions (supercritical units), you must verify that new components meet IBR plus appropriate codes (ASME, EN) and are properly certified.
- Economic & reliability impacts: Unplanned shutdowns due to boiler/piping failure can severely affect plant availability, increase O&M cost and fuel cost per kWh — thus IBR compliance ties into overall plant economics (CO5).

1.4.5 Summary Checklist for IBR in Steam Power Plant

- Identify all IBR-covered components in the plant (boiler drum, superheaters, economisers, steam piping, feed piping)
- Ensure design calculations, materials, fabrication, welding meet IBR (and additional codes where required)
- Confirm manufacturing/inspection process is certified with appropriate IBR forms and authority sign-offs
- Register boiler with state inspectorate, ensure periodic inspections, maintenance records, safety devices are functioning
- Align maintenance and operations planning with IBR regulation requirements: record keeping, inspection logs, safety valve tests, hydro/pneumatic tests.
- Factor in IBR compliance cost, inspection downtime, component replacement into the plant's maintenance and economic model.

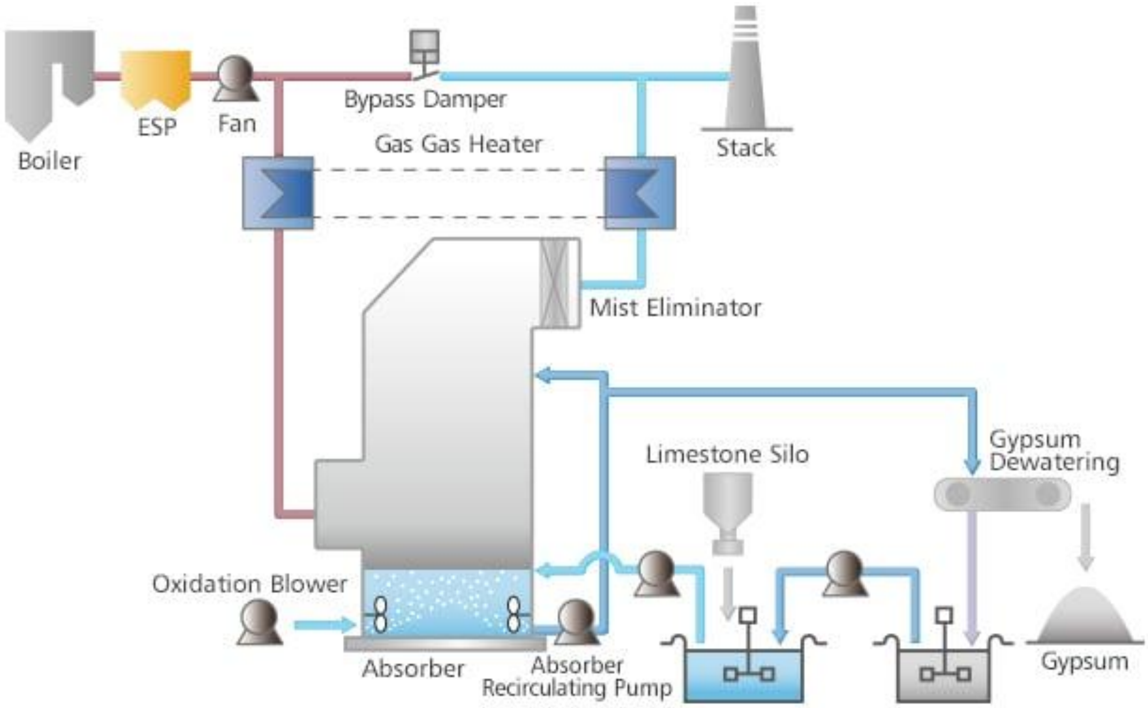
1.5 Central Pollution Control Board (CPCB) & Maharashtra Pollution Control Board (MPCB) Norms for Power Plants

Revised timeline for complying with the emission norms			
Category	**Location/Area**	**Timelines for compliance**	
		Non-retiring units	**Retiring units**
Category A	Within 10 km radius of the NCR or cities with a million-plus population*	Up to December 31, 2022	Up to December 31, 2022
Category B	Within 10 km radius of critically polluted areas or non-attainment cities#	Up to December 31, 2023	Up to December 31, 2025
Category C	Other than those included in Categories A and B	Up to December 31, 2024	Up to December 31, 2025

As per 2011 Census of India, #As defined by the CPCB

Source: MoEFCC

Power Range	Date of Implementation	$HC + NO_x$ (g/kWh)	CO	PM	Smoke* m^{-1}
Up to 19 kW	1.7.2013	7.5	3.5	0.3	0.7
> 19 kW up to 75 kW	1.7.2013	4.7	3.5	0.3	0.7
> 75 kW up to 800 kW	1.7.2013	4.0	3.5	0.2	0.7



Here are **deep and detailed notes** aligned with your syllabus for section 1.5: norms and regulation for power plants in India, focusing on CPCB/MPCB and the engineering implications.

1.5.1 Regulatory Framework: CPCB & State Boards

- The Central Pollution Control Board (CPCB) is a central body under the Ministry of Environment, Forest & Climate Change (MoEFCC) that sets national standards for emissions, effluents, wastewater, ash handling, and monitoring for industries including thermal power plants. (cpcb.nic.in)
- State Pollution Control Boards (SPCBs), such as the Maharashtra Pollution Control Board (MPCB), enforce CPCB norms at the state level, monitor compliance, issue alarms, penalise violations.
- Power plants must comply with: air emission standards (PM, SO_2, NOx, Hg), water / effluent standards (ash-pond drainage, cooling water discharge), stack height & dispersion norms, ambient air quality obligations, continuous emission/effluent monitoring systems (CEMS/OEMS). (cpcb.nic.in)
- New or retro-fitted plants (especially since 2017) face tighter norms (water consumption, zero liquid discharge, fly-ash utilisation). (cpcb.nic.in)

1.5.2 Emission & Effluent Norms for Thermal Power Plants

Air Emissions:

- For coal-fired power plants, CPCB / MoEFCC norms set limits for particulate matter (PM), sulphur dioxide (SO_2), nitrogen oxides (NOx), mercury, etc. (Comptroller and Auditor General of India)
- Example: In a 2015-notification, for a unit installed before 31 Dec 2003: PM ≤ 100 mg/Nm³, SO_2 ≤ 600 mg/Nm³; for unit after 01 Jan 2004: stricter values (PM ≤50 mg/Nm³ etc). (Wikipedia)
- Stack height requirements: e.g., stack height H = 14/(Q)^0.3 (Q = emission rate of SO_2 in kg/hr) or minimum values per capacity. (CORPSEED ITES PRIVATE LIMITED)

Water / Effluent / Ash Pond Discharges:

- For thermal plants: new plants commissioned after 1 Jan 2017 must restrict specific water consumption (e.g., ≤ 3 m³/MWh) and aim for zero wastewater discharge. (CORPSEED ITES PRIVATE LIMITED)
- Ash pond effluent pH: 6.5–8.5; suspended solids (SS) ≤100 mg/l; oil & grease ≤20 mg/l. (cpcb.nic.in)

Monitoring & Reporting:

- Continuous Emission Monitoring Systems (CEMS) for SO_2, NOx, PM; data to be transmitted online to CPCB/SPCB. (CORPSEED ITES PRIVATE LIMITED)
- Regular audits, stack tests, ambient monitoring; plants may receive show-cause notices or shutdown orders if norms not met. (Press Information Bureau)

1.5.3 Recent Changes & Key Issues

- In July 2025, a notification by MoEFCC relaxed SO_2 norms for many coal-based thermal power plants: plants in Category C (far from population centres) exempted from FGD installation; only Category A needed compliance by end 2027. (Reuters)

- Many plants have still not installed FGD systems; reports show low compliance in certain states. (Carbon Copy)
- These regulatory changes have strong implications for plant design, retrofits, maintenance, and economics.

1.5.4 Engineering Implications for Power Plant Design, Operation & Maintenance

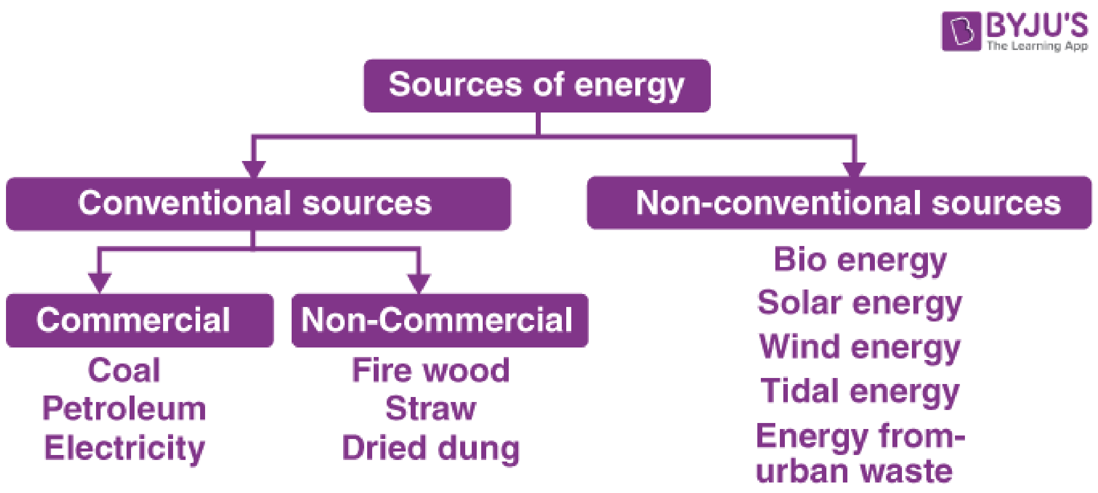
- **Equipment Design & Layout**: Need to allocate space for emission-control equipment: Electrostatic Precipitators (ESP) or bag filters (for PM), Flue Gas Desulphurisation (FGD) systems (for SO_2), Selective Catalytic Reduction (SCR) or Low-NOx burners (for NOx). These affect ducting, flue gas path, auxiliary power consumption.
- **Thermal Efficiency & Auxiliary Loads**: Installing FGD and other control systems increases auxiliary power consumption (fans, pumps), lowers net output—must be considered in design and economic calculations.
- **Ash Handling & Disposal**: Since fly-ash must be utilised or properly stored, the plant's ash circuit (ash yard/pond, transport, slurry handling) must meet effluent norms; corrosion, seepage control, monitoring are needed.
- **Water Use & Cooling**: With tighter water consumption norms, cooling system design (once-through vs cooling tower) and water treatment become important; effluent from cooling systems must meet pH, SS, oil/grease norms.
- **Monitoring & Compliance**: Real-time data from CEMS/OEMS must be maintained; maintenance teams must ensure sensors, stacks, monitoring equipment are functioning, calibrated—to avoid non-compliance penalties.
- **Operational Strategy & Maintenance**: Retrofitting old plants with pollution control equipment often involves shutdowns, plant modification, cost; maintenance cycles must accommodate these additional subsystems; planning for inspection, downtime, spare parts of FGD/ESP is necessary.

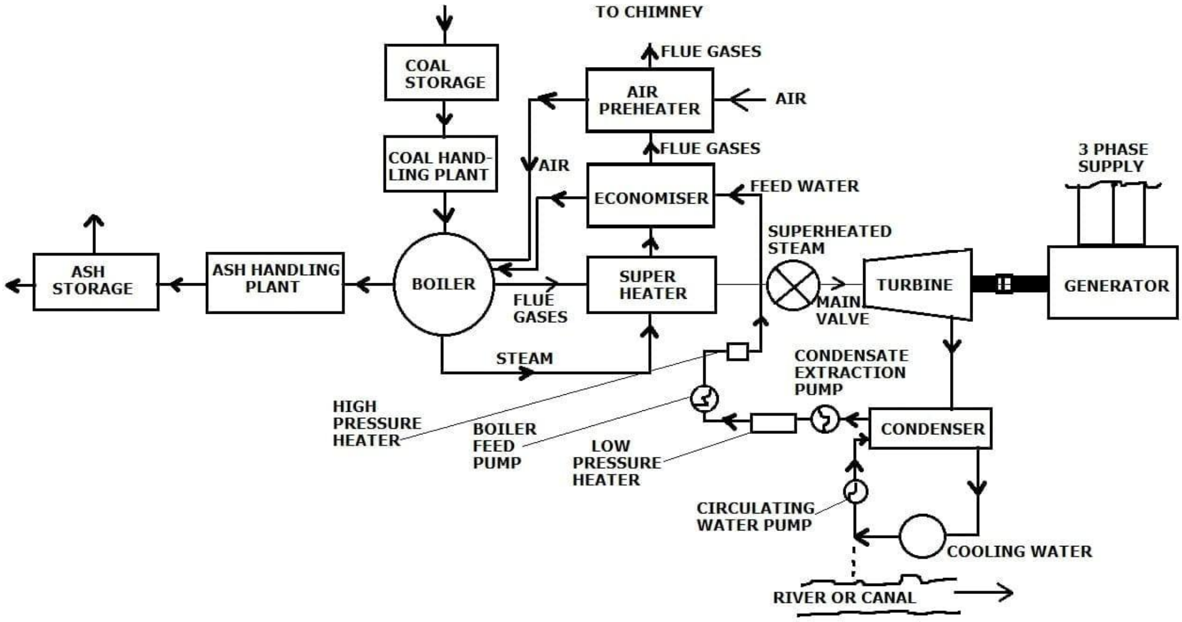
- **Economic Modeling**: When calculating cost per kWh (CO5), include capital cost of control equipment, repayment, auxiliary energy penalty, extra maintenance cost, possible fines. Failure to comply may lead to forced shutdown, affecting availability and plant economics.

1.5.5 Summary of Section

- Compliance with CPCB/SPCB norms is **mandatory** for conventional power plants — air emissions, effluent discharge, ash disposal, water consumption, monitoring systems are all covered.
- Recent regulatory relaxations exist but risks remain: non-compliance can cause legal, financial, operational consequences.
- As a mechanical/power engineering student, you should integrate regulatory requirements into every subsystem: boiler & flue gas systems, emission control, ash handling, cooling systems—not just as add-ons but as integral to plant design, lifecycle maintenance and economics.
- For your course: This section links to many outcomes: CO2 (maintenance & safe operation), CO3 (gas power plants & waste heat recovery may also face emission norms), CO5 (economic parameters include emission control cost).

Power Plant Engineering — Section 1.6: Introduction to Power Plants: Their Importance and Classification





1.6.1 Importance of Power Plants

- Power plants are the **backbone of modern infrastructure**. They generate electrical energy which powers industries, transportation, homes, digital services and more.
- Without reliable power generation, economic growth, social development and modern lifestyle cannot be sustained. In India's context, rapid urbanisation, industrial growth and increasing energy demand make power generation a strategic sector. (IEA)
- In the syllabus you noted: "Various power plants are playing a vital role … Most plants are using mechanical engineering equipment and components." This emphasises that for mechanical/plant engineers, understanding the equipment (boilers, turbines, pumps, piping) used in these plants is essential.
- Key reasons why this section is important:
  - Knowing **why** power plants matter helps in understanding why efficiency, maintenance, fuel choice and technology upgrades are critical.
  - Recognising the **role** of power plants enables you to align engineering decisions (design, maintenance, safety) with larger objectives (economy, environment, reliability).

   - Linking to your COs: For example, CO2 (maintain modern steam power plant) only makes sense if you understand the **importance** of the plant in the power supply chain.

1.6.2 Classification of Power Plants

Classification helps organise different types of power plants by technology, energy-source, load-type, ownership, etc. It enables you to understand what equipment and systems are used, and how operating/maintenance differs among them.

A. By Energy Source / Technology

According to a mechanical engineering reference:

- Steam/thermal power plants (coal, oil, gas)
- Hydroelectric power plants (water)
- Nuclear power plants (nuclear fuel) (Testbook Blog)
- Also renewable/non-conventional: solar, wind, biomass, tidal (though not part of "conventional")

Examples for each:

- Thermal: Large coal-fired plants in India.
- Hydro: Dams with turbines driven by water flow.
- Nuclear: Reactors generating heat by fission.
- (Non-conventional) Solar PV farms, wind turbines, etc.

B. By Mode of Operation / Load Type

- **Base Load Plants**: Operate almost continuously at near full capacity; usually hydro, nuclear or large coal plants designed for steady output.
- **Peak Load / Load Following Plants**: Operate when demand is high; may ramp up/down; e.g., gas turbines, diesel plants.
- **Stand-by / Emergency Plants**: Provide backup when main plants fail.

This classification matters because the mechanical systems design, maintenance schedule, efficiency requirements differ for base load vs peaking plants.

C. By Ownership / Sector

- Public Sector / Government-run power plants.
- Private Sector / Independent Power Producers (IPPs).
- Captive Power Plants (industry-owned for their own use).

Ownership influences technology investment, maintenance regime, fuel sourcing, cost control. (This links back to your Unit 1.2 section).

D. By Scale / Size / Technology Advancement

- Large suit-scale plants vs small/micro plants.
- Conventional vs advanced technology: e.g., sub-critical vs supercritical steam plants, combined-cycle plants, next-gen nuclear.
- Location-specific: thermal vs hydro vs nuclear have different site, water, fuel, equipment constraints.

E. By Conventional vs Non-Conventional

- **Conventional**: Typically coal, oil, gas, hydro, nuclear. These have been the traditional mainstay.
- **Non-Conventional / Renewable**: Solar, wind, biomass, small hydro, etc. Though your syllabus emphasises conventional, classification helps in understanding the transition. (Wikipedia)

1.6.3 Detailed Explanation of Key Types

Let's delve into some major types relevant to your syllabus:

1. **Steam/Thermal Power Plants**
   - Use fuel (coal/oil/gas) to generate steam which drives turbines.
   - Mechanical equipment: boiler, steam turbine, generator, condenser, feedwater pumps, cooling system, ash handling (for coal).
   - Key mechanical engineering issues: high pressure & temperature materials, boiler design, steam piping, turbine blade mechanics, maintenance of boiler tubes & combustion systems.
2. **Hydroelectric Power Plants**

- Use potential/kinetic energy of water (dams or run-of-river) to drive turbines.
- Mechanical equipment: penstocks, water turbines (Francis, Kaplan, Pelton), generators, gate valves.
- If you want, classification of hydro plants (by head, capacity) is deep dive.
- Advantages: low fuel cost; clean; but site-specific constraints (geography, environmental).

3. **Nuclear Power Plants**
    - Use nuclear fission to generate heat → steam → turbines.
    - Mechanical/engineering aspects: reactor coolant systems, steam generators, turbines, plant safety systems, large auxiliary equipment.
    - Example: As of 2025 India has 24–25 nuclear reactors across several plants. (Wikipedia)
    - Importance: long life, high capacity but high capital cost and stringent safety/maintenance.

1.6.4 Why Classification Matters for Engineering & Maintenance (Your Focus)

- Each type has **different equipment**, **different operating regimes**, **different maintenance challenges**. For instance:
    - A hydro turbine may require completely different maintenance than a high-pressure steam turbine.
    - Fuel handling and ash disposal are central to coal thermal plants but irrelevant for nuclear.
    - Nuclear plant maintenance has safety & regulatory aspects that regular thermal plants may not.
- For the syllabus outcomes:
    - CO2 (maintain steam power plant) → Focus on steam/thermal plant classification.
    - CO3 (gas/waste heat recovery) → Combined cycle or thermal classification knowledge helps.

   - CO4 (nuclear power plants safely) → Understanding nuclear classification helps.
   - CO5 (economic parameters) → Knowing which type of plant you're analysing affects cost, fuel, life-cycle.
- It enables **correct selection of fuel, site**, and equipment design — different for each classification.

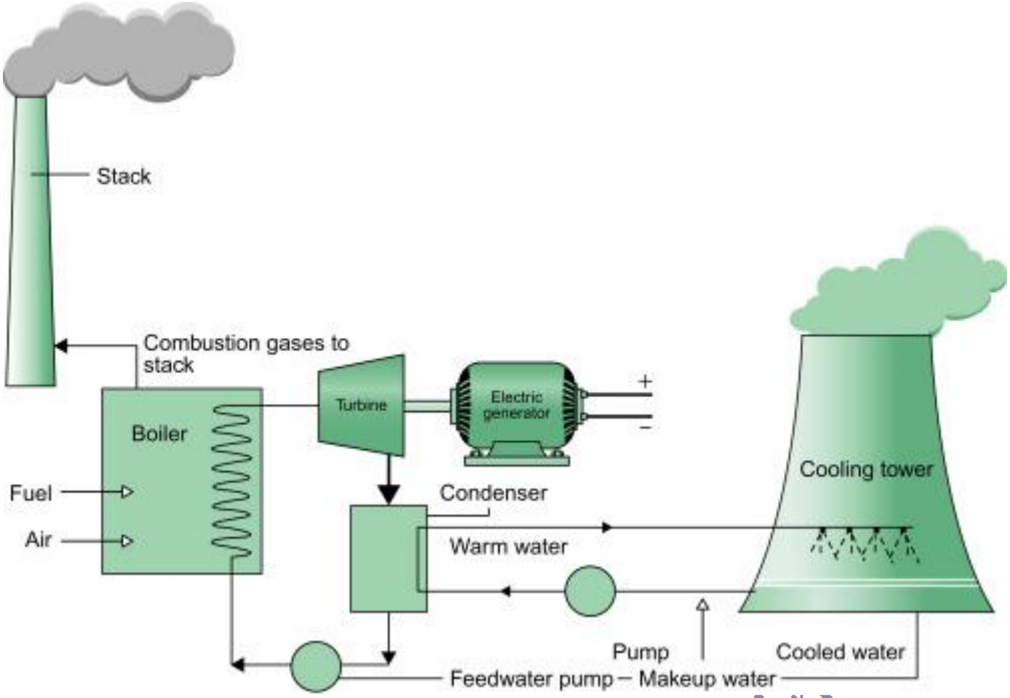
1.6.5 Key Terms for Deep Search/Indexing

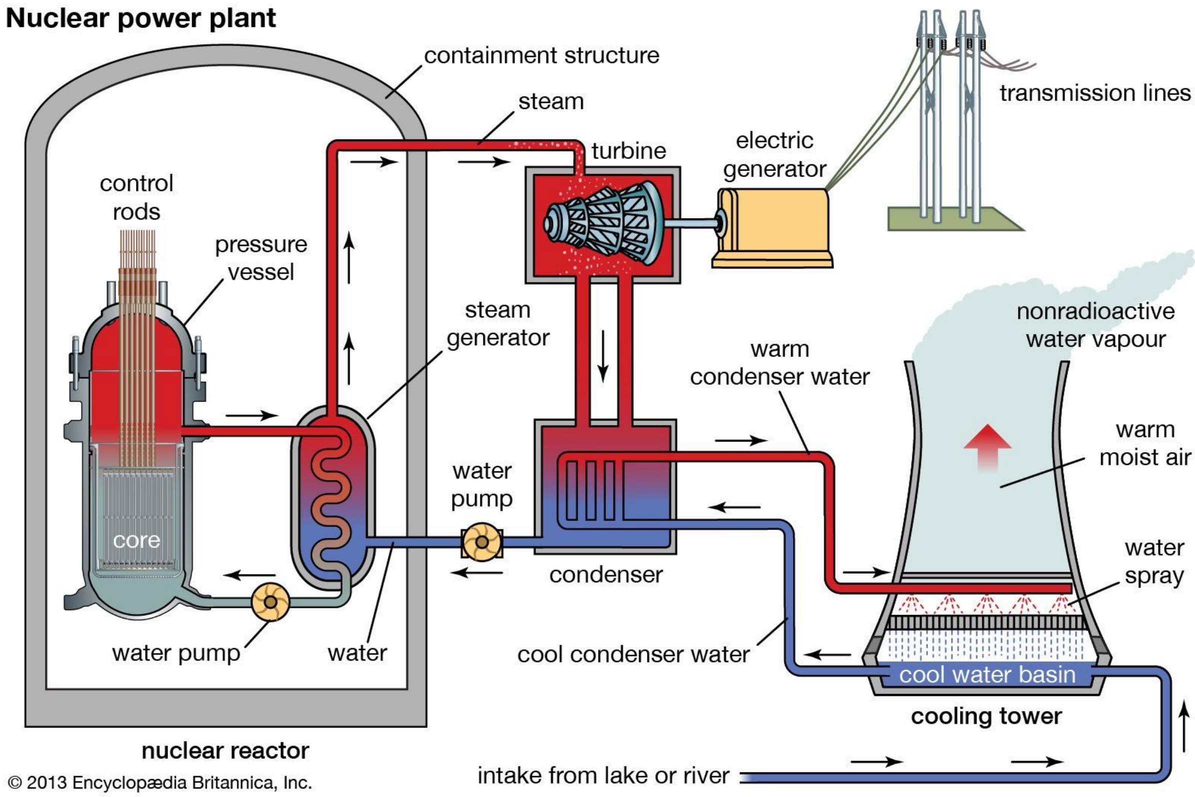
- "Classification of power plants steam hydro nuclear", "types of power plants conventional vs non-conventional", "base load vs peaking power plants mechanical equipment differences", "hydro power plant classification by head", "nuclear power plant types and reactor classification".
- Use these in your webpage to make it searchable and help students quickly navigate to definitions, diagrams, examples.

1.6.6 Summary

- Section 1.6 introduces **why** power plants are important and **how** they are classified.
- Importance: because power plants are central to energy supply, economy, infrastructure.
- Classification: by energy source, operation mode, ownership, size, technology; each class brings distinct engineering, mechanical, maintenance, economic and environmental implications.
- For your learning path: Ensure you can **recognise** different types, **compare** their mechanical/maintenance challenges, and **link** them to fuel choice, site selection, cost and regulatory aspects.

1.7 Types of Fuels Used in Conventional Power Plant & Their Properties (Calorific Value, Flash Point & Fire Point) & Relative Cost per kWh


Stack
Combustion gases to stack
Boiler
Fuel
Air
Turbine
Electric generator
+
-
Condenser
Warm water
Cooling tower
Pump
Cooled water
Feedwater pump
Makeup water



Here is a **detailed advanced-note** version of section 1.7, aligned with your syllabus, covering fuel types, their key properties (calorific value, flash point, fire point), and relative cost per kWh.

1.7.1 Fuel Types for Conventional Power Plants

In the context of conventional (non-renewable) power plants, typical fuels include:

- **Coal** (bituminous, sub-bituminous, lignite)
- **Petroleum / Liquid fuels** (diesel, furnace oil, heavy fuel oil)
- **Natural Gas** (or LNG when imported)
- **Nuclear Fuel** (uranium, thorium)
- *(Additionally, sometimes biomass or waste fuels blend, but for "conventional" major emphasis is on the above.)*
  The U.S. Energy Information Administration lists coal, natural gas, petroleum and nuclear energy among the major primary energy sources used for electricity generation. (U.S. Energy Information Administration)

A listing of conventional sources also includes coal, oil and natural gas as key fuels. (The Knowledge Academy)

Each fuel type differs in availability, handling, combustion characteristics, environmental emissions, cost structure, and suitability for a given plant type.

1.7.2 Key Fuel Properties — What They Mean & Why They Matter

For a power plant engineer or maintenance specialist (which you will become), understanding the following fuel properties is critical:

- **Calorific Value (CV)**: The amount of heat energy released when a unit mass (or volume) of fuel is completely combusted. It may be expressed as gross calorific value (including latent heat of water vapour) or net (excluding latent heat). Higher CV means more energy per kg (or per m^3 for gas) → more electricity per unit fuel → lower fuel cost contribution.
- **Flash Point**: For liquid fuels, the lowest temperature at which its vapours will ignite in the presence of a flame. Important for storage/handling safety.
- **Fire Point**: The temperature at which the vapour continues to burn for a certain period after ignition. Also relevant for safety & handling of liquids.
- **Ash content, sulphur content, moisture content** (for solid fuels): These are not always expressed simply as “property headings” in your syllabus but are influential for plant design, maintenance, cost.
- **Relative Cost per kWh (Fuel Basis)**: Ultimately, for economic assessment (CO5) you need cost per kWh-fuel + cost of handling + cost of emissions + plant efficiency. Fuel type inputs therefore drive operating cost, maintenance frequency (e.g., high-ash coal leads to more boiler tube cleaning), and equipment design (e.g., ash handling systems).

1.7.3 Comparative Overview of Fuel Types

Here's a comparative summary of the major fuel types in conventional power plants:

Fuel Type	Characteristics / Typical Use	Key Fuel Properties & Issues	Advantages & Disadvantages
Coal	Solid fuel, widely used in large thermal power plants in India.	Calorific Value: Indian coal bituminous ~ 5000-6500 kcal/kg (varies). High ash content often. Flash/Fire points are not relevant as liquid. Handling/ash disposal is major issue.	Advantages: abundant in India, relatively cheap per ton. Disadvantages: high ash, sulphur/pollution, lower efficiency, large footprint, environmental challenge.
Liquid Fuels (Diesel / Furnace Oil)	Used in small or peaking power plants, backup plants.	Calorific Value: approx ~9000-10000 kcal/kg (varies). Flash & fire point relevant for storage. Handling/storage cost, high fuel cost.	Advantages: quick start, flexible operation. Disadvantages: highest fuel cost per kWh, high emissions, less scale economy.
Natural Gas / LNG	Gas turbines or combined cycle plants use this fuel.	Very high CV per kg/m³; low ash; low sulphur. Requires	Advantages: Lower emissions, high efficiency (especially

	Cleaner combustion.	pipeline or LNG import infrastructure. Gas handling & storage issues.	combined cycle). Disadvantages: Fuel cost higher, supply may be variable, infrastructure cost high.
Nuclear Fuel (Uranium/Thorium)	Used in nuclear power plants; conversion via nuclear fission, rather than combustion.	Very high energy density (kg of uranium contains enormous energy); fuel handling, safety, radioactive waste major issue. (Wikipedia)	Advantages: Very high output, low fuel cost per kWh once running, stable baseload. Disadvantages: Very high capital cost, long lead time, regulatory/safety issues, waste disposal.

1.7.4 Fuel Properties in Detail & Examples for Engineering Use

While exact values vary by fuel source and location, here are engineering-level points you should note:

- For coal: Lower the CV, higher the fuel mass required for same output → larger fuel feed systems, larger ash disposal systems, higher maintenance of boiler tubes due to slag/ash.
- For liquid fuels: Flash/Fire point impact on storage tanks, safety standards (IBC / OISD for oil storage) – critical especially for plants in India.
- For gas: Very low ash → fewer boiler tube problems (if used in gas turbine/HRSG) but require high-quality gas, good filtration, and deal with possible sulphur/mercaptans/CO_2 impurities.

- For nuclear fuel: The mechanical systems around it (reactor coolant, steam generator, high-pressure piping) need high materials, high safety standards — though your syllabus only touches "use suitable strategies to run nuclear power plants safely" (CO4).
- Relative cost per kWh: You must factor in fuel cost *and* plant efficiency (heat rate). For example, even if liquid fuel has high CV, its cost per kWh may be high because of fuel price + lower scale economy. Likewise, high-ash coal may seem cheaper per ton but when factoring in lower efficiency and increased maintenance, cost per kWh may rise.

1.7.5 Relative Cost per kWh – Engineering/Economic Considerations

- When analysing cost per kWh for different plant options (CO5), fuel cost plays a major part. But also: heat rate (kcal/kWh), auxiliary power consumption, O&M cost (which depends on fuel cleanliness), emission control costs, ash disposal costs etc.
- Example: A coal plant using high ash fuel might have heat rate 3000 kcal/kWh vs a cleaner elite coal source plant with 2500 kcal/kWh → difference in fuel requirement per kWh.
- Fuel cost for natural gas plant might be higher per MJ, but because efficiency is higher (combined cycle might reach 50-60%), the fuel cost per kWh might approach coal in some cases—though infrastructure cost may still raise tariff.
- Nuclear may have very low variable fuel cost, but high fixed cost (capital cost, O&M, safety) so cost per kWh depends heavily on plant load factor, lifetime, financing etc.
- As you study economic parameters, you can build a simple formula:

$$\text{Fuel Cost per kWh} = \frac{\text{Fuel Rate (kg or m}^3\text{)} \times \text{Fuel Price (₹ per kg/m}^3\text{)}}{\text{Electrical Output (kWh)}}$$

But note you'll have to include: heat rate change, auxiliary consumption, downtime etc.

1.7.6 Fuel Selection Considerations for Engineers (Linked to CO1)

Since your CO1 is "Choose appropriate fuel for power plant in given situation", here are practical selection factors you should use:

- **Fuel availability & logistics**: Is the fuel locally available (coal mine, gas pipeline, oil terminal)? Transport cost and delays matter.
- **Fuel quality**: Ash content, moisture, sulfur content (for coal); calorific value (for all); impurities in gas. Higher ash/sulfur → more maintenance, pollution control cost.
- **Plant technology suitability**: If you have a combined cycle gas plant, gas is best; if you have older boiler, coal might be only option; nuclear requires heavy investment & long lead time.
- **Environmental/regulatory constraints**: Higher emissions (coal, oil) may be subject to stricter norms (like from CPCB) → cost of control equipment may influence fuel choice.
- **Fuel cost vs efficiency & scale**: A cheaper fuel per tonne may not result in cheaper per kWh if efficiency drops or maintenance cost increases.
- **Flexibility & operation profile**: If plant needs to operate for peaking/variable load, fuel handling speed, ramp capability matter. Liquid/diesel may suit peaking but cost is high; gas may suit quick ramp; coal is better for baseload.
- **Future sustainability & carbon policy**: With climate policies, high-carbon fuels may become more expensive (carbon tax, emission penalties) → influences long-term fuel choice.

1.7.7 Summary for Section 1.7

- Section 1.7 covers the major fuel types used in conventional power plants, their properties (calorific value, flash point/fire point for liquids, ash/sulfur for solids), how those properties affect plant design and operation, and how to evaluate cost per kWh.
- For the course, ensure you can:
  - **List major fuels** and their typical uses in power plants.

- **Explain key fuel properties** and how they affect plant design/operation (e.g., high ash coal → larger ash handling systems, more maintenance).
- **Compare fuels** in terms of cost per unit energy, efficiency, maintenance, environmental impact.
- **Apply fuel selection criteria** (availability, cost, quality, environmental/regulatory, technology fit) in sample situations.

- This section links strongly to CO1 (fuel selection) and CO5 (economic calculations) while having implications for maintenance (CO2) and other plant types (CO3, CO4) indirectly.

Diploma Wallah

Made with 💗 by Sangam