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Seizing opportunities in transforming power sector

Power Infrastructure is crucial for sustained growth of economy of any nation. Power Sector World-wide and in India is transforming and the focus is on efficient clean green power generation, transmission and distribution. India's power sector is on the verge of massive transformation.

India growth story

When India got independence in 1947, Its population was 380 million, whereas the per capita power consumption was 16. 3 kWh and the total power consumption was 4182 gWh. India has since grown on all fronts (Table 1). In the last seventy-five years, while the population has grown 4. 18 times, the per capita power consumption has grown almost 70 times to 1139 kWh (Fig.1) and the overall power consumption has risen 293 times to 1227000 gWH (Fig.2). The growth drivers in economy, population growth, electrification, increase in living standards leading to 2.5 times growth in % of power consumed in domestic sector.

The current total installed capacity is approximately 400 GW (Table 2). Out of which approx. 59% is thermal, whereas the balance 41% is nuclear, hydro and renewables. The major fuel requirement is of coal 51% of the installed capacity. There is a dire need to grow this capacity to match with further growth requirements of the country, which would more than double to 820 GW by the year 2030. This is both a challenge and an opportunity.

We therefore see necessity for a huge transformation of the power sector in coming years to address the challenges on hand. The way forward would be to seize opportunities in this metamorphosis.

Sector overview

Indian power sector is the most diversified wherein power generation ranges from conventional sources viz coal, lignite, natural gas, oil, hydro, nuclear power, non-conventional sources such as wind, solar, and agricultural and domestic waste (Table 2) and (Fig.3).

There is a focus on shoring up renewable energy sources sources (RES) which currently are 109887 GW, approximately 27/5 % of the total installed capacity primarily solar and wind as tabulated in Table 3 and Fig.4.

Challenges and Mitigation

While India needs to double its power generation capacity, the power sector is reeling with challenges of not meeting electricity requirements hurting industrial output, underutilization of installed capacity, ineffective State Electricity Boards (SEBs), limited role of private sector, shortage of inputs, skewed pattern of energy consumption. Coal shortage (whereas coal production remains key (51% contributor) to energy mix), slow pace of digitalisation, delayed project execution, further push to renewable energy to meet India's commitment under Paris agreement.

Let us dwell upon some of these key challenges, the prime causes and how to mitigate these in the form of transformation matrix.

Underutilisation of installed capacity: this is the foremost challenge and the primary reasons are fuel shortage, inadequate logistics, poor liquidity as detailed in Table 4.

Ineffective State Electricity Boards (SEBs)/Discoms

The distribution sector is ineffective and major bane for the power sector. The losses of distribution sector stood at over Rs 90, 000 cr for FY 21 and even more in FY 22 (figures yet to come). Th prime reason is weaknesses in operations, infrastructure, and regulation I including underinvestment, line losses, challenges related to billing, metering, and collection, high PPAs. As a result, the distribution companies, as a whole, are loss-making and debt-ridden and are not able to invest in better infrastructure, to provide better services to their customers.

The solution to this problem will include all the above suggested measures, reducing AT&C losses, forgetting popular schemes of free electricity and ensure a sustainable turnaround of the discoms, in terms of both finances and operations.

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Table 1: Indian power consumption 2022 vis-à-vis 1947

Year	Population Millions	Consumption GWH	Domestic %	Commercial %	Industrial %	Trac-tion %	Agriculture %	Misc. %	PerCapiita KWH
1947	330	4,182	10.11%	4.26%	70.78%	6.62%	2.99%	5.24%	16.3
2022	1,380	1,227,000	25.67%	8.31%	41.09%	1.51%	17.52%	5.89%	1139
# Of times	4.18	293.40	2.54	1.95	0.58	0.23	5.86	1.12	69.88

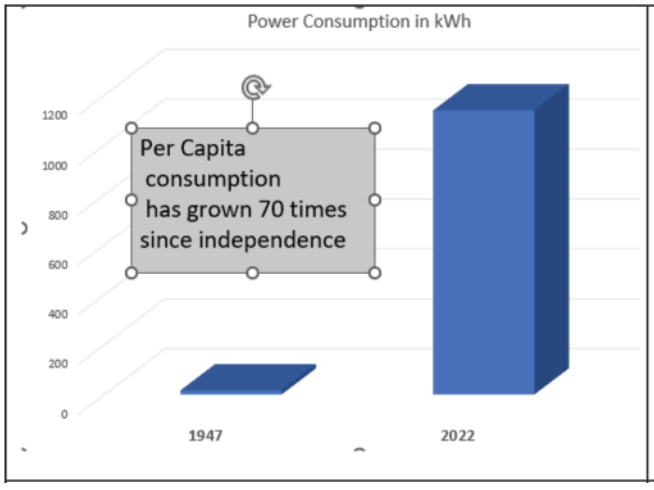

Fig.1: Per Capita consumption kWh

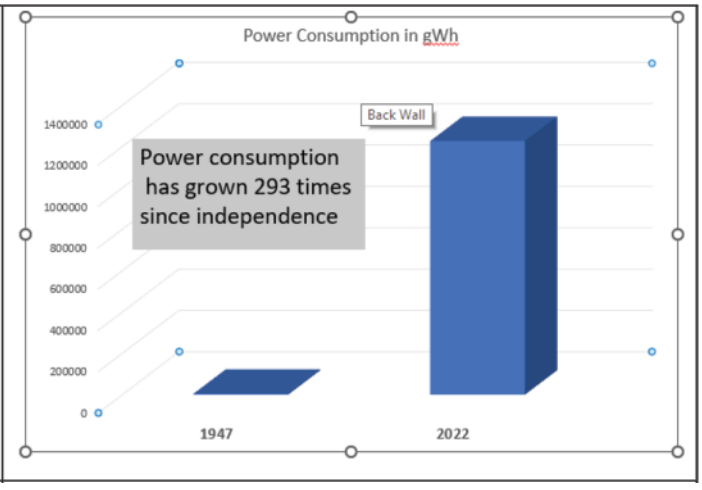

Fig.2: Power consumption gWh

Table 2: Total Indian power generation installed capacity in MW as on 31st March 2022

Coal	Lignite	Gas	Diesel	Thermal	Nuclear	Hydro	Renewable	Total
204080	6620	24900	510	236110	6780	46723	109887	399499
51.1%	1.7%	6.2%	0.1%	59.1%	1.7%	11.7%	27.5%	100.0%

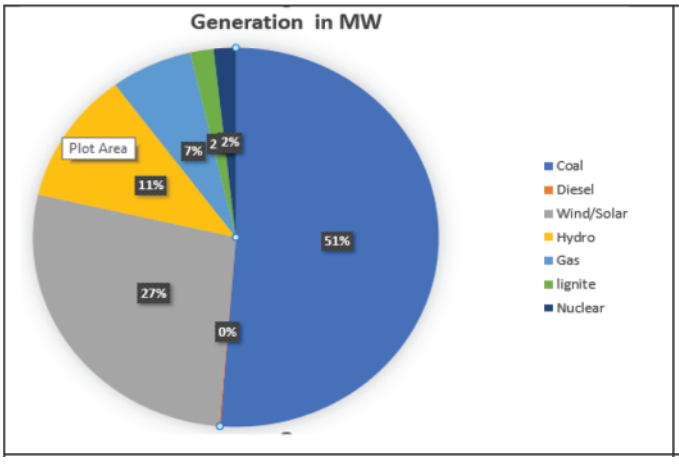

Fig.3: Sectorwise installed capacity

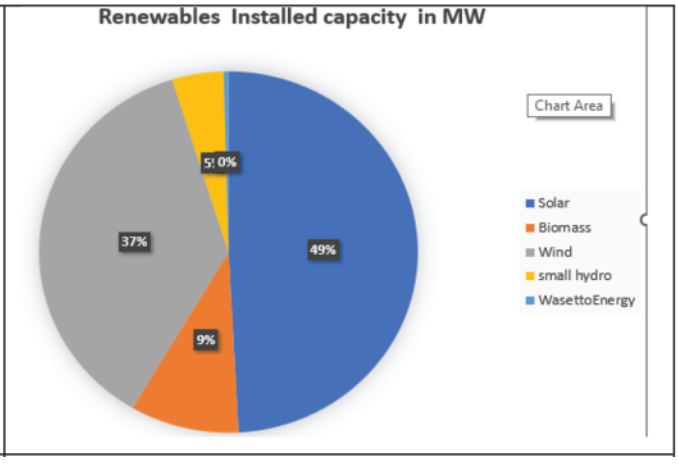

Fig.4: Renewables installed capacity

Table 3: Renewable energy sources (Res) installed capacity 31st March 2022

Solar	Biomass	Wind	Small Hydro	Waste to en- ergy	Total RES
53997	10206	40358	4849	477	109887
MW	aMW	MW	MW	MW	MW
49.1%	9.3%	36.7%	4.4%	0.4%	100.0%

Table 4: Transformation (challenge mitigation) Matrix : Under utilisation of installed capacity

	The Challenge Primary Causes	Transformation Required
Under-utilization of the installed capacity	Fuel Shortage: Coal Current Coal supplies is restricted to around 65% of actual coal requirement by coal based thermal plants	Enhance Coal Production, Import Coal to bridge the gap in the interim, retire inefficient coal- based plants. Accelerate development of new coal blocks
	Fuel Shortage: Gas More than 20, 000 MW is idle due to non-availability of gas.	Scout for New sources of Gas, Government is helping to do so
	Logistics: Inadequate and seamless logistics infrastructure, Rail Road availability, especially during Peak season	More Generation at Pit Heads, Better Loading and unloading facilities to have better turnround of Rail road resources
	Finance: Plants do not have cash flow even to meet working capital due to inordinate delays in getting payments for power sold	Do away with Populist tariff Schemes, place a mechanism of upfront payments to plants to generate and supply. Address Discoms financial vows

Table 5: Transformation (Challenge Mitigation) Matrix :Ineffective State Electricity Boards (SEBs)/Discoms

The Challenge	Primary Causes	Transformation Required
Ineffective State Electricity Boards (SEBs)/ Discoms	High-Cost Power purchase and PPAs Currently many of the Discoms are stuck with high cost long term PPAs they do not buy cheap as well as sell at market price. Poor mechanisms to buy cheap power	Restructure PPAs. Do dynamic purchasing of power to buy atlow cost utilising the Discovery of Efficient Electricity Price (DEEP) Dynamic tariffs, enabled by advanced metering and a smart grid, can reduce the discoms' power purchase costs and help manage peak loads. However, this may need building Storage capacity.
	Operational Deficiencies: Giving subsidised power to agriculture, no incentives to customers to have better demand patterns, Poor infrastructure to buy low cost RE. Inadequate monitoring of power Flows	Separate feeders for agricultural use from non-agricultural use. Encourage use of Solar pumpsfor agriculture Use time of day (ToD) tariffs to incentivise changes in demand patterns. Renewable Energy Integration (RE), large-scale energy storage by battery systems or pumped hydro-storage systems. Utilise MBED Market based Economic Dispatch
	Discoms yet to be restructured Many SEBs yet to restructure into separate entities for generation, transmission and distribution	Restructure SEBs into efficient entities with focused responsibility and accountability
	Non-Utilisation of Governmental Schemes - Many of the Discoms are yet to Leverage the policies of the Government for Power sector reforms	Leverage Ujjwal DISCOM Assurance Yojana (UDAY), Deen Dayal Upadhyaya Gram Jyoti Yojana (DDUGJY), and Integrated Power Development Scheme (IPDS).
	Financial Health Poor collections and profitability, Debt Ridden Poor collection, Poor access to cheapfinancial sources	Smart meters and smart grids, Finance savvy smart operations viz in power procurement, inensuring high quality regulation Encouraging private participation in distribution.

Skewed pattern of energy consumption

The skewed pattern of energy consumption leads to poor load factor of plants. Electricity demand is subject to fluctuations on a seasonal basis, across the week, and during the day. Demand can also be influenced by irregular events, such as particularly extreme weather conditions. They can also be swayed by television programmes or televised events, known as "TV pick-ups". The demand fluctuations occur on daily, monthly, seasonal and yearly cycles. For example, in recent summer months of current year 2022, the peak demand was so high that many of the States were reeling under huge power shortage. Since 51% of generation capacity is still dependent on coal, there was huge demand supply gap for coal.

Skewed pattern of demand puts extra load on the system and also leads to low plant load factors. We can optimise generation mix to meet skewed energy consumption pattern. Pumped storage generation is extremely responsive, can be used to meet demand peaks. With more and more of RE footprint, it is advisable to install bulk grid scale battery storage units. These hydro and battery stored power can be used at times of high demand and can be used for storing energy at times of low demand. On the demand side, steps suggested in Table 5 above should be used to incentivise consumption in non peak hours and penalties for using power in peak hours. When demand and price of electricity is low, we can store power in battery banks and also pumping water uphill.

Moreover, we need to maximise RE. Tariffs for rooftop solar should be set so that all consumers and producers face

Table 6: Transformation (Challenge Mitigation) Matrix :Combating Skewed pattern of Demand

The Challenge	Primary Causes	Transformation Required
Skewed Pattern of Energy Consumption	Peak Seasonal demand in Summers: The load consumption pattern is skewed based on weather for example in peak summers the demand rises due to huge demand for ACs/fans/coolers. Leading to huge shortage countrywide.	Higher generation in summers keeping coal reserves in advance. Use stored energy form batteries and also from hydro power. Shifting offices to Cooler places in More holidays in summers
	Peaks and Valleys due to Operational Reasons: The load consumption pattern is skewed dependent on economic development, climatic conditions, and electricity usage habits. Higher demand in evenings.	Change Industrial shift Timings. Maximise Rail Transportation in non-peak hours (Night) Incentivise usage of electricity in valley of demand hours. Renewable Energy Integration (RE), large-scale energy storage by battery systems or pumped hydro-storage systems.
	Generation yet to catch up with the skewed demand pattern through alternate sources of power	Utilise MBED Market based Economic Dispatch
	Demand Pattern is skewed due to Agriculture and Industrial demands. Together with subsidised power to agriculture and skewed demand patterns, inability to meet demand is due to poor infrastructure to utilise RE. and manage power Flows	Separate feeders for agricultural use from non-agricultural use. Encourage use of Solar pumps for agriculture. Develop infrastructure to integrate RE to meet skewed power demand. Monitor and control Power flows in real time
	Discoms yet to be take steps to change skewed demand PatternDiscoms do not yet to put systems in place to incentivise use of power in oof peak hours	Dicoms should use time of day (ToD) tariffs to incentivisechanges in demand patterns. Dynamic tariffs, enabled by advanced metering would help even out demand pattern

Table 7: Top 5 Companies of the World over a decade (Source Fortune 500 Rankings)

Rank	Year 2010	Year 2015	Year 2020
1	Walmart	Walmart	Apple
2	Exxon	Exxon	Microsoft
3	Chevron	Chevron	Alphabet
4	General Electric	Hathway	Amazon
5	Bank of America	Apple	Hathway

Table 8: The Use cases of Digitalisation in the Power Sector Value Chain

Generation	Transmission	Distribution	Overall
Optimal Plant Generation	Improved Decision Making	Customer Segmentation	Optimized Resource Planning
Optimal Plant Maintenance	Better overall Energy Balance	Workforce Productivity	Optimized Management
Spare Parts Management	Reduced Reactive Power Flow	Smart Metering and Collections	Optimized Operations
Fuel management	Reduced Line Losses	Digital Operations Better collections	Better Profitability

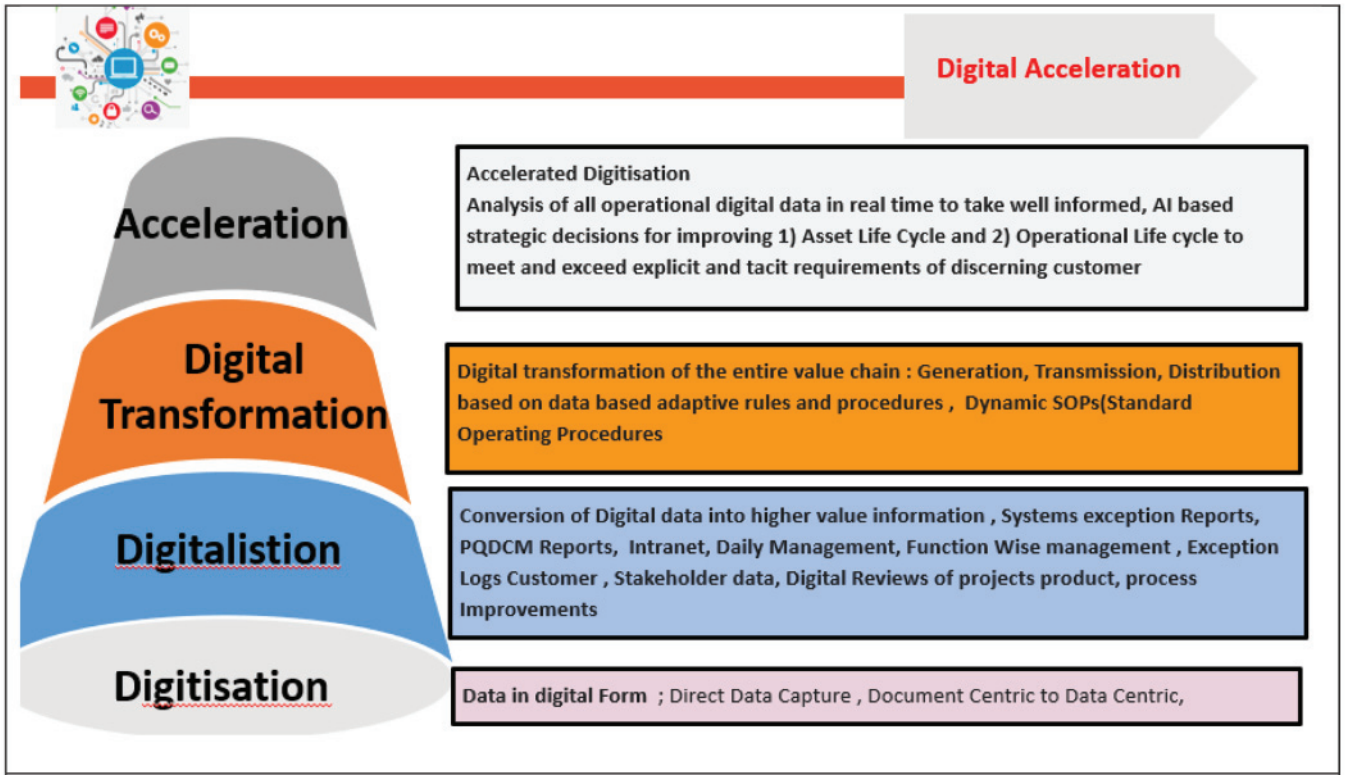

Fig.5: Digital Acceleration in Power Sector : A hierarchical Frame work

World's First Fully Solar Powered Airport

Fig.6: Cochin (Kochi) International Airport, Kerala India

fair price signals as relevant to their area. Off-grid solar plants should receive greater policy encouragement, as they can be cheaper and simpler than grid connected solar plants. mini-grids (an electricity distribution network involving decentralised small-scale generation from locally available renewable energy sources) can provide more predictable power in remote and sparsely populated areas. They can also be used to provide greater resilience to critical infrastructure such as hospitals. A PPP model can be explored.

Digitalisation

Digitalisation is no doubt the key the game changer in any industry. Let us review the top 5 companies of the world over the years. As can be seen in Table 7, there is a shift towards Digital World.

While earlier retail, energy and banking were the top performers but within a decade we can see all companies with digital footprint in the top 5 list. In power sector too digitization will be key to its survival and progress. A key aspect of digitization effort is providing easy access to data

to engineers and other experts, so that they can perform advanced analytics to improve outcomes. The improvements due to digitalisation in power sector could be many viz increased asset availabilities via predictive analytics, improving compliance through monitoring of key metrics, greater productivity, better plans, models, and budgets. In a typical power plant scenario, the use cases and benefits of digitalisation can be seen across the value chain as depicted in Table 8.

Digitalised systems have the capability to identify who needs energy and deliver it at the right time, in the right place and at the lowest cost. Digitalisation has helped in improving the safety, productivity, accessibility and sustainability of energy systems. It has helped in making power-generating assets more efficient, the electric grid more secure and resilient.

The sector needs to seize the opportunity and make full use of digital opportunity by way of adopting and accelerating its digital journey in a systematic manner as depicted in Fig.5

By following a step-by-step hierarchical approach as depicted in Fig.5, the power sector can gain immensely in its operations, viability and profitability. The actions have to all across the from planning stage itself, right and optimised, infrastructure creation and efficient and effective infrastructure utilisation across the value chain of generation, transmission and distribution.

The future trends

The power sector across the world and in India is in transition. Few futuristic trends in India would be:

Coal power to decline, natural gas to grow (an interim transition measure) renewables reaching grid parity, growth in industrial and residential solar, commercial renewable PPAs, Discoms would be getting in on the solar game, new distribution grids to integrate more renewables, battery based huge energy storage (albeit awaiting battery prices to come down), Discoms to become more customer centric and become "trusted energy advisor" to customers, electrification in various segments, data collection from smart meters, software tools for analysis and decision-making, cloud-based technology shall be harnessed to enhance the efficiency of the sector. Plant efficiency, micro grids, increased liquidity in the sector through government schemes, enhanced public private partnerships, Electrification leading to electricity for all, electrification of sectors to shift away from dependency on imported oil such as retiring of gas/oil fired furnaces in Industry, electrification in transportation (Rail, Road, EVs), more traction of EE (energy efficient) devices viz smart and efficient ACs, fans, lights, IoT based Industry 4.0 applications, System based on Internet of Things (ioT) based devices that can harvest heat, light and vibration energy from the environment.

Changes will require flexibility throughout the power sector. Most new generation capacity is likely to be renewable. Increased flexibility in generation will be required - both physical (flexible generation, and demand response) and institutional (such as access to markets). The transmission sector will require greater capacity to evacuate power from renewable-rich regions to the rest of the nation. Digitalisation of the grid will enable bidirectional flow of information and power. Utility-scale energy storage, being able to act as load or as supply, will play an important role in enhancing the flexibility of the system.

Electricity Policy 2021, the announcement of the Ancillary Services Market regulation and the Market-Based Economic Dispatch (MBED), signal promising progress. Once implemented, these developments will allow new assets such as batteries and demand response to participate in providing grid services and will transition power procurement to a market-based mechanism that enables least-cost, clean generation.

Within the renewables, solar will be a massive source of energy in India the solar energy tariffs in India have already reduced from Rs.7.36/kWh (US 10 cents/kWh) in FY15 to Rs.2.45/kWh (US 3.2 cents/kWh) in July 2021. There would be huge traction both at micro (Domestic household, agriculture and industrial) and at macro (solar farms, solar harvesting) levels. For example, Cochin Airport is already the world's first fully solar powered airport of the world (Fig.6).

In the world and also in India, emphasis would be on research and development to harness the non-conventional untapped and under tapped energy sources viz RE (wind/solar), fuel cells, small modular nuclear fission plants, Nuclear fission plants, harnessing tidal energy, harnessing geo-thermal energy, shell gas, hydrogen gas, developing battery storage systems of grid scale, micro grids, smart grid technologies (allowing bidirectional flow of power), energy efficient (EE) end use equipment and consumption devices,

We need to have a close watch on these trends and seize the opportunities thrown by these expected developments.

The way forward

While India is already 3rd largest producer and 2nd largest consumer of electricity, the demand is growing further, thus the sector is an attractive opportunity. Central Electricity Authority (CEA) estimates India's power requirement to grow to reach 817 GW by 2030. Whereas it is also envisaged that India should pitch for renewable energy capacity of 500 GW by 2030. Government is facilitating the process. In budget 2022-23, GOI gas announced sovereign green bonds, infrastructure status to energy storage and grid scale battery systems, allocated Rs.19500 crores to PLI scheme for high efficiency solar power generation. The DDUGJY (electricity to all villages) and integrated power development (IPDS) will augment electrification countrywide. 24% of total capex (~Rs

112 lakh crores) in the current 5-year plan is earmarked for energy sector. There is already steady traction of FDI flows.

We should seize this huge opportunity and the way forward is

- Continuous focus on de-carbonisation, (aim for negative carbon footprint)
- Sustainable, reliable and affordable transition to new power regime
- Improve overall generation capacity
  - * Continue with fossil fuel generation
  - * Promote natural gas as a 'transition fuel'
  - * Move towards using renewable energy as the main power source in the long run
- Address the challenges as per the transformation matrix presented
  - * Capacity utilisation: Raw material security coal, gas, logistics,
  - * Set up efficient new capacities (with mix and velocity to meet goals)
  - * Grid modernisation including adoption of micro grids
  - * Improve SEB/Discom efficiency,
  - * Finance management: Utilise PPP and FDI,
- Enhanced public private partnership model
- Accelerated digitisation: Adoption of Industry 4. 0, Cloud and AI based decision support measures to improve efficiency, smart metering, customer centric app-based systems,
- Energy storage Infrastructure

Our target should be to create a clean, prosperous, and secure low-carbon future. We need to engage all stakeholders to do so. Institutions like NPTI need to work as facilitators and encourage all stakeholders including generation, transmission and distribution entities entrepreneurs, business houses to accelerate the adoption of market-based solutions to cost-effectively migrate from fossil fuels to efficiency and renewables, accelerate digital journey.

Huge R&D and technological effort would be necessary in harnessing alternative sources of energy, battery storage systems, smart grids, micro-grids and for improving efficiencies and effectiveness of Indian power sector.

The opportunity is huge and we need to put our act together to seize it and participate in this invigorating transformation journey of Indian power sector in the coming few years, starting now.

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