

Lecture 1.2

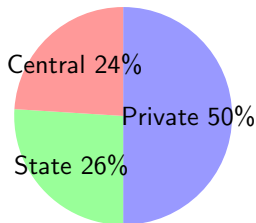
Indian Energy Scenario

Agenda

- Overview of the Indian Power Sector
- Key Organizations and Regulatory Bodies
- Thermal Power Dominance
- Renewable Energy and Nuclear Power Landscape
- Transmission and Distribution (T&D) Network
- Challenges in the Power Sector
- Government Policies and Future Trends

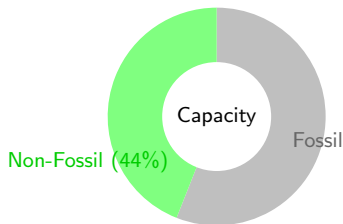
Overview of the Indian Power Sector

- India is the third-largest producer and consumer of electricity globally.
- Total installed capacity exceeds 416 GW (as of recent Central Electricity Authority data).
- Per capita electricity consumption is around 1,255 kWh, which is lower than the global average but growing steadily.
- The sector operates on a concurrent list framework, meaning both central and state governments have jurisdiction.
- Private sector contribution has grown significantly, now accounting for over 50% of installed capacity.



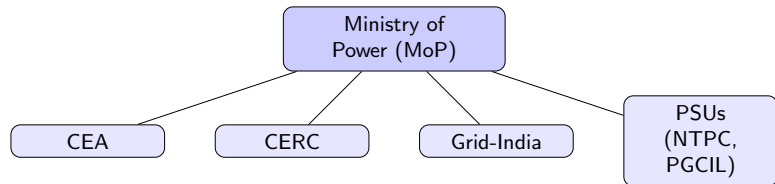
Generation Mix: Installed Capacity

- **Fossil Fuels (~56%):** Coal remains the backbone of Indian power generation, followed by lignite, gas, and diesel.
- **Non-Fossil Fuels (~44%):** Significant growth in renewables and large hydro.
- **Renewable Energy Sources (RES):** Solar and wind constitute the majority of RES, alongside biomass and small hydro.
- **Nuclear:** Contributes around 1.6% to the total installed capacity.
- India has committed to achieving 50% cumulative electric power installed capacity from non-fossil fuel-based energy resources by 2030.



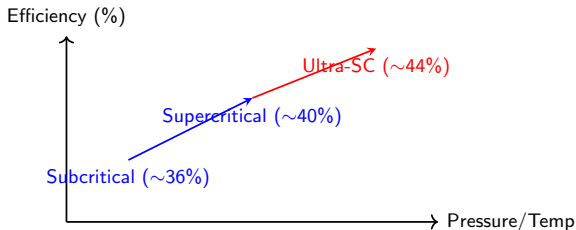
Key Regulatory Bodies and Organizations

- **Ministry of Power (MoP):** Apex body responsible for planning, policy formulation, and administration.
- **Central Electricity Authority (CEA):** Advises on national power policy and coordinates planning.
- **Central Electricity Regulatory Commission (CERC) & SERCs:** Regulate tariffs and promote competition.
- **Grid Controller of India (formerly POSOCO):** Ensures integrated operation of the National Grid through NLDC, RLDCs, and SLDCs.
- **Public Sector Undertakings (PSUs):** NTPC (thermal), NHPC (hydro), PGCIL (transmission).



Thermal Power Dominance

- Coal-fired plants provide the baseload power, ensuring grid stability.
- **Subcritical to Supercritical Transition:** New plants deploy supercritical (SC) and ultra-supercritical (USC) technology for higher efficiency and lower emissions.
- **Plant Load Factor (PLF):** The average PLF of thermal plants fluctuates based on demand and renewable integration.
- **Fuel Security:** Managed through domestic production (Coal India Ltd) and imports to blend for calorific value.
- **Flue Gas Desulfurization (FGD):** Mandatory installation for environmental compliance to reduce SO_x emissions.



Renewable Energy Landscape

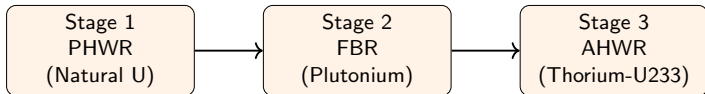
- India ranks 4th globally in Renewable Energy Installed Capacity (including Large Hydro).
- **Solar Power:** National Solar Mission drives rapid capacity addition, focusing on solar parks and rooftop installations.
- **Wind Power:** Concentrated in western and southern states (Tamil Nadu, Gujarat, Maharashtra) due to favorable wind corridors.
- **Intermittency Challenges:** Integration requires grid balancing, forecasting mechanisms, and flexible thermal operation.
- **Renewable Purchase Obligations (RPO):** Mandates DISCOMs to procure a minimum percentage of power from renewable sources.

Note

Solar irradiance is highest in Rajasthan and Gujarat, while wind density peaks along the western and southern coastlines.

Nuclear Power Generation

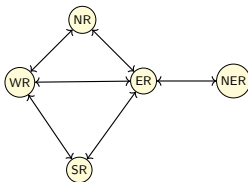
- Operated exclusively by Nuclear Power Corporation of India Limited (NPCIL) and BHAVINI.
- **Three-Stage Nuclear Power Programme:** Formulated by Homi Bhabha (PHWRs, FBRs, and Thorium-based reactors).
- **Pressurized Heavy Water Reactors (PHWR):** Form the bulk of the current operating fleet (e.g., Kakrapar, Rawatbhata).
- **Imported Technology:** Light Water Reactors (LWR) deployed with international cooperation (e.g., Kudankulam VVER reactors).
- **High Capacity Factor:** Nuclear plants operate continuously, providing reliable, zero-emission baseload power.



Transmission Network: The National Grid

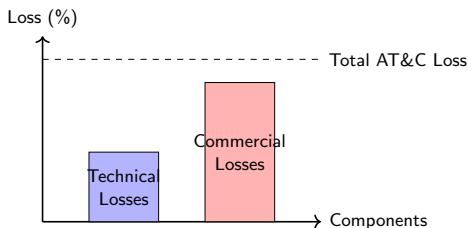
- **One Nation, One Grid, One Frequency:** Integration of five regional grids (Northern, Eastern, Western, North-Eastern, Southern).
- **Central Transmission Utility (CTU):** Power Grid Corporation of India Limited (PGCIL) manages the inter-state transmission system (ISTS).
- **High Voltage Direct Current (HVDC):** Crucial for bulk power transfer over long distances with minimal losses (e.g., ± 800 kV Champa-Kurukshetra line).
- **765 kV AC Lines:** Form the backbone of the extra-high voltage (EHV) AC network.
- **Green Energy Corridors:** Dedicated transmission infrastructure being built to evacuate power from renewable-rich states.

National Synchronous Grid



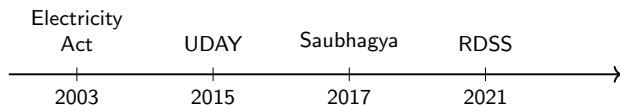
Distribution Sector Challenges (DISCOMs)

- The distribution sector is the weakest link in the value chain, primarily managed by State utilities.
- **Aggregate Technical & Commercial (AT&C) Losses:** High losses due to inefficient infrastructure, theft, and billing inefficiencies.
- **ACS-ARR Gap:** The difference between the Average Cost of Supply (ACS) and Average Realizable Revenue (ARR) leads to chronic financial distress.
- **Cross-Subsidization:** Industrial and commercial consumers pay higher tariffs to subsidize agricultural and domestic sectors.
- **Smart Metering:** Rollout of Advanced Metering Infrastructure (AMI) to improve collection efficiency and reduce losses.



Government Initiatives and Policies

- **Electricity Act, 2003:** De-licensed generation, promoted open access, and established regulatory commissions.
- **UDAY (Ujwal DISCOM Assurance Yojana):** Financial turnaround and revival package for state DISCOMs.
- **Saubhagya Scheme:** Achieved universal household electrification by providing last-mile connectivity.
- **RDSS (Revamped Distribution Sector Scheme):** Result-linked financial assistance to DISCOMs for infrastructure strengthening and smart metering.
- **PLI Scheme for High Efficiency Solar PV Modules:** Promoting domestic manufacturing of solar components.



Future Trends and Energy Transition

- **Energy Storage Systems (ESS):** Battery Energy Storage (BESS) and Pumped Storage Hydro (PSH) are critical for grid stability with high renewable penetration.
- **Green Hydrogen Mission:** Aiming to make India a global hub for production, usage, and export of Green Hydrogen.
- **E-Mobility:** Rapid integration of Electric Vehicles (EVs) creates new demand profiles and opportunities for Vehicle-to-Grid (V2G) technology.
- **Decarbonization of Hard-to-Abate Sectors:** Transitioning industries like steel and cement towards cleaner fuels.
- **Digitalization:** AI, IoT, and blockchain being integrated for predictive maintenance, smart grid management, and peer-to-peer trading.

Vision

The future is green and electric. Integrating variable renewables with massive energy storage and smart digital grids is the pathway to India's net-zero goal by 2070.

Summary

- India's power sector is characterized by massive scale, growing demand, and a concurrent regulatory framework.
- While coal remains the dominant baseload provider, the generation mix is rapidly shifting towards renewables (solar and wind).
- The “One Nation, One Grid” infrastructure effectively balances regional supply and demand using EHV AC and HVDC.
- Financial and technical inefficiencies in the distribution sector (DISCOMs) remain the primary bottleneck.
- Future growth depends on energy storage, green hydrogen, and modernization through schemes like RDSS.

Next Lecture Preview

- **Topic:** Load Curves and Load Factors
- Understanding base load and peak load demands.
- Mathematical analysis of load curve, load factor, demand factor, and diversity factor.
- Impact of these factors on the economics of power generation.

