“From Power Plants to People”

The Business of Electricity

Foundation Course to All India Services (AIS) & Central Civil Services (CCS) Officers, MCRHRD







Significance of Electricity

Why is Electricity Important?

Access to affordable, reliable and sustainable Electricity is essential for Nation's Economic development, social equity and National Security

ECONOMIC GROWTH & INDUSTRY

- Enables manufacturing, MSMEs and infrastructure
- Improves productivity and competitiveness

AGRICULTURE & RURAL PROSPERITY

- Supports irrigation, cold storage and food processing
- Raises farm productivity and rural incomes

HEALTH, EDUCATION & PUBLIC SERVICES

- Powers hospitals, schools, water and sanitation
- Supports policing, emergency response and e-governance

RELIABLE ELECTRICITY

JOBS & DIGITAL ECONOMY

- Enables telecom, data centres and digital payments
- Supports start-ups, services and electric mobility

QUALITY OF LIFE & SOCIAL EQUITY

- Provides lighting, cooling and modern appliances
- Improves safety, learning and connectivity

ENERGY SECURITY & SUSTAINABILITY

- Enables renewable-energy deployment
- Reduces fossil-fuel dependence and emissions

Power sector Fundamentals

Power or Energy??

Power & Energy

Power (Watt): The rate at which electrical energy is used



One bulb consumes a certain amount of Power every second to emit light



More Power is consumed every second when 3 bulbs are turned on, meaning more power is required to operate them

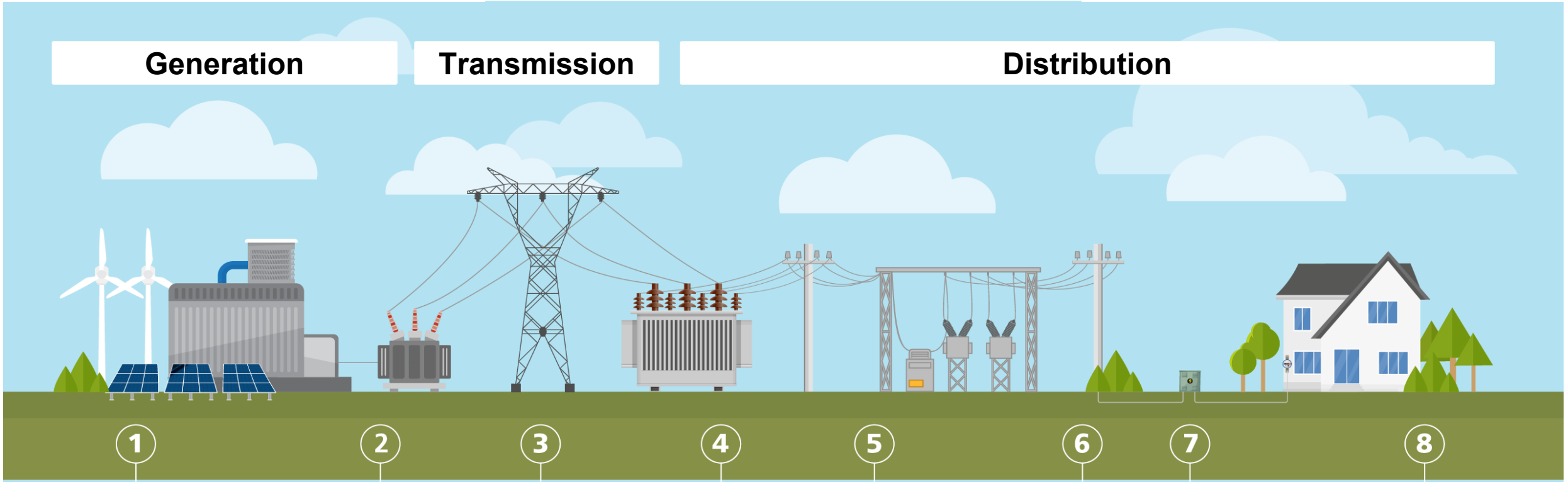
Energy (kWh): Total electrical power consumed over time. Expressed in kWh or units

Energy = Power x Time = kW x h = kWh (units)

Illustration: 1 kW load if operated for 2 hours continuouslyy will lead to 2 units Electricity consumption

Note : 1 Mega Watt (MW) = 1,000 kW

Typical Power System Components



Generation
Energy is generated from Renewable & Non-renewable sources

Step-up Transformer
Voltage is increased to transmit power over long distances

Transmission Line
High voltage Electricity moved over long distances through transmission lines

Transmission Sub-station
High voltage is reduced for use in local distribution system

Distribution Sub-station
Substation lower the voltage further for local use

Distribution lines
Low voltage Electricity is carried to homes & businesses

Distribution Transformer
Voltage is further reduced to be usable in Homes for appliances

End Consumer
Electricity flows through a meter and then to the appliances



Electricity Generation

Electricity Generation- Non-Renewable Sources

The energy sources that once exhausted, do not replenish themselves within a specific period are called Non-Renewable energy sources

Coal-based

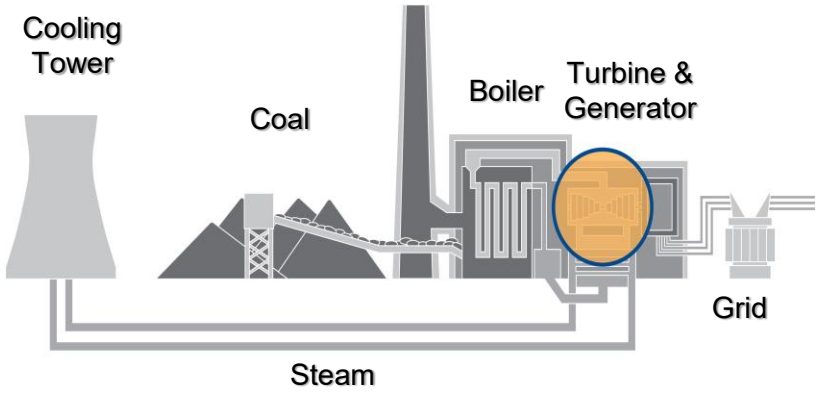
Uses heat from burning coal to convert water to steam that drives turbine and generate electricity

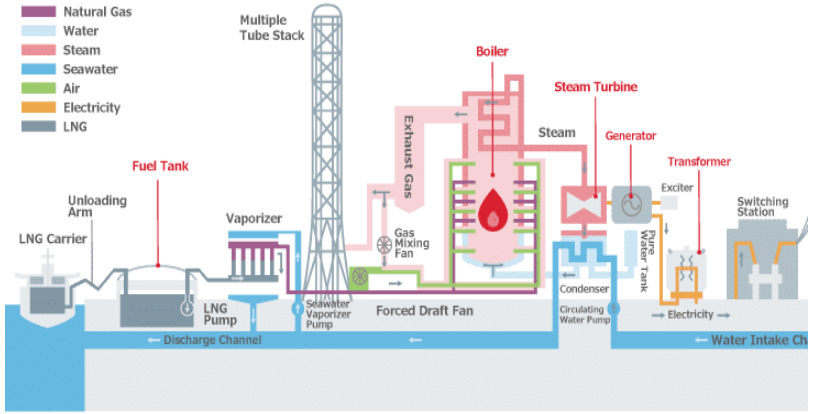
Gas-based

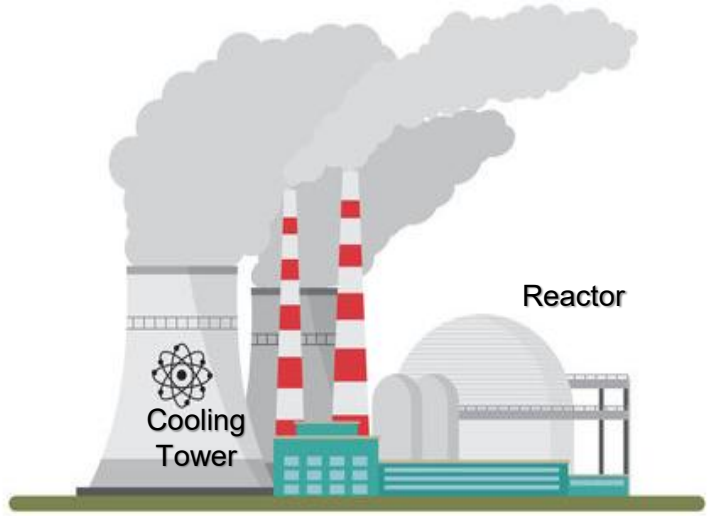
Natural gas/LPG is burnt to generate steam to drive turbines and generate electricity

Nuclear Power Plant

Heat from a nuclear fission reaction generates steam that drives turbines to generate electricity.







Electricity Generation- Renewable Sources

Sources that never run out because nature keeps producing them. Unlike coal or oil, which can finish, these sources are sustainable



1

Solar Energy

Solar Energy is radiant light and heat from the sun that is converted to Electricity

Wind Energy

Wind Energy uses air flow to rotate wind turbines to generate electricity



2



3

Hydro Energy

Hydro Electricity is power derived from the kinetic energy of water used to run turbines

Hydrogen

Hydrogen is a clean fuel that, when consumed in a fuel cell, generates Electricity by an Electrochemical process



4



5

Tidal Energy

Tidal Energy is a form of hydropower that converts the energy of the tides into electricity.

Solar Energy

Photo voltaic panels made of semiconductor materials (photovoltaics) capture sunlight and convert it directly into electricity.

- Solar Panels have CUF (Capacity Utilization Factor) of **~22%**
- **CUF -** It is the ratio of the actual energy generated to its installed capacity

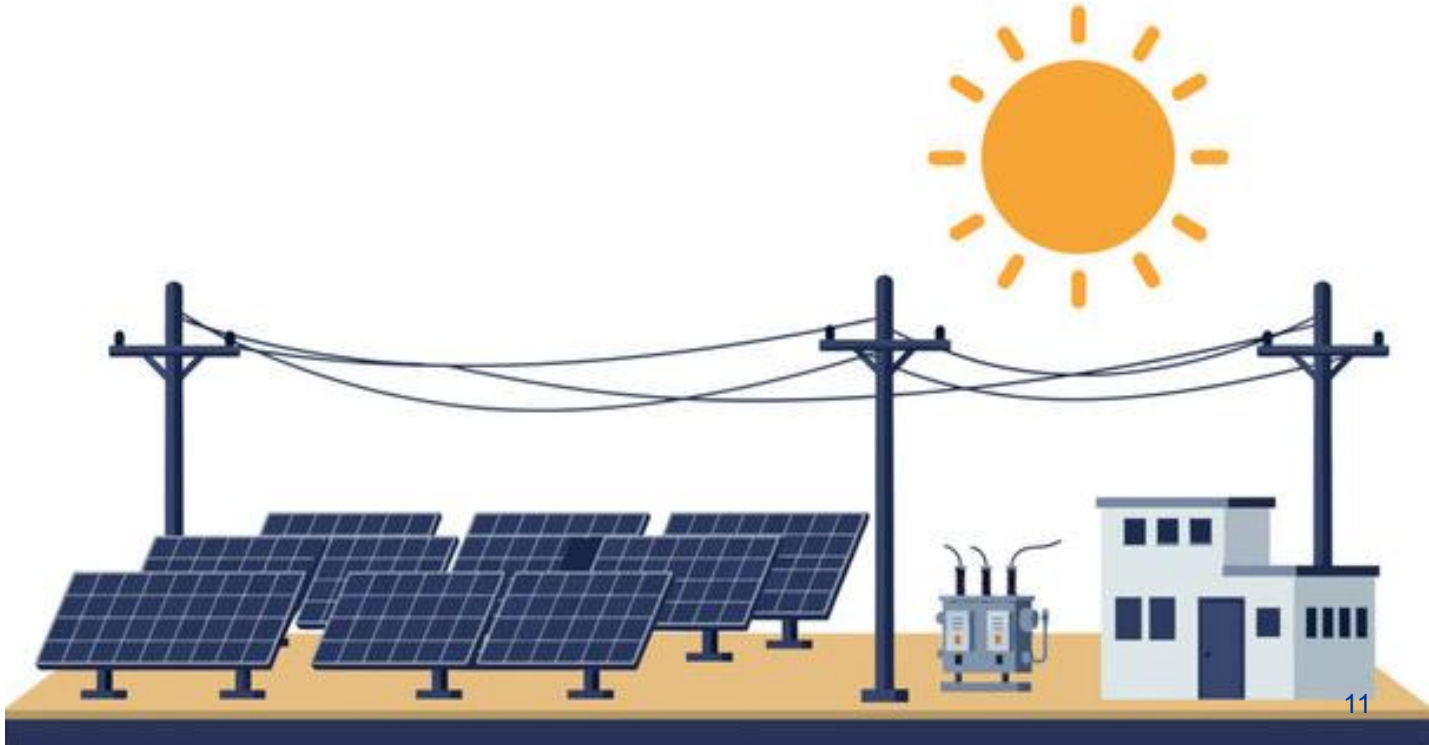
$$\text{CUF (\%)} = \frac{Actual\ Energy\ Generated\ (kWh)}{Installed\ Capacity\ (kW) \times Total\ Hours\ in\ Period}\ x\ 100$$

✅ Advantages

- Renewable & clean
- Low maintenance
- Reduces fossil fuel use

❌ Disadvantages

- Sun-dependent
- Needs space & storage



Wind Energy

It uses the kinetic energy of moving air to rotate blades and generate electricity.

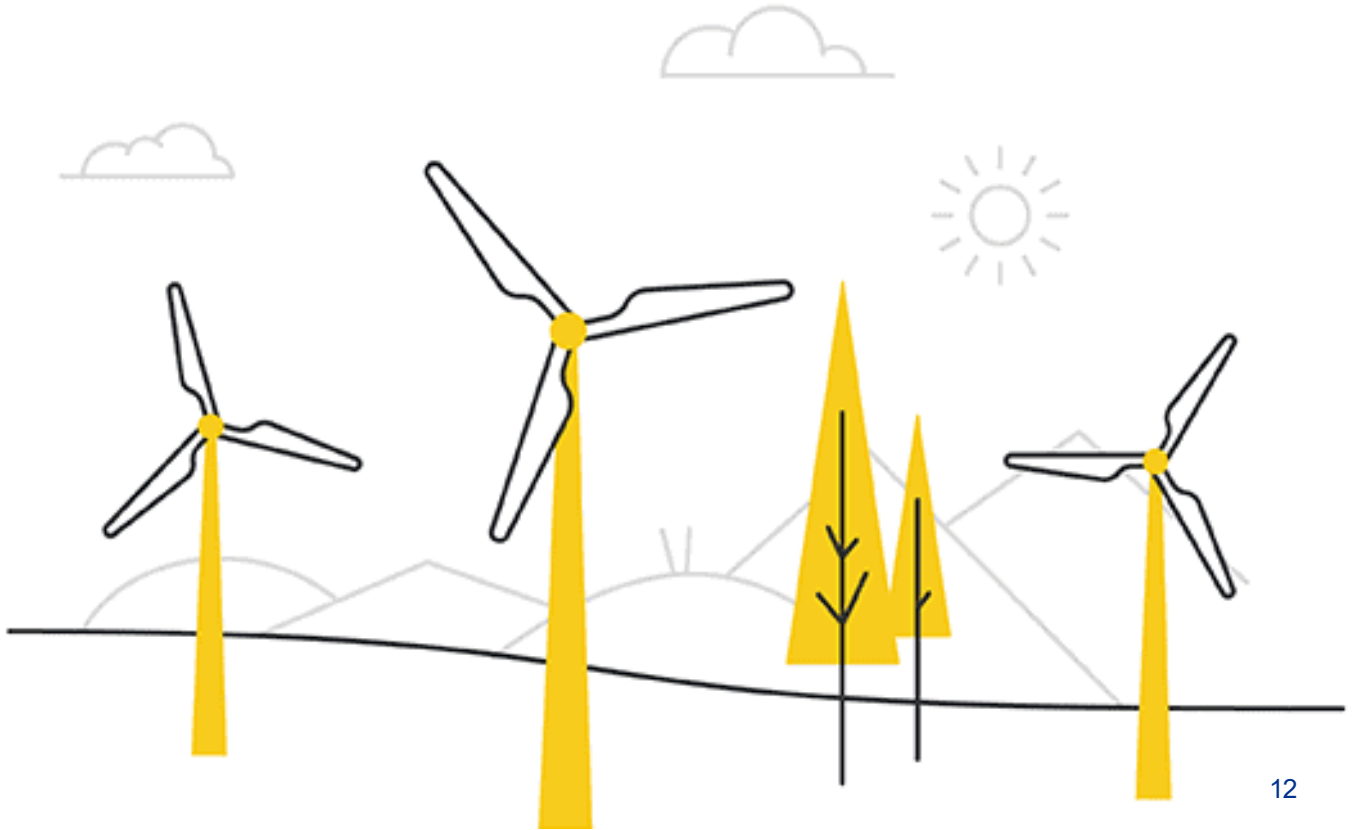
Wind Turbines have CUF (Capacity Utilization Factor) of **~30-35%**

✅ **Advantages**

- Clean & Renewable
- Cost-Effective in Long Term
- Scalable
- Land Use Efficiency

❌ **Disadvantages**

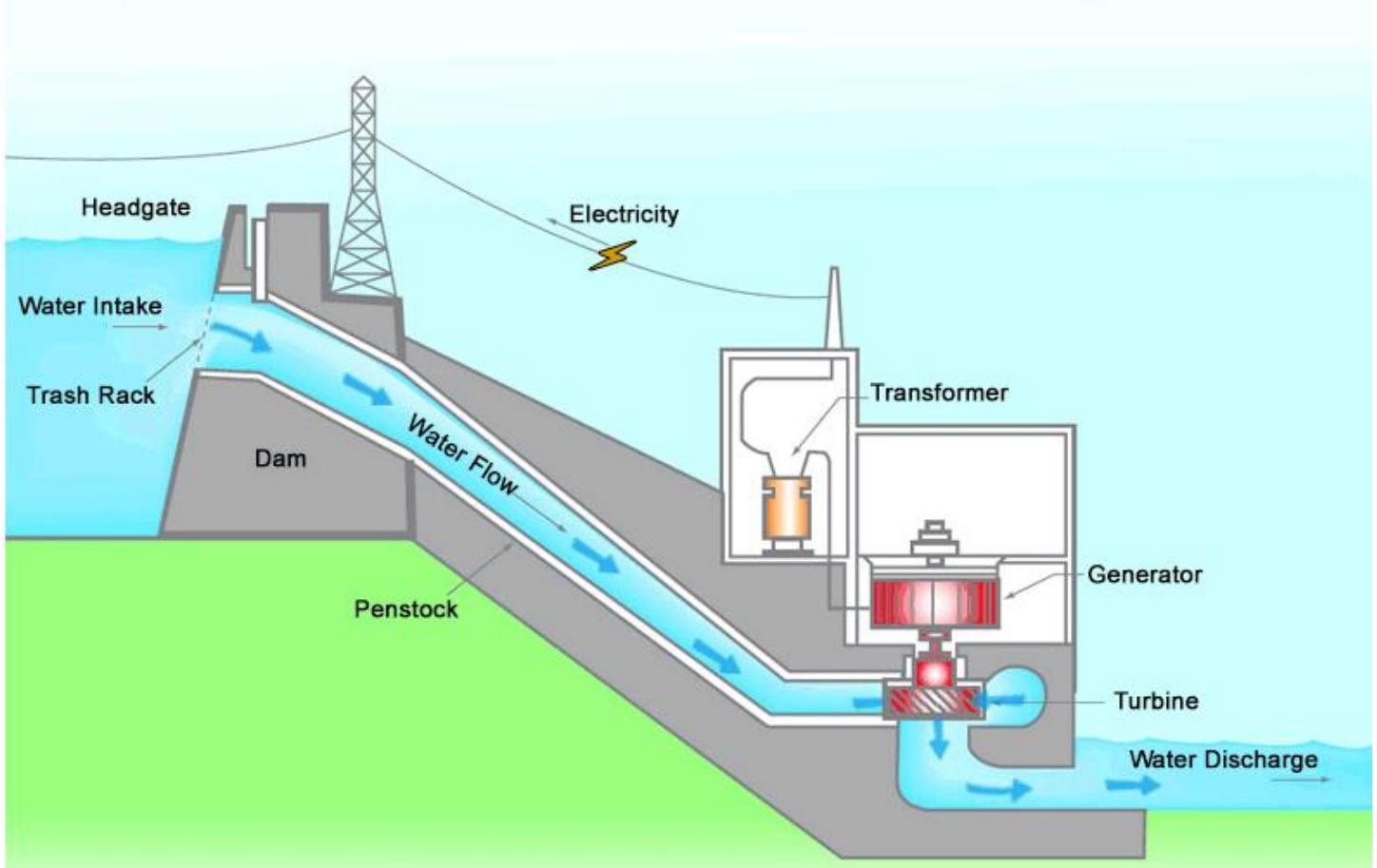
- Intermittent Resource
- High Initial Investment
- Wildlife Concerns
- Location Specific



Hydel Generation

It uses the potential energy of water stored in dams or flowing rivers **to rotate turbines and generate electricity.**

Hydropower plants typically have a CUF (Capacity Utilization Factor) of **~35–45%**



✅ Advantages

- Reliable and continuous power
- Low operating cost after setup
- Provides water storage and irrigation benefits
- Helps in flood control

❌ Disadvantages

- High initial cost for dam construction
- Environmental impact (ecosystem disruption)
- Displacement of communities
- Location-specific (needs suitable water source)

Waste to Energy Generation (WTE)

This converts municipal solid waste & industrial waste into usable energy

✅ Advantages

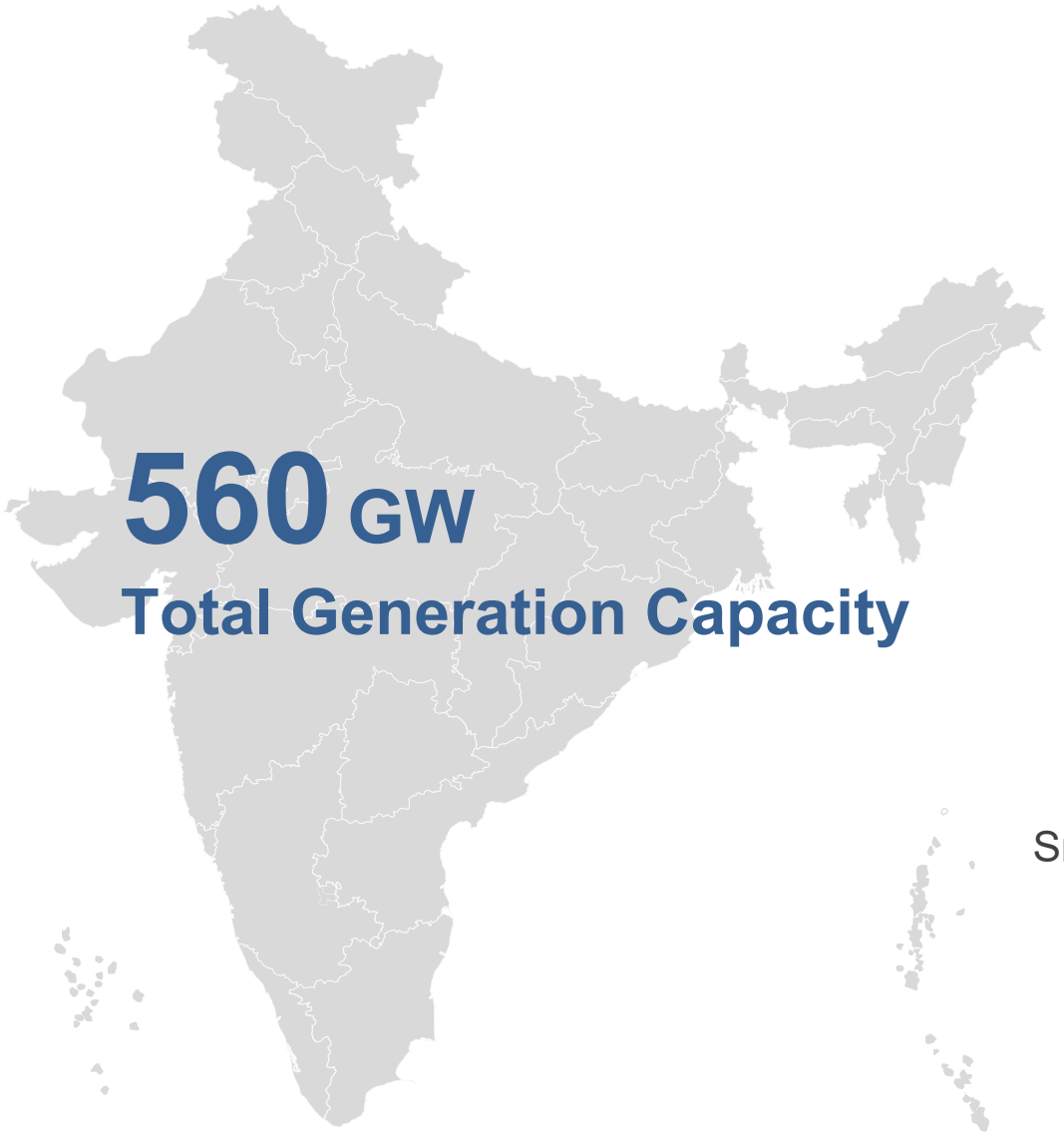
- ✓ Reduces landfill dependency
- ✓ Lowers greenhouse gas emissions
- ✓ Contributes to renewable energy generation.

❌ Disadvantages

- ✓ High capital investment
- ✓ Strict emission controls
- ✓ Logistic Challenges



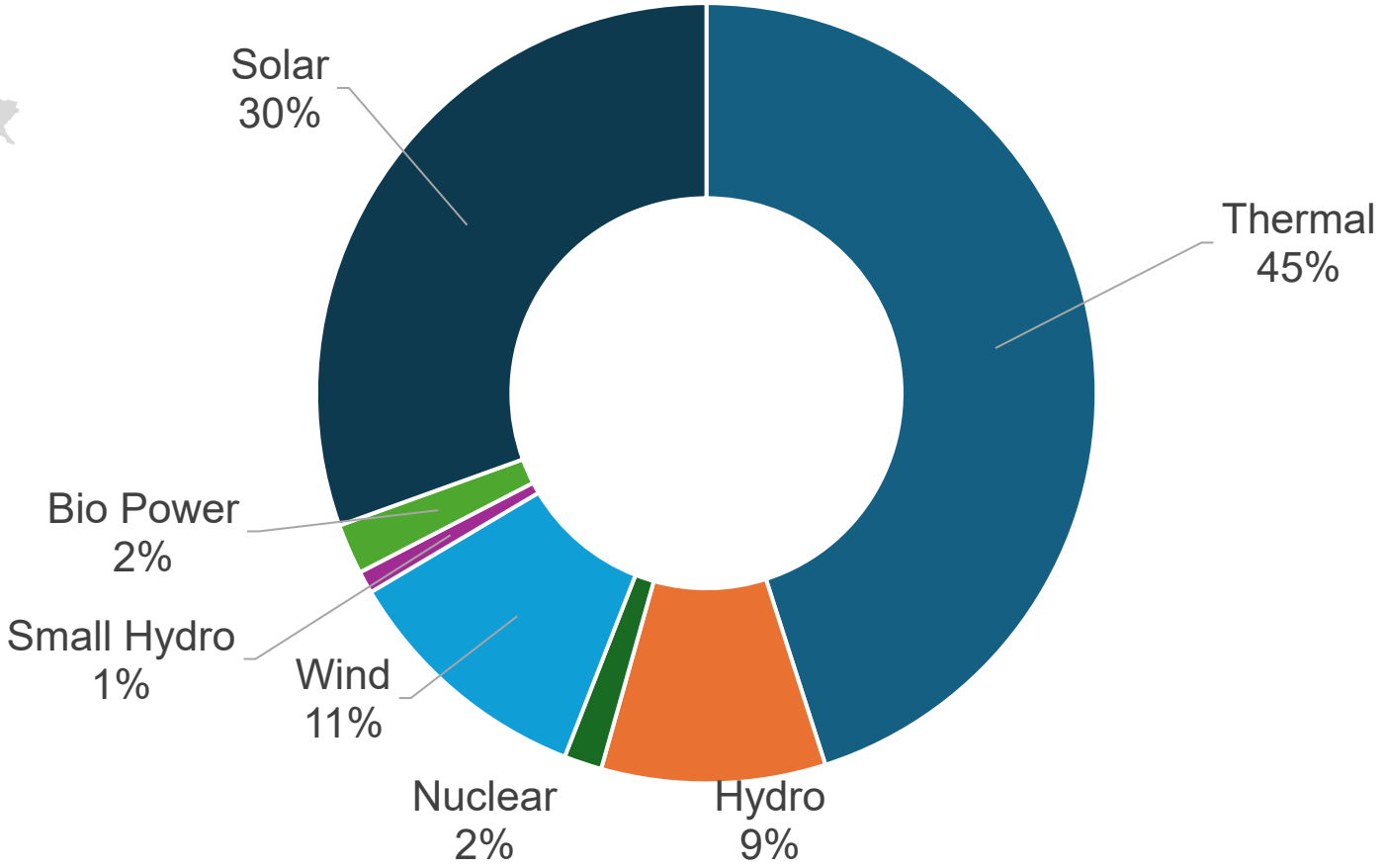
Indian Power Sector Overview - Supply



560 GW

Total Generation Capacity

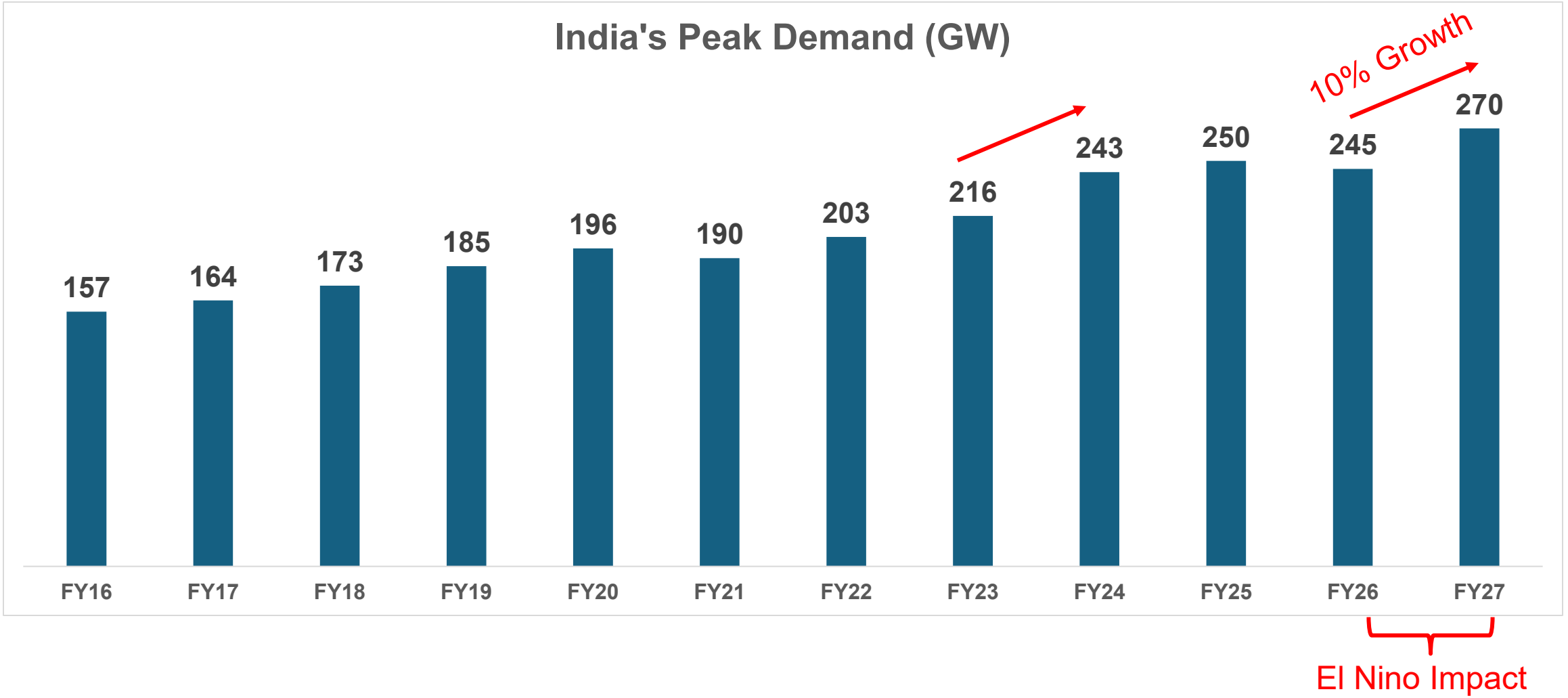
Generation Capacity Mix



*as on 14-10-2026

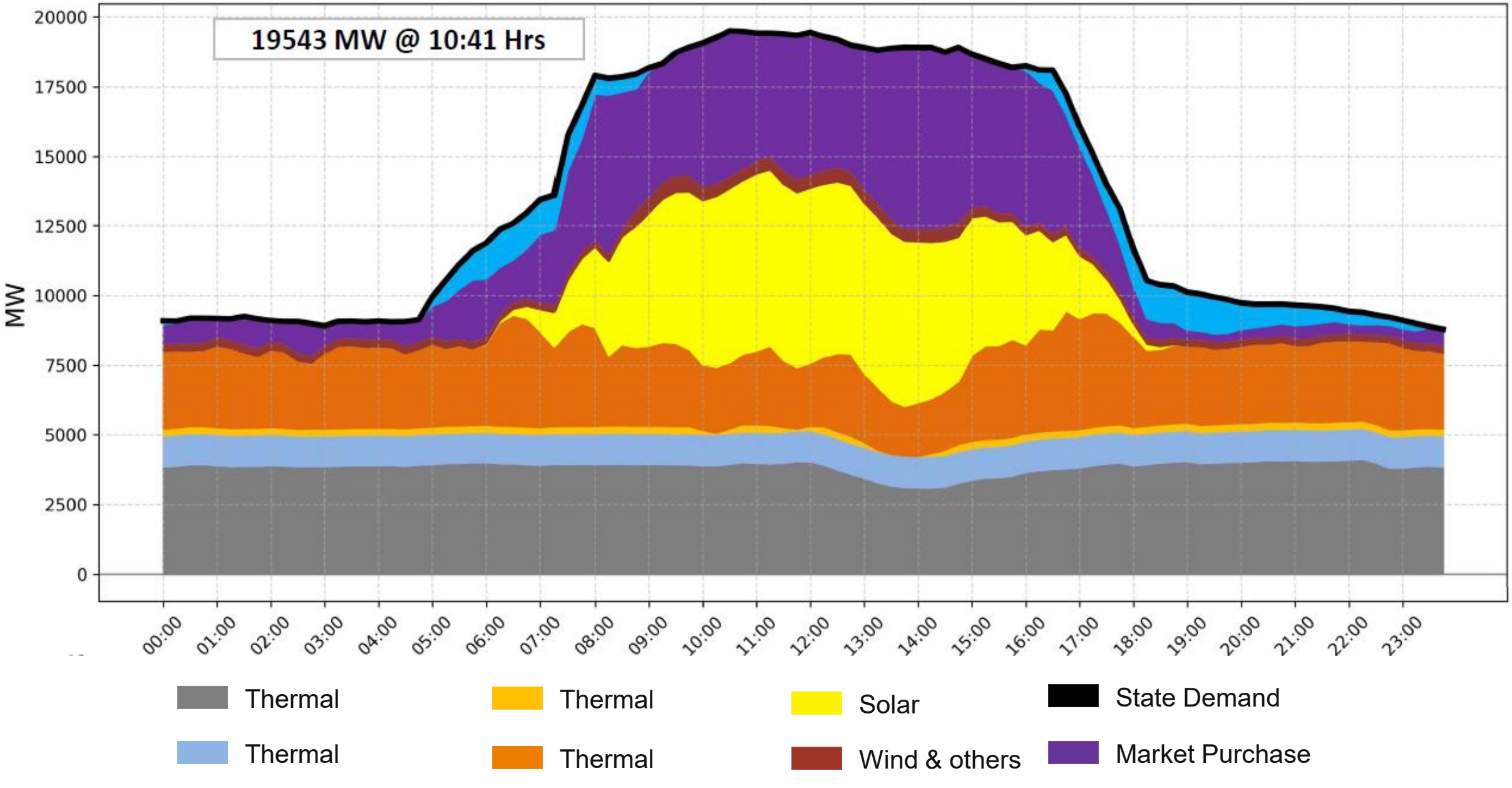
India has attained ~50% of Installed Capacity from Renewable Energy Sources

Indian Power Sector Overview - Demand



Power demand in India has grown steadily reaching an all time high of 270 GW in FY27, driven by industrial expansion and increasing sectoral electrification.

Typical Daily Load Curve



Importance of Solar

Why India Needs Solar Power?

Solar addresses energy security, growth and decarbonization together

ABUNDANT RESOURCE

Strong solar irradiation across large areas

DISTRIBUTED OPTION

Rooftops and pumps reduce local supply burden

DAYTIME MATCH

Supports daytime commercial and agricultural demand

LOW FUEL RISK

No imported fuel or commodity-price exposure

FAST TO BUILD

Modular projects from rooftops to utility scale

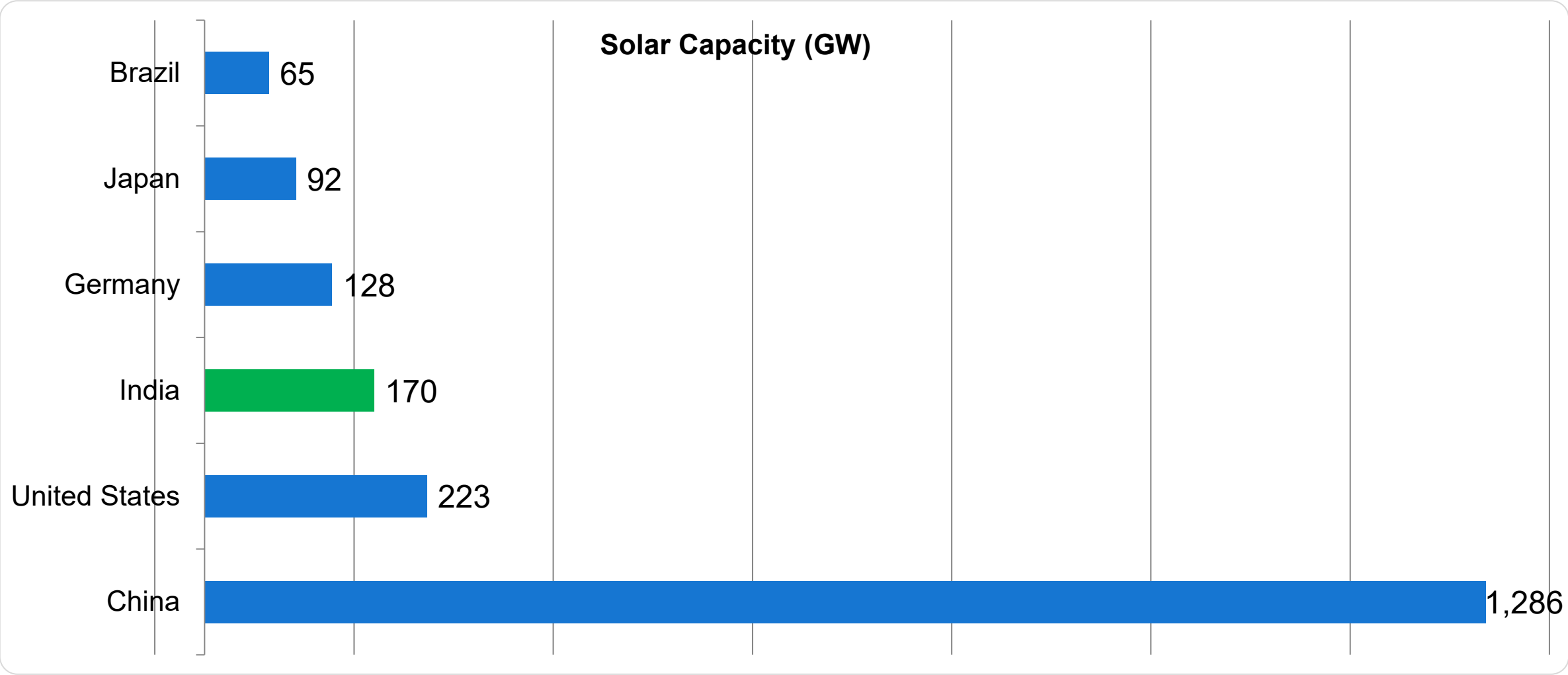
CLIMATE COMMITMENT

Supports non-fossil capacity goals



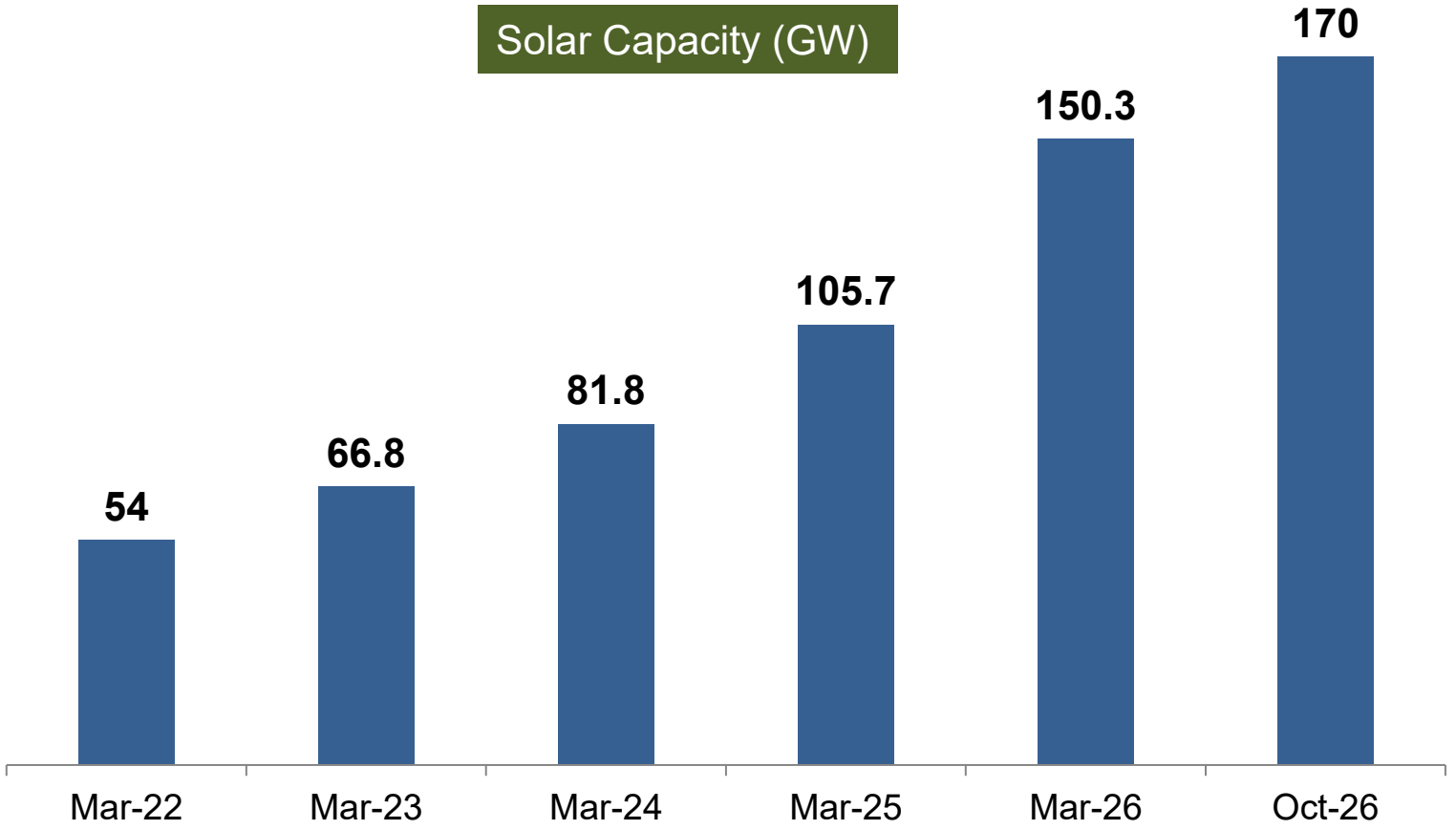
Solar Capacity: India in the Global Context

India ranked among the world's top Three solar markets



India’s Solar Capacity: Five Years of Rapid Growth

India’s Solar Generation Capacity increased by ~3.14X Times in last 4 Years contributing to ~30% of Total Installed Capacity



What accelerated growth?

- Competitive procurement
- Solar parks and rooftops
- Manufacturing Scale and Local Manufacturing
- Policy Support and Obligations

Renewable Consumption Obligation (RCO)

- **RCO**: Portion of Energy to be supplied by DISCOM from Renewable Energy sources
- Ministry of Power (GoI) has fixed below RCO targets for DISCOMs

Year	2024-25	2025-26	2026-27	2027-28	2028-29	2029-30
RCO Target	29.90%	33.01%	35.95%	38.81%	41.36%	43.33%

- As per MOP Notification vide number S.O. 4421(E). dated 27.09.25, non- compliance of RCO targets leads to imposition of penalty
- **Penalty:** ~Rs 0.36/Unit of Energy consumed

PM-KUSUM – Solar Power for Agriculture

Objective: De-dieselize farm sector, improve energy and water security, and create additional income opportunities for farmers.

A **DECENTRALISED SOLAR PLANTS**

10,000 MW target

500 kW–2 MW plants on farmers' land; power purchased by the DISCOM

B **STANDALONE OFFGRID SOLAR PUMPS**

14 lakh pumps target

Solar agriculture pumps in off-grid areas, generally up to 7.5 HP

C **GRID-CONNECTED SOLARISATION**

35 lakh pumps target

Individual pump solarisation and feeder-level solarisation

Financial Support: 30% of benchmark cost / 50% in specified special-category States/UTs;

Achievement:

2,426 MW Installed Capacity

~12 Lakh pumpset installed

18 Lakh Pumps Solarized

PM-Suryaghar: Muft Bijili Yojana

Objective: Enable residential consumers to install grid-connected rooftop solar, reduce electricity bills and expand citizen participation in clean energy.

CENTRAL FINANCIAL ASSISTANCE

Up to 2 kW	₹30,000 per kW
Additional capacity up to 3 kW	₹18,000 per kW
Systems above 3 kW	Total subsidy capped at ₹78,000
GHS / RWA common facilities	₹18,000 per kW, subject to scheme limits

1 CRORE

Households targeted to be Solarized by March 2027

ACHIEVEMENT MILESTONES

30 lakh

Household milestone achieved on 23 Feb 2026.

Need for Energy Storage

Energy Storage Projects

- Electricity has to be consumed at the time of generation
- Energy Storage **stores Electricity during higher generation hours and discharges during higher load** hours in the day

Types of Energy Storage Systems

Battery Energy Storage System (BESS)

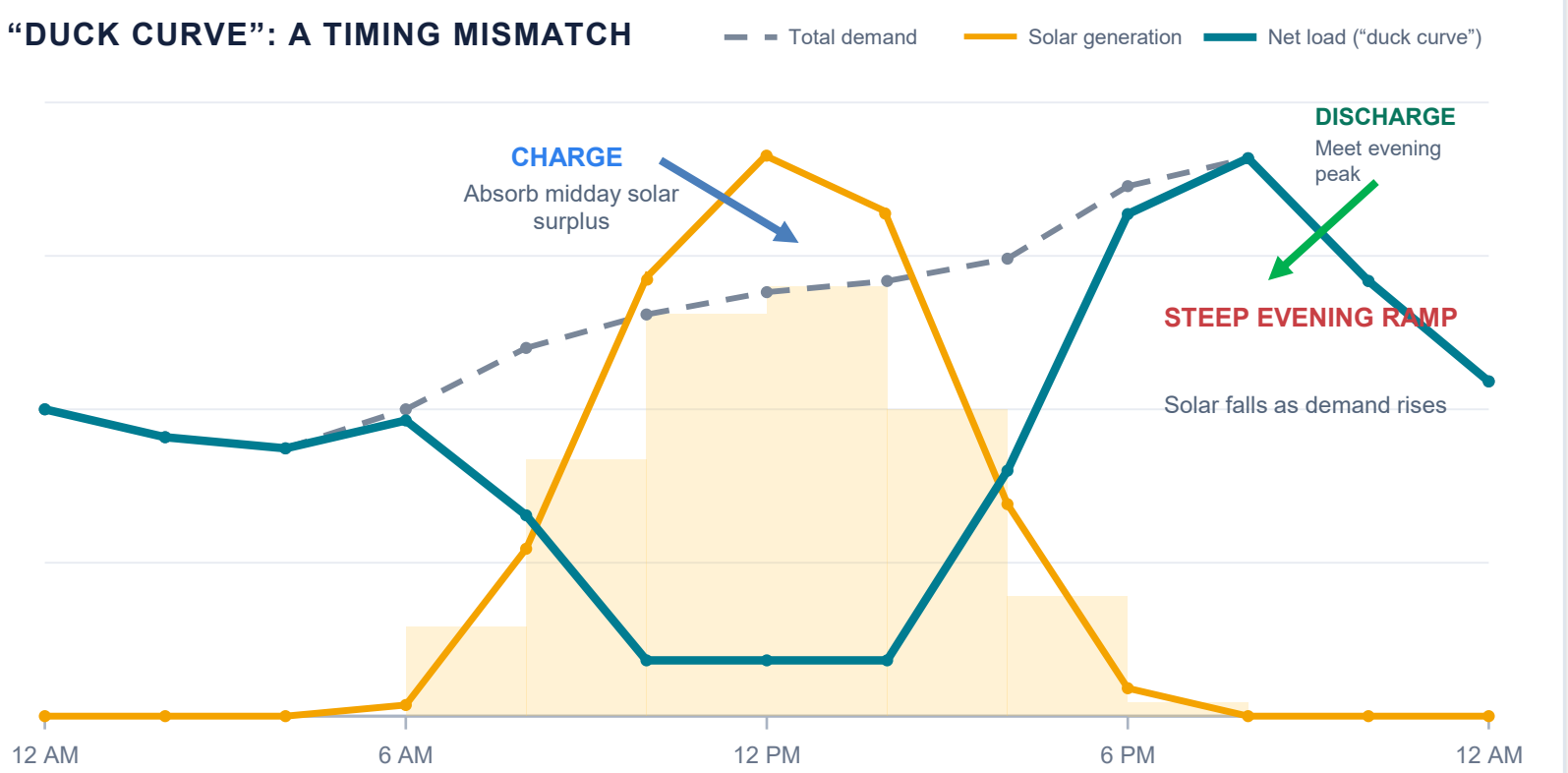


Pumped Storage System (PSP)



Need for Energy Storage

Solar generation peaks at noon, but electricity demand peaks after sunset. Storage shifts surplus energy to the hours when the grid needs it most.



GENERATION ≠ PEAK LOAD

GENERATION PEAK

~ 11 AM – 2 PM

High solar output; grid may face surplus / curtailment

LOAD PEAK

~ 6 PM – 10 PM

Solar output fades; flexible capacity must ramp quickly

STORAGE BRIDGES THE GAP

Store low-cost renewable energy during the daytime → discharge during evening peak

Battery Energy Storage Systems (BESS)

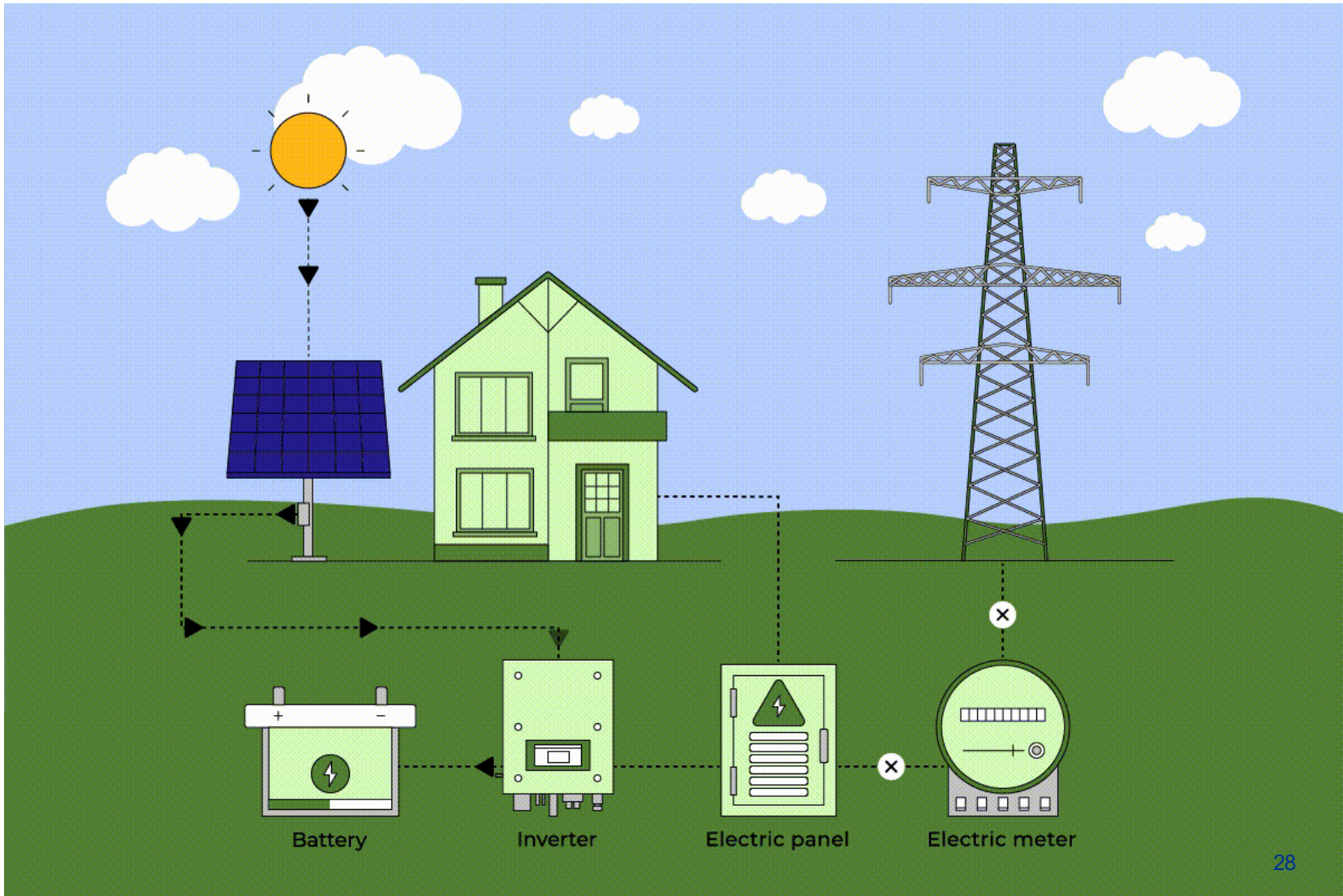
It stores electricity in batteries and discharge it when needed, helping **balance supply & demand and support renewable integration**.

✅ Advantages

- Grid Stability & Fast Response
- Supports Renewable Integration
- Modular & Scalable
- No Location Constraints

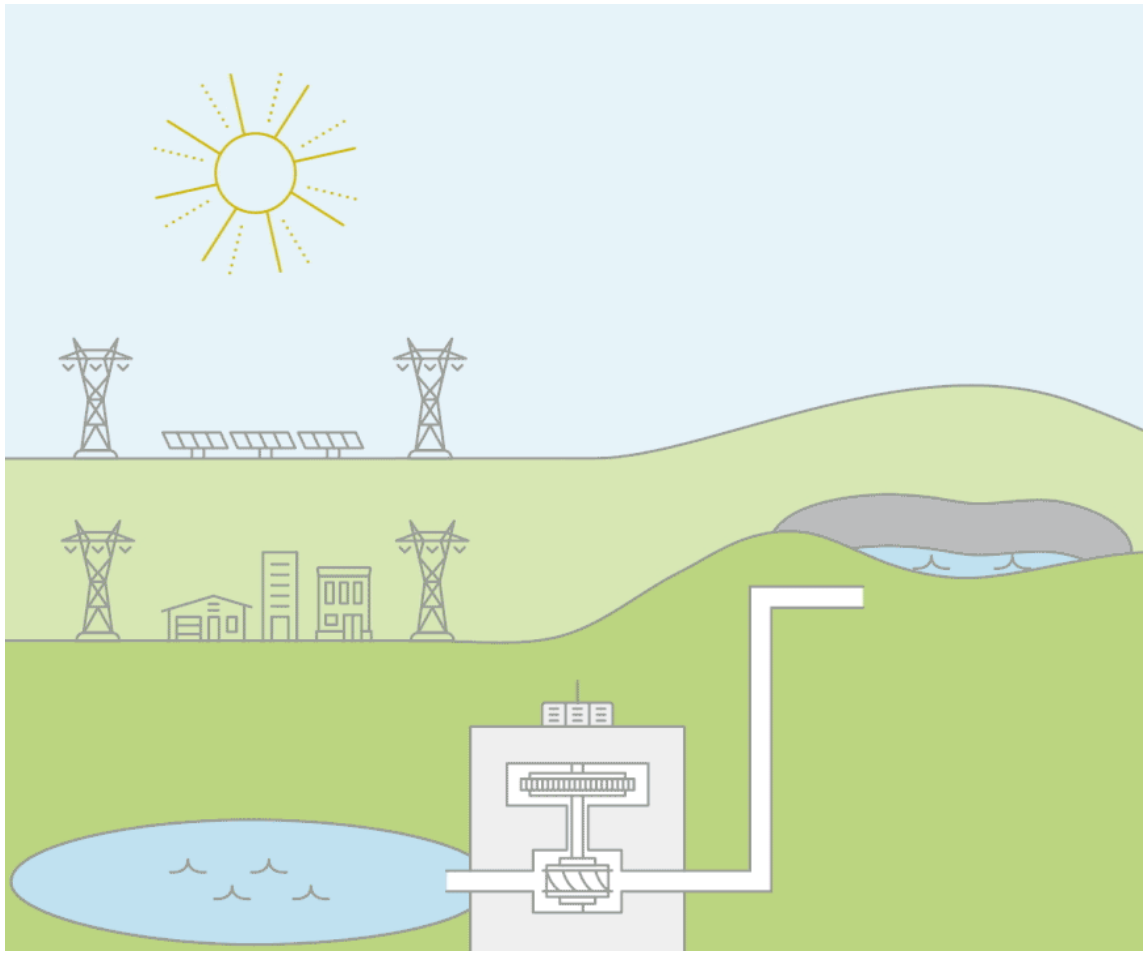
❌ Disadvantages

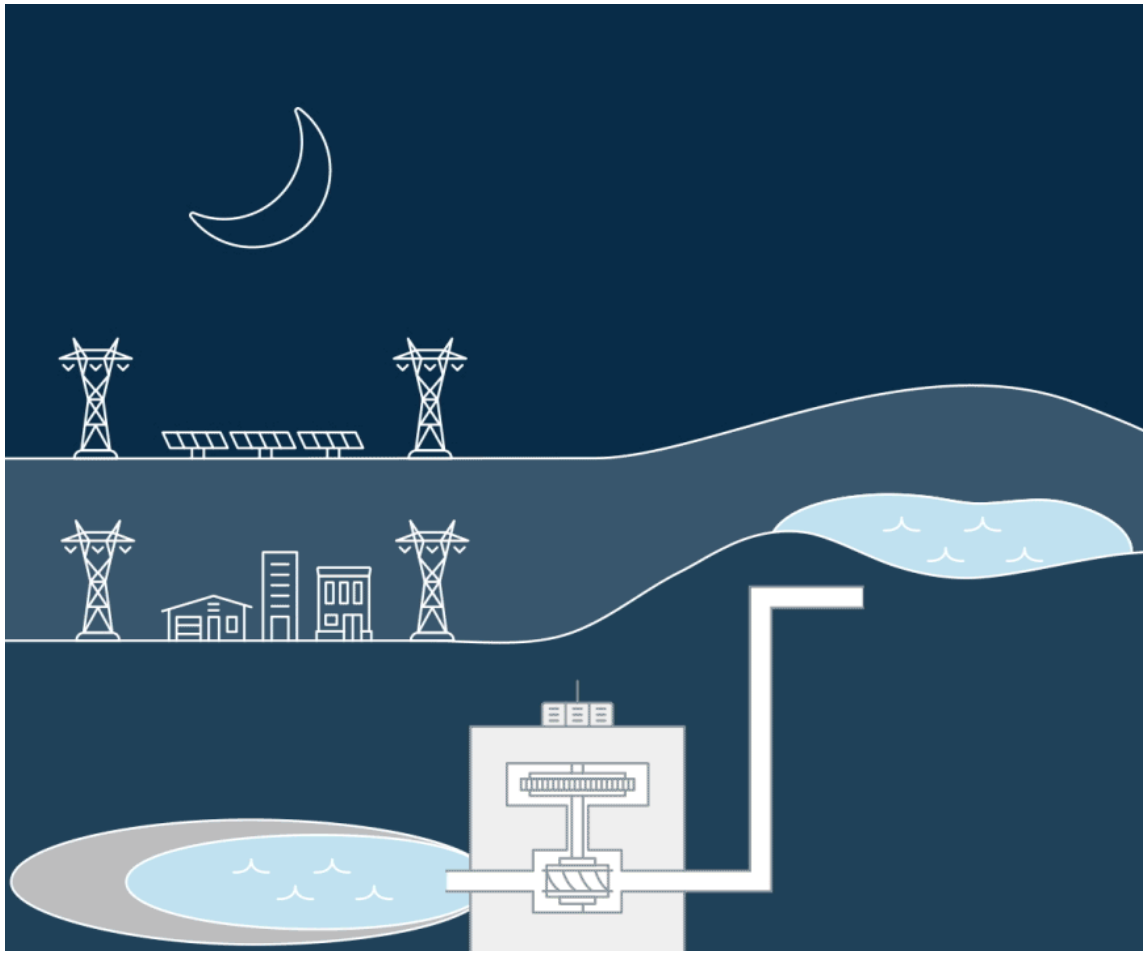
- High Cost & Limited Lifespan
- Energy Capacity Limits
- Fire Risk



Pumped Storage Projects (PSP)

Large-scale energy storage system that pumps water to an upper reservoir when excess Energy is available & releasing it to generate electricity during peak demand.







Quiz Time!

Question 1

Is Energy from Solar constant throughout the day?

Yes

✓ No

Question 2

What is the average CUF of Solar Generation?

	25%	15%
✓	22%	30%

Question 3

How can Solar Energy be used during the night?

Using Hydel plants	✓ Using Energy Storage
Using Thermal generation	Can’t be used

Question 3

What is the percentage of RE in India's Installed Generation capacity?

30%	✓ 50%
60%	40%



Transmission

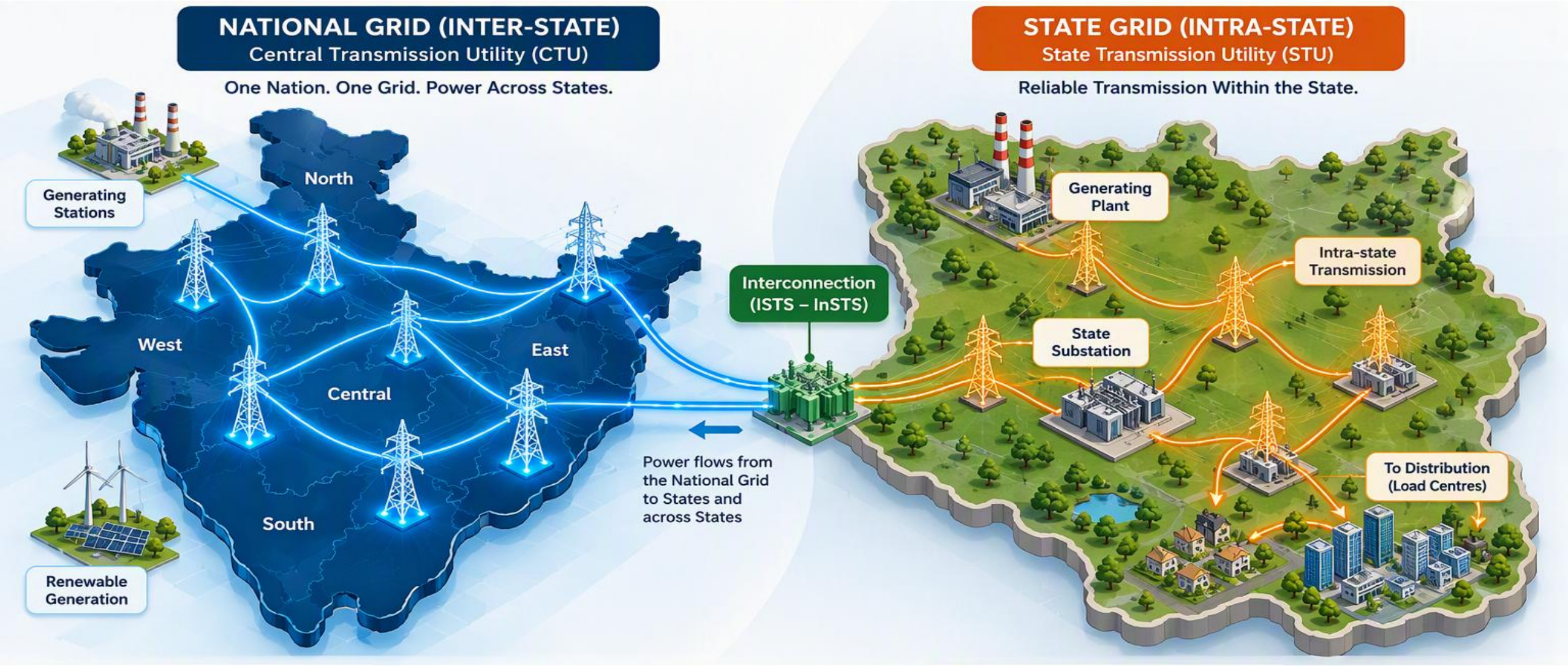
Transmission – The Electric Highway

- Electricity generated is **transmitted to the load centers/ consumer distribution network** through transmission lines.
- Transmission acts as bulk transport and operates at high voltages.
- Includes EHT Lines and Substations

- **Energy loss in Transmission/Distribution Network is based on Current**
  - **Higher Voltage >>> Lower Current >> Lesser Losses**
  - Electricity is stepped up to higher voltages for longer transmission to minimize electrical losses
  - Electricity Transmission is done at following voltages – 132kV,220kV,400kV, 765kV

Inter-State/Intra-State Transmission Network

India's regional power grids are interconnected into a single national network, enabling electricity transfer across States



CTU and STU – Typical Transmission Voltage Levels

Central Transmission Utility (CTU)

800 kV HVDC	Long-distance bulk transfer
765 kV AC	National / inter-regional corridors
400 kV AC	Major ISTS network
220 kV AC	Interface / selected ISTS assets

State Transmission Utility (STU)

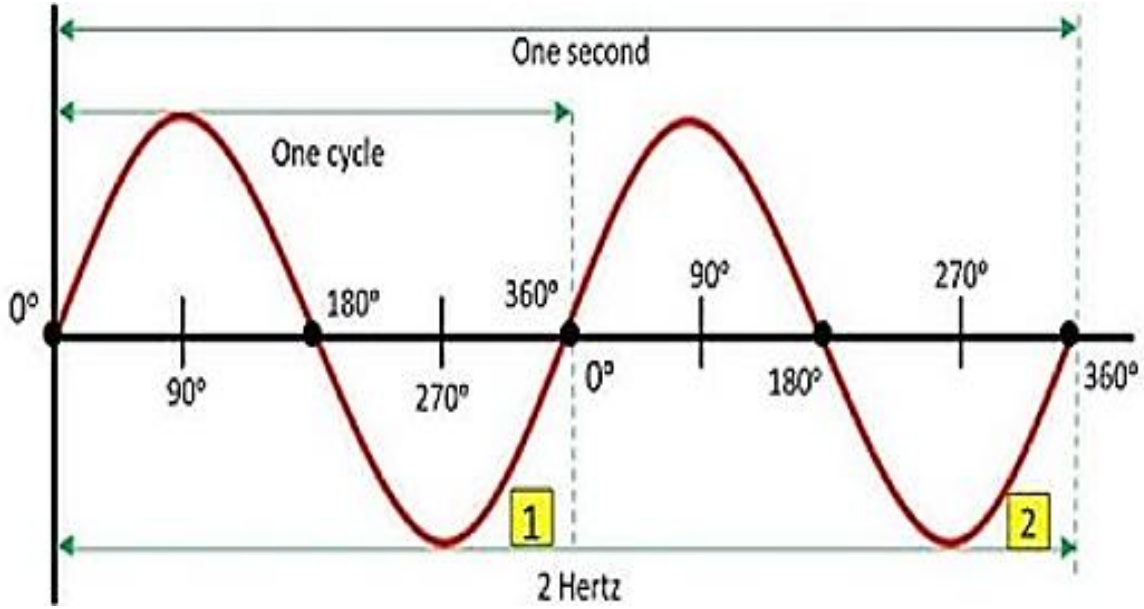
400 kV	State EHV in some States
220 kV	Major State transmission network
132 / 110 kV	Regional / sub-regional State network
66 kV	Sub-transmission in some States

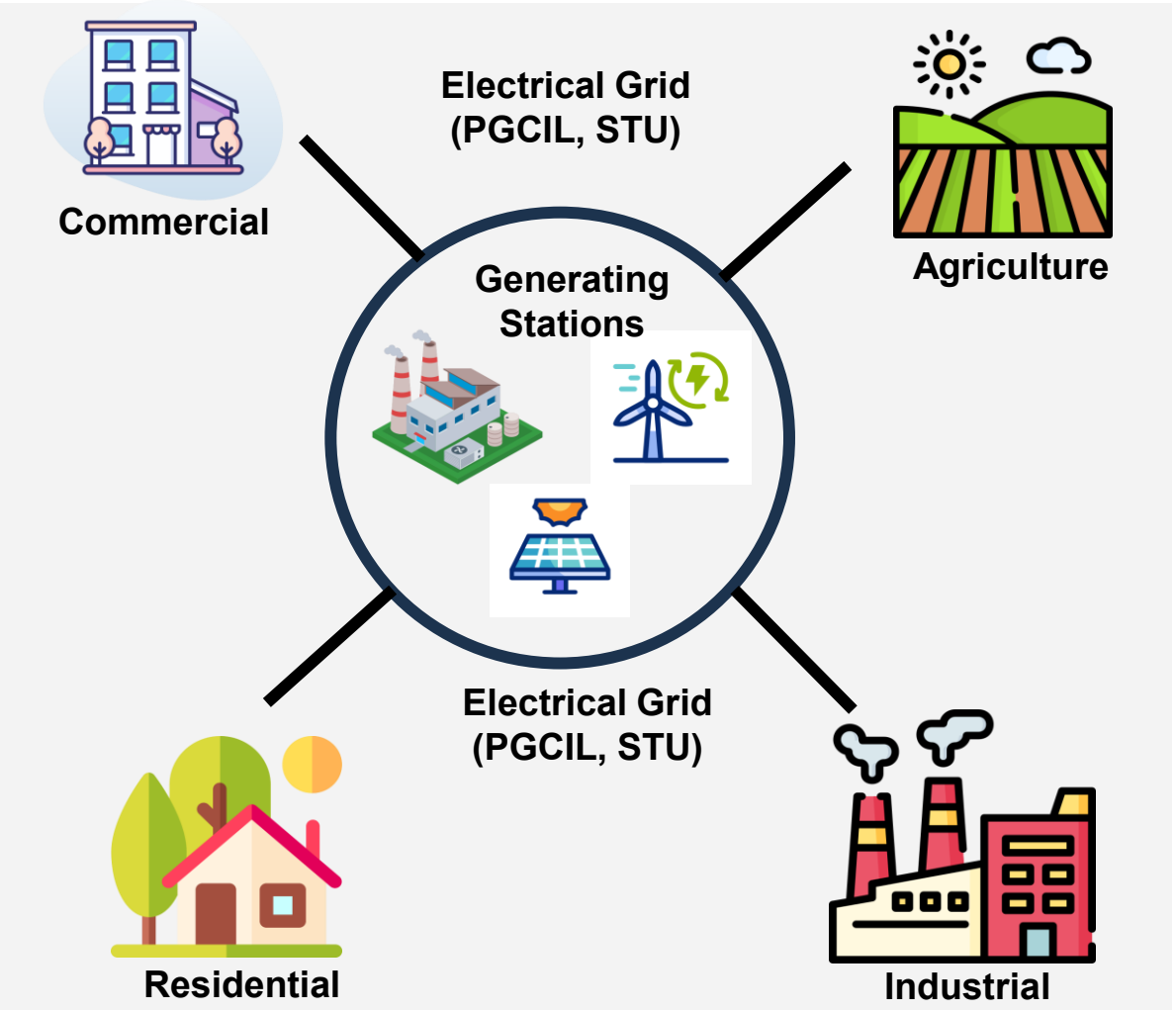


Electrical Grid

Entire system that connects power generation to end users. Includes Generation, Transmission and Distribution Network

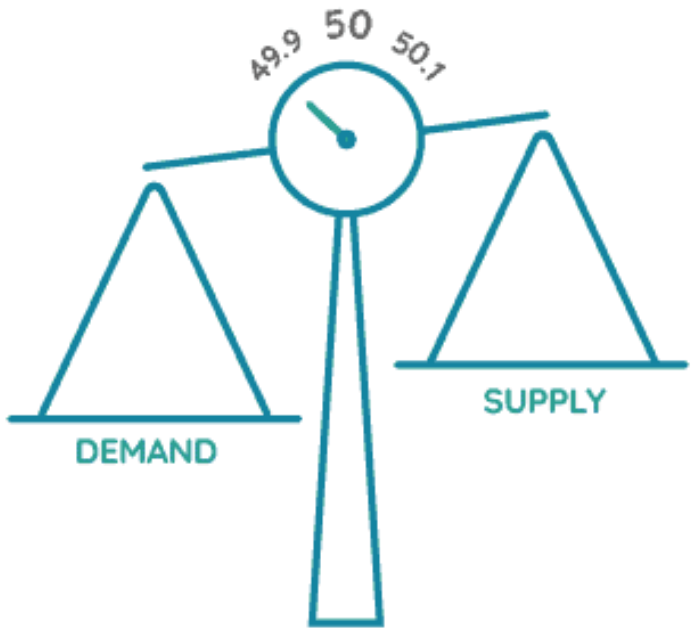
What is Frequency, how is it important ??





Grid Stability

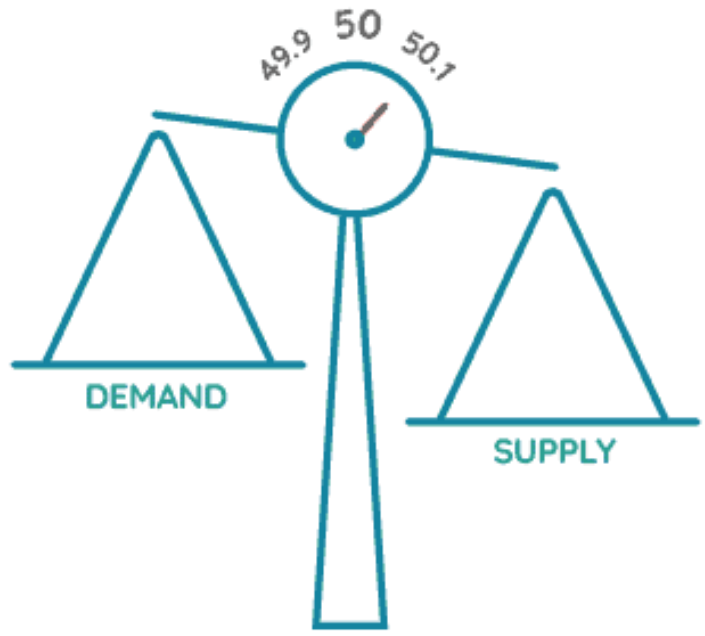
Grid stability (Demand & Supply balance) is important for reliable and quality power supply



More consumption than electricity generation

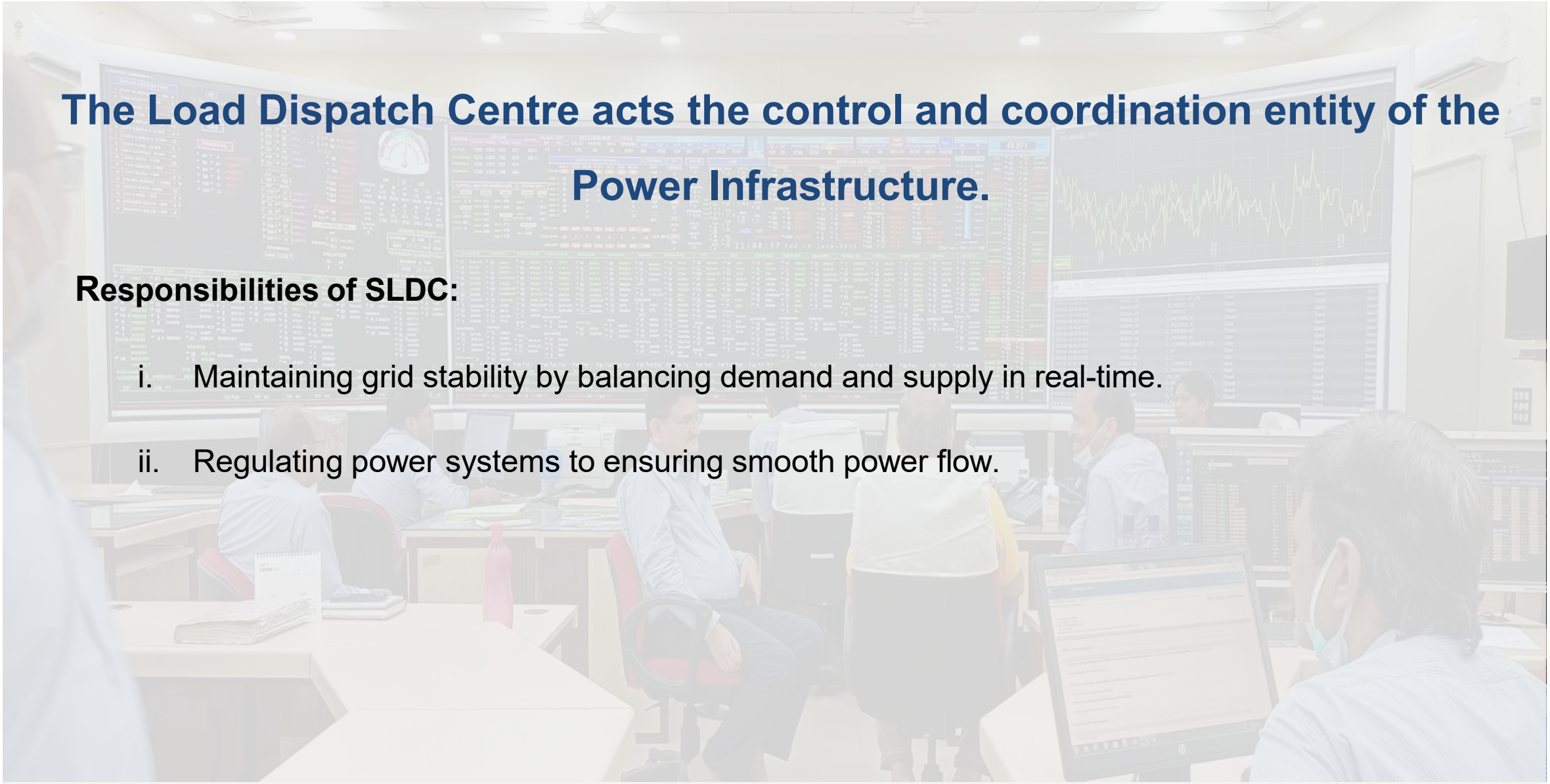


Electricity generation and consumption are in balance



More electricity generation than consumption

Load Dispatch Centers



The Load Dispatch Centre acts the control and coordination entity of the Power Infrastructure.

Responsibilities of SLDC:

i. Maintaining grid stability by balancing demand and supply in real-time.

ii. Regulating power systems to ensuring smooth power flow.

Role of Load Dispatch Centers



NLDC

National coordination

Cross-regional security and national scheduling

RLDCs

Regional operation

Regional scheduling, dispatch and grid security

SLDCs

State operation

State scheduling, dispatch and intra-State balancing



Distribution

Electricity Distribution

Last Mile of Electricity business. The Commercial and Consumer facing wing of Electricity

Includes Substations, Distribution Transformers and Distribution Lines connecting the Consumers



PROCURE

Forecast demand and buy power



NETWORK

Operate substations, feeders and transformers



SERVE

Connect and support consumers



METER

Measure consumption accurately



BILL

Apply approved tariff and collect revenue



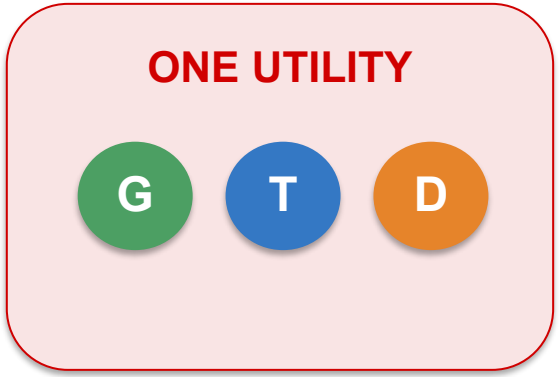
IMPROVE

Reduce losses and improve reliability

Structure of State Power Utilities (1/2)

BUNDLED

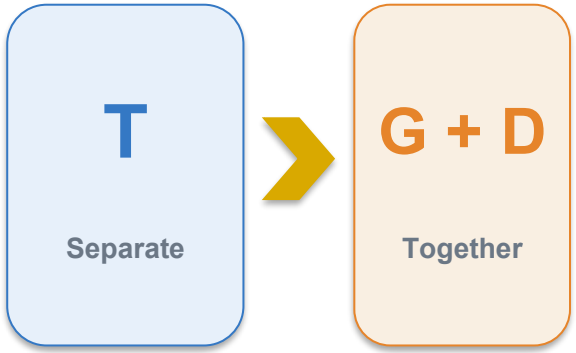
One organisation does everything



Generation, transmission and distribution are managed by the same electricity board / utility.

PARTIALLY UNBUNDLED

Some functions are separated



One function may be separated, while the remaining functions continue under one organization.

FULLY UNBUNDLED

Each function has a separate company



Separate organizations handle generation, transmission and distribution, with clear roles and accounts.

Structure of State Power Utilities (2/2)

Bundled	Partially Unbundled	Unbundled – One DISCOM	Unbundled – Multiple DISCOM
Sikkim	Punjab	West Bengal	Uttar Pradesh
Nagaland	Himachal	Uttarakhand	Rajasthan
Mizoram	Manipur	Meghalaya	Odisha
Goa	Tripura	Maharashtra	Madhya Pradesh
Kerala		Chattisgarh	Karnataka
Arunachal Pradesh		Assam	Haryana
Andaman & Nicobar		Tamilnadu	Delhi
		Jharkhand	Gujarat
			Andhra Pradesh
			Bihar
			Telangana

Distribution Company Operating Models

STATE-OWNED

Government-owned licensee

Most common model

PRIVATE LICENSEE

Private owner/operator

Examples: Adani, Tata Power

PPP / FRANCHISE

Private operations under contract

Loss reduction and collection focus

MULTIPLE LICENSEE

Competing supply arrangements

Policy-enabled in limited contexts to enable competition

How Distribution Companies Make Money?

Financial viability depends on the gap between cost to serve and revenue realized

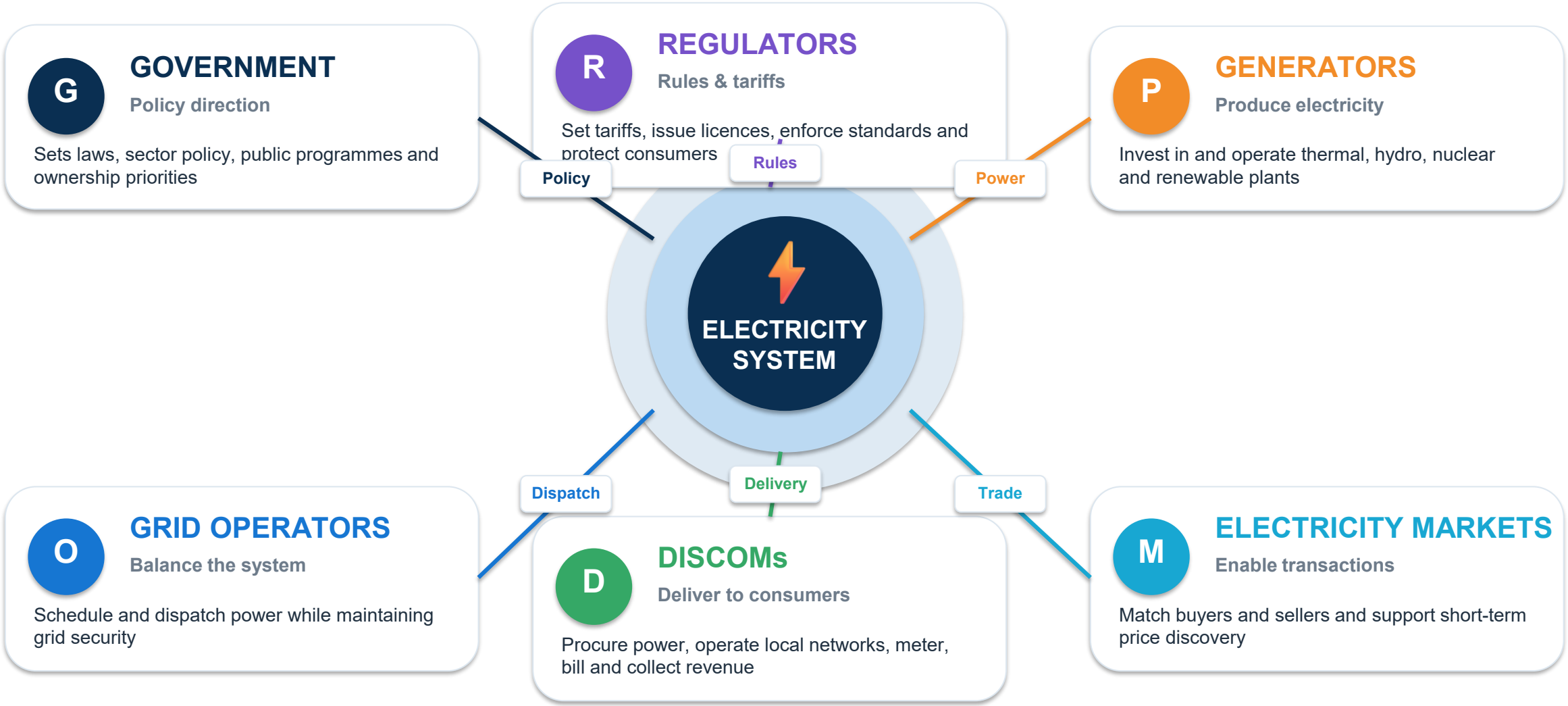
COST TO SERVE	REVENUE REALISED
Major costs	**Major revenues**
• Power purchase	• Consumer tariff
• Transmission & market charges	• Government subsidy
• Network O&M and employee cost	• Open-access and wheeling charges
• Interest and depreciation	• Other income



Electricity System

Who Makes Electricity System work?

Electricity system is a coordinated entity comprising multiple stakeholders



Electricity Regulatory Commission

Independent authority that regulates utilities and protects consumer interests.

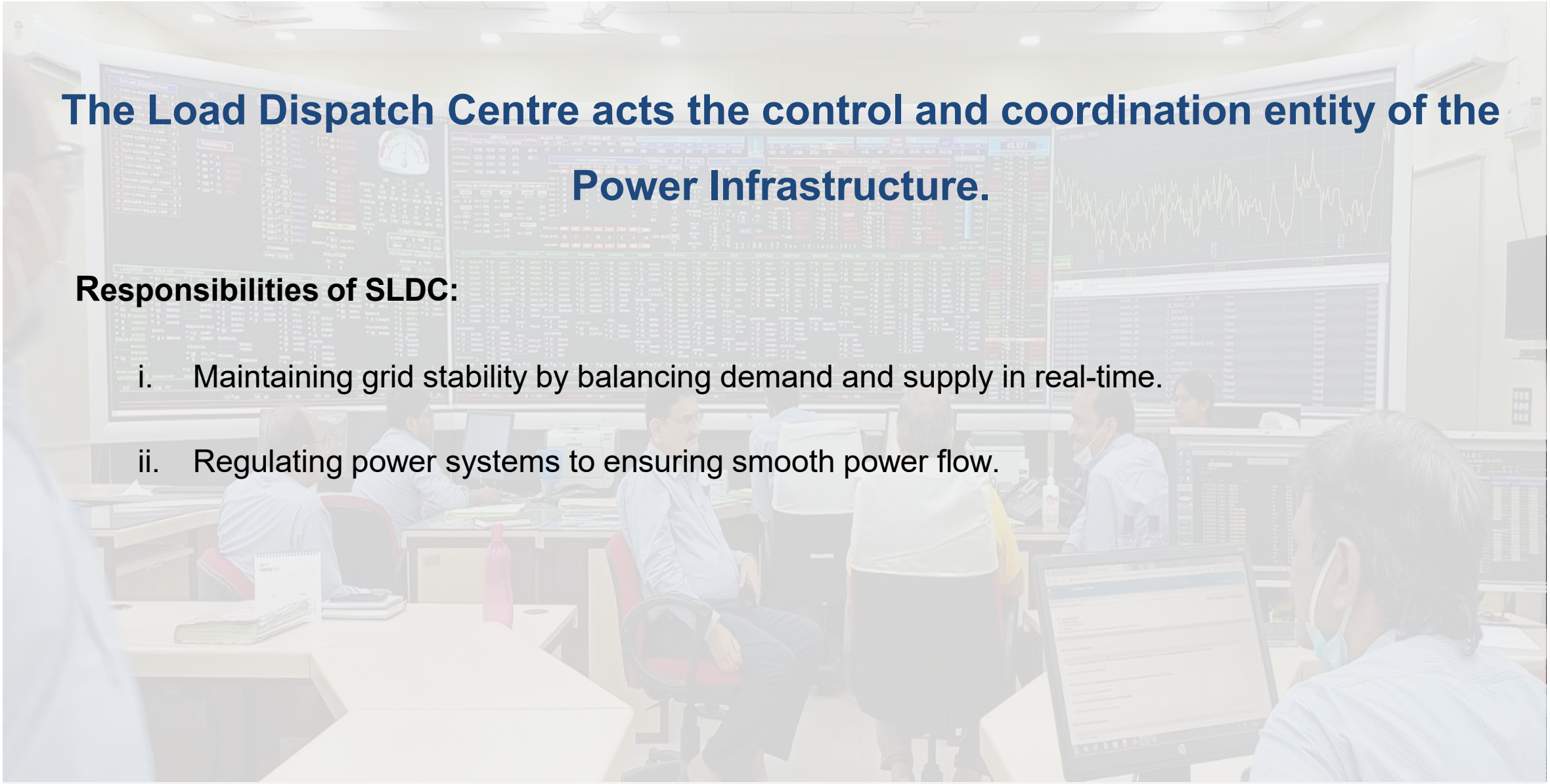
Central Electricity Regulatory Commission

- ₹ Sets Electricity tariffs
- ↔ Regulates inter-State flow of Electricity
- L Issues Transmission, Distribution, Trading license
- G Sets grid rules on quality and reliability
- ⚖ Manages Disputes

Central Electricity Regulatory Commission

- ₹ Sets State Electricity tariffs
- P Checks DISCOM power Procurement
- L Issues State License for Transmission, Distribution
- R Promotes renewable energy
- ⚖ Protects service standards

Load Dispatch Centers



The Load Dispatch Centre acts the control and coordination entity of the Power Infrastructure.

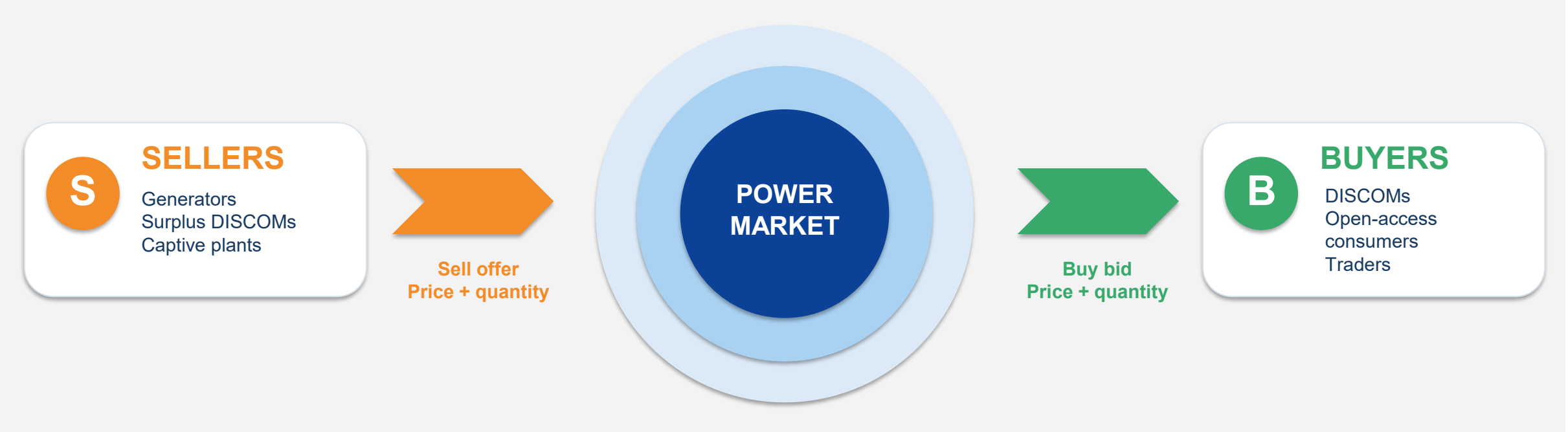
Responsibilities of SLDC:

i. Maintaining grid stability by balancing demand and supply in real-time.

ii. Regulating power systems to ensuring smooth power flow.

Electricity Markets

Electricity market is a mechanism that connects sellers with buyers, discovers a price



Electricity Markets in India

The market differs by contract duration, delivery timing and type of electricity

YEARS	MONTHS / WEEKS	DAY AHEAD	SAME DAY	REAL TIME
PPAs and contracts	Direct negotiated transactions	DAM / GDAM / HP-DAM	TAM / GTAM / HP-TAM	RTM
LONG-TERM / MEDIUM-TERM	**BILATERAL & TRADER MARKET**	**DAY-AHEAD MARKET**	**TERM-AHEAD & INTRADAY**	**REAL-TIME MARKET**
Capacity and energy are contracted in advance for longer periods	Buyer and seller agree quantity, price and delivery; a licensed trader may facilitate	Power is traded for delivery on the following day	Exchange contracts cover intraday, contingency, daily and weekly requirements	Close-to-delivery market used to adjust short-term power positions

GREEN MARKETS GDAM and GTAM provide exchange-based avenues for renewable electricity.



Time for Questions!

Thank You