

NATIONAL ELECTRICITY PLAN (Draft)

Generation Vol- I

[In fulfilment of CEA's obligation under section (4) of the Electricity Act 2003]



Government of India
Ministry of Power
Central Electricity Authority
September, 2022



National Electricity Plan

(Volume I)

Generation

[In fulfilment of CEA's obligation under
Section 3(4) of the Electricity Act 2003]

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September, 2022

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ACRONYMS

ACRONYMS	EXPANSION
AC	Alternating Current
ACC	Air Cooled Condensers
ACQ	Annual Contracted Quantity
AGDSM	Agricultural Demand Side Management
AHEC	Alternate Hydro Energy Centre
AHP	Ash Handling Plant
APC	Auxiliary Power Consumption
APDRP	Accelerated Power Development and Reforms Programme
APM	Administered Price Mechanism
AT&C	Aggregate Technical and Commercial
BAU	Business As Usual
BCD	Basic Custom Duty
Bcum, BCM, Bm³	Billion cubic metre
BEE	Bureau of Energy Efficiency
BHEL	Bharat Heavy Electricals Ltd.
BIS	Bureau of Indian Standards
BLY	Bachat Lamp Yojna
BoP	Balance of Payment/Balance of Plant
BESS	Battery Energy Storage System
BPL	Below Poverty Line
BT	Billion Tonnes
BTG	Boiler Turbine Generator
BU	Billion Units
BWR	Boiling Water Reactor
CAD	Computer-Aided Design
CAES	Compressed Air Energy Storage
CAGR	Compounded Annual Growth Rate
CBIP	Central Board of Irrigation & Power
CBM	Coal Bed Methane
CCEA	Cabinet Committee on Economic Affairs
CCGT	Combined Cycle Gas Turbine
CDM	Clean Development Mechanism
CEA	Central Electricity Authority
CED	Chandigarh Electricity Department
CERC	Central Electricity Regulatory Commission
CFBC	Circulating Fluidized Bed Combustion
CFD	Computational Fluid Dynamics
CFL	Compact Fluorescent Lamp
CFFP	Central Forge & Foundry Plant
CHP	Combined heat and power
CIL	Coal India Limited

ACRONYMS	EXPANSION
CIMFR	Central Institute of Mining and Fuel Research
CII	Confederation of Indian Industry
CIL	Coal India Ltd.
CLA	Central Loan Assistance
COD	Date of Commercial Operation
CO	Carbon mono oxide
CO₂	Carbon di oxide
COP 26	Conference of the Parties 26
CPP	Captive Power Plant
CPRI	Central Power Research Institute
CPSU	Central Public Sector Undertaking
Crs	Crores
CRGO	Cold Rolled Grain Oriented
CRNGO	Cold Rolled Non Grain Oriented
CS	Central Sector
CSIR	Council for Scientific and Industrial Research
CSP	Concentrated solar power
CST	Central Sales Tax
CT	Cooling Tower
CTO	Consent To Operate
CUF	Capacity Utilization Factor
DAE	Department of Atomic Energy
DBFOT	Design-Build-Finance-Operate-Transfer
DBFOO	Design, Build, Finance, Own, and Operate
DC	Designated Consumers
DDG	Decentralised Distributed Generation
DDUGJY	Deen Dayal Upadhyaya Gram Jyoti Yojana
DEEP	Discovery of Efficient Electricity Price
DELP	Domestic Efficient Lighting Programme
DFC	Dedicated Freight Corridor
DGH	Director General Hydro Carbon
DG	Diesel Generating
DISCOM	Distribution Company
DPR	Detailed Project Report
DR	Demand Response
DSM	Demand Side Management
DST	Department of Science & Technology
DVC	Damodar Valley Corporation
DVR	Dynamic Voltage Restorer
EA 2003	Electricity Act 2003
EC	Energy Conservation
EC Act	Energy Conservation Act
ECBC	Energy Conservation Building Code

ACRONYMS	EXPANSION
EE	Energy Efficiency
EEFP	Energy Efficiency Financing Platform
EESL	Energy Efficiency Services Limited
EEZ	Exclusive Economic Zone
EGoM	Empowered Group of Ministers
EIA	Environmental Impact Assessment
ELCOMA	Electric Lamp and Component Manufacturers' Association of India
EMU	Electrical Multiple Units
ENS	Energy Not Served
EPC	Engineering Procurement Contract
EPS	Electric Power Survey
EPSC	Electric Power Survey Committee
ERDA	Electric Research & Development Association
ESCos	Energy Service Company or Energy Savings Company
ESCert	Energy Saving Certificate
ESP	Electro Static Precipitator
EU	European Union
EV	Electric Vehicles
FAUP	Fly Ash Utilisation Programme
FBC	Fluidised Bed Combustion
FEEED	Framework for Energy Efficient Economic Development
FESS	Fly wheels energy storage system
FGD	Flue-gas desulfurization
FICCI	Federation of Indian Chambers of Commerce & Industry
FO	Forced Outage
FOR	Forum of Regulators
FRP	Fibre-Reinforced Plastic
FSA	Fuel Supply Agreement
GAIL	Gas Authority of India Limited
GBI	Generation Based Incentive
GCV	Gross Calorific Value
GCF	Green Climate Fund
GDP	Gross Domestic Product
GEF	Green Energy Fund
GHAVP	Gorakpur Haryana Anu Vidyut Pariyojana
GHG	Green House Gas
GIS	Geographic Information System
GPS	Geographic Positioning System
GR	General Review
GSPC	Gujarat State Petroleum Corporation
GT	Gas Turbine
GTAM	Green Term Ahead Market
GW	Giga Watt

ACRONYMS	EXPANSION
H2FC	Hydrogen Fuel Gas
HBJ	Hazira-Bijapur-Jagdishpur (pipeline)
HCSD	High Concentration Slurry Deposit
HFO	Heavy Fuel Oil
HEP	Hydro Electric Project
HELP	Hydrocarbon Exploration and Licensing Policy
HHV	Higher Heating Valve
HLEC	High-Level Empowered Committee
HoG	Head on Generation
HPO	Hydro Purchase Obligation
HRD	Human Resource Development
HSD	High Speed Diesel
HT	High Tension
HVDS	High Voltage Distribution System
HVAC	High Voltage Alternating Current
HVDC	High Voltage Direct Current
HVJ	Hazira-Vijaipur-Jagdishpur
IAEA	International Atomic Energy Agency
IC	Installed Capacity
ICAR	Indian Council for Agricultural Research
ID	Induced Draft
IEA	International Energy Agency
IEP	Integrated Energy Policy
IEEMA	Indian Electrical and Electronics Manufacturers Association
IGCAR	Indira Gandhi Centre for Atomic Research
IGCC	Integrated Gasification Combined Cycle
IISC	Indian Institute of Science
IIT	Indian Institute of Technology
IMTF	Inter-Ministerial Task Force
INDC	Intended Nationally Determined Contribution
IPCC	Intergovernmental Panel on Climate Change
IPDS	Integrated Power Development Scheme
IPP	Independent Power Producer
IR	Indian Railway
IRP	Integrated Resource Planning
ISA	International Solar Alliance
ITI	Industrial Training Institutes
IS	Indian Standard
ISCC	Integrated Solar Combined Cycle
ISO	International Standard Organisation
IT	Information Technology
JMVP	Jalmarg Vikas Project
JVs	Joint Ventures

ACRONYMS	EXPANSION
KAPP	Kakrapar Atomic Power Plant
kCal	kilo Calorie
kgoe	Kilogram of oil equivalent
KGD6	Krishna Godavari Dhirubhai 6
KKNPP	Kudankulam Nuclear Power Project
kW	kilo Watt
kWh	kilo Watt hour
LCAC	Light Commercial Air Conditioners
LE	Life Extension
LEP/LE	Life Extension Programme
LED	Light Emitting Diode
LF	Load Factor
LIDAR	Light Detection and Ranging
LNG	Liquefied Natural Gas
LOA	Letter of Award
LOLP	Loss of Load Probability
LP	Linear Programming
LSHS	Low Sulphur Heavy Stock
LT	Low Tension
LWR	Light Water Reactor
Mcm	Million cubic metre
MCP	Market Clearing Price
MEMU	Mainline Electrical Multiple Unit
MII	Make in India Initiative
MMPA	Million Metric Tonnes Per Annum
MMSCMD	Million Metric Standard Cubic Metre per Day
MNRE	Ministry of New & Renewable Energy
MNP	Minimum Need Programme
MOC	Ministry of Coal
MoEF&CC	Ministry of Environment ,Forest & Climate Change
MoP	Ministry of Power
MoP&NG	Ministry of Petroleum and Natural Gas
MoRTH	Ministry of Road Transport and Highways
MoU	Memorandum of Understanding
MPA	Major Port Authority
MuDSM	Municipality Demand Side Management
MT	Million Tonne
MTEE	Market Transformation for Energy Efficiency
MToe	Million Tonnes Oil equivalent
MU	Million Units
M&V	Monitoring & Verification
MW	Mega Watt
NAPCC	National Action Plan on Climate Change

ACRONYMS	EXPANSION
NAPS	Narora Atomic Power Station
NCDP	New Coal Distribution Policy
NDCs	Nationally Determined Contributions
NDT	Non Dispatchable Technologies
NECA	National Energy Conservation Awards
NEERMAN	National Energy Efficiency Roadmap for Movement towards Affordable & Natural Habitat
NEF	National Electricity Fund
NEP	National Electricity Plan
NELP	New Exploration Licensing Policy
NETRA	NTPC Energy Technology Research Alliance
NHDP	National Highway Development Project
NHM	National Hydrogen Energy Mission
NHPC	National Hydroelectric Power Corporation
NISE	National Institute of Solar Energy
NIWE	National Institute of Wind Energy
NLC	Neyveli Lignite Corporation Limited
NMDC	National Mineral Development Corporation
NMEEE	National Mission for Enhanced Energy Efficiency
NML	National Metallurgical Laboratory
NO_x	Oxides of Nitrogen
NPP	National Perspective Plan
NPCIL	Nuclear Power Corporation of India Ltd.
NPTI	National Power Training Institute
NPMU	National Smart Grid Mission Project Management Unit
NSGM	National Smart Grid Mission
NSM	National Solar Mission
NTPC	National Thermal Power Corporation
NW	National Waterway
OCGT	Open Cycle Gas Turbine
O&M	Operation & Maintenance
ODC	Over Dimension Consignment/ Over Dimension Cargo
OHE	Over Head Equipment
OSOWOG	One Sun One World One Grid
OWC	Over Weight Cargo
PAP	Project Affected People
PAT	Perform Achieve & Trade
PC	Pulverized Coal
PCRA	Petroleum Conservation Research Association
PDC	Project Development Cell
PFA	Power For All
PFBC	Pressurised Fluidized Bed Combustion
PFC	Power Finance Corporation

ACRONYMS	EXPANSION
PGCIL	Power Grid Corporation of India Limited
PHWR	Pressurised Heavy Water Reactor
PIE	Partnership In Excellence
PIB	Public Investment Board
PLF	Plant Load Factor
PLI	Performance Linked Incentive
PLL	Phase-locked loop
PMC	Project Management Consultants
PMGY	Pradhan Mantri Gramodaya Yojna
PMP	Phased Manufacturing Programme
PM KUSUM	Pradhan Mantri Kisan Urja Suraksha Evam Utthan Mahabhiyan
PPMP	Power Project Monitoring Panel
PPP	Public Private partnership
PRGF	Partial Risk Guarantee Fund
PRSF	Partial Risk Sharing Facility
POSO	Power System Operation Corporation
PPA	Power Purchase Agreement
PPM	Parts Per Million
PRGFEE	Partial Risk Guarantee Fund for Energy Efficiency
PS	Private Sector
PSA	Power Supply Agreement
PSC	Production Sharing Contract
PSDF	Power System Development Fund
PSP	Pump Storage Plant
PV	Photovoltaic
PSS	Pumped Storage Schemes
PSU	Public Sector Undertaking.
R&D	Research & Development
R&M	Renovation & Modernisation
R-APDRP	Restructured Accelerated Power Development and Reforms Programme
RAPS	Rajasthan Atomic Power Station
REB	Regional Electricity Board
REC	Rural Electrification Corporation
RECTPCL	REC Transmission Projects Limited
RES	Renewable Energy Sources
RFP	Request for Proposal
RFQ	Request for Quotation
RGGVY	Rajiv Gandhi Grameen Vidyutikaran Yojana
RGTEL	Reliance Gas Transportation Infrastructure Ltd
RHE	Rural Household Electrification
RLA	Residual Life Assesment
RLDC	Regional Load Dispatch Centre
RLNG	Regasified Liquefied Natural Gas

ACRONYMS	EXPANSION
RM	Reserve Margin
ROM	Run Of Mines
ROR	Run Of River
ROSHANEE	Roadmap of Sustainable and Holistic Approach to National Energy Efficiency
ROW	Right Of Way
RPCs	Regional Power Committees
RPO	Renewable Purchase Obligation
RSOP	Research Schemes on Power
R&M	Renovation & Modernisation
R&R	Rehabilitation & Resettlement
RTC	Round the Clock
SAARC	South Asian Association for Regional Corporation
SBDs	Standard Bidding Documents
SCADA	Supervisory Control and Data Acquisition
SCCL	Singareni Collieries Company Limited
SCR	Selective Control Reduction
SDAs	State Designated Agencies
SDL	State Development Loan
SEAD	Super-Efficient Appliance Development
SEB	State Electricity Board
SEC	Specific Energy Consumption
SECI	Solar Energy Corporation of India
SEEP	Super-Efficient Equipment Program
SERC	State Electricity Regulatory Commission
SIDHIEE	Simplified Digital Hands-on Information on Energy Efficiency
SJVNL	Satluj Jal Vidyut Nigam Limited
SLC(LT)	Standing Linkage Committee (Long-Term)
SLDC	State Load Dispatch Centre
SDL	Statutory Liquidity Ratio
S&L	Standard & Labelling
SMEs	Small & Medium Enterprises
SOG	Sanctioned & Ongoing
SO _x	Oxides of Sulphur
SPM	Suspended Particulate Matter
SS	State Sector
SSTS	Solid State Transfer Switches
STPP	Super Thermal Power Plant
STPS	Super Thermal Power Station
STUs	State Transmission Utilities
SWHS	Solar Water Heater System
T&D	Transmission & Distribution
TERI	The Energy Research Institute
TG	Turbine Generator

ACRONYMS	EXPANSION
TIFAC	Technology Information Forecasting & Assessment Council
TOD	Time Of The Day
TOR	Terms of Reference
TOU	Time of Use
TPES	Total Primary Energy Supply
TPP	Thermal Power Plant
TPS	Thermal Power Station
UAVs	Unmanned Aerial Vehicles
UDAY	Ujwal DISCOM Assurance Yojana
UHD	Ultra High Definition
ULB	Urban Local Bodies
UJALA	Unnat Jyoti by Affordable LED for All
UMPP	Ultra Mega Power Project
UN	United Nations
UNDP	United Nations Development Programme
UNFCCC	United Nations Framework Convention on Climate Change
UNNATEE	Unlocking National Energy Efficiency Potential
USC	Ultra Super Critical
UT	Union Territory
VAT	Value Added Tax
VCFEE	Venture Capital Fund for Energy Efficiency
VRE	Variable Renewable Energy
WTE	Waste to Energy

PREAMBLE FOR NATIONAL ELECTRICITY PLAN, 2022-27

Section 3(4) of Electricity Act, 2003 stipulates that, the Central Electricity Authority (CEA) shall prepare a National Electricity Plan in accordance with the National Electricity Policy and notify such plan once in five years.

Provided that the Authority while preparing the National Electricity Plan shall publish the draft National Electricity Plan and invite suggestions and objections thereon from licensees, generating companies and the public within such time as may be prescribed:

Provided further that the Authority shall –

- a) Notify the plan after obtaining the approval of the Central Government;
- b) Revise the plan incorporating therein the directions, if any, given by the Central Government while granting approval under clause (a).

Further Section 3(5) of said act stipulates that, the Authority may review or revise the National Electricity Plan in accordance with the National Electricity Policy.

Para 3 of National Electricity Policy, 2005 stipulates that, assessment of demand is an important pre-requisite for planning capacity addition. Also, section 73 (a) of the Electricity Act provides that formulation of short-term and perspective plans for development of the electricity system and coordinating the activities of various planning agencies for the optimal utilization of resources to sub serve the interests of the national economy shall be one of the functions of the CEA. The Plan prepared by CEA and approved by the Central Government can be used by prospective generating companies, transmission utilities and transmission/distribution licensees as reference document.

Accordingly, CEA shall prepare the National Electricity Plan that would be for a short-term framework of five years while giving a 15-year perspective and would include:

- Short-term and long term demand forecast for different regions;
- Suggested areas/locations for capacity additions in generation and transmission keeping in view the economics of generation and transmission, losses in the system, load centre requirements, grid stability, security of supply, quality of power including voltage profile etc. and environmental considerations including rehabilitation and resettlement;
- Integration of such possible locations with transmission system and development of national grid including type of transmission systems and requirement of redundancies; and
- Different technologies available for efficient generation, transmission and distribution.
- Fuel choices based on economy, energy security and environmental considerations.

While evolving the National Electricity Plan, CEA will consult all the stakeholders including State Governments and the State Governments would, at state level, undertake this exercise in coordination with stakeholders including distribution licensees and State Transmission Utilities (STUs). While conducting studies periodically to assess short-term and long-term demand, projections made by distribution utilities would be given due weightage. CEA will also interact with institutions and agencies having economic expertise, particularly in the field of demand forecasting. Projected growth rates for different sectors of the economy will also be taken into account in the exercise of demand forecasting.

Accordingly, the first National Electricity Plan covering the review of 10th plan, detailed plan for 11th plan and perspective Plan for 12th Plan was notified in the Gazette in August, 2007.

The Second National Electricity Plan covering the review of 11th plan, detailed plan for 12th plan and perspective Plan for 13th plan was notified in the Gazette in December, 2013 in two volumes (**Volume-I, Generation and Volume-II, Transmission**).

The Third National Electricity Plan covers the review of 12th Plan, detailed Plan for 2017-22 and perspective Plan for 2022-27 and was notified in the Gazette of India (Volume-I-Generation in March 2018 and Volume-II – Transmission in January, 2019)

In order to initiate the work of preparation of NEP for the next five years (2022-27), a committee on National Electricity plan under the chairmanship of Chairperson, CEA has been constituted by CEA vide office order no.

File No.CEA-PL-11-12/1/2019-IRP Division dated 16.06.2020.In order to elicit views of various experts in Power Sector in the work relating to the preparation of the National Electricity Plan for the next five years (2022-2027), a committee for National Electricity Plan is constituted with following composition and Terms of Reference (TOR).

COMMITTEE FOR PREPARATION OF NATIONAL ELECTRICITY PLAN 2022-27

A. CONSTITUTION:

- i. Chairperson, CEA - **Chairman**
- ii. Chief Engineer(IRP), CEA - **Member Secretary**

MEMBERS

- i. All Members of CEA
- ii. Economic Advisor, MOP
- iii. Representative of MNRE not below the rank of JS, (MNRE)
- iv. Director General, BEE
- v. Advisor(Energy), NITI Aayog
- vi. Director General, CPRI
- vii. Chairman cum Managing Director, NTPC
- viii. Chairman cum Managing Director, NHPC
- ix. Chairman cum Managing Director, PGCIL
- x. Chairman cum Managing Director, PFC
- xi. Chief Executive Officer, (POSOCO)
- xii. Chairman cum Managing Director, NPCIL
- xiii. Chairman cum Managing Director, REC
- xiv. Chairman cum Managing Director, EESL

B. TERMS OF REFERENCE OF THE COMMITTEE FOR NATIONAL ELECTRICITY PLAN, 2022-27

- i. To review the likely achievements vis-à-vis targets set for the 2017-22 period towards generation from conventional sources along with reasons for shortfalls, if any.
- ii. To assess the peak load and energy requirement for the period 2022-27 and perspective forecast for 2027-32.
- iii. To assess the incremental capacity requirement to meet the projected load and energy requirement after considering retirements, renewable and captive injection and suggest the feasible break up in terms of thermal, hydro, nuclear ,renewables etc.
- iv. To make an assessment of the resource requirement like fuel, land, water, indigenous manufacturing capabilities, infrastructural, human resource for meeting the capacity addition requirements.
- v. To assess investment requirement for generation and transmission capacity addition during 2022-27 and beyond.
- vi. To suggest energy conservation measures through Demand Side Management and suggest a strategy for low carbon growth.
- vii. Review of latest technological development and R & D in the power sector and to assess its suitability for Indian conditions.
- viii. Development of integrated Transmission Plan for the period from 2022-27 and perspective plan for 2027-32 including Grid Security, evacuation of Renewable Energy Sources and exploring SAARC integration.

- C. 1. The NEP committee may co-opt any expert as may be considered necessary.
2. NEP committee may constitute separate sub-Committees on any aspect. The report of the Sub-Committee(s) shall be submitted to NEP Committee for consideration.

The first meeting of the Committee for the National Electricity Plan (NEP), 2022-27 was held on 6th August, 2020 under the chairmanship of Chairperson, CEA wherein, it was decided to constitute 10 nos. of Sub-Committees to look into different aspects of power sector and provides inputs to committee for NEP. Thereafter NEP Committee had met on 21.01.2022.The constitution and TOR of the Sub-Committees are given as:

**CONSTITUTION AND TERMS OF REFERENCE OF 10 SUB COMMITTEES CONSTITUTED UNDER
COMMITTEE FOR NATIONAL ELECTRICITY PLAN, 2022-27**

1. SUB-COMMITTEE- 1- DEMAND SIDE MANAGEMENT, ENERGY EFFICIENCY & CONSERVATION

CONSTITUTION:

- Director General(BEE)- Chairman
- Chief Engineer(TPE&CC), CEA - Member Secretary

MEMBERS:

- Representative from NTPC, EESL,PCRA,CII,IEEMA,ELCOMA
- Chief Engineer(DP&T), CEA
- Representative from Energy Intensive Industry
- Representative from Major DISCOM

TERMS OF REFERENCE OF SUB-COMMITTEE:

- Assess and review energy efficiency & conservation measures implemented and achievements till 2022.
- Major Plans for efficiency improvement during the period 2022-27 and 2027-32
- Assessment of reduction in energy requirement and peak load demand through demand side management (DSM) and energy efficiency.

2. SUB-COMMITTEE 2: DEMAND PROJECTION

CONSTITUTION:

- Member (Planning), CEA - Chairman
- Chief Engineer (PS& LF), CEA - Member Secretary

MEMBERS:

- Representative from MNRE, NITI Aayog, BEE, POSOCO,NTPC
- Chief Engineer(DP&T),CEA
- Representative from State Discoms
- Representative from Energy Intensive Industry

TERMS OF REFERENCE OF SUB-COMMITTEE:

- In coordination with the 20th EPS committee, demand assessment in terms of peak load and energy requirements for the period from 2022-2027 & 2027-2032.
- To assess captive demand including Solar roof top and its impact on Grid demand.
- To assess the impact of various Govt. schemes for ex. Kusum, Saubhagaya, National Electric mobility mission plan, etc on Grid demand.

3. SUB-COMMITTEE 3: REVIEW OF GENERATION CAPACITY ADDITION (2017-22) AND GENERATION PLANNING

CONSTITUTION:

- Member (Planning), CEA- Chairman
- Chief Engineer (IRP), CEA – Member Secretary
-

MEMBERS:

- Representative from MNRE,CTU,POSOCO, NPCIL,BHEL ,Sterlite, L&T, TPPDL,

- Representative from Solar Energy Corporation of India
- Representative from National Institute for Wind Energy
- CEA- CE(RPM),CE(TPM),CE(TPRM),CE(HPM),CE(TPP&D),CE(HPI),CE(GM)

TERMS OF REFERENCE OF SUB-COMMITTEE:

- To review generation capacity addition achievements vis-à-vis targets during 2017-22 including new & renewable energy and reasons for shortfalls if any.
- Assessment of generation capacity addition during 2022-27 and 2027-32 including renewable energy sources and its integration thereof.

4. SUB-COMMITTEE 4- RESEARCH AND DEVELOPMENT IN POWER SECTOR**CONSTITUTION:**

- Director General, CPRI - Chairman
- Chief Engineer(R&D),CEA - Member Secretary

MEMBERS:

- Representative from MNRE, National Institute for Solar Energy & National Institute for Wind Energy
- Representative from NETRA,NTPC
- Representative from IEEMA, IIT Kanpur, PGCIL, DST, BHEL
- CEA- CE(TETD), CE(HETD), CE(SETD)

TERMS OF REFERENCE OF SUB-COMMITTEE:

- Review of existing R&D facilities & programmes in Power sector
- Recommendation regarding R&D activities to be taken up during 2022-27 & 2027-32,
- Issues relating to cyber security
- To assess the infrastructure requirement to promote R&D activities in Power Sector.
- To identify future technologies in power generation including waste (Municipality, hospital, Industrial etc.)

5. SUB-COMMITTEE 5- FUEL REQUIREMENT**CONSTITUTION:**

- Member(Planning), CEA as Chairman
- Chief Engineer,(FM), CEA as Member Secretary

MEMBERS:

- Representative from MOP&NG, MOC, NTPC, NPCIL, NLC, GAIL,CIL
- CEA- CE(IRP),CE(TPP&D)

TERMS OF REFERENCE OF SUB-COMMITTEE:

- Identify and quantify the different types of fuels required to meet the electricity demand for the period 2022-27 and 2022-32
- To assess the availability of fuel source wise.

6. SUB-COMMITTEE 6- FUND REQUIREMENT**CONSTITUTION:**

- Member, (E&C), CEA as chairman
- Chief Engineer(F&CA), CEA as Member Secretary

MEMBERS:

- Representative from MOP, MNRE, NITI Aayog, NTPC,PGCIL ,NHPC, NPCIL, PFC, REC
- CEA-CE(TPP&D),CE(HPI),CE(PSP&A I)

TERMS OF REFERENCE OF SUB-COMMITTEE:

- Review of financial issues related to power sector
- Identify the investment required to meet the capacity addition and associated transmission system and possible sources of fund etc.

7. SUB-COMMITTEE 7: KEY INPUTS FOR POWER SECTOR**CONSTITUTION:**

- CMD, NTPC as Chairman
- Chief Engineer(TETD), CEA as Member Secretary

MEMBERS:

- Representatives of MoP&NG, Ministry of Railways, Ministry of Steel, Ministry of Road Transport and Highway, Ministry of Shipping, MNRE, CPRI,PFC,BHEL, NHPC, Private Equipment Manufacturer, CII.
CEA-CE(TPP&D),CE (PSP&A-I), CE(SETD), CE(TPRM)

TERMS OF REFERENCE OF SUB-COMMITTEE:

- Identify the key inputs required for meeting the capacity addition requirements
- To assess infrastructural support required for Power capacity addition during 2022-27 & 2027-32.
- Land , water Requirement & its availability
- Transport(Railways, Roads, Waterways, pipeline, LNG terminals), Port facilities
- Construction & manufacturing capabilities specifically erection machinery and agencies including civil and BOP contractors. Steel, cement, aluminium & other materials required for construction work in power sector.
- Assessment of sourcing inputs for power Sector under the Atmanirbhar Bharat initiative.

8. SUB-COMMITTEE 8- TRANSMISSION PLANNING**CONSTITUTION:**

- Member(PS), CEA as Chairman
- Chief Engineer (PSP&A-I) as Member secretary

MEMBERS:

- Representative of MNRE,PGCIL,POSOCO,PFC,REC, State Transmission Utility, CTU Distribution Licensee
- CEA- CE(PSP&A-II),CE(PSPM),CE(SETD),RPCs

TERMS OF REFERENCE OF SUB-COMMITTEE

- Review of achievement of targets for the period of 2017-22 for transmission and reasons of shortfall if any.
- Development of integrated transmission plan for the period from 2022-27 and perspective plan for 2027-32.
- Technology development in transmission

9. SUB-COMMITTEE 9- HUMAN RESOURCE REQUIREMENT

CONSTITUTION:

- Member(E&C), as Chairman
- Chief Engineer(HRD),CEA as Member Secretary

MEMBERS:

- Representatives of MNRE,PGCIL,NTPC,NHPC, POSOCO , two State GENCOs
- Representative from NPTI, PSTI
- Representative from National Skill Development Corporation

TERMS OF REFERENCE OF SUB-COMMITTEE:

- Assess the human resource requirement in power sector for the period 2022-27 and 2027-32.
- Human Resource Development Plans including training need assessment and infrastructure required.

10. SUB-COMMITTEE-10: REQUIREMENT OF FLEXIBLE RESOURCES FOR GRID STABILITY

CONSTITUTION:

- Member (Planning), CEA as Chairman
- Chief Engineer (PSP&A -II) as Member Secretary of the Sub-committee.

MEMBERS:

- Representative from MNRE, NITI AAYOG, CTU, POWERGRID, NHPC, NTPC,NPCIL, POSOCO,PFC
- CEA- Chief Engineer (IRP), Chief Engineer (TETD), Chief Engineer (PSP&A I), Chief Engineer (R&D), Chief Engineer(HETD), Chief Engineer(HP&I), Chief Engineer (TPRM)

TERMS OF REFERENCE OF SUB-COMMITTEE:

- To assess the requirement of flexible resources for grid stability.
- To identify various flexible resources available for grid operation including energy storage options for better operational characteristics, better utilization of Renewable energy, etc.
- Development of future roadmap for integration of energy storage system for better Operational characteristics, better utilization of Renewable energy, etc.
- To formulate roadmap for maximum utilization of renewable energy by flexible operation of conventional generating units keeping in consideration Grid stability, Security, reliability and cost constraints.

MAJOR HIGHLIGHTS

The National Electricity Plan includes a review of the period 2017-22, detailed capacity addition requirement during the years 2022-27 and Perspective Plan projections for the years 2027-32. Major Highlights are as follows.

- i) The scheduled capacity addition from conventional sources during the period of 2017-22 was 51,561.15 MW as per National Electricity Plan, 2018. The capacity addition achieved from conventional sources is 30,667.91 MW for the year 2021-22.
- ii) India has achieved a cumulative installed renewable energy capacity (including large hydro) of 156607.9 MW as on 31.03.2022.
- iii) Capacity consisting of Coal (18320 MW), Hydro (4801.5 MW) and Nuclear (3300 MW) envisaged during the period 2017-22 is slipped where COVID-19 being the major reason resulting in delay.
- iv) The projected electrical energy requirement and peak electricity demand on all-India basis is estimated as 1874 BU and 272 GW for year 2026-27 and 2538 BU and 363 GW for year 2031-32 respectively.
- v) Projections of energy savings for utility and non-utility is estimated to be 213 TWh for the year 2026-27 and 404 TWh for year 2031-32.
- vi) The projections of reduction of energy demand through implementation of various programmes of Demand side management is 398.49 BU for year 2026-27 and 590.53 BU for year 2031-32.
- vii) The Installed Capacity of the country as on 31.03.2022 was 398986 MW(excluding 510 MW of Diesel) comprising of 235599 MW thermal, 6,780 MW Nuclear and 156607MW renewables This is considered as a base installed capacity for the study period 2022-32.
- viii) Under construction plants comprising of 25,950 MW of Thermal Power Plants, 10,903 MW of Hydro Power plants, 1580 MW of Pumped storage plants and 7,000 MW of Nuclear Power plants has been considered for the studies during period of 2022-27. Additionally, a likely capacity of 8700 MW of Nuclear Power plants which are at under various stages of construction (or in advance stages of development) likely to benefit during period 2027-32.
- ix) The retirement for period 2022-27 has been considered as 4629 MW.
- x) The capacity addition required during 2022-27 to meet the peak demand and energy requirement for the year 2026-27 is 2,28541 MW comprising of 40,632 MW of Conventional capacity addition (Coal-25580MW, Gas-370 MW and Nuclear-7000MW) and 187,909 MW of Renewable based Capacity Addition (Large Hydro-10951 MW, Solar-132,080, Wind-40500 MW, Biomass-2318 MW, PSP-2700 MW) excluding 5,856 MW of likely Hydro based Imports.
- xi) The capacity addition required during 2027-32 to meet the peak demand and energy requirement for the year 2031-32 is 2,43,042 MW comprising of 18,134 MW of Conventional capacity addition (Coal-9,434 MW, Nuclear-8700 MW) and 224,908 MW of Renewable based Capacity Addition (Large Hydro-10,888 MW, Solar-147,400, Wind-53,100(Onshore- 43,100 and Offshore 10,000 MW, Biomass-1,500 MW, PSP-12,020 MW) excluding 5,856 MW of likely Hydro based Imports

- xii) All India installed capacity is likely to be 6,22,899 MW at the end of year 2026-27 and 8,65,941 MW at the end of year 2031-32.
- xiii) It is seen that apart from under construction coal based capacity of 25GW, the additional coal based capacity required till 2031-32 may vary from 17 GW to around 28 GW. It is also seen that the BESS (5-hour) requirement in 2031-32 is varying from 51 GW to 84GW.
- xiv) The Projection of Total capacity addition are in line with the target of the country to achieve a non-fossil based installed capacity of 500 GW by the year 2029-30.
- xv) A PSP based storage capacity of 6.81 GW is required to meet the projected peak electricity demand and energy requirement in 2026-27. A PSP based capacity of 18.82 GW and 5-hour BESS capacity of 51.56 GW is likely to be required to meet the peak electricity demand and energy requirement in 2031-32.
- xvi) A generation of 1968 BU comprising of coal based -1158.8 BU, Gas based-35 BU, Nuclear based- 82 BU, Large Hydro based- 189 BU (including generation from Hydro imports), PV based-326 BU, Wind based- 170 BU and SHP based-8 BU, is projected during the year 2026-27 based on the generation planning studies to meet the projected hourly demand.
- xvii) The average PLF of the total Installed coal capacity of 239.3 GW was found to be about 55% in 2026-27. The average PLF of the total Installed coal capacity of 248.9 GW was found to be about 62 % in 2031-32.
- xviii) The domestic coal requirement in the year 2026-27 have been estimated as 831.5 Million Tonnes and in 2031-32 as 1018.2 MT and Imports by plants designed on imported coal to be 40 Million tonnes.
- xix) The total fund requirement for the period 2022-2027 is estimated to be Rs. 14,30,718 Crores, which also includes the likely expenditure during 2022-27 for advance action for the projects expected to get commissioned during 2027-2032.
- xx) The total fund requirement for the period 2027-2032 has been estimated to be Rs. 17,15,608 Crores. This fund requirement does not include advance action for the projects which may get commissioned after 31.03.2032
- xxi) Based on the estimation of fund requirement for the period 2022-27 and considering sector-wise equity contribution mentioned in para 11.3.1, it is estimated that developers will be required to infuse equity amount totalling to Rs. 3,57,679 Crores. Further, they will have to arrange for total debt of Rs. 10,73,039 Crores.
- xxii) Similarly, the equity and debt requirement (excluding fund requirement for advance action for projects during the period beyond 31.03.2032) for the period 2027-2032 have been estimated as Rs. 4,28,902 Crores and Rs. 12,86,706 Crores respectively.
- xxiii) The average CO₂ emission rate from coal based stations in the country has been on declining trend indicating improvement in efficiency of power generation from coal based power plants.
- xxiv) During 2020-21, the country has achieved Fly Ash Utilization of 107.77 Million tonnes with percentage utilization of 60.97%.
- xxv) The total CO₂ emissions projected will increase from 910 Million tonnes in 2020-21 to 1030 Million tonnes in the year 2026-27 and 1180 Million tonnes in 2031-32.
- xxvi) The average emission factor is expected to reduce to 0.524 kg CO₂/kWh in the year 2026-27 and to 0.441 kg CO₂/kWh by the end of 2031-32.



DRAFT

CHAPTER 1

INTRODUCTION

1.0 BACKGROUND

Power infrastructure is one of the most critical component for prosperity and economic growth of country. The development of requisite power infrastructure is key for sustained growth of Indian economy. With the increase in economic activity, the demand for power is also increasing. India has witnessed electricity demand increase of around 4.1 % during the last decade and it is projected that the increase in electricity demand is likely to be 6 % per year for next decade. To meet the ever-increasing electricity demand, power sector in India has grown considerably. The enactment of Electricity Act, 2003, has brought in revolutionary changes in almost all the areas of the sector. Through this Act a conducive environment has been created to promote private sector participation and competition in the sector by providing a level playing field. This has led to significant investment in generation, transmission and distribution areas. Over the years the installed capacity of Power Plants (Utilities) has increased to 399496 MW as on 31.03.2022 from a meagre 1362 MW 1947. Similarly, the electricity generation increased from about 5.1 Billion units in 1950 to 1491.9 BU (including imports) in the year 2021-22. Regional grids have been integrated into a single national grid with effect from 31.12.2013 thereby providing free flow of power from one corner of the country to another through strong inter regional AC and HVDC links. As a result, the all India peak demand (MW) not met as well as energy (MU) not supplied have registered steady decline. The peak power deficit during 2021-22 has been 1.2 % and Energy Deficit has been 0.4 % only. This marginal shortage seen is on account of reasons other than unavailability of Generation Capacity.

To ascertain the objective of carbon free energy capacity addition through RE [excluding hydro above 25 MW] sources has exhibited a remarkable CAGR of 19 % since FY 2006–07. The contribution of RE sources(including Large Hydro) to the installed capacity has increased from 5.8% in 2006–07 to 39 % in 2021-22 till 31.03.2022 and its energy contribution in the total generation has increased to 21.54 % in 2021-22 from 1.5 % in 2006-07.

1.1 STIPULATION REGARDING NATIONAL ELECTRICITY PLAN

1.1.1 Stipulations Regarding National Electricity Plan in Electricity Act 2003

The Electricity Act, 2003 provides an enabling legislation conducive to development of the Power Sector in transparent and competitive environment, keeping in view the interest of the consumers.

As per Section 3(4) of the Electricity Act 2003, Central Electricity Authority (CEA) is required to prepare a National Electricity Plan in accordance with the National Electricity Policy and notify such Plan once in five years. The draft plan has to be published and suggestions and objections invited thereon from licensees, generating companies and the public within the prescribed time. The Plan has to be notified after obtaining the approval of the Central Government. The National Electricity Policy stipulates that the Plan prepared by CEA and approved by the Central Government can be used by prospective generating companies, transmission utilities and transmission/distribution licensees as reference document.

1.1.2 Stipulations Regarding National Electricity Plan in National Electricity Policy 2005

National Electricity Policy stipulates that the National Electricity Plan would be for a short-term framework of five years while giving a 15-year perspective and would include:

- Short-term and long term demand forecast for different regions;
- Suggested areas/locations for capacity additions in generation and transmission keeping in view of the economics of generation and transmission, losses in the system, load centre requirements, grid stability, security of supply, quality of power including voltage profile, etc.; and environmental considerations including rehabilitation and resettlement;
- Integration of such possible locations with transmission system and development of national grid including type of transmission systems and requirement of redundancies; and
- Different technologies available for efficient generation, transmission and distribution.
- Fuel choices based on economy, energy security and environmental considerations.

The Policy also stipulates that while evolving the National Electricity Plan, CEA will consult all the stakeholders including State Governments and the State Governments would, at State level, undertake this exercise in coordination with stakeholders including distribution licensees and State Transmission Utilities (STUs). While conducting studies periodically to assess short-term and long-term demand, projections made by distribution utilities would be given due weightage. CEA will also interact with institutions and agencies having economic expertise, particularly in the field of demand forecasting. Projected growth rates for different sectors of the economy will also be taken into account in the exercise of demand forecasting.

The Policy stipulates that in addition to enhancing the overall availability of installed capacity to 85%, a spinning reserve of at least 5% at national level would be needed to be created to ensure grid security, quality and reliability of power supply.

The Policy states that efficient technologies, like super-critical technology, Integrated Gasification Combined Cycle (IGCC) etc. and large size units would be gradually introduced for generation of electricity as their cost effectiveness gets established.

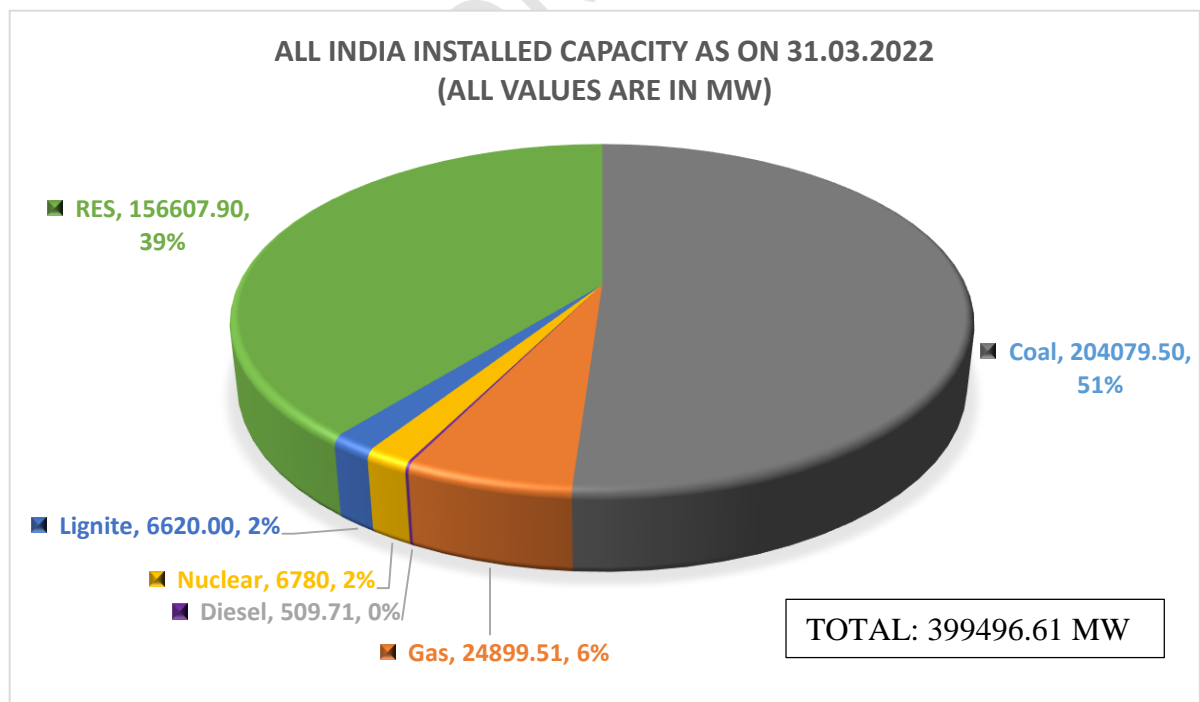
The present National Electricity Policy was enunciated in 2005 and since then it's various Aims and Objectives have achieved different levels of implementation. Keeping in view of these and to cater to the further challenges of the sector the National Electricity Policy is under revision.

1.2 POWER SCENARIO IN COUNTRY

1.2.1 Installed Capacity

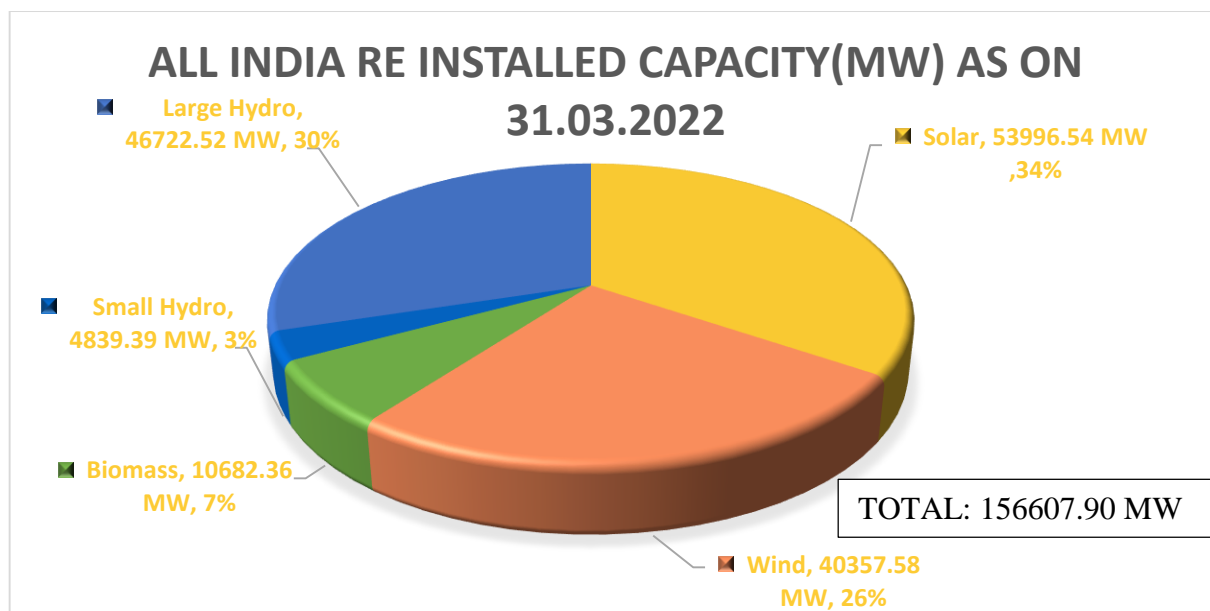
The Installed Capacity of the country as on 31.03.2022 was 399496.61 MW comprising of 236108.72 MW thermal, 6,780 MW Nuclear and 156607.90 MW renewables and is depicted in the **Exhibit 1.1**.

Exhibit 1.1



The country has significant potential of generation from renewable energy sources. All efforts are being made by Government of India to harness this potential. The Installed capacity as on 31st March, 2022 from renewable energy sources is 156607.90 MW. The total renewable installed capacity comprises of 46722.52 MW of Large Hydro, 40357.58MW of wind, 53996.54 MW of solar, 10682.36 MW of bio-Power & waste power and 4848.9MW of small hydro plants as shown in **Exhibit 1.2**.

Exhibit1.2



The growth of Installed Capacity and Electricity Generation in India from various sources is shown in **Table 1.1, Exhibit 1.3 and 1.4**.

Table 1.1

Growth of Installed Capacity & Electricity Generation

Plan/Year	Installed Capacity (MW)	IC Growth Rate YoY basis (%)	CARG for IC (%)	Generation (BU)	Generation Growth YoY basis (%)	CAGR for Generation (%)
At the end of 12 th Year plan	326832			1242		
2017-18	344002	5.25	4.1	1307.76	5.35	3.72
2018-19	356100	3.52		1375.95	5.21	
2019-20	370106	3.93		1389.12	0.96	
2020-21	382151	3.25		1381.86	-0.522*	
2021-22	399496	4.54		1491.9	7.96	

* COVID YEAR

Exhibit 1.3

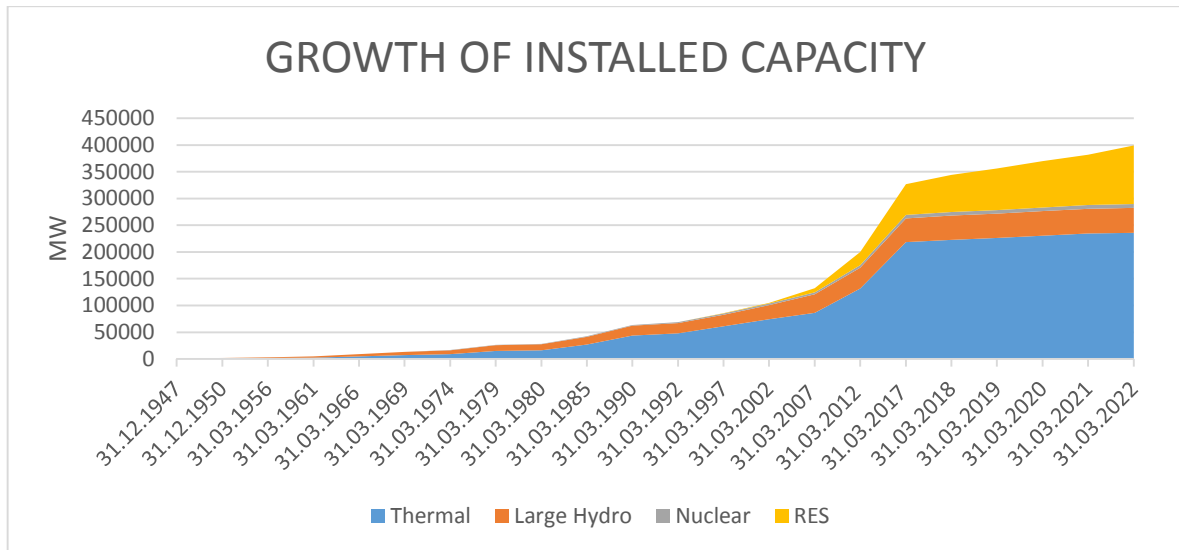
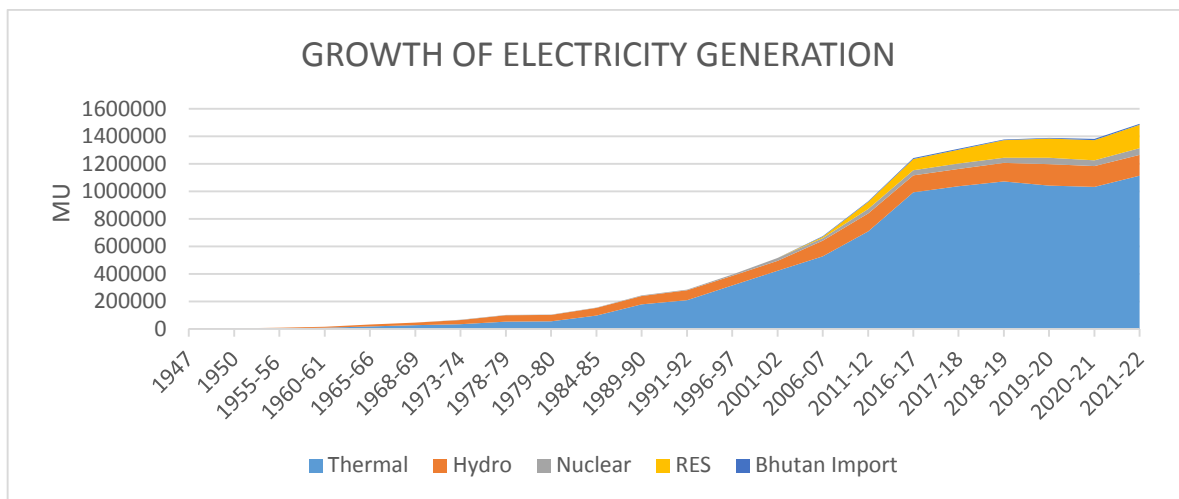


Exhibit 1.4



1.2.2 Per Capita Electricity Consumption

The per capita electricity consumption was 1122.00 kWh at the beginning of the 2017-18 i.e. 01.04.2017 and as on 31.03.2021 the per capita electricity consumption has increased to 1161 kWh. The per capita electricity consumption during 2017-22 is summarized in Table 1.2.

Table 1.2
Per Capita Electricity Consumption

YEAR	PER CAPITA CONSUMPTION (KWh)
2017-18	1149
2018-19	1181
2019-20	1208
2020-21	1161

1.2.3 Actual Power Supply Position

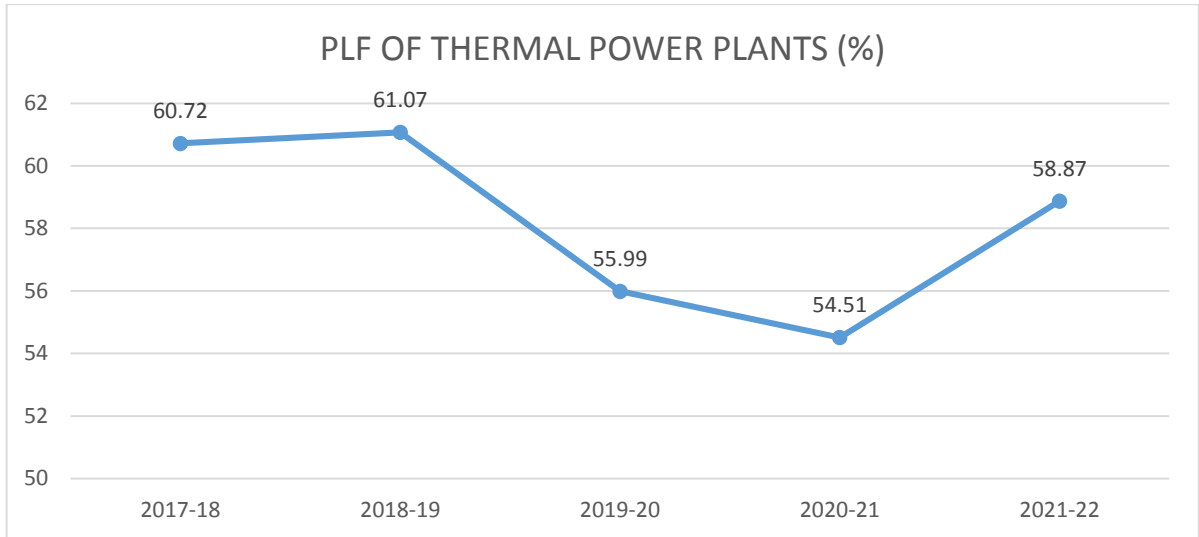
The peak demand not met was about 3,314 MW (2.0%) and the average energy not supplied in the country was about 8,629 MU (0.7%) during 2017-18. The peak not met and energy not supplied of the country has substantially declined to 2475 MW (1.2 %) and 5,787 MU (0.4%) respectively by the end of 2021-22. The power supply position in the country during 2017-22 is summarized in Table 1.3.

Table 1.3
All-India Actual Power Supply Position (2012-17)

Period	Peak Demand (MW)	Peak Met (MW)	Peak Not Met/ Surplus (MW) (- / +)	Peak Not Met/ Surplus (%) (- / +)	Energy Requirement (MU)	Energy Availability (MU)	Energy Not Supplied/ Surplus (Mu) (- / +)	Energy Not Supplied / Surplus (%) (- / +)
2017-18	164,066	160,752	3,314	2.0	1,213,326	1,204,697	8,629	0.7
2018-19	177,022	175,528	1,494	0.8	1,274,595	1,267,526	7,070	0.6
2019-20	183,804	182,533	1,271	0.7	1,291,010	1,284,444	6,566	0.5
2020-21	190,198	189,395	802	0.4	1,275,534	1,270,663	4,871	0.4
2021-22	2,03,014	2,00,539	2,475	1.2	13,79,812	13,74,024	5,787	0.4

1.2.4 Plant Load Factor of Thermal Based Power Plant

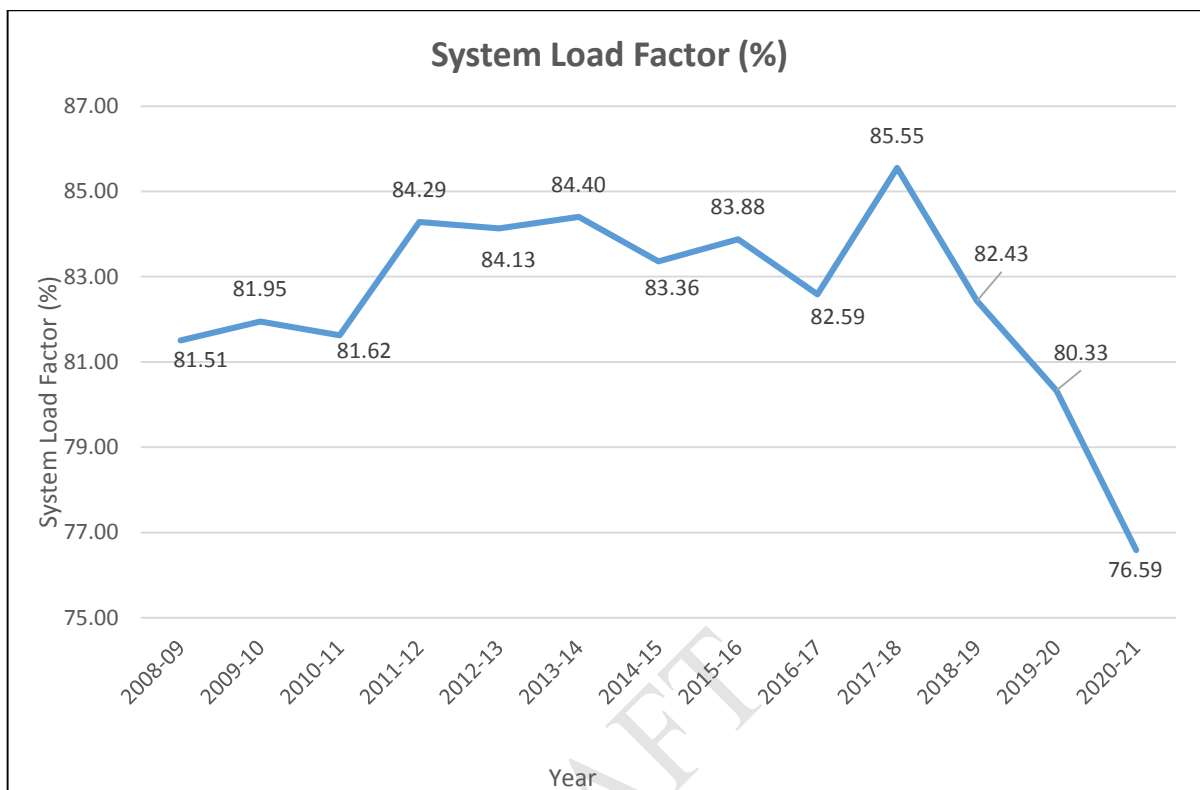
The national average Plant Load Factor (PLF) of Thermal based power generating stations for the year 2017-22 has been shown in **Exhibit 1.5**

Exhibit 1.5

1.2.5 Annual System Load Factor

The Annual System Load Factor is the ratio of the energy availability in the system to the energy that would have been required during the year if the annual peak load met was incident on the system throughout the year. This factor depends on the pattern of utilization of different categories of load. The Annual System Load factor has remained in the range of 82% to 86% since 2011-12 till 2017-18, primarily because of prevailing energy shortages in the system and the load staggering measures adopted in the various states particularly in agriculture sector. However, it has witnessed a gradual decline from 85.5% in 2017-18 to 76.6% in 2020-21 predominantly due to higher growth in the peak load met as compared to the increase in energy terms. The year-wise Annual System Load Factor is graphically depicted in the **Exhibit 1.6**.

Exhibit 1.6



1.3 VARIOUS INITIATIVES OF THE GOVERNMENT

1.3.1 Tariff Policy 2016

The Central Government has notified the revised Tariff Policy vide Gazette notification dated 28.01.2016 in exercises of powers conferred under section 3(3) of Electricity Act, 2003. The Tariff Policy has been evolved in consultation with the State Governments, the Central Electricity Authority (CEA), the Central Electricity Regulatory Commission and various stakeholders.

The tariff policy , 2016 ensure availability of electricity to consumers at reasonable and competitive rates, ensure financial viability of the sector and attract investments, Promote transparency, consistency and predictability in regulatory approaches across jurisdictions and minimize perceptions of regulatory risks. It will further facilitate competition, efficiency in operations and improvement in quality of supply. The tariff policy among other things also includes promotion of renewable generation (Renewable Generation Obligation, Long term growth trajectory of RPOs and increase in Solar RPO). Compulsory 100% procurement of power from waste to energy plants by DISCOMs, mandatory use of sewage treated water by thermal Plants, continuation of exemption of tariff based competitive bidding for hydro

projects up to 15th August 2022, smart meters recovery of regulated assets, revision of formula for calculation of cross subsidy etc.

1.3.2 Guidelines and Standard Bidding Documents (SBDs) for Procurement of Electricity by Distribution Licensees through Tariff based bidding process

In compliance with section 63 of the Electricity Act 2003, the Central Government has notified guidelines for procurement of power by Distribution Licensees through competitive bidding. Competitive procurement of Power requirement by the Distribution Licensees reduces the overall cost of procurement of power and in turn leads to significant benefits for consumers.

- i) Long Term procurement of power: Central Government had initially issued the Standard Bidding Documents (SBDs) containing Request for Qualification (RfQ), Request for Proposal (RfP) and Power Purchase Agreement (PPA) for long term procurement of power from Case-2 projects (having specified site and location) through tariff based competitive bidding in 2006 and amended it from time to time. The Standard Bidding Documents for long term procurement of power from Case-1 projects (where the location, technology or fuel is not specified) were issued in the year 2009 and amended it in 2010. In pursuance of the decision of the EGoM on Ultra Mega Power Projects (UMPPs) having specified site and location, the SBDs for Case-2 have been further reviewed and the Model Bidding Documents (MBDs) comprising the Model RFQ, Model RFP and the Model PPA for construction and operation of power generation projects/UMPPs on design, Build, Finance, Operate and Transfer (DBFOT) basis have been issued on 20 Sept, 2013. The Guidelines for procurement of electricity from Thermal Power Stations set up on DBFOT basis for Case-2/UMPPs have been published in the Gazette of India on 21st September, 2013. Model Bidding Documents (MBDs) for Thermal Power Stations set up on Design, Build, Finance, Own and Operate (DFBOO) basis for Case-1 issued on 8.11.2013. Further, amendments have been issued in the Documents on 5.5.2015. In order to facilitate use of linkage coal in the long term procurement of power by Distribution Licensees as per the provisions of SHAKT Policy, SBDs and Guidelines for long term Procurement of Electricity from Thermal Power Stations set up on Design, Build, Finance, Own and Operate (DFFOO) basis have been revised and issued in March, 2019.
- ii) Medium Term Procurement of power: Model Bidding Documents (MBDs) for procurement of electricity for medium term from power generating stations set up and/or operated on Finance, Own and Operate (FOO) basis was issued on 29.1.2014.

Further, amendments have been issued in the Documents of 20.8.2015. Model Bidding Documents (MBDs) for procurement of peaking power for medium term issued on 20.2.2014. In order to introduce e-bidding process along with reverse action, revised Guidelines and Model Bidding Documents for medium-term procurement of power by Distribution Licensees through tariff based competitive bidding process was notified on 17 January, 2017. Introduction of e-bidding process along with reverse auction will result in greater transparency and fairness in the procurement process for ultimate benefit of the consumers. Further, for enabling the use of linkage coal as per the new coal linkage policy (SHAKTI Policy) of Ministry of Coal, Revised MBDs and revised Guidelines for Procurement of Electricity for Medium Term were issued on 29.01.2019 and 30.01.2019 respectively.

- iii) Short Term procurement of power The Central Government has issued Guidelines for short-term procurement of electricity i.e. for a period of less than or equal to one year under section 63 of the Electricity Act, 2003 on 16 May, 2012. For introduction of e-reverse auction, the revised guidelines for short-term procurement of electricity were also issued on 30 March, 2016.

1.3.2.1 Pilot Scheme-II for procurement of 2500MW for three years under medium Term

In an attempt to revive the stressed power projects, a Pilot Scheme was introduced by Ministry of Power in April 2018. Capacity totalling to 1900 MW has been awarded under the scheme. Based on the experience gained from the Pilot Scheme, MOP has issued the Bidding Documents and Guidelines for Pilot Scheme-II to facilitate procurement of aggregated Power of 2500 MW for the period of 3 (three) years (covered under Medium Term) on 30.01.2019 and 01.02.2019 respectively.

1.3.3 Mega Power Policy 2017

Based on the CCEA decision dated 31.3.2017, time period for the provisional Mega projects (25 projects) for furnishing the final Mega Certificates to the Tax authorities has been extended to 120 months from the date of import. Further, guidelines for the release of Proportionate Bank/FDRs for the Provisional Mega Power Projects have been finalized and circulated on 21.9.2017. This is expected to ease out stress in the power sector to a great extent as the money realized by the developer, if any, as a result of release of proportionate Bank Guarantee would first be utilized towards the repayment of the Bank dues by the developer. So far, four projects have been granted proportional Mega Certificate

1.3.4 Promotion of Renewable Power

1.3.4.1 Competitive Bidding Guidelines for procurement of power from Solar and Wind Power projects:

To promote competitive procurement of electricity from solar PV power plants and Wind Power Plants, by distribution licensees and to protect consumer interests, Bidding Guidelines have been issued for long term procurement of electricity by the distribution licensees. Guidelines for Tariff Based Competitive Bidding Process for Procurement of Power from Grid Connected Solar PV Power Projects issued vide Resolution dated 3rd August, 2017. Guidelines for Tariff Based Competitive Bidding Process for Procurement of Power from Grid Connected Wind Power Projects issued vide Resolution dated 8th December, 2017. Necessary Amendments to these guidelines were made considering the views of the Stakeholders, encouraging investment and timely commissioning of such projects.

1.3.4.2 Waiver of inter-state transmission charges and losses on transmission of the electricity generated from solar and wind sources of energy

In Order to promote the capacity addition of Solar and wind Power Projects, Central Government in compliance with the para 6.4(6) of tariff policy has issued Inter State Transmission system (ISTS) waiver charges. The first order was issued on 30.09.2016 in which ISTS transmission charges and losses was waived for transmission of electricity from solar projects commissioned till 30.06.2017 and wind projects commissioned till 31.03.2019. Further the date of waive of ISTS transmission charges and losses was extended for solar projects upto 31.12.2019 vide MoP order dated 14.06.2017. Thereafter, the waiver available for use of ISTS for transmission of electricity by Solar or Wind power projects commissioned till December 2022 vide MoP order dated 13.02.2018. The waiver of ISTS charges on transmission of electricity generated from Solar and Wind sources is further extended for projects to be commissioned up to 30th June 2025 vide MoP order dated 21.06.2021. The Waiver shall be applicable for the twentyfive years from the commissioning of such projects. The ISTS waiver will be available for solar and wind projects entering into PPAs with all entities, including Distribution Companies, for sale of power from solar and wind power projects for compliance of their renewable purchase obligation. As a condition the above waiver will be allowed only to those solar and wind projects that are awarded through competitive bidding process in accordance with the guidelines issued by Central Government.

1.3.4.3 Waiver of inter-state transmission charges on transmission of the electricity supplied by Pumped Storage Plants and Battery energy Storage Systems

In Order to promote commissioning and optimum utilization of Storage projects, Central Government in compliance with the para 6.4(6) of tariff policy has issued Inter State Transmission system (ISTS) waiver charges for PSP and BESS projects. As per MoP order no. 23/12/2016-R&R-Part(1)[239444] issued on 21.06.2021, Inter State transmission system charges (excluding losses) were waived for transmission of electricity supplied by Hydro PSP and BESS projects commissioned till 30.06.2025, if the following conditions are met:-

- i. At least 70% of the annual electricity generation requirement of pumping of water of the PSP plant is met by use of solar and wind based generation.
- ii. At least 70% of the annual electricity generation requirement of charging of the BESS system is met by use of solar and wind based generation.

The ISTS charges for power supplied from Hydro PSP or BESS projects shall be levied gradually as follows:-

- i. 25% of STOA charges for initial 5 years of operation.
- ii. After 5 years, the charges will be increased in steps of 25% every 3rd year to reach 100% of STOA charges from 12th year onwards.

These will also be aligned with the gradual reduction in tariff and payment of debt.

The aforementioned order also mandates the waiver of transmission charges for trading of electricity generated/supplied from Solar, Wind, PSP and BESS in Green Term Ahead Market (GTAM) and Green Day Ahead Market (GDAM) for till 30.06.2023.

This arrangement will be reviewed on annual basis depending upon the future developments in power market.

1.3.4.4 Renewable Purchase Obligations (RPOs)

In light of par 6.4(1) of tariff policy 2016 and with the objective of creating renewable power capacity of 175 GW by March 2022; the Ministry of power after consultation with Ministry of New and Renewable Energy, had notified the long term trajectory of RPOs for Solar and Non-Solar power vide its order dated 22.07.2016 and 14.06.2018. In super-session of the orders Ministry of Power has issued RPO trajectory vide order dated 29.01.2021 and specified Hydro Purchase Obligation (HPO) with non-solar renewable purchase obligation. This has been issued to promote the Large Hydro Projects commissioning after 03.03.2019 and to add 30,000 MW of Hydro power capacity by 2029-30.

1.3.4.5 Flexibility in Generation and scheduling to reduce emissions of Thermal Power Stations:

In order to reduce emissions and to encourage RE capacity addition, Central Government on 05.04.2018 has issued the mechanism for flexibility in generation & scheduling of thermal

power station. Thermal Power Plants can supply power from RE sources under existing contractual agreement.

1.3.4.6 National Mission on use of Biomass in coal based thermal power plants

In order to address the issue of air pollution due to farm stubble burning and to reduce carbon footprints of thermal power generation, Ministry of Power has decided to set up a National Mission on use of Biomass in coal based thermal power plants. This would further support the energy transition in the country and our targets to move towards cleaner energy sources.

The "National Mission on use of biomass in thermal power plants" will have the following objectives; (a) To increase the level of co-firing from present 5% to higher levels to have a larger share of carbon neutral power generation from the thermal power plants.

(b) To take up R&D activity in boiler design to handle the higher amount of silica, alkalis in the biomass pellets.

(c) To facilitate overcoming the constraints in supply chain of bio mass pellets and agro-residue and its transport upto to the power plants.

(d) To consider regulatory issues in biomass co-firing.

1.3.4.7 Guidelines for procurement of Round the Clock power (RTC Power) from Renewable Projects through Tariff Based Competitive Bidding

With the aim of promoting RE power and to provide RoundThe-Clock (RTC) power to the DISCOMs from renewable energy sources, Ministry of Power has issued RTC power Guidelines vide notification dated 22.07.2020. The amendments made in the said guidelines were notified in Gazette of India on 03.11.2020. Now the complemented power may be used from any fuel sources

1.3.5 Reduction of Power Cost

1.3.5.1 Flexibility in Generation and scheduling of thermal power stations to reduce the cost of power to the consumer

Ministry of Power (MoP), Government of India, notified the scheme on „Flexibility in Generation and scheduling of thermal power stations to reduce the cost of power to the consumer“ on 30th August, 2018 (MoP scheme of Flexibility). The objective of the scheme is to reduce the overall cost of power for the country by utilizing any un-despatched surplus in existing cheaper generating stations by way of flexibility in scheduling of generation. The scheme advocates flexibility to a generating company to supply power from any of its generating stations against schedule received for its stations. As per the scheme, the

cheaper generating stations could be dispatched up to its maximum capacity before scheduling the costlier stations till the power requisitioned by all its beneficiaries is met. The Scheme proposes Merit Order operation based on the Generation Bucket Filling (GBF) schedule to meet the entire schedule of all beneficiaries. The Scheme also advocates suitable provision of Gate Closure to take into account revision of schedule by beneficiaries from ISGS power stations. (ii) The Scheme also proposes sharing of gain between the beneficiaries and the generating company in the ratio of 50: 50 on monthly basis with quarterly reconciliation. The share in the surplus, if any, is to be passed on to the beneficiaries during the month in proportion to the total drawl by the beneficiaries from the generating company

1.3.5.2 Ensuring sustainability in the Power Sector:

An Order was issued by Ministry of Power on 28.06.2019 on "Opening and maintaining of adequate Letter of Credit (LC) as Payment Security Mechanism under Power Purchase Agreements by Distribution Licensees". As per Order for power purchases after 1st August 2019, an adequate payment security mechanism as per contracts is to be established for the Generators for power to be scheduled. This has been successfully implemented from 01.08.2019 and has helped in streamlining the payment to the generators from the distribution companies. This measure is expected to bring sustainability in the Power Sector. Considering the unprecedented and force majeure situation due to Covid-19 pandemic, it has been decided that power may be scheduled even if payment security mechanism is established for 50% of the amount for which payment security mechanism is to be otherwise established contractually. This relaxation was available during the period 24.03.2020 to 30.06.2020.

1.3.5.3 Reduction in cost of power due to pre-payment in entire value chain of power sector

Ministry of Power on 15.11.2019 had issued an order on "Reduction in cost of power due to pre-payment in entire value chain of power sector". Due to pre-payment by the consumer to Distribution licensee or advance payment by distribution company to Generating company, the working capital requirements of these companies would get reduced. This would therefore result in reduced generation tariff and the retail tariff to the consumer.

1.3.5.4 Security Constraint Economic Despatch (SCED)

In order to reduce the cost of power procured by the Distribution Licensees, a Pilot system of Security Constraint Economic Despatch (SCED) was introduced in the last year where for thermal Inter State Generating Stations (ISGS), the merit order dispatch at national level shall be followed. Hence the cheapest generation will be available at the maximum level.

This mechanism has resulted in savings of approximately Rs 3 Crores every day towards power procurement cost of Distribution licensees. Central Electricity Regulatory Commission has vide order dated 18.04.2020 has extended the time for pilot for a further period up to 31st March, 2021. The Commission has also expanded the ambit of SCED by including the generators other than the thermal ISGS whose tariff is determined by the Commission.

1.3.6 Distribution Reforms

1.3.6.1 Power for All

Government of India has taken a joint initiative with respective State Governments for preparation of State specific documents for providing 24x7 Power for All (PFA) to all households/homes, industrial & commercial consumers and adequate supply of power to agricultural consumer as per State Policy. This initiative aims at ensuring uninterrupted supply of quality power to existing consumers and providing electricity access to all unconnected consumers by 2019 in a phased manner. This joint initiative of Government of India and State Governments also aims to enhance the satisfaction levels of the consumers, improve the quality of life of people, and increase the economic activities resulting into inclusive development of the States.

State Specific Documents for the all the States/UTs have been approved by the respective State Governments and signed by State & Central Government for implementation. Following has been achieved so far.

- i) All inhabited villages of 5, 97,464 (Census 2011) stood electrified as on 28.04.2018 in the country.
- ii) All the willing households totaling to 2.82 crore have been electrified as on 31.03.2021 under Saubhagya scheme on launched in October 2017.
- iii) System strengthening and augmentation in Distribution infrastructure including metering of distribution transformers/ feeders/ consumers have been assisted by GOI through its ongoing Schemes launched in December 2014 namely -IPDS for Urban areas and DDUGJY for Rural areas (Details given in Subsequent paragraph)
- iv) Status of 24x7 Power Supply:

As per the status available in National Power Portal (NPP) the Power supply position in respect of States and UTs (under various Discoms) for the month of March, 2021 is as under:

- In case of Urban area, in 20 states comprising 24nos. of Discoms [Andhra Pradesh, Assam, Bihar, Goa, Gujarat, Himachal Pradesh, Jammu and Kashmir, Jharkhand, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Manipur, Meghalaya, Mizoram, Rajasthan, Telangana, Tripura, Uttarakhand, West Bengal) having more than 20 average Hours of Power supply in a day has been achieved.
- Similarly, in case of Rural areas 17 states and 1 UT comprising 35 nos. of Discoms [Andhra Pradesh, Bihar, Chhattisgarh, Gujarat, Haryana, Himachal Pradesh, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Odisha, Puducherry, Punjab, Rajasthan, Tamilnadu, Telangana, Uttarakhand, Uttar Pradesh] having more than 20 average Hours of Power supply in a day has been achieved.

1.3.6.2 Integrated Power Development Scheme (IPDS)

To facilitate state utilities to ensure quality and reliable 24x7 power supply in the urban areas, Government approved the “Integrated Power Development Scheme” (IPDS) on 20.11.2014 with a total outlay of Rs. 32,612 Crore, which includes a budgetary support of Rs. 25,354 Crore from Government of India. Erstwhile R-APDRP has been subsumed in IPDS and CCEA-approved R-APDRP outlay of Rs. 44,011 crore including a budgetary support of Rs.22,727 crore for 12th & 13th Plan carried forward to the new scheme of IPDS.

1.3.6.3 Deendayal Upadhyaya Gram Jyoti Yojana (DDUGJY)

Government of India had launched **Deendayal Upadhyaya Gram Jyoti Yojana (DDUGJY)** in December, 2014 for augmentation and strengthening of rural sub-transmission and distribution works, feeder segregation and rural electrifications in the rural areas in the country. As reported by the States, all the inhabited un-electrified villages as per Census 2011 stand electrified on 28th April, 2018 across the country under DDUGJY. The overall progress under the scheme is 94%.

1.3.6.4 Pradhan Mantri Sahaj Bijli Har Ghar Yojana – Saubhagya

Government of India has launched Saubhagya" on 11th October, 2017 with the objective to achieve universal household electrification by providing last mile connectivity and electricity connections to all households in rural and urban areas. The sunset timeline for the scheme is March 2022. REC is the nodal Agency for implementation of this Scheme. Government of

India had sanctioned an amount of Rs. 14,109 crore under Saubhagya scheme for various States. Based on the eligible demand submitted by the States under Saubhagya scheme, Grant Rs. 5,234 crore has been disbursed to the States during last three years and current year up to 28.02.2021.

As reported by the States, 2.81 crore households have been electrified since the launch of Saubhagya, up to 28.02.2021.

1.3.6.5 Ujwal DISCOM Assurance Yojana (UDAY),

The scheme was launched for financial and operation turnaround of State owned Distribution Utilities (DISCOMs) in 2015. UDAY aimed at easing out the supply side gaps impeding achievement of the goal of 24X7 reliable and quality power by catalysing the efforts of the states and DISCOMs through the spirit of competitive and cooperative federalism

UDAY had primarily two outcome parameters: (i) AT&C loss reduction to 15% and (ii) ACS-ARR gap reduction to zero by March 2019. Due to the large scale problems/ challenges in some States, as well as their late joining, some States were allowed to complete the turnaround process of their DISCOMs by one to two years. In all 32 States/UTs finally joined UDAY, with 16 States joining for comprehensive operational and financial turnaround measures and the remaining for operational measures only.

While UDAY has contributed towards improvements in the DISCOM's performances, the Government of India is formulating additional reform frameworks to complement the efforts under UDAY to achieve a complete financial and operational turnaround of State owned Utilities.

1.3.6.6 Atmanirbhar Package for State Power Distribution Companies

Amid COVID-19 crisis, Government of India has announced special economic package on 13.05.2020, which included liquidity injection for distribution companies. The liquidity injection package envisaged funding by PFC and REC to the tune of Rs. 1,35,497 crore to provide much needed support to power sector. The purpose of the liquidity scheme under Atmanirbhar Bharat Package was for clearance of outstanding dues of CPSU GENCOs & TRANSCO, IPPs and RE Generators as on 31st March 2020.

Further, MOP vide its letter dt 02.09.2020 granted a one-time permission to PFC & REC for extending loans to DISCOMs above working capital limits of 25% of last year's revenues under UDAY to discharge the liabilities of CPSU Gencos & Transcos, IPPs and RE Generators existing as on 30th June 2020.

Accordingly, PFC & REC have also formulated policy (ies) for offering Special Long-term Transition Loans to Power DISCOMs for clearance of dues of CPSU Gencos & Transcos, IPPs and RE Generators outstanding as on 31st March 2020 & 30th June 2020 .

As on 05.04.2021 PFC & REC has sanctioned Rs. 1,35,497 crore and disbursed Rs. 77,205 crore to various State Power Discoms under the liquidity package announced by Gol.

A reforms-based result-linked power distribution sector scheme is proposed with an outlay of Rs.3,05,984 crore over 5 years. The scheme will provide assistance to DISCOMs for infrastructure creation and up-gradation, prepaid smart metering, feeder separation, up-gradation of systems, etc. The release of funds will be tied to improvement in performance including reduction in AT&C losses. Once finalize this scheme will subsume UDAY also.

1.3.6.7 Electricity (Rights of Consumers) Rules, 2020

Government of India MoP has notified Electricity (Rights of Consumers) Rules, 2020 in December, 2020. These Rules specify the obligations of the licensee and sets the practices that must be adopted by the licensee to provide efficient, cost-effective, reliable and consumer friendly services so as to facilitate ease of use as well as ease of doing business by the consumers. These Rules would provide a pathway to the SERCs to further improve upon the Supply Code and SoPs already laid down by them so as to ensure 24*7 quality power and better services to consumers by Distribution Licensees.

1.3.7 DIGITAL INITIATIVES

1.3.7.1 Mob App 'Vidyut PRAVAH'

A Mobile App 'Vidyut PRAVAH' on Electricity Pricing and Availability Highlights was launched on 31st March, 2016. The application provides highlights of the power availability in the country on real time basis. This app will empower common people to demand 24x7 power from the states and will take transparency to the next level by making State governments more accountable.

1.3.7.2 DEEP (Discovery of Efficient Electricity Price) e-Bidding & e-Reverse Auction portal.

In order to bring uniformity and transparency in power procurement by the DISCOMs and also to promote competition in electricity sector, "DEEP (Discovery of Efficient Electricity Price) e-Bidding Portal" was been launched on 12th April, 2016. This Portal is being used for Short Term and Medium Term procurement of Power by Discoms. The e-Reverse Auction method has also been introduced in the short term and medium term power procurement.

1.3.7.3 MERIT (Merit Order Despatch of Electricity for Rejuvenation of income and Transparency) web portal

In pursuance to the recommendations of the Merit Order Dispatch Committee headed by Chairperson, CEA, a Web Portal 'MERIT' i.e. Merit Order Despatch of Electricity for Rejuvenation of Income and Transparency, was launched on 23rd June 2017. Subsequently, MERIT Mobile App was also launched on 5th July 2017. This Mobile App/Web Portal displays the details of power purchased by the states from various power Stations/Sources and the

rates thereof on day to day basis transparently and provides opportunity to states for improving their power purchase portfolio. (<http://www.meritindia.in>)

1.3.7.4 e-Bidding portal for utilization of domestic coal in IPP Power Stations for reducing the cost of power generation

An e-bidding portal was launched on 5th July 2017 for providing e-Bidding solution to States to select Independent Power Producers (IPPs) for procurement of power by transferring their domestic coal under the scheme of flexibility in utilization of domestic coal. The e-Bidding portal has been designed to facilitate States in inviting bids for procurement of power from the prospective IPPs in transparent and fair manner. The successful bidder shall be selected through e-Reverse Bidding process. The flexibility in utilization of domestic coal scheme envisages transferring coal to more efficient IPPs generating stations, leading to lower generation costs and ultimately lesser cost of electricity for the consumers

1.3.7.5 Monitoring of 24x7 power supply through Integration of Distribution Sector data with National Power Portal (NPP):

NPP, launched on 14th Nov, 2017, is a centralized system which facilitates online data capture/ input (daily, monthly, and annually) and to disseminate related information (operational, capacity, demand, supply, consumption etc.) through various analysed reports, graphs, statistics etc. for Indian Power Sector. National Power Portal is a common platform, where all data related to Power sector (Generation, Transmission, Distribution etc.) are available on single window.

In Distribution Sector, NPP captures both operational and commercial data at feeder-level for Rural and Urban areas. Operational data includes power supply position, outage data, reliability data etc. and commercial data includes Billing efficiency, collection efficiency for A&TC loss etc. CEA is upgrading the formats for data capturing and its presentation in NPP.

1.3.7.6 Power Rail Koyla Availability through Supply Harmony (PRAKASH)

Benefits of Portal to the Stake-holders: On a single platform, the following information is available:

- i. Coal company: Stocks and the coal requirement at power stations
- ii. Indian Railways: Actual coal available at siding.
- iii. Power stations can plan future schedule by knowing rakes in pipe line and expected time of receipt.
- iv. Ministry of Power /Ministry of Coal/ Ministry of Railways /CEA /POSOCO can review the overall availability of thermal power in different regions and coal available for the same.

1.3.8 PROMOTION OF HYDRO PROJECTS

For boosting the generation of Hydro Power, the Government of India on 8th March, 2019, approved a number of measures for promoting hydropower sector in the country which are as under:

- i. Declaring Large Hydro Power (LHPs) (> 25 MW projects) as Renewable Energy source.
- ii. Hydro Purchase Obligation (HPO) as a separate entity within Non-Solar Renewable Purchase Obligation (RPO).
- iii. Tariff rationalization measures for bringing down hydro power tariff.
- iv. Budgetary Support for Flood Moderation/Storage Hydro Electric Projects (HEPs).
- v. Budgetary Support to Cost of Enabling Infrastructure, i.e. roads/bridges. a) Rs. 1.5 crore per MW for projects upto 200 MW. b) Rs. 1.0 crore per MW for projects above 200 MW

1.3.8.1 HYDRO POLICY NOTIFICATION, 2019

Hydro Policy, 2019 was notified by Govt. of India on 08.03.2019. The salient features of the policy are given below:

- Declaring Large Hydro Power Projects (LHPs, i.e. >25 MW) AS Renewable Energy Source.
However, LHPs would not automatically be eligible for any differential treatment for statutory clearances such as Forest clearances, environmental clearance, National Board for Wildlife clearance, related impact Assessment and carrying capacity study, etc., available to Small Hydropower Projects (SHPS), i.e., projects capacity up to 25 MW.
- Hydro Purchase Obligation (HPO) as a separate entity within non-solar Renewable Purchase, The HPO shall cover all LHPs commissioned after this notification as well as untied capacity (i.e. without PPA) of the commissioned projects.
- Tariff rationalization measures to bring down hydropower tariff: Tariff rationalization measures including providing flexibility to the developers to determine tariff by back loading of tariff after increasing project life to 40 years, increasing debt repayment period to 18 years and introducing escalating tariff of 2%;
- Budgetary support for funding flood moderation component and funding cost of enabling infrastructure i.e. roads and bridges on case to case basis as per actual, limited to Rs. 1.5 crore per MW for up to 200 MW projects and Rs. 1.0 crore per MW for above 200 MW projects.

1.3.8.2 GUIDELINES FOR THE RELEASE OF BUDGETARY SUPPORT FOR ENABLING INFRASTRUCTURE I.E. ROADS/BRIDGES AND FLOOD MODERATION COMPONENT OF HYDROELECTRIC PROJECTS

"In line with Hydro Policy notified by Govt. of India (GoI) on 08.03.2019, Ministry of Power (MoP), GoI vide OMs dated 28.09.2021 issued the detailed guidelines for release of budgetary support towards cost of enabling infrastructure i.e. roads/bridges and flood moderation component of hydroelectric projects including PSP."

1.3.9 GO ELECTRIC

Ministry of Power, Government of India, launched "Go Electric" Campaign on 19th February, 2021 with the objective of creating awareness among masses on benefits of adopting Electric Vehicles and Electric Cooking appliances such as Induction cook hobs, Electric pressure cooker etc. This initiative is intended to encourage consumers to switch over to Electric Vehicles and Electric Cooking in place of currently used conventional modes and appliances, thereby, reducing dependency of the country on imported fuel. The "Go Electric" Campaign is aimed at promoting adoption of Energy Efficient Electric Vehicles and Electric Cooking appliances and is expected to help the country to achieve energy transition as well as low carbon economic growth in the future. These technologies being energy efficient, are expected to scale down mobility and cooking related emissions, securing cleaner and greener future. The share of renewables in the energy mix is expected to increase due to integration of more renewable based power generation. Benefits of adopting these electricity based technologies shall be completely realized by enhancing share of renewables in the Grid.

1.3.10 CHARGING INFRASTRUCTURE

Government of India has taken the following actions to create and increase the electric vehicle charging infrastructure to promote electric vehicles across the country:

- i) There is no requirement of license for setting up charging stations for Electric Vehicles: Ministry of Power on 13.04.2018, has issued clarification that no license is required for setting up Charging Infrastructure for Electric Vehicles (EVs) with reference to the provisions of the Electricity Act, 2003.
- ii) Charging Infrastructure for Electric Vehicles – Revised Guidelines and Standards: Ministry of Power, after extensive consultations with State Governments, different departments/agencies of Central Government and the stakeholders, issued "Charging Infrastructure for Electric Vehicles – Guidelines and Standards" dated 14.12.2018, which was revised on 01.10.2019 and further, an amendment to it was issued on 08.06.2020. After careful consideration of progress made and suggestion received

- from various stakeholders, MoP amended the guidelines to accelerate the E-mobility transition in the country vide MoP order dated 14.01.2022.
- iii) Grid Connectivity and Safety regulations for charging stations for electric vehicles: Central Electricity Authority (CEA) has issued amendments to following regulations of CEA with reference to facilitation for charging stations: a. Central Electricity Authority (Technical Standards for Connectivity to the Distributed Generation Resources) Amendment Regulations, 2019. b. Central Electricity Authority (Measures relating to Safety and Electric Supply) Amendment Regulations, 2019.
 - iv) Ministry of Housing and Urban Affairs (MoHUA) has issued following amendments to building by-laws and Urban and Regional Development Plan Formulation for facilitation of Charging Infrastructure for Electric Vehicles: a. Amendments in Model Building Bye-Laws (MBBL – 2016) for Electric Vehicle Charging Infrastructure. b. Amendments in Urban and Regional Development Plans Formulation and Implementation Guidelines (URDPFI – 2014) for Electric Vehicle Charging Infrastructure.
 - v) Energy Efficiency Services Limited (EESL), Power Grid Corporation Ltd. (PGCIL) and NTPC Ltd. under Ministry of Power have been engaged in installation of Public Charging Stations (PCS) in the country.

1.3.11 ENERGY CONSERVATION AND EFFICIENCY

1.3.11.1 Performance Achieve and Trade (PAT):

Perform, Achieve and Trade (PAT) scheme is one of the flagship programs of Bureau of Energy Efficiency aimed at reduction in Specific Energy Consumption (SEC) in energy intensive industries. The energy saved by these industries is converted into tradable instruments called Energy Saving Certificates (ESCerts) and are traded at the Power Exchanges.

PAT cycle II, PAT cycle III, IV, V and VI were notified in 2017, 2018, 2019 and 2020 respectively. PAT cycle III was completed on the 31st of March 2020, with the evaluation of 116 new Designated Consumers (DCs) and the monitoring and verification of the energy savings in progress. PAT cycle VI has been notified vide Gazette Notification S.O. 1254 (E) dated 13th April, 2020. Under PAT cycle –VI, 135 new DCs have been notified with a total energy saving target of 1.277 MTOE.

1.3.11.2 Buildings Energy Efficiency Programme (BEEP) of EESL

Building Energy Efficiency Program (BEEP) was launched to implement energy efficiency measures in Government buildings across India. Under this Program 10,451 buildings have been retrofitted with energy efficient equipment like LED Lights, 5 Star rated fans and super-

efficient air-condition. Under this Programme, energy efficiency measures have been implemented in approx. 7,000 railway stations/service buildings and approx. 66 Airports' buildings

1.3.11.3 Unnat Jyoti by Affordable LEDs for All (UJALA)

UnnatJyoti by Affordable LEDs for All (UJALA) was launched on 5th January, 2015 as an attempt to provide energy efficient LED bulbs to consumers. As on date 36.72 Crore LED bulbs have been distributed under UJALA programme. This has resulted in energy saving of 47,691 million units of electricity per annum, peak demand reduction of 9,548 MW and 38.62 million tonnes of CO2 emission reduction annually.

1.3.11.4 Street Lighting National Programme (SLNP)

Street Lighting National Programme (SLNP) was launched to replace conventional street lights with smart and energy efficient LED street lights across India. Till date, EESL has installed over 1.15 crore LED street lights in Urban Local Bodies (ULBs) and Gram Panchayats across India. This has resulted in estimated energy savings of 7.75 billion units kWh per year with avoided peak demand of about 1,300 MW, GHG emission reduction of 5.33 million t CO2 per year and estimated annual monetary savings of Rs.5,523 crore in electricity bills of municipalities.

1.3.11.5 Standards and Labeling (S&L) Programme

The programme aims at providing consumers an informed choice regarding the energy saving potential of various energy consuming appliances. This Programme prescribes minimum energy performance levels for appliances/equipment, rated on a scale of 1 to 5 Star with 5 Star being the most energy efficient ones. As on date, 28 appliances are covered under S&L Programme, out of which 10 appliances are under mandatory regime and remaining 18 are under voluntary regime.

1.3.11.6 Energy Conservation Building Code

ECBC 2017 (Energy Conservation Building Code) was launched in 2017 and is applicable for large commercial buildings with connected load of 100 kW and above or 120 kVA and above. ECBC focuses on building envelope, mechanical systems and equipment including heating, ventilating, and air conditioning (HVAC) system, interior and exterior lighting systems, electrical system and renewable energy.

The Eco Niwas Samhita, Part – I Building Envelope (Energy Conservation Building Code for Residential Sector) is developed and launched on 14th December, 2018 to set minimum building envelope performance standards to limit heat gains (for cooling dominated climates) and to limit heat loss (for heating dominated climate) as well as for ensuring

adequate natural ventilation and day lighting. The code is applicable to all residential use building projects built on plot area ≥ 500 m². In 2018, the government launched Eco-Niwas Samhita 2018(link is external), which is the ECBC for residential buildings, to push for energy efficiency in the residential sector. The code aims for promoting design and construction of homes including apartments and townships to give the benefits of energy efficiency to the occupants.

In the subsequent years, new components will be added to the Eco-Niwas Samhita in the Part-II, which will address other aspects such as, Energy Efficiency in Electro-Mechanical Equipment for Building Operation, Renewable Energy Generation, Embodied Energy of Walling Materials and Structural Systems.

1.3.12 Promotion of Energy Storage system

Ministry of Power (MoP), GoI notification no. 23/16/2020-R&R Part(1) dated 10.03.2022 issued the detailed Guidelines for Procurement and Utilization of Battery Energy Storage Systems as part of Generation, Transmission and Distribution assets, along with Ancillary Services.

CHAPTER 2

REVIEW OF CAPACITY ADDITION DURING THE PERIOD OF 2017-22

2.0 INTRODUCTION

Review of the previous plan is a very useful and powerful way to evaluate strengths, weaknesses, and progress in order to create a strong foundation for the development of future strategic plans and priorities. Review creates a base of knowledge and shared understanding that provides a critical backdrop about decision-making processes, including the setting of priorities, budget setting, dealing with problem arising in the future. It helps to identify projects that have commissioned as per the schedule or ahead of schedule and reasons for the delay in projects.

The COVID-19 pandemic has affected our day-to-day life, businesses, disrupted the world trade and movements. Power sector is also one of the various industries and sectors affected by the pandemic. The generation capacity addition from various sources got adversely impacted in the short run as:

- The strict lockdown to arrest the pandemic halted the constructions activities, due to a lack of manpower.
- Delay in up gradation/transition-related activity in the power sector, due to slow growth of economy and investment by the public and private sector.
- Delay in manufacturing and installation of various projects due to disruption in the global supply chain led to difficulties with the availability of key components leading to delay in execution of projects, for instance, solar segment manufacturing companies faced delays in the procurement of material.
- Reduced revenue for companies due to weak demand which left companies with less capacity for capital expenditure.

In this chapter, review of generation capacity which was scheduled to be added in National Electricity Plan notified in 2018 has been carried out with reasons for the delay of projects which were scheduled to be commissioned during the period 2017-22.

2.1 SCHEDULED GENERATION CAPACITY ADDITION FROM CONVENTIONAL SOURCES

As per the National Electricity Plan notified in 2018, scheduled generation capacity addition from conventional sources was envisaged 51,561.15 MW for the period 2017-22. Details of sector wise and mode wise scheduled capacity addition is given in **Table 2.1** and subsequently in **Exhibits 2.1** and **Exhibits 2.2**.

Table 2.1
Scheduled Capacity Addition from conventional sources for year 2017-22

(Figures in MW)

Source	Central	State	Private	Total
Coal	22900	18340	6615	47855
Gas	0	406.15	0	406.15
Nuclear	3300	0	0	3300
Total	26200	18746.15	6615	51561.15

Note: Large hydro has been categorized as Renewable Energy Source.

Exhibit 2.1

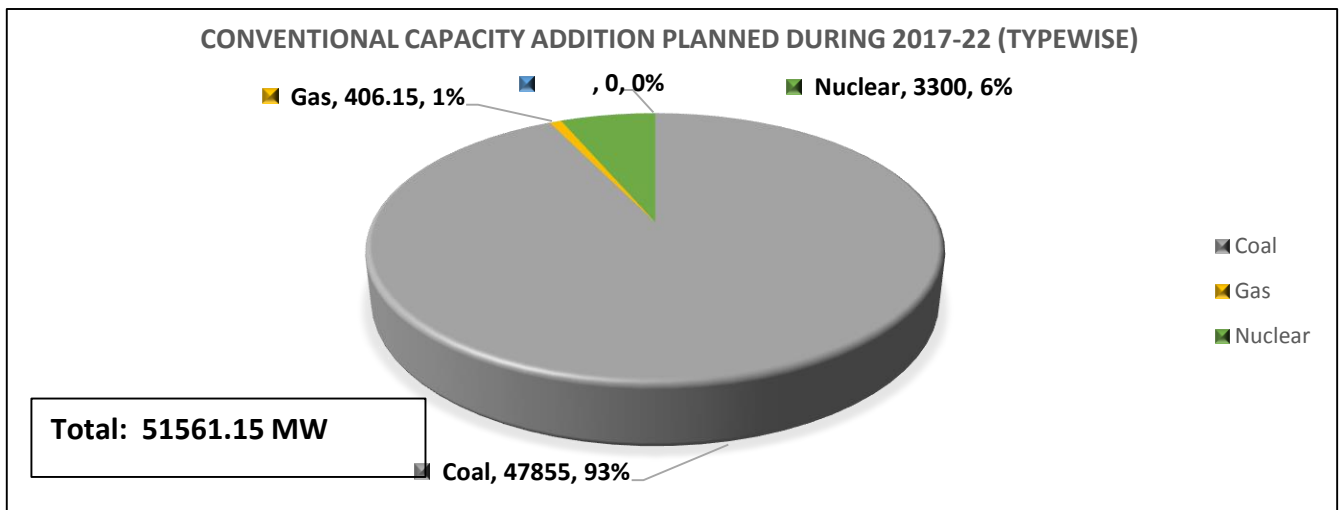
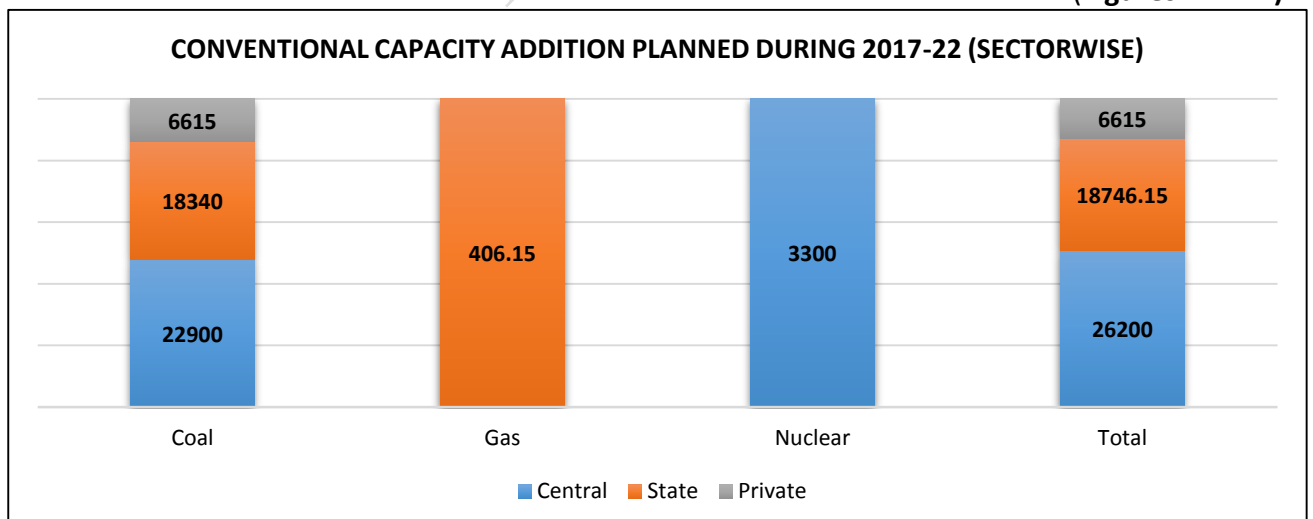


Exhibit 2.2

(Figures in MW)



2.2 GENERATION CAPACITY ADDITION ACHIEVED FROM CONVENTIONAL SOURCES DURING 2017-22

During period, 2017-22 capacity totaling to 30667.91MW from conventional sources has been achieved as on 31.03.2022 comprising of 30562 MW of Coal, 105.91 MW of Gas, and 0 MW of Nuclear. This also includes projects totaling to 726.76 MW which were originally not scheduled for the period 2017-22 but have also been commissioned.

During the period 2017-22, the year wise capacity addition achieved from conventional sources is shown in **Table 2.2**.

Table 2.2
Year wise capacity addition achieved during 2017-22

(Figures in MW)

Year	Source	Thermal			Nuclear	Total
		Coal	Gas	Total		
2017-18	Centre	3670	0	3670	0	3670
	State	1260	0	1260	0	1260
	Private	3780	0	3780	0	3780
	Total	8710	0	8710	0	8710
2018-19	Centre	1960	0	1960	0	1960
	State	2780	69.755	2849.755	0	2849.755
	Private	972	0	972	0	972
	Total	5712	69.755	5781.755	0	5781.755
2019-20	Centre	3940	0	3940	0	3940
	State	2780	0	2780	0	2780
	Private	45*	0	45	0	45
	Total	6765	0	6765	0	6765
2020-21	Centre	4080	0	4080	0	4080
	State	810	36.15	846.15	0	846.15
	Private	0	0	0	0	0
	Total	4890	36.15	4926.15	0	4926.15
2021-22	Centre	2370	0	2370	0	2370
	State	1590	0	1590	0	1590
	Private	525	0	525	0	525
	Total	4485	0	4485	0	4485

*: NIWARI TPP, UNIT-2 (45 MW) HAD ACHIEVED COD ON 20.03.17 BUT THE INTIMATION REGARDING COD WAS RECEIVED IN JUNE'19. THEREFORE, THE PROJECT HAS TAKEN INTO CAPACITY ADDITION ON 06.06.2019 AFTER APPROVAL OF CHAIRPERSON, CEA

During the period 2017-22, sector wise and type wise capacity addition sector wise achieved from conventional sources is shown in **Table 2.3** and shown in **Exhibit 2.3** and **Exhibit 2.4**.

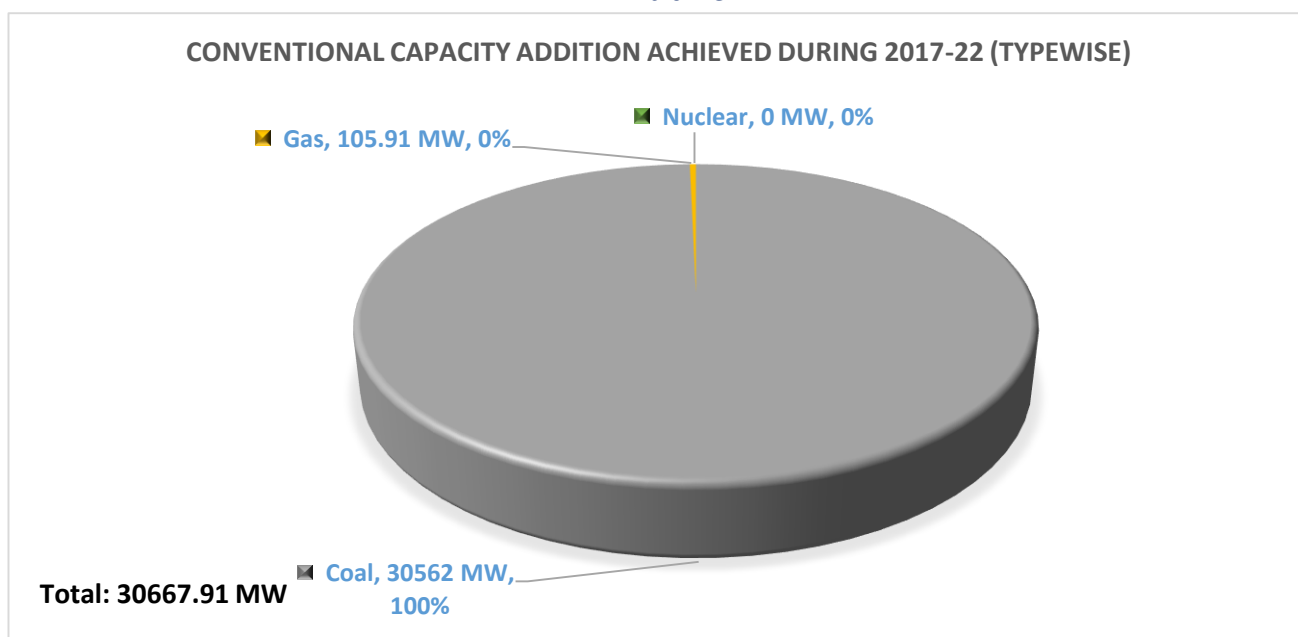
Table 2.3
Capacity addition achieved during 2017-22

(Figures in MW)

Source	Thermal			Nuclear	Total
	Coal	Gas	Total		
Central	16020	0	16020	0	16020
State	9220	105.91	9325.91	0	9325.91
Private	5322*	0	5322	0	5322
Total	30562	105.91	30667.91	0	30667.91

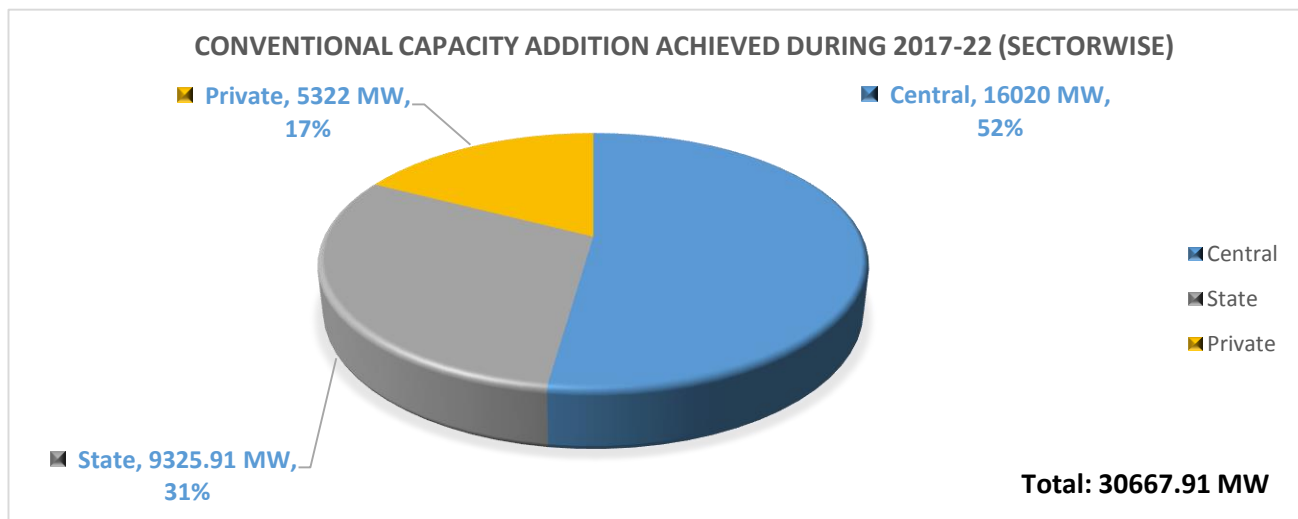
*: NIWARI TPP, UNIT-2 (45 MW) HAD ACHIEVED COD ON 20.03.17 BUT THE INTIMATION REGARDING COD WAS RECEIVED IN JUNE'19. THEREFORE, THE PROJECT HAS TAKEN INTO CAPACITY ADDITION ON 06.06.2019 AFTER APPROVAL OF CHAIRPERSON, CEA

Exhibit 2.3



* Large Hydro considered in RES

Exhibit 2.4



The State wise (Conventional Sources) summary of the capacity added during period 2017-22 is given in **Annexure 2.1** and the list of the commissioned conventional sources projects is given in **Annexure 2.2**.

Out of scheduled generation capacity addition of 51561.15MW to be achieved during the period 2017-22, generation capacity addition totaling to 30667.91 MW is achieved AS ON 31.03.2022, which includes 726.76 MW projects which were not envisaged in NEP,2018. Projects totaling to 21620 MW have slipped on account of various reasons viz. delay in placement of order for main plant, slow progress of civil works, poor geology, legal issues, Covid-19 pandemic etc.

A summary of the total capacity addition during period 2017-22 is given in **Table 2.4**.

Table 2.4
Summary of generation capacity addition during period 2017-22

(Figures in MW)

A	Scheduled Capacity Addition during period 2017-22	51561.15
B	Capacity addition achieved as per schedule (51561.15MW)	29941.15
C	Additional Capacity commissioned which were not envisaged in NEP, 2018	726.76
D	Total Generation Capacity Addition as per the schedule	30667.91
H	Capacity slipped from the scheduled capacity addition during period 2017-22	21620

Out of Scheduled capacity addition of 51561.15MW, a capacity of 21620 MW (41.93% of the target) has slipped during the period. Sector wise and mode wise details of capacity slipped are shown in **Table 2.5**.

Table 2.5
Summary of capacity Slipped during period 2017-22

Sector	Centre	State	Private	Total
Nuclear	3300	0	0	3300
Coal	7380	8990	1950	18320
Total	10680	8990	1950	21620

List of slipped Nuclear and Coal plants which were envisaged to be commissioned in National Electricity Plan, 2018 is mentioned along with the detail of reason of delays in **Annexure 2.3**.

2.3 CAPACITY CONSIDERED FOR RETIREMENT DURING PERIOD 2017-22

Scheduled retirement as per National Electricity Plan 2018, was 22690.5 MW, out of which coal-based capacity of 5,901.5 MW were considered for retirement due to old age and 16,789 MW (101 units) (as on August, 2017) due to not having sufficient space for installation of FGD to control SOx emissions were identified.

Capacity totaling to 10044.295 MW for period (2017-22) have been retired. This includes retired coal and gas-based capacity totaling to 2695.295 MW, which were not envisaged to retire during the period 2017-22.

A summary of the total capacity retired during period 2017-22 is given in **Table 2.6**.

Table 2.6
Summary of Capacity Retired during period 2017-22
(Figures in MW)

A	Scheduled Retirement during the period 2017-22	22690.5
B	Capacity Retired due to Old Age Criteria during period 2017-22 against 5901.5 MW envisaged in NEP 18	4589
C	Capacity retired due to New Environmental Norms during period 2017-22 against 16789MW envisaged in NEP 18	2760
D	Additional Capacity retired during period 2017-22 outside the retired capacity envisaged in NEP 18	2695.295
E	Total Capacity retired during period 2017-22 (B+C+D)	10044.295
F	Capacity which did not retired but was scheduled for Retirement as per Old Age Criteria during period 2017-22(5901.5 MW-B)	1312.5
G	Capacity which did not retired but was scheduled for Retirement due to New Environmental Norms during period 2017-22(16789MW-C)	14029

List of plants retired during period 2017-22 is given in **Annexure 2.4**.

List of plants which were envisaged to get retired in National Electricity Plan, 2018 but do not get retired during period 2017-22 is attached in **Annexure 2.5**.

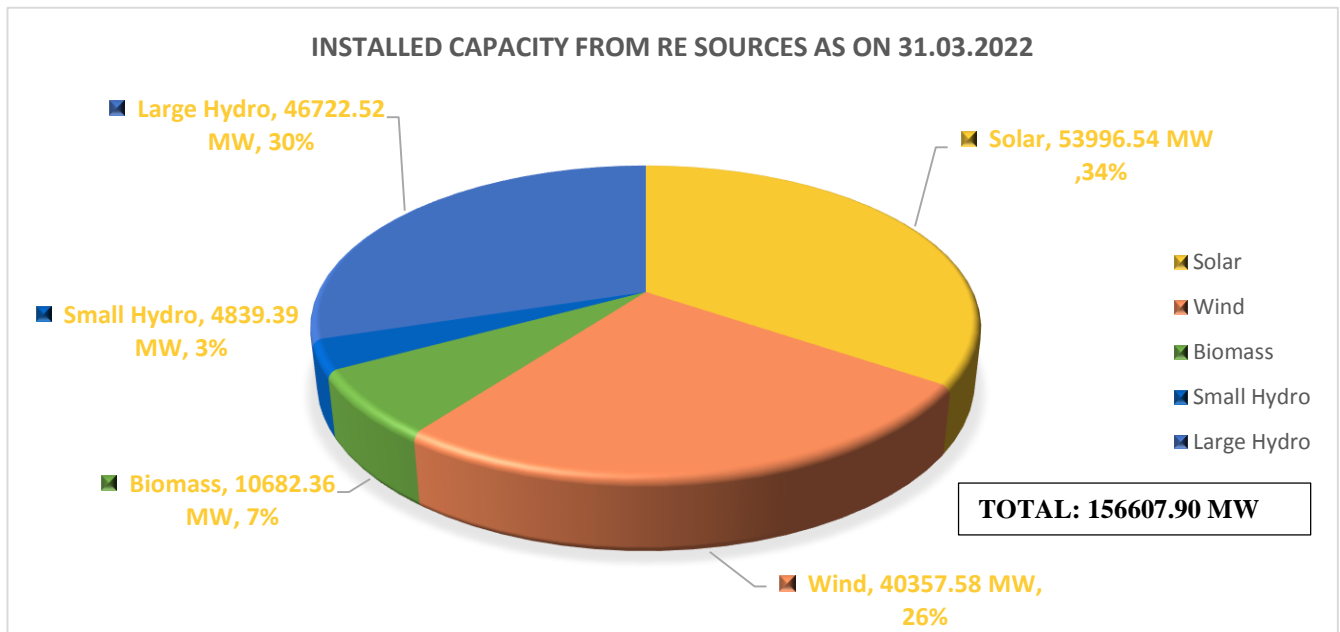
2.4 CAPACITY ADDITION FROM RENEWABLE ENERGY SOURCES DURING 2017-22

The installed capacity from renewable energy sources in the country is 156607.9 MW including large hydro as on 31.03.2022. Source wise installed capacity of renewable energy sources is shown in **Table 2.7** and **Exhibit 2.5**.

Table 2.7
Installed capacity of Renewable energy sources as on 31-03-2022
(Figures in MW)

Source	Capacity
Large Hydro (including PSP)	46722.52
Solar	53996.54
Wind	40357.58
Biomass & Waste to Energy	10682.36
Small Hydro	4848.9
Total	156607.90

Exhibit 2.5



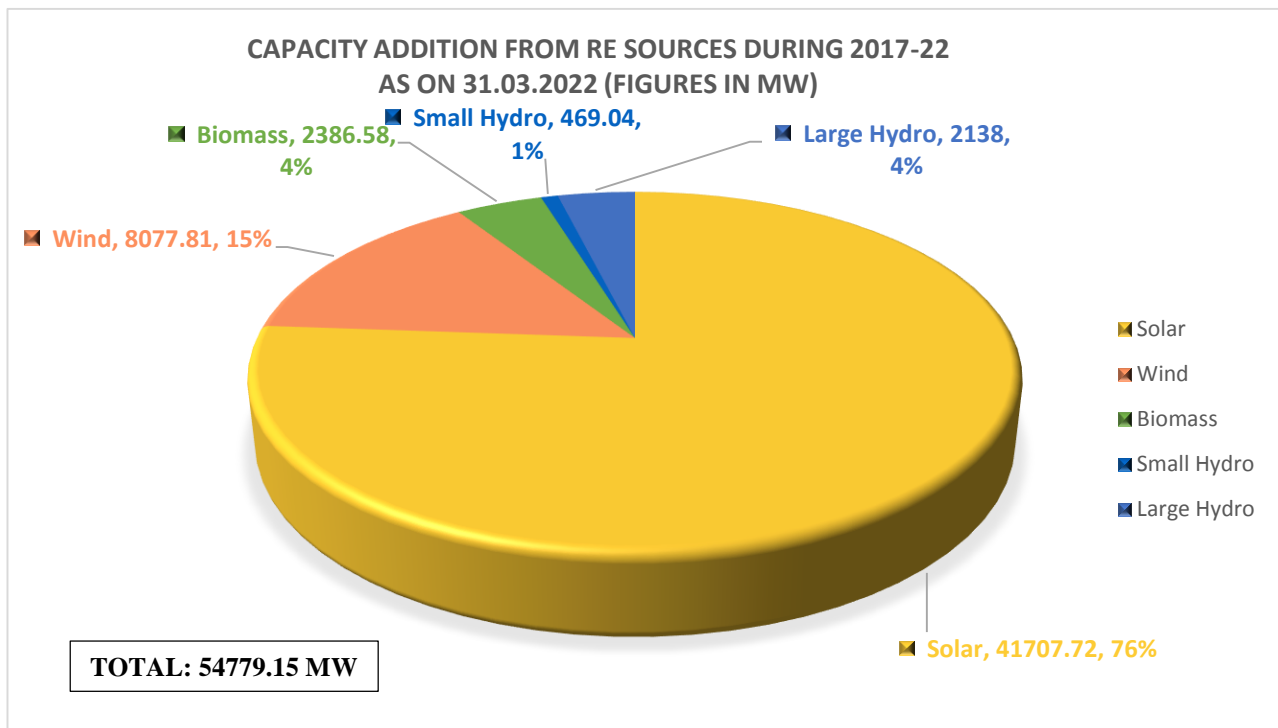
As on 31.03.2022, a capacity addition of 54,779.15 MW from renewable energy sources including large hydro has been achieved during the period 2017-2022. The details of capacity added source wise during 2017-22 is given in **Table 2.8** and **Exhibit 2.6**.

Table 2.8
Capacity addition from Renewable Energy Sources during 2017-22
As on 31.03.2022

(Figures in MW)

Source	Capacity
Large Hydro (including PSP)	2138
Solar	41707.72
Wind	8077.81
Biomass & Waste to Energy	2386.58
Small Hydro	469.04
Total	54779.15

Exhibit 2.6



During period, 2017-22 capacity totaling to 2138 MW from Large Hydro sources has been achieved as on 31.03.2022 comprising of 1100MW of Central Sector, 341 MW of State Sector and 697 MW of Private Sector. This also includes projects totaling to 100 MW which were at various stages of construction and originally not scheduled for the period 2017-22 but have also been commissioned. The list of the commissioned Large Hydro projects is given in **Annexure 2.2**.

Out of Scheduled capacity addition of 6839.5MW from Large Hydro Projects for period 2017-22, a capacity of 4801.50 MW is to be slipped during the period for the year 2017-22, comprising of 2884MW of Central Sector, 1775.5 MW of State Sector and 142 MW of Private Sector. List of slipped Large Hydro plants which were envisaged to be commissioned in National Electricity Plan, 2018 is mentioned along with the detail of reason of delays in **Annexure 2.4**.

2.5 MAJOR REASONS FOR SLIPPAGE OF PROJECTS DURING 2017-22

There are various reasons for slipping of plants during period 2017-22, with most important being the COVID-19 pandemic, which halted the construction activities during the strict lockdown conditions to arrest the pandemic. It has resulted into reduced revenue for companies due to weak demand, which left companies with less capacity for capital expenditure. The global supply chain also was disrupted which affected imports of various key components which resulted in delay of execution of the projects.

Broad Reasons for delay of projects for Hydro, Coal projects are mentioned below and reasons for delay for individual projects are attached in detail in **Annexure 2.4**.

Hydro Projects

- Delay in award of works
- Land Acquisition
- Environment and Forest issues
- Rehabilitation & Resettlement
- Natural Calamities
- Law & order problem & Local issues
- Contractual problems
- Geological uncertainties
- Difficult Terrain & Poor Accessibility
- Funds constraints with Contractor
- Force Majeure Risk
- Issues related to Quarry / Crushers Plants
- Inter-state issues
- Court / NGT / NCLT Cases.
- Teething trouble during commissioning

Thermal Projects

- Problems in acquisition of land for construction of power plant, ash dyke, raw water reservoir, corridor for pipelines, Railway siding etc. and Right of Way /Right of Use for raw water pipe line, ash slurry disposal pipelines and transmission lines etc.
- Local agitations including aspects such as R&R issues, labor disputes and law and order problems. Further, ethnic violence in some specific regions has also resulted in long interruptions at work site.
- Delay in timely availability of railway transport system and healthiness/load carrying capacity of road transport system for smooth transportation of equipment and fuel to the plant site.
- Change in State policies viz. in respect of sand mining, extraction of ground water etc. during plant construction period.
- Issues in timely availability of startup power at site.
- Issues in timely completion of power evacuation system and capacity of transmission system to evacuate full power generated at the plant.
- Shortage of Natural Gas
- Cost overruns on account of delay in timely completion of power projects
- Issues in availability of adequate finances from banks and financial institutions for completion of projects leading to cost overruns/increased cost of the plant.
- Poor performance of main contractor and sub-vendors including BoP sub-vendors for various reasons/issues involved.
- Contractual disputes resulting in termination of contract and re-tendering etc. resulting in project delays and cost overrun.
- Natural calamities and extreme weather conditions including heavy rains, cyclones etc., specifically in coastal areas.
- Not signing of long term PPA with DISCOMs and non-fulfillment of PPA conditions by the project developers. In some cases, even no PPA is available for sale of power from the power plant.

- Delay in availability of Consent to Establish, Consent to Operate (CTO) from respective State Governments.
- Court / NGT / NCLT Cases.

2.6 CONCLUSIONS

- During the period 2017-22, the capacity addition achieved from conventional sources is 30,667.91 MW.
- During the period 2017-22 as on 31.03.2022 the capacity addition from RE sources is 54,779.15 MW including large hydro.
- There has been considerable slippage in the Coal, Hydro and Nuclear capacity addition envisaged during the period 2017-22 with COVID-19 being the major reason resulting in delay.

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Annexure 2.1

**STATE-WISE SECTOR-WISE CAPACITY FROM CONVENTIONAL SOURCES COMMISSIONED DURING
2017-22**

(Figures in MW)

S.NO	STATE	CENTRAL	STATE	PRIVATE	TOTAL
1	DELHI	0	0	0	0.00
2	HARYANA	0	0	0	0.00
3	HIMACHAL PRADESH	0	0	0	0.00
4	JAMMU & KASHMIR	0	0	0	0.00
5	PUNJAB	0	0	0	0.00
6	RAJASTHAN	0	2640	0	2640.00
7	UTTAR PRADESH	2640	660	660	3960.00
8	UTTARAKHAND	0	0	0	0.00
9	CHANDIGARH	0	0	0	0.00
SUB TOTAL NR		2640	3300	660	6600.00
10	CHHATTISGARH	1600	0	2220	3820.00
11	GUJARAT	0	800	0	800.00
12	MAHARASHTRA	1320	0	960	2280.00
13	MADHYA PRADESH*	2920	1320	645*	4885.00
14	GOA	0	0	0	0.00
15	DAMAN & DIU	0	0	0	0.00
16	DADRA & NAGAR HAVELI	0	0	0	0.00
SUB TOTAL WR		5840	2120	3825	11785.00
17	ANDHRA PRADESH	0	510	0	510.00
18	TELANGANA	0	1970	0	1970.00
19	KARNATAKA	800	0	0	800.00
20	KERALA	0	0	0	0.00
21	TAMIL NADU	1000	0	525	1525.00
22	PUDUCHERRY	0	0	0	0.00
SUB TOTAL SR		1800	2480	525	4805.00
23	BIHAR	3890	0	0	3890.00
24	JHARKHAND	0	0	0	0.00
25	ODISHA	1600	1320	0	2920.00
26	SIKKIM	0	0	0	0.00
27	WEST BENGAL	0	0	312	312.00
SUB TOTAL ER		5490	1320	312	7122.00
28	ARUNACHAL PRADESH	0	0	0	0.00
29	ASSAM	250	105.91	0	355.91
30	MANIPUR	0	0	0	0.00
31	MIZORAM	0	0	0	0.00
32	MEGHALAYA	0	0	0	0.00
33	NAGALAND	0	0	0	0.00

34	TRIPURA	0	0	0	0.00
SUB TOTAL NER		250	105.91	0	355.91
35	ANDMAN & NICOBAR	0	0	0	0.00
36	LAKSHDWEEP	0	0	0	0.00
ALL INDIA TOTAL		15360	8395.91	5322	30667.91

*: NIWARI TPP, UNIT-2 (45 MW) HAD ACHIEVED COD ON 20.03.17 BUT THE INTIMATION REGARDING COD WAS RECEIVED IN JUNE'19. THEREFORE, THE PROJECT HAS TAKEN INTO CAPACITY ADDITION ON 06.06.2019 AFTER APPROVAL OF CHAIRPERSON, CEA

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Annexure 2.2

LIST OF CONVENTIONAL SOURCES PROJECTS COMMISSIONED WHICH WERE ENVISAGED DURING 2017-22

(Figures in MW)

S.NO.	PROJECT NAME	TYPE	STATE	DEVELOPER	CAPACITY
CENTRAL SECTOR					
1	NABI NAGAR TPP U2,3,4	COAL	BIHAR	JV OF NTPC & RAILWAYS	750
2	SOLAPUR STPP U1-2	COAL	MAHARASHTRA	NTPC	1320
3	BARAUNI TPS EXTN U8-9	COAL	BIHAR	NTPC	500
4	KUDGI STPP PH-I U3	COAL	KARNATAKA	NTPC	800
5	MEJA STPP U1-2	COAL	UTTAR PRADESH	JV OF NTPC & UPRVUNL	1320
6	LARA TPP U1-2	COAL	CHHATTISGARH	NTPC	1600
7	BONGAIGAON TPP U3	COAL	ASSAM	NTPC	250
8	GADARWARA TPP U1-2	COAL	MADHYA PRADESH	NTPC	1600
9	NABINAGAR STPP U1-3	COAL	BIHAR	NPGCL	1980
10	TANDA TPS, STAGE-II U5-6	COAL	UTTAR PRADESH	NTPC	1320
11	KHARGONE STPP U1-2	COAL	MADHYA PRADESH	NTPC	1320
12	NEYVELLI NEW TPP U1-2	COAL	TAMILNADU	NLCIL	1000
13	DARLIPALLI STPP U1-2	COAL	ODISHA	NTPC	1600
14	BARH STPP STAGE-I UNIT- 1	COAL	BIHAR	NTPC	660
SUB TOTAL (CENTRAL SECTOR)					16020
STATE SECTOR					
1	CHHABRA SCTPP U5	COAL	RAJASTHAN	RRVUNL	660
2	RAYAL SEEMA TPP U6	COAL	ANDHRA PRADESH	APGENCO	600
3	SHRI SINGHAJI TPP (PHASE-II) U3-4	COAL	MADHYA PRADESH	MPPGCL	1320
4	KOTHAGUDEM TPS STAGE-VII U12	COAL	TELANGANA	TSGENCO	800
5	CHHABRA TPP EXTN. U6	COAL	RAJASTHAN	RRUVNL	660
6	IB VALLEY TPP U3-4	COAL	ODISHA	OPGCL	1320
7	WANAKBORI TPS U8	COAL	GUJARAT	GSECL	800
8	SURATGARH SCTPP U7-8	COAL	RAJASTHAN	RRVUNL	1320
9	BHADRADRI-TPP U1-4	COAL	TELANGANA	M/S TSGENCO	1080
10	HARDUAGANJ EXP.-II TPP	COAL	UTTAR PRADESH	M/S UPRVUNL	660
11	NAMRUP CCGT-GAS	GAS	ASSAM	M/S APGCL	36.15
SUB TOTAL (STATE SECTOR)					9256.15
PRIVATE SECTOR					
1	BINJKOTE TPP U1-2	COAL	CHHATTISGARH	SKS POWER GENERATION (CHHATTISGARH) LTD	600
2	NAWAPARA TPPU2	COAL	CHHATTISGARH	TRN ENERGY	300
3	NASIK TPPPH-I U 3-5	COAL	MAHARASHTRA	RATTAN INDIA NASIK POWER LTD	810
4	BARA TPP U3	COAL	UTTAR PRADESH	PRAYAGRAJ POWER GENERATION CO.LTD.	660
5	INDIA POWER TPP (HALDIA) U1-2	COAL	WEST BENGAL	INDIAN ENERGY LTD (HALDIA)	300
6	UCHPINDA TPP U3-4	COAL	CHHATTISGARH	RKM POWER GEN PVT. LTD.	720

7	SHIRPUR TPP U1	COAL	MAHARASHTRA	SHIRPUR POWER PVT. LTD.	150
8	AKALTARA (NARIYARA)	COAL	CHHATTISGARH	K.S.K MAHANADI POWER COMPANY LIMITED	600
9	TUTICORIN TPP ST-4	COAL	TAMIL NADU	SEPC	525
SUB TOTAL (PRIVATE SECTOR)					4665
TOTAL (2017-2021)					29941.15

LIST OF ADDITIONAL CONVENTIONAL SOURCES PROJECTS ADDED DURING 2017-22 BUT NOT ENVISAGED IN NEP 2017-22

S.NO.	PROJECT NAME / IMPLEMENTING AGENCY	FUEL	SECTOR	CAP. (MW)
1	MAHAN TPP U2 / ESSAR POWER MP PVT. LTD.	COAL	PRIVATE	600
2	DISHERGARH TPP	COAL	PRIVATE	12
3	NIWARI TPP, UNIT-2	COAL	PRIVATE	45*
4	LAKWA REPLACEMENT PROJECT U1-7/APGCL	GAS	STATE	69.76
TOTAL				726.76

*: NIWARI TPP, UNIT-2 (45 MW) HAD ACHIEVED COD ON 20.03.17 BUT THE INTIMATION REGARDING COD WAS RECEIVED IN JUNE'19. THEREFORE, THE PROJECT HAS TAKEN INTO CAPACITY ADDITION ON 06.06.2019 AFTER APPROVAL OF CHAIRPERSON, CEA

LIST OF LARGE HYDRO PROJECTS COMMISSIONED WHICH WERE ENVISAGED DURING 2017-22 (Figures in MW)

S.NO.	PROJECT NAME	TYPE	STATE	DEVELOPER	CAPACITY
CENTRAL SECTOR					
1	TUIRIAL HEP U1-2	HYDRO	MIZORAM	NEEPCO	60
2	KISHAN GANGA HEP U1-3	HYDRO	J&K	NHPC	330
3	PARE U1-2	HYDRO	ARUNACHAL PRADESH	NEEPCO	110
4	KAMENG HEP U1-4	HYDRO	ARUNACHAL PRADESH	NEEPCO	600
SUB TOTAL (CENTRAL SECTOR)					1100
STATE SECTOR					
1	NEW UMTRU U1-2	HYDRO	MEGHALAYA	MEPGCL	40
2	SAINJ HEP U1-2	HYDRO	HIMACHAL PRADESH	HPPCL	100
3	PULICHINTALA U2-4	HYDRO	ANDHRA PRADESH	TSGENCO	90
4	SAWRA KUDDU U1-3	HYDRO	HIMACHAL PRADESH	HPPCL	111
SUB TOTAL (STATE SECTOR)					341
PRIVATE SECTOR					
1	DIKCHU U-1	HYDRO	SIKKIM	SNEHA KINETIC POWER PROJECTS PVT. LTD.	96
2	CHANJU-IU3	HYDRO	HIMACHAL PRADESH	IA ENERGY	12
3	TASHIDING U1-2	HYDRO	SIKKIM	SNEHA KINETIC POWER PROJECTS PVT. LTD.	97
4	SINGOLI BHATWARI U1-3	HYDRO	UTTARAKHAND	L&T UHPL	99

5	RONGNICHU UNIT 1-2	HYDRO	SIKKIM	MADHYA BHARAT POWER CORPN.	113
6	BAJOLI HOLI UNIT 1,2,3	HYDRO	HIMACHAL PRADESH	GMR	180
SUB TOTAL (PRIVATE SECTOR)					597
TOTAL (2017-2022)					2038

LIST OF ADDITIONAL LARGE HYDRO PROJECTS ADDED DURING 2017-22 BUT NOT ENVISAGED IN NEP 2017-22

S.NO.	PROJECT NAME / IMPLEMENTING AGENCY	FUEL	SECTOR	CAP. (MW)
1	SORANG UNIT 1-2	HYDRO	PRIVATE	100
	TOTAL			100

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SLIPPED COAL BASED PROJECTS ENVISAGED DURING 2017-22

S.NO.	PROJECT NAME / IMPLEMENTING AGENCY	SECTOR	UNIT NO	CAP. (MW)
CENTRAL SECTOR				
1	BARH STPP-I /NTPC	C	U-2,3	2*660=1320
2	NORTH KARANPURA TPP/ NTPC	C	U-1,2,3	3*660=1980
3	TELANGANA PH-I/NTPC	C	U-1,2	2*800=1600
4	GHATAMPUR TPP/ NLC JV	C	U-1,2,3	3*660=1980
5	BARSINGSAR TPP EXT/NLC	C	U-1	250
6	BITHNOK TPP /NLC	C	U-1	250
TOTAL (CENTRAL SECTOR)				7380
STATE SECTOR				
1	ENNORE EXP. SCTPP(LANCO) / TANGEDCO	S	U-1	660
2	ENNORE SCTPP / TANGEDCO	S	U-1,2	2*660=1320
3	UPPUR SCTPP/TANGEDCO	S	U-1,2	2*800=1600
4	JAWAHARPUR STPP/ UPRVUNL	S	U-1,2	2*660=1320
5	OBRA-C STPP/ UPRVUNL	S	U-1,2	2*660=1320
6	SRI DAMODARAM TPS ST-II	S	U-1	800
7	NORTH CHENNAI TPP ST-III	S	U-1	800
8	DR. NARLA TATA RAO TPS ST-V	S	U-1	800
9	YELAHANKA CCPP-GAS	S	GT+ST	370
TOTAL (STATE SECTOR)				8990
PRIVATE SECTOR				
1	THAMMINAPATNAM TPP STAGE -II / MEENAKSHI ENERGY PVT. LTD.	P	U-3,4	2*350=700
2	AKALTARA TPP (NAIYARA) / KSK MAHANDI POWER COMPANY LTD.	P	U-4	600
3	SHIRPUR TPP/ SHIRPUR POWER PVT LTD	P	U-2	150
4	INDIA POWER TPP / HALDIA ENERGY LTD.	P	U-3	150
5	UTKAL TPP/IND BHARAT	P	U-2	350
TOTAL (PRIVATE SECTOR)				1950
GRAND TOTAL				18320

Note: C- Center, S-State, P- Private

SLIPPED NUCLEAR BASED PROJECTS ENVISAGED DURING 2017-22

S.NO.	PROJECT NAME	STATE	NO. OF UNITS X MW	CAPACITY (MW)
1	KAKRAPAR ATOMIC POWER PLANT	GUJARAT	2X700	1400
2	RAJASTHAN ATOMIC POWER STATION	RAJASTHAN	2X700	1,400

3	PFBR	TAMIL NADU	1X500	500
	TOTAL (2017-22)			3300

SLIPPED HYDRO BASED PROJECTS ENVISAGED DURING 2017-22

S.NO.	PROJECT NAME	STATE	AGENCY	NO. OF UNITS X MW	CAPACITY (MW)
	CENTRAL SECTOR				
1	PARBATI ST. II	HIMACHAL PRADESH	NHPC	4x200	800
2	TAPOVAN VISHNUGAD	UTTARAKHAND	NTPC	4x130	520
3	TEHRI PSS	UTTARAKHAND	THDC	4x250	1,000
4	VISHNUGAD PIPALKOTI	UTTARAKHAND	THDC	4x111	444
5	RAMMAM - III	WEST BENGAL	NTPC	3x40	120
	CENTRAL SECTOR TOTAL				2884
	STATE SECTOR				
1	INDIRA SAGAR (POLLAVARAM MPP)	ANDHRA PRADESH	APID	12x80	960
2	SHONGTONG KARCHAM	HIMACHAL PRADESH	HPPCL	3x150	450
3	UHL-III	HIMACHAL PRADESH	BVPC	3x33.3	100
4	PALLIVASAL	KERELA	KSEB	2x30	60
5	PARNAI	J&K	JKSPDC	3x12.5	37.5
6	LOWER KALNAI	J&K	JKSPDC	2x24	48
7	VYASI	UTTARAKHAND	UJVNL	2x60	120
	State Sector Total				1775.5
	PRIVATE SECTOR				
1	RANGIT-II	SIKKIM	SHPL	2x33	66
2	PHATA BYUNG	UTTARAKHAND	LANCO	2x38	76
	PRIVATE SECTOR TOTAL				142
	TOTAL				4801.5

ANNEXURE 2.4

LIST OF PROJECTS RETIRED DUE TO OLD AGE CRITERIA

(All figures in MW)

S.NO.	NAME OF THE UTILITY	NAME OF THE STATION	UNIT NO.	CAPACITY (MW)
1	DPL	DPL TPS	3,4,5	1*70+2*75=220
2	ASEB	CHANDRAPUR TPS	1,2	2*30=60
3	GSECL	SIKKA TPS	1	120
4	GSECL	UKAI TPS	1,2	2*120=240
5	IPGCL	RAJGHAT TPS	1,2	2*67.5=135
6	UPRVUNL	HARDUAGANJ	5	60
7	UPRVUNL	OBRA TPS	8	94
8	NLC	NEVYELI LIGNITETPS-I	1-9	6*50+3*100=600
9	TSPGCL	KOTHADUDEM TPS	1-8	4*60+4*120=720
10	PSPCL	GND (BATHINDA) TPS	1,2	2*110=220
11	CSPGCL	DSPM KORBA TPS	1-4	4*50=200
12	UPRVUNL	OBRA TPS	1,2	1*40+1*50=90
13	UPRVUNL	PANKI TPS	3,4	2*105=210
14	PSPCL	ROPAR TPS	1	2*210=420
15	MSPGCL	KORADI TPS	5	200
16	PVUNL	PATRATU TPS	4,6,7,9,10	1*40+1*90+1*105+2*110=455
17	NTPC LTD.	BADARPUR TPS	1,2,3	3*95=285
18	DVC	CHANDRAPUR TPS	2,3	2*130=260
	TOTAL			4589

LIST OF PROJECTS RETIRED DUE TO NEW ENVIRONMENTAL NORMS

(THERMAL STATION UNITS WITHOUT SPACE FOR FGD INSTALLATION AND SHALL ATTAIN AGE OF =>25 YEARS ON 1/1/2022)

S. NO.	NAME OF PROJECT	SECTOR	STATE	REGION	UNIT NO	TOTAL CAPACITY (MW)
1	BOKARO `B` TPS	CENTRAL SECTOR	JHARKHAND	ER	1,2,3	3*210=630
2	TALCHER (OLD) TPS	CENTRAL SECTOR	ODISHA	ER	1-6	4*60+2*110=460
3	BANDEL TPS	STATE SECTOR	WEST BENGAL	ER	1,3,4	3*60=180
4	BADARPUR TPS	CENTRAL SECTOR	DELHI	NR	4,5	2*210=420
5	PANIPAT TPS	STATE SECTOR	HARYANA	NR	5	210
6	GND TPS(BHATINDA)	STATE SECTOR	PUNJAB	NR	3,4	2*110=220
7	KORBA-III	STATE SECTOR	CHHATTISGARH	WR	1,2	2*120=240
8	SIKKA REP. TPS	STATE SECTOR	GUJARAT	WR	2	120
9	SABARMATI	PRIVATE SECTOR	GUJARAT	WR	15,16	2*30=60
10	MUZAFFARPUR TPS	CENTRAL SECTOR	BIHAR	ER	1,2	2*110=220
	TOTAL					2760

LIST OF RETIRED DURING 2017-22 BUT NOT ENVISAGED FOR RETIREMENT IN NEP 2017-22

S. NO.	NAME OF PROJECT	FUEL	STATE	UNIT NO	TOTAL CAPACITY (MW)
1	DISHENGARH	COAL	WEST BENGAL	1,3,4,5	18 (1*3+3*5)
2	SEEBPORE TPS	COAL	WEST BENGAL	1,2,3,4	8.375 (3+1.5+1.875+2)
3	NAMRUP CCPP	GAS	ASSAM	1,4,5	55(1*20+1*11+1*24)
4	LAKWA GT	GAS	ASSAM	2,3,4	45 (3*15)
5	CHINAKURI TPS	COAL	WEST BENGAL	1,2,3	30 (3*10)
6	KUTCH LIGNITE	COAL	GUJRAT	1,2	140
7	BARAMURA	GAS	TRIPURA	1,2,3	16.5(2*5+1*6.5)
8	ROKHIA	GAS	TRIPURA	1,2	16(2*8)
9	D.P.L. TPS	COAL	WEST BENGAL	6	110
10	PARLI TPS	COAL	MAHARASHTRA	4,5	420(2*210)
11	TROMBAY TPS	COAL	MAHARASHTRA	6	500
12	YELHANKA DG	DIESEL	KARNATAKA	1,2,3,4,5,6	127.92 (6*21.32)
13	BASIN BRIDGE DG	DIESEL	TAMIL NADU	1,2,3,4	200 (4*50)
14	BHUSAWAL TPS	COAL	MAHARASHTRA	2	210 (1*210)
15	UTRAN CCPP	GAS	GUJARAT	1	144 (3*33+1*45)
16	KORADI TPS	COAL	MAHARASHTRA	7	210
17	ADAMTILA CCPP	GAS	ASSAM	1,2,3	9(3*3)
18	BASKHANDI	GAS	ASSAM	1,2,3,4	15.5(3*3.5+1*5)
19	KOLAGHAT TPS	COAL	WEST BENGAL	1,2	420(2*210)
	TOTAL				2695.295

ANNEXURE 2.5

LIST OF PROJECTS WHICH WERE NOT RETIRED AS ENVISAGED DURING THE PERIOD 2017-22 DUE TO OLD AGE CRITERIA

S.NO.	NAME OF THE UTILITY	NAME OF THE STATION	UNIT NO.	CAPACITY (MW)
1	TSPGCL	RAMAGUNDEM-B TPS	1	62.5
2	PSPCL	ROPAR TPS	3,4	2*210=420
3	MPPGCL	SATPURA TPS	6,7,8,9	1*200+3*210=830
	TOTAL			1312.5

LIST OF PROJECTS WHICH WERE NOT RETIRED AS ENVISAGED DURING THE PERIOD 2017-22 DUE TO NEW ENVIRONMENTAL NORMS

S. NO.	NAME OF PROJECT	SECTOR	STATE	REGION	UNIT NO	TOTAL CAPACITY (MW)
1	BARAUNI TPS	STATE SECTOR	BIHAR	ER	6,7	2*105=210
2	PARICHHA TPS	STATE SECTOR	UTTAR PARDESH	NR	1,2	2*110=220
3	TENUGHAT TPS	STATE SECTOR	JHARKHAND	ER	1,2	2*210=420
4	IND BARATH TPP	PRIVATE SECTOR	ODISHA	ER	1	350
5	TITAGARH TPS	PRIVATE SECTOR	WEST BENGAL	ER	1-4	4*60=240
6	DURGAPUR TPS	CENTRAL SECTOR	WEST BENGAL	ER	4	210
7	BAKRESWAR TPS	STATE SECTOR	WEST BENGAL	ER	1-5	5*210=1050
8	BANDEL TPS	STATE SECTOR	WEST BENGAL	ER	2,5	1*60+1*210=270
9	ROPAR TPS	STATE SECTOR	PUNJAB	NR	5,6	2*210=420
10	KOTA TPS	STATE SECTOR	RAJASTHAN	NR	1-5	2*110+3*210=850
11	TANDA TPS	CENTRAL SECTOR	UTTAR PARDESH	NR	1-4	4*110=440
12	HARDUAGANJ TPS	STATE SECTOR	UTTAR PARDESH	NR	7	105
13	DR. N.TATA RAO TPS	STATE SECTOR	ANDHRA PRADESH	SR	1-6	6*210=1260
14	RAICHUR TPS	STATE SECTOR	KARNATAKA	SR	1-8	7*210+1*250=1720
15	TUTICORIN (P) TPP	PRIVATE SECTOR	TAMIL NADU	SR	1,2	2*150=300
16	NEYVELI (EXT) TPS	CENTRAL SECTOR	TAMIL NADU	SR	1,2	2*210=420
17	NEYVELI TPS- II	CENTRAL SECTOR	TAMIL NADU	SR	1-7	7*210=1470
18	METTUR TPS	STATE SECTOR	TAMIL NADU	SR	1-4	4*210=840
19	NORTH CHENNAI TPS	STATE SECTOR	TAMIL NADU	SR	1-3	3*210=630
20	TUTICORIN TPS	STATE SECTOR	TAMIL NADU	SR	1-5	5*210=1050
21	KOTHAGUNDEM TPS (NEW)	STATE SECTOR	TELANGANA	SR	9,10	2*250=500
22	KORBA-WEST TPS	STATE SECTOR	CHHATTISGARH	WR	1-4	4*210=840
23	GEPL TPP PH-I	PRIVATE SECTOR	MAHARASHTRA	WR	1,2	2*60=120
24	OBRA TPS	STATE SECTOR	UTTAR PARDESH	NR	7	94
	TOTAL					14029

CHAPTER 3

ENERGY EFFICIENCY & CONSERVATION

3.0 BACKGROUND

India stands at the forefront of addressing global challenge of climate change and has committed to an ambitious Nationally Determined Contributions (NDCs) (proposed) of reducing emission intensity by 45 % in 2030 against the levels of year 2005. In its Third Biennial Update Report (BUR 3) submitted to United Nations Framework Convention on Climate Change (UNFCCC), it has been highlighted that India has proactively pursued mitigation and adaptation activities and achieved a reduction in emission intensity of GDP by 24% over the period 2005-2016. India is one of the very few countries on track to fulfilling its declared voluntary mitigation action up to 2020. As per the proposed NDCs, India is committed to achieve 500GW of non-fossil fuel electric power installed capacity by 2030, with the help of transfer of technology and low cost international finance including from Green Climate Fund (GCF). India's third NDC commitment is to create an additional carbon sink of 2.5 to 3 billion tons of carbon dioxide equivalent through additional forest and tree cover by 2030.

Energy efficiency simply means using less energy to perform the same task – that is, eliminating energy waste. Energy efficiency brings a variety of benefits: reducing greenhouse gas emissions, reducing demand for energy imports, and lowering our costs on a household and economy-wide level. While renewable energy technologies also help accomplish these objectives, improving energy efficiency is the cheapest – and often the most immediate way to reduce the use of fossil fuels. There are enormous opportunities for efficiency improvements in every sector of the economy, whether it is buildings, transportation, industry, or energy generation.

3.1 ENERGY CONSERVATION ACT AND FORMATION OF BUREAU OF ENERGY EFFICIENCY

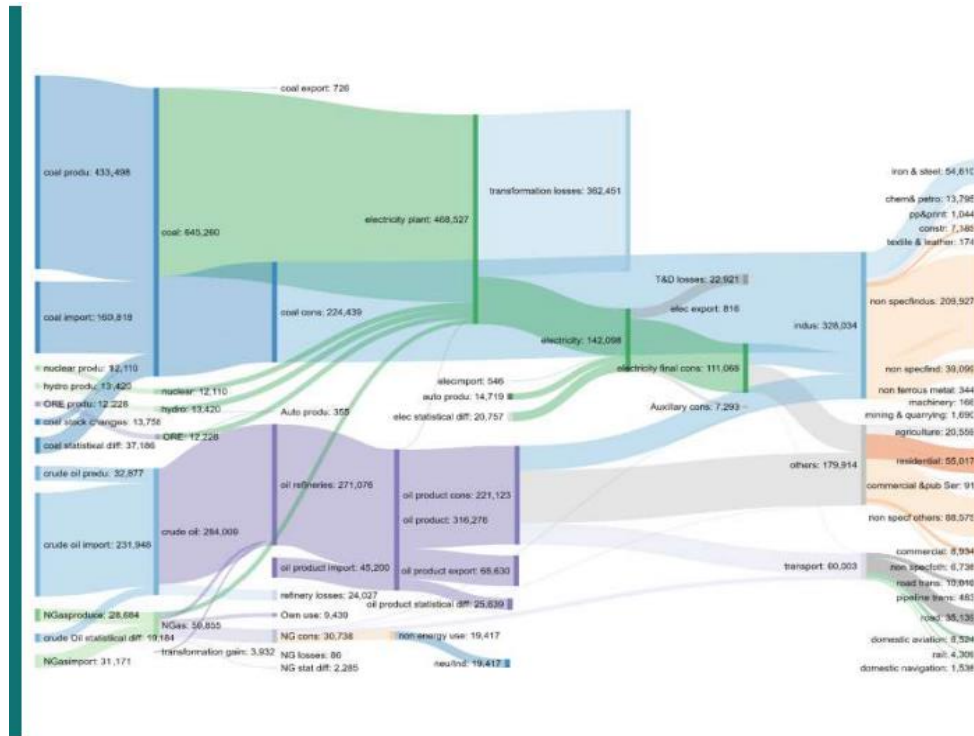
The Government of India set up Bureau of Energy Efficiency (BEE) on 1st March 2002 under the provisions of the Energy Conservation (EC) Act, 2001. As a quasi-regulatory and policy advisory body, the Bureau helps in developing policies and strategies that emphasize self-regulation and market principles to achieve the primary objective of reducing the energy intensity of the economy. The EC Act also empowers the State Government to facilitate and enforce the efficient use of energy through their respective State Designated Agencies (SDAs) in consultation with BEE. It also empowers the Central Government to specify energy performance standards.

The Act came into force in March, 2002. The broad objectives of EC Act, 2001 are:

- Promote faster adoption of energy efficiency and conservation through regulation, participation and cost-effective measures
- Involve States and other stakeholders in the energy efficiency initiatives

- Create a sustainable environment for demand of energy efficient products, technologies and professionals
- Energy Supply and Consumption

Exhibit 3.1
Sankey Diagram Overall Energy Balance of India 2019-20(P) in KToe



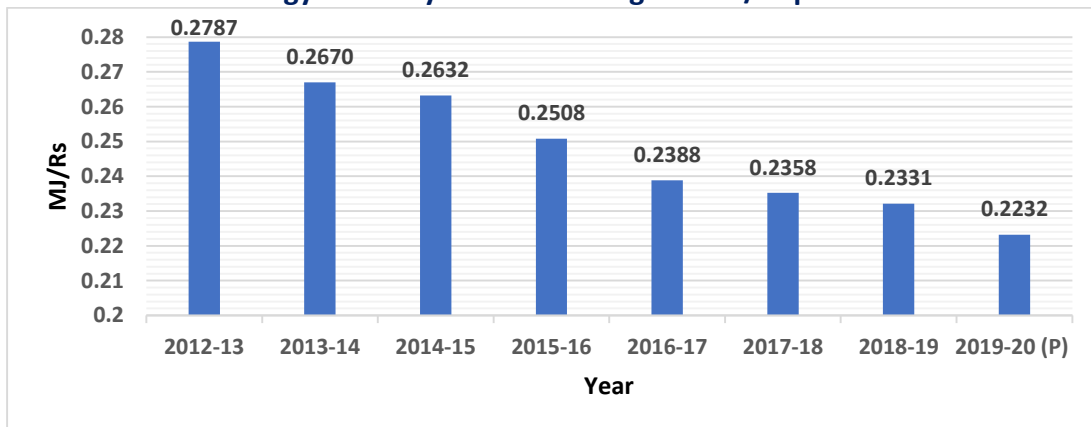
Source: Energy Statistics, 2021-(MOSPI)

3.2 ASSESSMENT OF ENERGY EFFICIENCY MEASURES AND ACHIEVEMENTS

Energy intensity of the country has declined from 0.2787 mega joule per INR in 2012-13 to 0.2232 mega joule per INR in 2019-20(P)

Exhibit 3.2

Energy Intensity of India in Mega Joule / rupee



Source: Energy Statistics, 2021-(MOSPI)

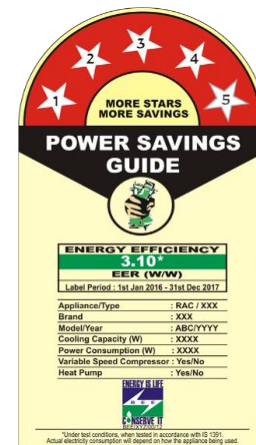
3.3 Energy Efficiency Initiatives

- India has assumed leadership role in promotion of energy efficiency and conservation towards addressing global issue of climate change. Government of India has undertaken a two-pronged approach to cater to the energy demand of its citizens while ensuring minimum growth in CO2 emissions, so that the global emissions do not lead to irreversible damage to the ecosystem.
- In the generation side, the Government is promoting greater use of renewable in the energy mix mainly through solar and wind and at the same time shifting towards ultra-supercritical and supercritical technologies for coal based power plants.
- In the demand side, government have launched various schemes/programs targeted towards improving efficiency under the overall ambit of Energy Conservation Act 2001 (EC Act).

Energy Efficiency initiatives of Government of India are as below:

3.3.1 ENERGY EFFICIENCY IN APPLIANCE SECTOR- STANDARDS & LABELLING PROGRAMME:

- This scheme promotes energy efficiency at the citizens’ level through use of more efficient appliances like Air Conditioners, Refrigerators, Televisions, Geysers etc. by regulation of standards and increasing awareness through informative campaigns. It was launched with the key objective of providing consumers an informed choice about the energy and cost saving potential of the labelled appliances/equipment being sold commercially. This scheme entails laying down minimum energy performance norms for appliances / equipment, rating the energy performance on a scale of 1 to 5, 5 star being the most energy efficient one. Energy labelling is one of the most cost-effective policy tools for improving energy efficiency and lowering associated energy cost of appliances or equipment. As on August 2021, the programme covers 28 appliances out of which 10 appliances are under the mandatory regime while as the remaining 18 appliances are under the voluntary regime.



- The star labelling program for Chillers was introduced on a voluntary basis in September, 2018 for Microwave Oven in February, 2019 and for Solar Water Heater in December, 2019. Further, BEE has expanded the coverage by including Energy Efficient “Deep Freezers” and “Light Commercial Air Conditioners (LCAC)” in March, 2020 on voluntary basis. Voluntary star labelling program for UHD TV and Air Compressor has been launched in January, 2021.

- Initially appliances are covered under voluntary regime and then included under mandatory regime before the standards being gradually ratcheted. The process adopted by BEE for this transition is shared in **Table 3.1** below:

Table 3.1

S. No	Mandatory Appliances	S.No	Voluntary Appliances
1.	Room Air Conditioners	1.	Induction Motors
2.	Frost Free Refrigerator	2.	Agricultural Pump Sets
3.	Tubular Florescent Lamp	3.	Ceiling Fans
4.	Distribution Transformer	4.	LPG-Stoves
5.	Room Air Conditioner (Cassette, Floor Standing)	5.	Washing Machine
6.	Direct Cool Refrigerator	6.	Computer (Notebook/ Laptops)
7.	Colour TV	7.	Ballast (Electronic/ Magnetic)
8.	Electric Geysers	8.	Office Equipment (Printer, Copier, Scanner, Multifunctional Display)
9.	Variable Capacity Inverter Air Conditioners	9.	Diesel Engine Driven Mono-set Pumps, submersible and open-well
10.	LED Lamps	10.	Solid State Inverter
		11.	DG Sets
		12.	Chillers
		13.	Microwave oven
		14.	Solar Water Heater
		16.	Deep Freezers
		16.	Light Commercial Air Conditioners (LCAC)
		17.	Air Compressor
		18.	Ultra-High-Definition Television

3.3.2 EXPANDING COVERAGE OF INDUSTRIAL EFFICIENCY ADOPTION

NATIONAL MISSION FOR ENHANCED ENERGY EFFICIENCY (NMEEE)

- National Mission for Enhanced Energy Efficiency (NMEEE) is one of the eight national missions under the National Action Plan on Climate Change (NAPCC) that was released in June 2008 by the Government of India.
- One of the flagship schemes under NMEEE, the Perform, Achieve and Trade (PAT) scheme is a mechanism designed to achieve emissions reduction in energy intensive industries and it is designed on the concept of reduction in Specific Energy Consumption (SEC). It involves assessment of SEC in the baseline year and projected SEC in the target year covering different forms of net energy going into the boundary of the plant and the products leaving out of it over a particular cycle.



- The implementation of PAT cycle –I that completed in the year 2015 has led to energy saving of 8.67 MTOE which is about 30 % more than the notified targets. This energy saving also translates in to avoiding of about 31 million tonne of CO₂ emission. This energy saving has been converted to Energy Saving Certificates (ESCerts) tradable at the Power Exchanges. Ministry of Power had issued about 38.25 lakh ESCerts to 306 industrial units for excess energy saving and 110 industrial units have been entitled to purchase about 14.25 lakh ESCerts to meet the shortfall to meet energy saving targets. The total volume of ESCerts traded is about 12.98 lakhs resulting into a business of about INR 100 crores during 17 weekly trading sessions.
- Subsequently, the second cycle of PAT (2016-19) was notified in March, 2016 covering 621 Designated Consumers (DCs) from 11 sectors which include eight existing sectors and three new sectors viz. Railways, Refineries and DISCOMs. PAT cycle –II has ended on 31st March 2019 wherein 621 Designated Consumers (DCs) from 11 sectors have achieved total energy savings of 14.08 Million Tonne of Oil Equivalent (MTOE) which exceeds the notified target of 11.28 MTOE by about 16 %. A total of 57.38 lacs ESCerts were issued to 349 industrial units and 193 industrial units are entitled to purchase 36.68 lacs ESCerts.
- Since PAT scheme is being implemented on a rolling cycles basis i.e. new sectors are included every year, PAT cycle –III was notified with effect from 1st April, 2017. PAT scheme in its third cycle seeks to achieve an overall energy saving target of 1.06 MTOE for which SEC reduction targets have been assigned to 116 industrial units from six energy intensive sectors. Subsequently, PAT cycle-IV has commenced with effect from 1st April 2018 in which 109 units have been notified from the existing sectors and two new sectors i.e. Petrochemicals and Commercial Buildings (Hotels).
- PAT cycle –V has commenced with effect from 1st April 2019. Under PAT cycle –V, 110 units from the existing sectors of PAT i.e. Aluminum, Cement, Chlor-Alkali, Commercial Buildings (Hotels), Iron & Steel, Pulp & Paper, Textile and Thermal Power Plant have been notified. The total energy consumption of these DCs comes out to be 15.244 million toe and it is expected to get a total energy savings of 0.5130 million toe through the implementation of PAT cycle –V.
- Under PAT Cycle VI 117 new units have been given targets to reduce their specific energy consumptions through deepening and widening under the PAT scheme during FY 2019-2020. These targets are effective for compliance from April, 2020 under PAT cycle VI. As on the beginning of PAT Cycle VI, total of 1073 industrial and commercial units from 13 energy intensive sectors are included under the PAT Scheme.
- Energy savings potential of 12 new sectors included in June 2020 (Airport, Cement, Railway Prod unit) & feasibility studies for 4 new sectors (Glass, Chemicals, Mining, Zinc and Copper) completed.

“Roadmap of Sustainable and Holistic Approach to National Energy Efficiency” (ROSHANEE), a booklet on Revised National Mission for Enhanced Energy Efficiency was launched on 14 May 2019 by Secretary (Power). The document is a detailed action plan till 2030. The revised mission includes all existing activities of BEE that have contributed significantly towards enhancing energy efficiency and consequent CO₂ mitigation as well as the activities proposed in future, some of which have been identified and others which need to be explored.

3.3.3 ENERGY CONSERVATION BUILDING CODE (ECBC)

- The Energy Conservation Building Code (ECBC) of BEE sets minimum energy performance standards for commercial buildings having a connected load of 100kW or contract demand of 120 KVA and above. While the Central Government has powers under the EC Act, the State Governments have the flexibility to modify the code to suit local or regional needs and notify them.
- In June 2017, BEE rolled out the updated version of ECBC which provides current as well as futuristic advancements in building technology to further reduce building energy consumption and promote low-carbon growth. ECBC 2017 sets parameters for builders, designers and architects to integrate renewable energy sources in building design with the inclusion of passive design strategies. The code aims to optimise energy savings with the comfort levels for occupants, and prefers life-cycle cost effectiveness to achieve energy neutrality in commercial buildings.
- As on June 2021, 18 States and 2 UTs have notified ECBC for their states. Other states are at advance stages of adopting the ECBC.
- Energy Conservation Building Code (ECBC) Cells of BEE, housed at State Designated Agencies (SDAs), are supporting implementation of ECBC at State level. As on August 2021, 48 Urban Local Body (ULBs) from 8 States have incorporated provisions of ECBC for building approval process.
- Recently, residential building energy conservation code (Eco Niwas Samhita) and labelling program for residential building was launched. In order to promote energy efficiency in residential building sector, “ECO-NIWAS” Portal (www.econiwass.com) has been developed. The scope for energy efficiency improvements in existing buildings is immense. Energy Audit Studies have revealed a savings potential to the extent of 40% in end use such as lighting, cooling, ventilation, refrigeration etc.
- In order to create a market pull for energy efficient buildings, BEE developed a voluntary Star Rating Programme for commercial buildings which is based on the actual performance of a building, in terms of energy usage in the building over its area expressed in kWh/sq.



m/year. This Programme rates buildings on a 1-5 star scale, with 5-Star labelled buildings being the most energy efficient. Currently the scheme is applicable to 4 categories of buildings i.e. Day use Office buildings, Shopping Malls, BPOs and Hospitals. As on August, 2021, 264 buildings have been rated under various categories.

- Union Minister of Power and New & Renewable Energy announced various initiatives being taken by Government of India towards energy efficiency in the building sector, as part of 'Azadi Ka Amrit Mahotsav' on 16th July, 2021. The initiatives launched included:
 - Specifying code compliance approaches and minimum energy performance requirements for building services, and verification framework with Eco Niwas Samhita 2021.
 - The web-based platform 'The Handbook of Replicable Designs for Energy Efficient Residential Buildings' as a learning tool, which can be used to create a pool of ready-to use resources of replicable designs to construct energy-efficient homes in India.
 - Creating an Online Directory of Building Materials that would envisage the process of establishing Standards for energy efficient building materials.
 - Announcement of NEERMAN Awards, (National Energy Efficiency Roadmap for Movement towards Affordable & Natural Habitat), with the goal of encouraging exceptionally efficient building designs complying with BEE's Energy Conservation Building Codes.
 - Online Star Rating tool for Energy Efficient Homes created to improve energy-efficiency and reduce energy consumption in individual homes. It provides performance analysis to help professionals decide the best options to pick for energy-efficiency of their homes. Training of over 15,000 Architects, Engineers and Government officials on Energy Conservation Building Code (ECBC) 2017 and Eco Niwas Samhita (ENS) 2021).

3.3.4 ENERGY EFFICIENCY AND DEMAND SIDE MANAGEMENT (DSM)- DEMAND SIDE ENERGY EFFICIENCY


- Energy Efficiency and Demand Side Management (DSM) measures in the Energy Sector is a cost-effective tool. Energy Efficiency programs encourage the installation of end-use technologies that consume less energy, thereby reducing and/ or shifting the customers' overall electric bill. Energy Efficiency and DSM programs can help utilities to reduce their peak power purchases on the wholesale market thereby lowering their overall cost of operations.
- The capacity building and other support is helpful for the DISCOMs to implement DSM in their respective areas. Total 62 DISCOMS are covered under the programme. During the period 2012-17, BEE had selected 34 DISCOMs for their capacity building and provided necessary support for the implementation of DSM related activities. During second phase (2017-20), additional 28 DISCOMs were included under this programme.

- The objective of the programme is to carry out load management programme, development of DSM action plan and implementation of DSM activities in their respective areas.

During FY 2017-20, the major activities are as follows:

BEE has engaged 5 Project Management Consultants (PMCs) zone wise for undertaking activities under “Capacity Building of DISCOMs” programme for the additional 28 DISCOMs and existing 34 DISCOMs. The PMCs have carried out load research studies and development of DSM Action Plan for each of the new DISCOMs and resulted in training of around 1000 officers, 764 Master Trainers on DSM and Energy Efficiency.

Energy Efficiency Measures in Agriculture Sector

- Energy Efficiency in Agriculture provides immense opportunity in reducing the overall power consumption, improving efficiencies of ground water extraction and reducing the subsidy burden on the states without sacrificing the service obligation of this sector. Pump set efficiency up-gradation is one of the key aspects of energy efficiency measures in agriculture sector. The mere replacement of existing inefficient pump sets with energy efficient star rated pump sets is proven to deliver savings of 30-40%.
- In order to tap the energy savings potential, Agriculture Demand Side Management (Ag DSM) program was initiated by BEE with an objective to induce energy efficiency in agriculture sector by creating market based framework for implementation of few pilot projects and create awareness among end users & other stakeholders for adoption of energy efficient pump sets (EEPS).
- MOU was signed between BEE and Indian Council for Agricultural Research (ICAR). 508 awareness programs have been conducted by Kisan Vigyan Kendras (KVKs) and SDAs with 11,000 farmers trained.

Barriers & Challenges:

- Implementation of AgDSM program promises a lot of benefits for all its stakeholders. However, there are various barriers and challenges that exist at present which needs to overcome in order to realise the actual benefits of the program :
 - Limited Policy dialogues at national and state level on sector reforms regarding developing an integrated energy DSM framework for agriculture.

- Unsuitable energy pricing for agriculture sector.
- Limited state level policies to encourage use of energy efficient pump sets
- Unavailability of local technology / service provider for energy efficient pumps and other accessories.
- Limited availability of capital to invest in AgDSM projects.

Energy Efficiency Measures in Municipal Sector

- Identifying the immense energy saving potential in municipal sector, BEE initiated Municipal Energy Efficiency Programs. The basic objective of the project was to improve the overall energy efficiency of the Urban Local Bodies (ULBs), which could lead to substantial savings in the electricity consumption, thereby resulting in cost reduction/savings for the ULBs. 34 capacity building programs on Energy Efficiency and O&M measures conducted by SDAs with 2024 number of officials from ULBs, UDDs and MCs trained in 10 states.

3.3.5 ENHANCING ENERGY EFFICIENCY OF SMALL AND MEDIUM INDUSTRIES (SMES)

- The MSMEs in India are around Sixty-Three million – and a majority of them have not implemented any energy efficiency (or) technology upgradation measures and continue to depend on obsolete, low efficiency technologies that result in wasteful energy consumption, also reducing profitability and competitiveness of MSMEs sector in India.
- Considering the importance of MSMEs in promoting energy efficiency, ‘National Programme on Energy Efficiency and Technology Upgradation of MSMEs’ has been developed by Bureau of Energy Efficiency. Some of the key achievements are:
 - A knowledge portal namely Simplified Digital Hands-on Information on Energy Efficiency in MSMEs (SIDHIEE) was developed. The portal hosts variety of knowledge resources like case studies, best operating practices, details of latest energy efficient technologies etc.
 - A MoU has been signed between O/o DC, MSME and BEE for joint implementation of the programme titled “Promoting Energy Security of MSME sector”.
- Bureau of Energy Efficiency is implementing Energy Efficiency technologies in many energy intensive clusters of India with the support from Global Environment Facility through UNIDO and World Bank towards common goal of facilitating the development of



the SME sector in India through the promotion and adoption of clean, energy efficient technologies and practices. Some of the major achievements of the programs are as below:

GEF – UNIDO – BEE programme

- Energy Management Centres have been established under this project in 12 clusters.
- Implementation of more than 50 energy efficient technologies as pilot projects.
- Implemented 17 demo projects in 7 clusters and the project has resulted in annual energy savings of more than 8500 TOE

GEF – WB – BEE programme

- Technical Assistance to around 750 Energy Professionals
- Training Programs for Bankers/FI on energy efficiency projects and appraisals
- More than 5000 MSME units are covered through various awareness and capacity building initiatives
- Annual Energy savings of 25000 TOE with average ROI of 18 months has been achieved

Clean energy technology adoption by MSME sector

- Under the vision for 'Atmanirbhar Bharat' Hon'ble Minister launched "Energy Efficiency Enterprise (E3) Certifications Programme for Brick manufacturing Sector" in March, 2021 to kick-start a series of events from Ministry of Power, Government of India under 'AzadiKaAmritMahotsav'.

3.3.6 AIMING TOWARDS GREENER TRANSPORT SECTOR

Fuel efficiency norms to save energy in transport vehicles

- Average fuel consumption standards for passenger cars on 23rd April 2015 issued. The fuel consumption standards are under implementation from April'2017 onwards, and a second set of standards would come into force from 2022-23.
- Fuel economy norms for Heavy Duty Vehicles have been notified. These norms are applicable for M3 (Buses) and N3 (Trucks) category vehicles complying with BS IV norms with gross vehicle weight exceeding 12 tonnes.
- Fuel Economy norms for Light Commercial Vehicles notified. These norms shall apply on the vehicles being sold or manufactured in India and having gross vehicle weight ranging between 3.5 tonnes and 12 tonnes.

Low Carbon and less pollution Fuels

- "Charging Infrastructure for Electric Vehicles - Guidelines and Standards" issued on 14.12.2018 which were revised on 01.10.2019 and thereafter on 08.06.2020 (Battery Swapping stations included in this revision)
- Hon'ble Minister for Road Transport & Highways in the august presence of the Hon'ble Minister of Power launched the "Go Electric" Campaign to spread awareness on the benefits of e-mobility and EV Charging Infrastructure as well as electric cooking in India.
- The Ministry of Railways, with a view to transform Indian Railways (IR) into "Green Railways" has planned to achieve 100 % electrification of Broad Gauge (BG) routes by 2023-24. This will facilitate elimination of diesel traction resulting in significant reduction in its carbon footprint and environmental pollution. As of May 2021, IR has electrified 45,881 route kilometer (RKM) (71 per cent – of total 64,689 RKM BG routes). IR has also introduced Head on Generation (HOG) system, whereby electrical power is fed to the coaches directly from the Over Head Equipment (OHE) through the Locomotive. It eliminates the need for separate diesel fueled power cars in trains and thus reduces the need for pulling extra coaches and increases efficiency, which furthers results in reduction in carbon footprint. To improve energy efficiency in Electric traction, IR has introduced three phase technology in locomotives and Electrical Multiple Units (EMU)/Mainline Electrical multiple units (MEMU), these locomotives and EMU/MEMU rakes are equipped with regenerative braking feature capable to regenerate electricity during braking action which is fed back to grid (15-20 % improvement in efficiency). From 1st April, 2016 conventional electric locomotives (DC Motor based) were discontinued.

Electric Vehicle Charging Infrastructure and R&D program

- DST is supporting industry-academia collaborations to develop indigenous low-cost technologies like chargers for light Electric Vehicles (2/3 Wheelers), lighter cars, Buses and Trucks.
- DST had conducted a series of stakeholder discussions on EV R&D Program, monitored the EV Charging Standards Program at BIS and participated in the deliberations under the Faster Adoption and Manufacture of Hybrid and Electric Vehicles (FAME) and Phased Manufacturing Program Mission to identify the scope and potential for undertaking R&D Program.

3.3.7 FISCAL INSTRUMENTS

Partial Risk Sharing Facility (PRSF): BEE supports Partial Risk Sharing Facility (PRSF) for Energy Efficiency which is implemented by World Bank through SIDBI in India. PRSF guarantee is for maximum 75% of loan amount or Rs. 15 crore per project, whichever is less. This guarantee scheme is similar to PRGFEE and till date SIDBI has issued 18 guarantees with project cost worth Rs. 275 crore (approx.) and guarantee of worth Rs. 63.45 crore has been issued.

3.3.8 STATE DESIGNATED AGENCY

- The EC Act mandates creation of a two-tier organization structure to promote the efficient use of energy and its conservation in the country with BEE as the nodal agency at central level and State Designated Agencies (SDAs) as nodal agencies at State / Union Territory (UT) level. Section 15(d) of the EC Act stipulated that the State Government/ UT Administration may designate any agency at the State level to co-ordinate, regulate and enforce the provisions of the Act within the State/UT.
- Till June, 2021, 36 States/UTs have nominated SDA in their respective State/UT. Only two States – Kerala and Andhra Pradesh have established Stand-Alone SDA. However, remaining 34 States/UTs have assigned additional responsibility of facilitation and enforcement of the provisions of the EC Act at the State level to one of their existing agencies/departments, wherein, the SDA shares key facilities / staff / budget with the parent department.
- Functions of SDA

SDAs have a crucial role to play in promoting energy efficiency among energy consumers in all sectors within the State such as agriculture, building, industry/MSME, municipality, and transport by undertaking the following activities.

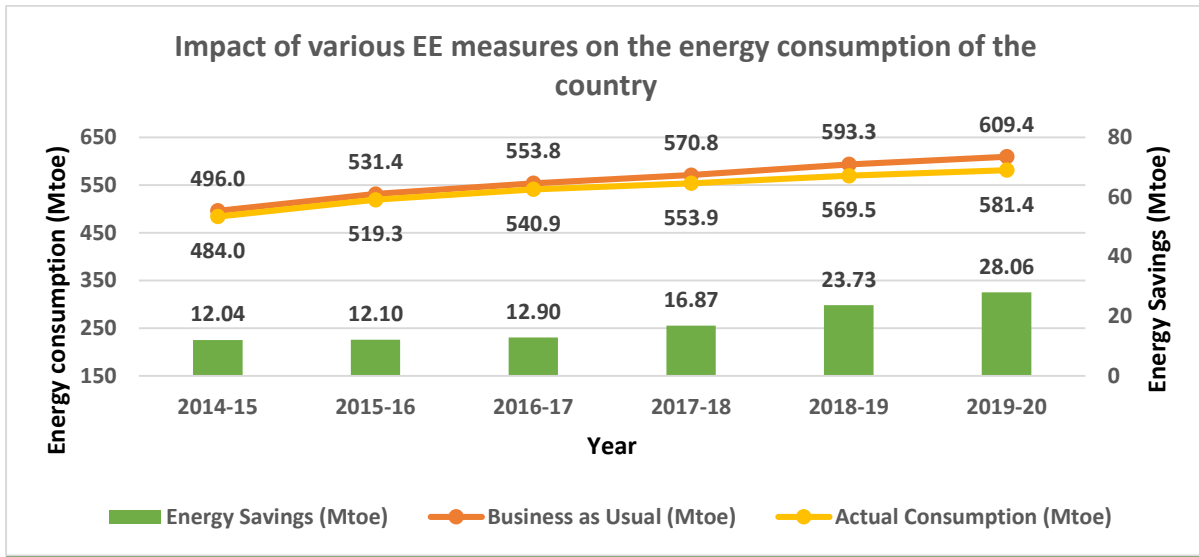
- a) Energy Efficiency Demonstration Projects to showcase the effectiveness of energy efficient equipment / appliances / technologies to facilitate large scale replication.
 - b) Outreach / publicity activities for creating awareness and increasing consciousness towards the importance and beneficial impacts of energy efficiency.
 - c) Research and innovation activities on energy efficiency in collaboration with various private organizations, academic / technical / research institutions and laboratories;
- Workshops / capacity building programmes to disseminate latest information relating to specific areas/aspects amongst respective stakeholders and provide them with the required training on Energy Efficiency
 - State Energy Efficiency Index

The Bureau of Energy Efficiency (BEE) has developed the State Energy Efficiency Index program with an objective to help drive Energy Efficiency policies and program implementation at the state and local level; highlight best practices and encourage healthy competition among states and track progress in managing the States and India's energy footprint.

3.4 Impact of various EE measures on the energy consumption of the country

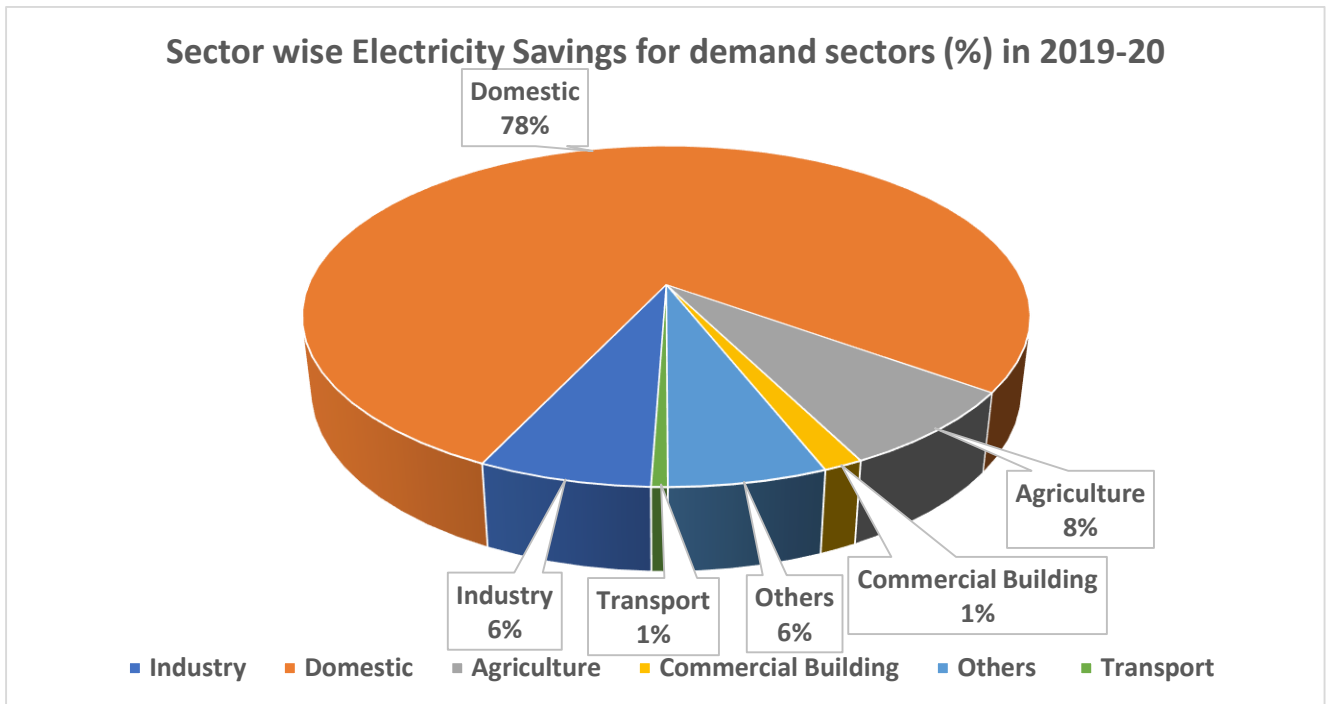
The total energy consumption and energy savings due to energy efficiency measures are shown in **Exhibit 3.3** below:

Exhibit 3.3



Data Source:- BEE, MOSPI Energy Statistics Report & Impact of Energy Efficiency Measures (2019-20)

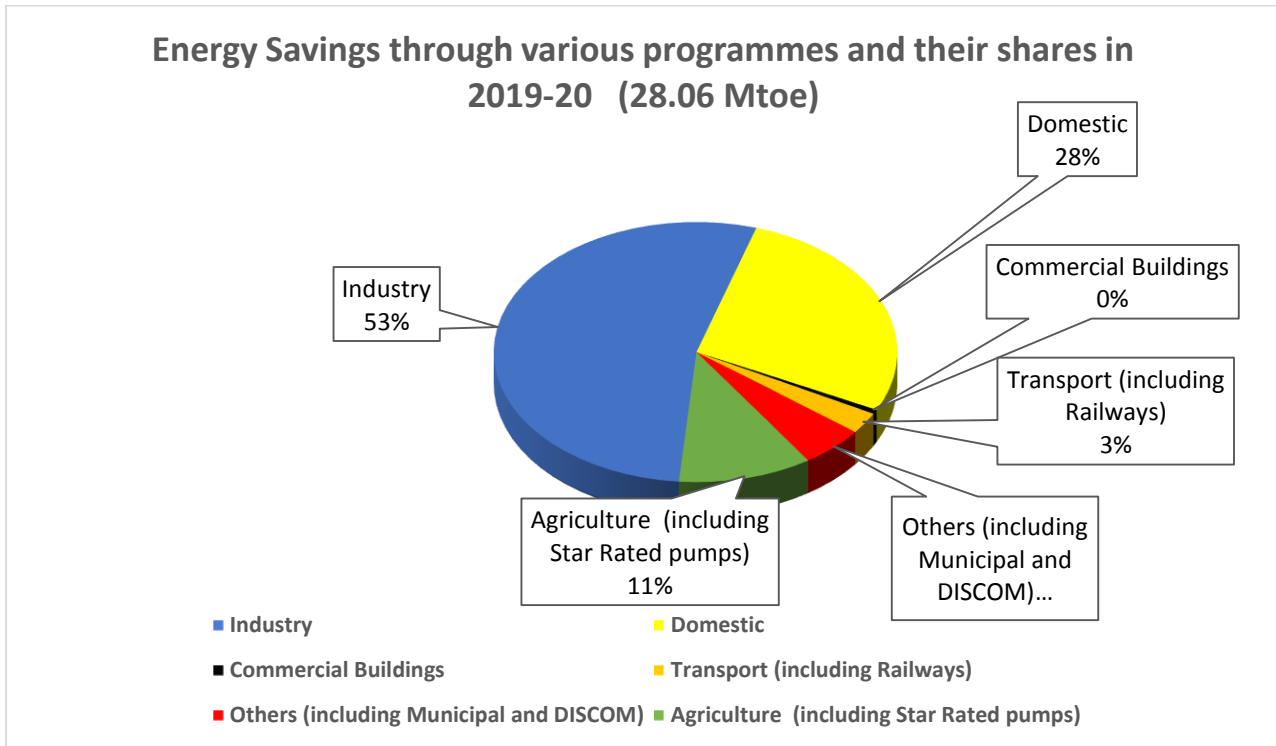
Exhibit 3.4



Net savings is **115.25 BUs** i.e. **9.71%** of net electricity consumption. **Electrical Savings from PAT Supply Side sectors is not considered here**

(Source: Impact of Energy Efficiency Measures (2019-20), BEE)

Exhibit 3.5



Source: Impact of Energy Efficiency Measures (2019-20), BEE

3.5 Details of Energy Savings and CO2 emission reduction (2017-21) through Key Energy Efficiency Initiatives by BEE

Table 3.2

Name of the scheme / Programme	2017-18			2018-19			2019-20			2020-21(Provisional)		
	Energy Saved		Reduction in CO ₂ emission (Million tonnes CO ₂)	Energy Saved		Reduction in CO ₂ emission (Million tonnes CO ₂)	Energy Saved		Reduction in CO ₂ emission (Million tonnes CO ₂)	Energy Saved		Reduction in CO ₂ emission (Million tonnes CO ₂)
Thermal (MTOE)	Electrical (BU)	Thermal (MTOE)		Electrical (BU)	Thermal (MTOE)		Electrical (BU)	Thermal (MTOE)		Electrical (BU)	Thermal (MTOE)	
PAT Scheme	9.4	3.0	37.0	11.1	30.3	62.0	14.3	37.9	86.9	14.3	37.9	86.9
SME Programme	0.0	0.0	2.2	0.0		0.1	0.0	0.0	0.1	0.0	0.0	0.1
Standards & Labeling Programme	0.0	48.5	40.0		55.7	45.7	0.0	56.3	46.2	0.0	56.3	46.2
Building Programme	0.0	0.3	0.2		0.1	0.1	0.0	0.2	0.2	0.0	0.2	0.2
Agriculture DSM Programme	0.0	0.1	0.1		0.2	0.1	0.0	8.7	7.1	0.0	8.7	7.1
Mu DSM (SLNP)		3.7	3.1		5.6	4.6		6.9	5.6		8.1	6
Transport	0.0	0.0	0.0		0.9	2.7	1.2	0.0	2.7	1.2	0.0	2.7
Other	0.0	0.0	0.0									
UJALA		31.4	26.0		44.6	36.6		35.0	29.0		48.0	39.0
Total Energy Savings	9.4	86.9	108.5	11.1	137.4	151.8	15.6	145.0	177.9	15.6	159.2	188.3

3.6 PROJECTIONS OF ENERGY SAVINGS

Bureau of Energy Efficiency (BEE) has developed a Strategy Plan towards Developing an Energy Efficient Nation (2017-2031) - Unlocking National Energy Efficiency Potential (UNNATEE) which lays framework and implementation strategy, in the medium term and long term, to establish a clear linkage between energy demand scenarios and energy efficiency opportunities in order to conceptualize a comprehensive roadmap to address India's environmental and climate change commitments.

The breakup of projections of energy savings for utility and non-utility for the years 2022-27 and 2027-32 have been estimated and are shown in **Table 3.3** below:

Table 3.3
Projections of energy savings during 2022-27 and 2027-32

Year	Moderate scenario		Ambitious Scenario	
	Electricity (BU)	Primary Energy (Mtoe)	Electricity (BU)	Primary Energy (Mtoe)
2022-23	159	28.95	214	43.8
2023-24	171	34.79	230	52.52
2024-25	184	40.98	247	61.71
2025-26	198	47.53	265	71.41
2026-27	213	54.98	285	81.67
2027-28	229	61.85	306	92.51
2028-29	246	69.67	328	103.99
2029-30	265	77.99	353	116.15
2030-31	285	86.83	379	129.04
2031-32	304	107	404	160

3.7 MEASURES TO BE ADOPTED TO ACHIEVE THE TARGET

Table 3.4

SN	Area	Programme	Broad Activity
1	Policy and Institutional framework	Energy Conservation Act (EC Act)	Propose amendment to the EC Act, 2001, for streamlining and enhancing the scope of the Act
		Strengthening institutional framework	Institutional set-up of the Bureau of Energy Efficiency
			Strengthening of State Designated Agencies/establishment of State BEEs
			Cooperation with International Bodies
2	Industries	Perform Achieve and Trade (PAT)	Expanding coverage of the scheme to other sectors. Introducing a similar programme for Small and medium scale Enterprises (SME)
		Energy Conservation guidelines and manual	Preparing guide materials for industry for strengthening energy conservation through operational and maintenance practices
		Promoting energy efficient technologies	Promoting uptake of emerging technologies, e.g. Waste Heat Recovery/ co-generation/ tri-generation/micro turbine, etc.
		Benchmarking	Initiate periodic benchmarking and energy efficiency gap assessment for industrial sectors.
		Database of Energy Efficiency technology	Creation of a public database of Energy Efficiency technology suppliers, to be updated periodically
3	Small & Medium Enterprise	SME cluster programme for Energy Efficiency	Promotion of innovative demo projects and capacity building of SMEs
		Low Carbon technologies	Promotion of innovative low carbon technologies in the SME cluster
		Brick Kilns	Market transformation for energy efficient bricks
		SAMEEEKSHA	Knowledge sharing and synergizing the efforts of various organizations and institutions
4	Equipment and appliances	Standards and Labeling Programme	Widen coverage of the current scheme, specify norms and standards for industrial processes, and digitization of S&L database

		Super Energy Efficient Programme	Market transformation for super-efficient equipment/appliances
5	Buildings	Energy Conservation Building Code	Strengthening states institutions to operationalize Commercial and Residential Building Codes
		Buildings under PAT	Improving energy performance index of buildings through mandatory targets
		Energy Efficiency label	Develop energy efficiency labels for buildings
		Financing incentives under buildings	Promoting Energy Efficiency in buildings through financial incentives
6	Demand Side Management (DSM) and Data analytics	DSM activities	Widen coverage of the current scheme for AgDSM and MuDSM
7	Sustainable Transportation Network	Vehicle Fuel Efficiency Programme	Develop fuel efficiency norms and standards for vehicles
		Energy Efficiency in Railways	Improving energy efficiency in Railways through PAT scheme
		Electric vehicles	Develop market approaches to enhance EV affordability and promote public private partnerships
		Standards for EVs and charging station	Prescribing minimum energy performance standards for EVs and charging stations
		Labeling program for vehicles	Labeling of the vehicles on their fuel efficiency levels
		Alternative Fuel	Promoting the use of alternate technologies in the transport sector, e.g., hydrogen fuel cell
8	Agriculture sector	Technology	Encourage uptake of energy efficient technology through development of norms and standardizing technology to aid development of business models viz, Cold Chains, farm machinery and agricultural pumping

		Knowledge sharing	Disseminating the knowledge on Energy Efficiency among users through relevant universities, demo projects, etc.
		Innovative financing	Developing/ integrating innovative financing schemes focusing exclusively on energy efficiency in agriculture sector
9	Capacity building and awareness	Capacity Building of DISCOMs	Promoting use of analytical tool to assess data for load management, demand shift, etc. to formulate DSM action plan and implementation of DSM activities
		Awareness in school Children	Module on Energy Efficiency for school children
			National level Painting competition for school children
			Energy Clubs in schools
		Certification Examination for Energy Managers and Energy Auditors	Enhancing the curriculum; accreditation and empanelment of auditors
		ESCO	Improving capacity through workshops, trainings etc.
		Energy Management System	Promoting Energy Management by encouraging ISO 50001 adoption
		National Energy Conservation Award (NECA)	Expand the scope of NECA to more sectors
		Capacity building of operators and supervisors	Dedicated training modules for the operators and supervisors of utilities, Open Online Course
Campaign for Optimum Space Cooling	Generating consumer awareness and benefits in maintaining air conditioning temperature at 24°C or more		
10	Knowledge Management	Knowledge sharing/ Exchange Platform	Sectoral platforms to be operationalized for better and accelerated learning by the sectors including peer to peer learning, Open Online Course
11.	Finance	Mobilize energy efficient investment	To set up Energy Efficiency Financing Department in Power Finance Corporation (PFC) and execute interest subvention scheme and credit guarantee scheme for promoting energy efficiency financing in industries sector.

			To set up energy efficiency financing cells in few nationalized banks which will help banks in identifying and appraising EE projects
			Partial Risk Sharing Facility (PRSF) to support ESCO projects by issuing partial risk guarantees to EE loans.
			Energy Efficiency Financing Facility (EEFF) is to provide direct financing of EE loans by IREDA and PFC.
		Other initiatives	New financing initiatives like financing through Micro Financing Institutions (MFIs), absorption of transaction cost of FIs for small projects, Green bonds, etc. to support energy efficiency financing for Industries, MSMEs, buildings and any other areas having substantial energy saving opportunities.
12	Research & Development (R&D)	Research & Development and Innovation	Promote public/private partnerships, incubators and accelerators, basic R&D on energy efficient technology
13	Monitoring Reporting & Verification (MRV)	Monitoring, Reporting and Verification (MRV)	Standardized baseline establishment and assessment of savings for ESCO projects and further refinements in M&V guidelines under PAT

The investment potential of the country in order to achieve the potential energy efficiency saving target is estimated to be between INR 10 lakh cr. to INR 13 Lakh cr. By adoption of energy efficiency measures, India holds a potential to reduce 438 MtCO₂ to 623 MtCO₂ by 2030.

3.8 Initiatives of Government for enhancing energy efficiency and for decarbonisation of the power sector

- I. **Adoption of ultra-super critical/ super-critical technology in thermal generation:**
 Ultra supercritical & Supercritical units are designed with higher steam parameters of 280 kg/cm² at 600/600°C and 247kg/cm² at 565/593 °C respectively. With the higher steam parameters of ultra-super critical/ supercritical units, the efficiency of these ultra-supercritical and supercritical units would be 9% and 5% respectively higher than the efficiency of present typical 500 MW sub-critical units. This would lead to corresponding savings in coal consumption and reduction in GHG emissions. The thermal units in the country so far have largest size unit capacity of 800 MW. 90 Nos. ultra supercritical/ supercritical units of sizes varying between 660 to 800MW with a total capacity of 62370 MW (including 2 units of ultra-supercritical of capacity of 1320MW) till 01.02.2022 have been commissioned and 27840 MW ultra-supercritical/ supercritical units capacity are under construction (excluding construction of 9,900 MW which is held up due to various reasons). In the period 2021-25, coal based capacity addition would be mainly through ultra-super critical / supercritical units.

Higher size units of 660-800 MW based on ultra-super critical/ supercritical technology will not only accelerate pace of capacity addition but will have lesser impact on environment due to lower CO₂ & SO_x emissions per unit of electricity generated. Emissions of other pollutants like NO_x & SPM would also reduce with adoption of latest technologies of low NO_x burners, efficient ESPs etc. Higher efficiency, besides leading to corresponding savings in coal consumption, would also lead to lower ash generation. The land requirement for ash dump areas would also correspondingly reduce and there would be reduction in auxiliary power consumption.

The national average thermal efficiency of coal/lignite based power plants has increased from 34.94% in 2015-16 to about 35.69% in 2019-20. It is expected that the efficiency of coal based generation would further improve in the period 2022-27 due to commissioning of ultra super critical / supercritical units.

II. **Renovation and Modernization (R&M) & Life Extension (LE) of existing old power stations:**

R&M and LE works of Thermal capacity of 16,146 MW and 7202MW have been completed in 11th Plan and 12th Plan period respectively. During the years 2017-22 R&M and LE works of Thermal capacity of 14,929 MW (tentative) are being considered.

III. **National Hydrogen Mission**

Hydrogen has found various applications in the end-user industry, for power generation and as a clean fuel. Extensive research is supported by the Ministry of New and Renewable Energy on production of hydrogen from renewable energy sources, its safe and efficient storage and its utilization for energy and transport through combustion and fuel cells.

Hydrogen is the most abundant element on the planet. Most of the hydrogen is produced from fossil fuels by steam reforming or partial oxidation of methane and coal gasification with only a small quantity by alternative routes such as biomass gasification or electrolysis of water or with no carbon emissions. Green hydrogen is produced using renewable energy and electrolysis to split water and is distinct from grey hydrogen (which is produced from methane and releases greenhouse gases into the atmosphere).

India has also launched the National Hydrogen Energy Mission to enable cost competitive green hydrogen production. India would be conducting competitive bids for green hydrogen to pave the road for viable usage of hydrogen as a fuel. But, the world needs to come up with more electrolysis plants to bring down the costs.

3.9 CONCLUSION AND RECOMMENDATIONS

1. Having notified the DSM regulations, the DISCOMs may be encouraged to prepare action plan. The DISCOMs may be suitably incentivized to implement energy

- efficiency projects like lighting, air-conditioning, agricultural pumps, refrigerators and ceiling fans etc.
2. Develop strong coordination of energy policy across the different ministries at the Central Government level.
 3. Ensure more alignment between the Central Government and the States on key energy efficiency related activities.
 4. Encourage SME sector to adopt clean energy technologies.
 5. Deployment of policy on Electric Vehicle Charging infrastructure at state level may be encouraged.
 6. Enhance efforts to promote adoption of Electric cooking.
 7. Improve the collection, consistency, transparency and availability of energy data across the energy system at Central and State Government levels.
 8. In distribution, encourage implementation of ToD Tariffs for industries and commercial consumers in phased manner and include domestic consumers subsequently.
 9. Voluntary carbon markets should be considered within the existing regulatory framework of the PAT scheme through limited modifications, to enhance private sector participation in energy transition.

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Annexure 3.1

State energy-saving target (in Mtoe) by 2032

State/ UT	Domestic	Commercial	Industrial	Municipal	Transport	Agriculture	Total
Chandigarh	0.0382	0.0320	0.0456	0.0012	0.0172	0.0000	0.1342
Delhi	0.8939	0.4925	1.4234	0.0394	0.5393	0.0012	3.3910
Haryana	0.5196	0.2561	2.1055	0.0320	0.7031	0.3805	3.9980
Himachal Pradesh	0.1096	0.0443	0.7326	0.0209	0.1244	0.0049	1.0355
Jammu and Kashmir	0.1428	0.0640	0.3349	0.0234	0.2093	0.0148	0.7893
Punjab	0.4888	0.2389	1.4862	0.0246	0.5098	0.4593	3.2075
Rajasthan	0.6169	0.2844	2.7975	0.0850	1.0232	0.7954	5.6024
Uttar Pradesh	1.4628	0.3595	3.6976	0.0960	1.9701	0.5307	8.1155
Uttarakhand	0.1244	0.0788	1.3175	0.0148	0.1182	0.0074	1.6623
Chhattisgarh	0.2573	0.0825	1.4948	0.0135	0.2500	0.1613	2.2607
Gujarat	0.6932	0.3054	7.2314	0.0813	0.7006	0.4568	9.4675
Madhya Pradesh	0.4827	0.1896	1.7731	0.0616	1.0232	0.7597	4.2911
Maharashtra	2.1449	0.9727	10.0302	0.1625	2.1880	1.1254	16.6250
Daman and Diu	0.0025	0.0037	0.0332	0.0000	0.0000	0.0000	0.0406
Dadra and Nagar Haveli	0.0025	0.0025	0.1022	0.0000	0.0000	0.0000	0.1071
Goa	0.0517	0.0246	0.3755	0.0000	0.0431	0.0012	0.4962
Andhra Pradesh	0.5898	0.1712	2.0747	0.0308	1.4234	0.4519	4.7405
Telangana	0.7055	0.3398	2.0784	0.0406	0.9222	0.4753	4.5620
Karnataka	1.3754	0.4297	3.5942	0.1305	1.2867	0.7622	7.5799
Kerala	0.6748	0.2894	1.6512	0.0222	0.9087	0.0197	3.5658
Tamil Nadu	1.5182	0.6624	4.9769	0.1367	1.3815	0.4642	9.1399
Puducherry	0.0345	0.0135	0.1773	0.0037	0.0172	0.0025	0.2475
Lakshadweep	0.0012	0.0012	0.0000	0.0000	0.0000	0.0000	0.0012
Bihar	0.3349	0.0800	0.8779	0.0037	0.6784	0.0246	1.9984
Jharkhand	0.2019	0.0357	1.4148	0.0099	0.3842	0.0086	2.0550
Odisha	0.3041	0.1022	1.8051	0.0086	0.5479	0.0197	2.7877
West Bengal	0.8361	0.3805	3.4612	0.0517	2.0169	0.0776	6.8226
Sikkim	0.0086	0.0037	0.1404	0.0000	0.0135	0.0000	0.1675
Andaman and Nicobar Islands	0.0037	0.0049	0.0000	0.0000	0.0000	0.0000	0.0086
Arunachal Pradesh	0.0123	0.0025	0.0566	0.0000	0.0197	0.0012	0.0923

Assam	0.1761	0.0628	0.8619	0.0037	0.3078	0.0086	1.4197
Manipur	0.0172	0.0025	0.0332	0.0012	0.0234	0.0012	0.0788
Meghalaya	0.0197	0.0062	0.1207	0.0012	0.0369	0.0000	0.1859
Mizoram	0.0123	0.0025	0.0431	0.0025	0.0172	0.0000	0.0763
Nagaland	0.0172	0.0049	0.0296	0.0000	0.0222	0.0012	0.0751
Tripura	0.0234	0.0049	0.1071	0.0049	0.0259	0.0025	0.1687
Total (all India)	14.90	6.03	58.49	1.11	19.45	7.02	107.00

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CHAPTER 4

DEMAND PROJECTION

4.0 INTRODUCTION

Demand assessment is an essential prerequisite for planning of generation capacity addition and commensurate transmission and distribution system to meet the future electricity requirement. Reliable planning of capacity addition for future is largely dependent on accurate assessment of future electricity demand. This chapter looks into the aspects related to “Demand Projection” for the period of 2022-27 and 2027-32.

4.1 DEMAND ASSESSMENT BY CENTRAL ELECTRICITY AUTHORITY- ELECTRIC POWER SURVEY COMMITTEE

Electricity demand of the country is periodically assessed by the Electric Power Survey Committee (EPSC), taking into account the actual electricity demand incident on the system in the past years, planned and under implementation policies and programs of the Government, various developmental activities projected in future, impact of energy conservation measures, etc. The last exercise to assess the demand was the 19th Electric Power Survey (EPS) and the report of 19th EPS was brought out in January, 2017. The 19th EPS Report covered year-wise electricity demand for States/ UTs, Regions and for the country and perspective electricity demand up to the year 2036-37. The 20th Electric Power Survey Committee (EPSC) has been constituted by CEA. The terms of reference of the Committee were as under:

- i. To forecast the year- wise electricity demand for each State/ UT, Region and for the country for the years 2021-22 to 2031-32.
- ii. To project the perspective electricity demand for each State/ UT, Region and for the country the year 2036-37 and 2041-42.

The Electric Power Survey Committee has wide representation from the stake holders in the power sector with representatives from Niti Aayog, Ministry of Power, Bureau of Energy Efficiency, NTPC, NHPC, REC, BBMB, State Transmission Companies, State Distribution companies, Electricity Departments, TERI, FICCI, CII, NCAER, etc. The work on 20thth EPS report is under progress and expected to be published by June, 2022.

4.2 Demand Assessment

The estimated electricity demand of the country as per Electric Power Survey (EPS) forecasts serves as a key input for preparing the National Electricity Plan (NEP). However, in absence of 20th EPS projections, the task of Demand projections was given to a Subcommittee on Demand projections to assess the electricity demand of the country in terms of peak load and energy requirements for the period from 2022-27 & 2027-2032.

The subcommittee deliberated on the options available for assessing the electricity demand of the country especially to prepare National Electricity Plan. On the possibility of using the 19th EPS figures, the sub-committee was of the view that it may not be appropriate especially considering the dynamic changes happening in the demand and supply system in recent years such as increasing share of RE, emergence of distributed generation sources including solar rooftop systems, Solar Pumps and increasing penetration of Electric Vehicles in India transport sector etc. The prevailing pandemic conditions that have a huge impact on the electricity demand were also not factored in during the 19th EPS exercise. Further, it was observed that the actual electricity demand is less than 19th EPS projection. Therefore, the sub-committee believed that the 20th EPS figures may ideally be considered for further planning exercises as the power sector is highly capital extensive and accuracy of the report plays a crucial role in future investments. However, keeping in view the statutory obligation of preparing NEP with in a definite time frame, the committee recommends the projected peak electricity demand and energy requirement based on the preliminary studies under 20th EPS may be considered for the planning studies.

The estimates of future electricity demand given in the chapter are based on the past trends in the electricity sector and after factoring in several emerging aspects such as impacts of COVID pandemic, SAUBHAGYA scheme, energy efficiency measures, solar roof top, solar pumps, penetration of electric vehicles and the newly announced "National Hydrogen Energy Mission".

Based on these developments, the Electrical Energy Requirement & Peak Demand figures have been worked out for the years 2021-22 to 2031-32.

The estimated Energy Requirement & Peak Demand figures on all-India basis are summarized below:

Table 4.1
Projected Energy Requirement & Peak Demand figures on all-India basis

Year	Energy Requirement (in BUs)		Peak Demand (in GW)
	On Grid	Incl. Roof Top	
2026-27	1852	1874	272
2031-32	2459	2538	363

The projected region wise electrical energy and peak demand figures have been arrived at based on the present ratios of actual region wise demand over all India demand and is given in **Table 4.2**.

Table 4.2
Projected Region-wise electrical energy requirement & peak electricity demand for the years 2026-27 & 2031-32

Region	Electrical Energy Requirement (MU)		Peak Electricity Demand (MW)	
	2026-27	2031-32	2026-27	2031-32
Northern	564774	762045	86187	117126
Western	573200	782574	84097	114285
Southern	504245	682202	74108	100710
Eastern	200611	266775	31638	42295
North - Eastern	31170	44862	5951	8087
All-India	1874000	2538458	272000	363188

Note: The electricity demand projection covers electricity demand only for the utility system. The projections do not include the portion of electricity demand of Industries and other consumers that would be met from captive power plants.

4.3 CONCLUSIONS

1. The electrical energy requirement and peak electricity demand on all-India basis has been projected at 1874 BU and 272 GW in 2026-27 & 2538 BU and 363 GW in 2031-32 respectively. These projections include impact of solar rooftop, green hydrogen, EV and Energy efficiency measures.
2. It is proposed to revise the studies once the final figures of Electricity Demand is worked out by 20th Electric Survey if the figures are found to be in variation to what are considered.

CHAPTER 5

GENERATION PLANNING

5.0 INTRODUCTION

India's demand for electricity has been growing steadily as electricity being the key enabler for achieving socio-economic development of the country. Generation capacity addition along with other measures to meet the ever-increasing demand for electricity has been the top priority of the country. However, with the growing concerns on environment and climate change the options available for power generation have shown a significant shift globally, changing the generation capacity mix. India being an active participant globally has shown initiative towards sustainable development and cleaner environment. Intermittent but clean sources of power generation have been affordable and are playing significant and prominent role in meeting the demand. The generation capacity mix, which is economically viable, environmentally sound, and socially just to meet the future electricity demand reliably can be ascertained from generation expansion planning studies. This chapter highlights the Principles and Methodology of Generation Planning adopted to assess the capacity addition required by the end of year 2026-27 and 2031-32 keeping in view the shift.

5.1 RESOURCES FOR POWER GENERATION IN INDIA

Coal has been the major source for power generation in our country thus far but the environmental concerns coupled with abundance of solar and wind resources available in the country along with reduction in their cost have given opportunities to exploit these resources to the fullest possible extent, keeping in view the grid stability and security.

Presently, following options are available for Power Generation:

- Conventional Sources – Coal and lignite, Nuclear, Natural gas
- New and Renewable Energy Sources- Solar, Wind, Biomass, large and small Hydro, Geothermal, Waste to energy, Battery Energy Storage system, Hydrogen/ fuel cells, etc.

5.2 GENERATION SOURCES IN INDIA

5.2.1 Coal/Lignite

Coal based power generation is backbone of Indian Power sector and may continue to play a significant role in power generation in the country due to the abundant availability of domestic coal. However, environmental concerns necessitate clean coal technologies such as supercritical Resource and ultra-super critical technologies to be adopted. The coal including lignite based installed capacity was 2,10,700 MW as on 31.3.2022 which was almost 52.7% of the total installed capacity of the country. However, growing environmental concerns and global thrust on adoption

of clean generation technologies is going to have an impact on share of coal based installed capacity in the country in foreseeable future though the share of coal-based generation may continue to be high. Operation of coal-based plants in a more flexible mode unlike as base load stations earlier, needs to be emphasized in the wake of huge intermittency of renewable based generation.

5.2.2 Gas

Gas-based capacity has the capability to fast ramp-up and ramp-down. The advantage of fast ramping capability becomes more important in view of large-scale integration of renewable energy. Modern combined cycle gas turbines (CCGTs) have high efficiency of around 55% as compared to coal-based plants (Gross efficiency of supercritical units is about 40%). Gas turbines/Engines could be operated in a manner to maximize the output during the peak hours and minimize during the off-peak hours. However, the production and supply of domestic gas had not been keeping pace with the growing demand of natural gas in the country, including power sector. The domestic gas supply for gas-based power stations in the country is inadequate owing to which the country is facing potential generation loss from gas-based stations. As on 31.3.2022, the installed capacity of gas-based power stations was 24899.51 MW (including liquid based) which is 6.2 % of the total installed capacity of the country.

Presently, existing gas-based power plants are operating at extremely low PLF of about 24% and few gas-based power plants are lying idle due to non-availability of domestic natural gas.

5.2.3 Nuclear

As on 31.3.2022 Nuclear Power Corporation India Limited is operating 21 reactors with an installed capacity of 6,780 MW, which is 1.7% of the total installed capacity of the country.

5.2.4 Hydro

Total Hydro Electric Power potential in the country was assessed as 84,044 MW (at 60% load factor) from a total of 845 number of identified Hydro Electric Schemes, which when fully developed would result in an installed capacity of about 1,48,701 MW based on probable average load factor out of which potential of H.E. schemes above 25 MW installed capacity works out to be 1,45,320 MW from a total of 592 H.E. schemes. The total energy potential is assessed as 600 billion units per year. However, the full development of India's hydro-electric potential, while technically feasible, faces various issues including issues of water rights, resettlement of project affected people and environmental concerns etc. and all these issues need to be resolved to exploit full potential. As on 31.03.2022, the installed capacity of hydroelectric power plants (above 25 MW) in the country was 46,722.52 MW (including 4,746 MW of PSP) which is 11.7% of the total installed capacity of the country.

5.2.5 Solar

India has abundant source of Solar irradiance due to its location in the solar belt and has vast solar potential of about 749 GW (as per data furnished by MNRE) for power generation. The falling prices of solar panels has brought the solar tariffs lower in an unprecedented way making it as one of the

best sources for power generation economically. However, the diurnal nature of solar power lends it unable to meet the peak demand occurring during the evening hours and necessitates the need to find other generation resources to meet the evening peak demand of the country. The installed capacity from Solar was 53,996.54 MW as on 31.03.2022. Share of Solar capacity in the total installed capacity was about 13.5 % as on 31st March ,2022 which is likely to increase substantially in coming years.

5.2.6 Wind

India also has substantial wind potential of about 302.25 GW at the height of 100 m and 695.5 GW at 120m due to its long coastline (as per MNRE). India has also taken up developing offshore wind generation which has increased the wind potential apart from wind generation at higher hub heights. The installed capacity from Wind was 40,357.58 MW as on 31.03.2022. Share of Wind capacity in the total installed capacity was about 10.1 %. With increase in the hub height and increase in wind-based capacity addition, the share of wind capacity is also likely to increase substantially in coming years.

5.2.7 Biomass

Based on the availability of biomass, the potential of power generation from biomass has been assessed as around 25 GW. Present installed capacity from Biomass was 10,682.36 MW as on 31.03.2022. Share of Biomass capacity in the total installed capacity was about 2.7 %.

5.2.8 Small hydro

Hydro plants with installed capacity of up to 25 MW are categorized as small hydro in our country. Small Hydro based plants have a power generation potential of around 20 GW. Present installed capacity from small hydro was 4,848.9 MW as on 31.3.2022, which is 1.2% of total installed capacity.

5.2.9 Storage systems

The next phase of energy transition driven by the large-scale deployment of variable renewable energy sources (VREs) like solar and wind power can be fully realized by key technologies of Energy Storage. The grid integration challenges of the intermittent generation sources ensuring quality of supply on real time basis along with the capability to store excess electricity over different time horizons (minutes, days, weeks) can be achieved by the electricity storage systems. Many grid scale energy storage systems are commercially available worldwide which includes Pumped storage plants, Battery energy storage systems etc. However, many other energy storage technologies like Green Hydrogen are in nascent stages of development.

5.2.9.1 Pumped hydro storage systems

While many forms of energy storage systems have been installed globally, Pumped Storage Plants (PSP) are playing an increasingly significant role in providing peaking power and maintaining system stability in the power system of many countries. Pumped storage Resource is the long term

technically proven, highly efficient, environment friendly and flexible way of energy storage on a large scale to store intermittent and variable energy. PSPs improve overall economy of power system operation and reduce operational problems of thermal stations during low load period. The other advantages of pumped storage Resource are availability of spinning reserve at almost no cost to the system and regulating grid frequency to meet sudden load changes in the network. It also can provide ancillary benefits such as flexible capacity, voltage support and Black start facility etc. Pumped storage Resource has advanced significantly since its original introduction and now includes adjustable speed pumped turbines which can quickly shift from motor, to generator, to synchronous condenser modes, for easier and more flexible operation of the Grid. The concept of off-river PSP is getting popular in recent years due to huge benefits arising out of its fewer capital cost/operations. Currently India is exploring the off-river storage systems which can be executed with lesser cost and at a fast pace.

5.2.9.2 Battery Energy Storage systems (BESS)

Battery Energy Storage systems especially based on Lithium – ion battery is one of the storage options. The cost of the BESS is reducing in an unprecedented way making it as one of the preferred options for deployment. BESS has various advantages of balancing the grid against load fluctuations, intermittency in generation etc. Energy storage can provide energy time-shifting which can be useful with the large-scale deployment of variable renewable energy sources. However, the storage requirement depends on the shape of the demand curve and the extent of RE penetration. Energy storage technologies can also provide operating reserve requirements, balancing, ramping and RE integration services.

5.3 PRINCIPLES OF GENERATION PLANNING

The objective of Generation Planning process is to obtain an optimal generation capacity mix in the least cost manner to meet the demand at every instance of time while ensuring the most efficient use of resources. The purpose of Energy modelling is not to predict or forecast the future, but a Collaboratory effort to understand and explore the key factors and relationships shaping the future of the power sector. Planning is therefore an activity encompassing balancing demand and supply at all instances of time and at all locations which makes it a regular ongoing process.

The major aspects considered in planning process are:

- To achieve regulation targets and objectives of all policies of Government of India
- To achieve sustainable development.
- To fulfil desired operational characteristics of the system such as reliability and flexibility.
- Most efficient use of resources
- Fuel availability.

The above aspects have been considered within realms of feasibility, while drawing up this National Electricity Plan along with the economics and the status of the various projects.

5.3.1 Sustainable Development

The importance and relevance of power development within the confines of Clean and Green Power is crucial for sustainable economic growth. Such a development depends upon the choice of an appropriate fuel / Resource for power generation. Accordingly, the plan takes into account the development of renewable energy sources including Hydro projects along with other measures and technologies promoting sustainable development in the country.

5.3.2 Operational Flexibility and Reliability

Generating units utilizing different fuels have different operational characteristics. The demand of our electric system varies with time of the day, season, year and the spatial location. Therefore, matching the generation with demand at all instances of time requires not only installation of adequate capacity but also to be sensitive to the type of generation capacity, each with its unique characteristics of altering its output and the time taken to do so. Accordingly, this requirement of the system also needs to be considered when deciding upon the type of generation. It is, therefore, necessary to widen the scope of the planning process to take into account aspects of 'reliability' and 'quality' of power, apart from the adequacy and quantum of power.

Reliable power system operation requires constant balancing of supply and demand in accordance with established operating criteria such as maintaining system voltages and frequency within acceptable limits. Changes in demand pattern and generation from variable renewable energy sources throughout the day and over the seasons are met by controlling generation from dispatchable sources when needed. To achieve reliability in the system, adequate reserve capacity, spinning as well as non-spinning, needs to be planned in the system. The National Electricity Policy, 2005 stipulates creation of spinning reserve of 5% in our system. This has been considered while planning capacity addition requirement during the years 2022-27 and 2027-32.

To meet system stability requirements, a certain degree of flexibility in terms of ability of the generators to respond rapidly to the changing demand and generation from renewable energy sources must be introduced into the system through appropriate power generating plants and financial mechanism. System should also be able to meet additional demand which arises due to unexpected demand fluctuations and sudden outages of some generating units.

5.3.3 Fuel availability constraints

A significant Gas-based capacity is presently stranded due to lack of domestic gas and high cost of imported LNG. Additionally, due to seasonal availability of Biomass, fuel restriction for the Biomass has also been considered.

5.3.4 Efficient Use of Resources

The fossil fuels for power generation are scarce and must therefore be used most judiciously. From the point of view of environment, it is essential that energy produced per unit of fuel is maximum to the extent possible. This would minimize the pollution caused during the process of power production therefore, achieving cleaner production. Maximum utilization of renewable sources of

generation should be preferred as their variable cost of energy is minimal. However, a strategic amount of VRE curtailment may be part of a cost-effective planning solution while ensuring grid reliability.

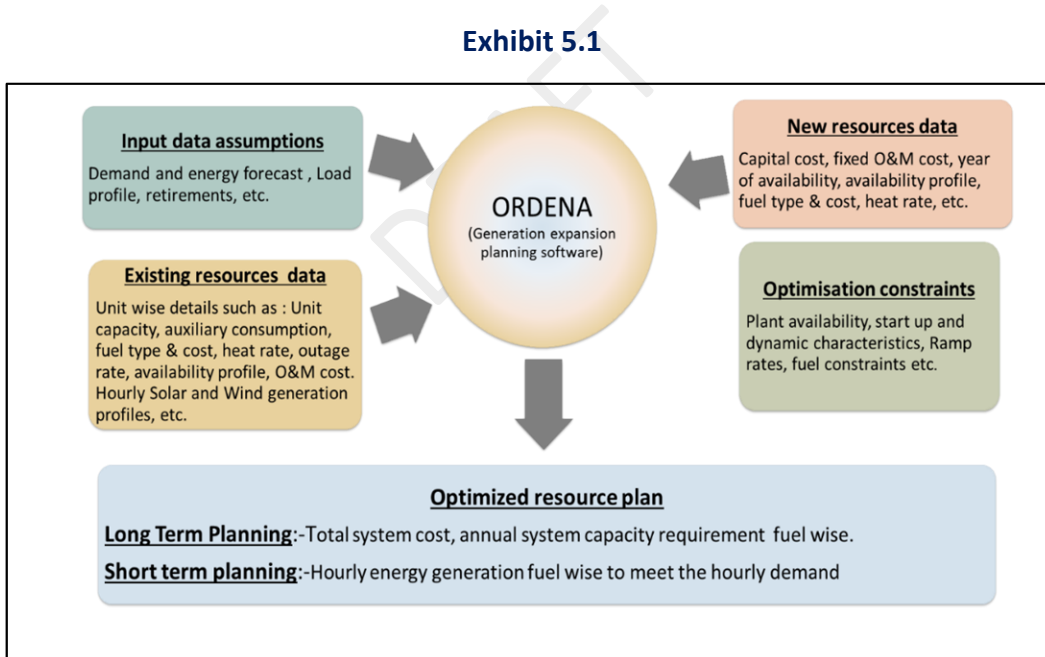
5.4 PLANNING TOOLS - DETAILS OF PLANNING MODEL

5.4.1 Generation Expansion Planning Tool -ORDENA

The studies were carried out using generation expansion planning model namely ORDENA. Ordена is a mixed integer linear optimization program that minimizes the net present value of investment and operating costs subject to several constraints. The major constraints include balancing electricity supply and demand, resource supply limits, planning and operating reserve limits and policy targets. These constraints are met considering a broad portfolio of conventional generation, renewable generation and storage.

The software is also capable of carrying out hourly/sub hourly economic generation dispatch considering all the technical constraint associated with various generation technologies.

The schematic diagram of the software is given as **Exhibit 5.1**.



5.4.2 Generation Expansion Planning Tool –PLEXOS

PLEXOS is a powerful simulation engine that provides analytics and decision-support to modelers, generators, and market analysts. Unlike other optimization platforms, PLEXOS offers both flexible and precise simulations across several markets—electric, water, gas and renewable energy.

PLEXOS unifies the market simulations across electric, water, and gas energy systems which helps to perform long-term planning, medium-term and short-term scheduling at once.

5.5 PLANNING NORMS

The planning studies require accurate performance parameters of all types of generating units to assess their availability and energy generation capabilities. The peaking availability and energy generation capacity are important parameters for meeting the projected demand of the country. The key performance factors required for the planning studies are the auxiliary power consumption, heat rate, capital cost of the generating units, fuel cost, gross calorific value, O&M schedules, etc. Different generating technologies have varied operational performance and accordingly different norms have been used for thermal (coal and lignite), combined cycle gas projects, hydro and nuclear projects. The generation planning norms for varied sizes of thermal units are different. Accordingly, separate categories based on unit sizes have been derived. Combined Cycle Gas Turbines (CCGT) are very efficient and have lower heat rates, however, their availability and PLF depend on the availability of natural gas. The peaking availability, auxiliary power consumption, heat rate for several types of generating units, as considered in the expansion planning studies are given in **Annexure 5.1**.

5.5.1 NORMS ADOPTED FOR RELIABILITY CRITERIA

The Power System is planned to meet the forecasted demand while ensuring an expected level of reliability. Reliability is a measure of the ability of a system to perform its designated function under the designed conditions. In our Studies, Loss of Load Probability (LOLP) and Energy Not Served (ENS) are the criteria adopted to reflect the capability of the system to meet the peak load and for reflecting the Energy Requirement not met in the System respectively. LOLP is the probability that a system will fail to meet its peak load under the specified operating conditions. It is the proportion of days per year or hours per year when the available generating capacity is insufficient to serve the peak demand. This index is dimensionless and can also be expressed as a percentage.

ENS is the expected amount of energy which the system will be unable to supply to the consumers as a fraction of the total energy requirement. This index again is dimensionless and can also be expressed as a percentage. In other words, this criterion indicates the quantum of energy requirement in a year which is not met. Various countries in the world have adopted their own Reliability Criteria depending upon the status of their power system and the price affordability of the consumers to pay for the reliability of the system. It is evident that a more stringent and reliable system would yield higher cost of electricity which has to be borne by the consumer. Earlier, while formulating the National Electricity Plan 2018, LOLP of 0.2% and ENS of 0.05% has been adapted for the country however, the studies carried out by CEA for preparation of current National Electricity Plan is based on deterministic modeling wherein cost of ENS is estimated & is provided as a constraint to the planning model. The results so obtained from above have been verified for derived LOLP & ENS. Details of LOLP adopted in some countries are as given in **Table 5.1**.

Table 5.1

LOLP of some countries

Name of country	LOLP (%)
Cambodia	1.8
Laos	0.27
Thailand	0.27
Vietnam	0.27
Hong Kong	0.006
Belgium	0.2
USA	0.03
China	0.14

Source: Information collected from websites of above countries.

5.6 PLANNING APPROACH FOR GENERATION EXPANSION PLANNING DURING THE PERIOD 2022-27 AND 2027-32

The Planning approach has been based on the premise of meeting the peak demand and energy requirements for the period 2022-27 and 2027-32 at the least cost. In view of clean generation technologies like Solar, Wind, etc. becoming increasingly cost competitive compared to the conventional technologies, the optimal generation capacity mix would achieve the right balance between cost economics and grid reliability. This requires the power system to be more flexible and resilient, to accommodate the intermittency of renewable generation, seasonal spikes or time-of-day variations – expected and unexpected in electricity demand etc. The dynamic response characteristics of such a balanced system would contribute to higher reliability. This will ensure the most rapid, real-time response to local peaking needs and variation in generation from RES.

Studies using sophisticated state of the art planning tools like ORDENA and PLEXOS have been carried out to assess the installed capacity required to meet the demand projections for the years 2026-27 and 2031-32 in a reliable and cost-effective manner considering the five regions as nodes. For carrying out the long-term generation expansion studies on regional basis, five Nodes have been created with inter regional transmission links between them for Inter regional power transfer.

5.6.1 All India Peak Demand and Energy requirement forecast

Generation expansion planning studies have been carried out on regional basis considering the DC load flow and inter-regional transmission lines only. The studies have been carried out to meet the regional as well as All India Peak Demand and Energy requirement projections based on preliminary

Demand estimates. The estimated peak demand (MW) and Energy requirement (BU) in the years 2026-27 and 2031-32 for all the five regions and All India are given in Table 5.2 below.

Table 5.2

All India Peak Demand & Energy Requirement

Region	Peak Demand (MW)		Energy Requirement (BU)*	
	2026-27	2031-32	2026-27	2031-32
Northern	86187	117126	565	762
Western	84097	114285	573	782
Southern	74108	100710	504	682
Eastern	31638	42995	201	267
North-Eastern	5951	8087	31	45
All India	272000	363188	1874	2538

(* Including solar Roof Top Energy)

The early estimates for the Peak and Energy demand on the electricity grid are inclusive of impact due to factors like energy efficiency, penetration of electric vehicles, installation of solar roof tops and production of green hydrogen.

5.6.2 Preparation of Hourly Load profile for the years 2026-27 and 2031-32

Region-wise hourly Load profile and Solar and Wind generation profiles

The most important aspect of any generation planning study is formulation of the annual hourly demand projections. Hence, the endeavor has been to meticulously project hourly demand for the years 2026-27 and 2031-32. The hourly demand profiles on regional basis of the previous five years (2015-16 to 2019-20) were examined. The demands data for the three years 2015-16 to 2017-18 was found to be more representative of the historical trend of the annual load curve. Therefore, the three years’ demand data has been considered to obtain hourly average demand profile for each of the five regions which is then Normalized and subsequently extrapolated w.r.t the projected annual Peak Demand and Electrical Energy Requirement for the years 2026-27 and 2031-32 to obtain the most probable load profile for the years 2026-27 and 2031-32 for each of the five regions.

Region wise hourly Solar and wind profiles

The actual hourly generation profile of solar and wind have been gathered from states having considerable share in the All-India VRE generation.

The hourly normalized generation profiles for Solar and wind of various states were then aggregated to obtain hourly normalized generation profiles for each of the five regions.

The region wise solar & wind CUF (Capacity Utilization Factor) is given in **Annexure 5.1**.

5.6.3 Seasonal Variation of VRE and Hydro Generation

To capture the seasonal variation associated with hydro and RE generation, the time series hourly data (demand, RE generation, hydro generation) for a year has been divided into five seasons. The five seasons are as follows:

- Summer: April-June
- Monsoon: July-September
- Autumn: October-November
- Winter: December- January
- Spring: February-March

The hydro energy availability varies significantly across the years as it depends on the monsoon rains in a particular year. The actual monthly hydro generation of the existing hydro power plants for the years 2015-16, 2016-17 and 2017-18 has been studied to account for variation in generation availability due to the eventualities of drought or excess rainfall in any particular year. The monthly energy generation has been summed up to arrive at the seasonal energy. The energy of the hydro units which are under construction or are in concurred/ S&I stage which are likely to yield benefits, has been taken based on the design energy of the project in 90% dependable year.

The model optimizes available hydro generation in such a way that maximum benefit of hydro can be exploited during peak hours along with ensuring minimum required outflow during off-peak hours. In this context, both central and state-owned hydro power plants have been assumed to contribute towards grid stability and peaking requirement of the country.

Creation of aggregated time Blocks for Generation Expansion Planning Studies

The long-term models with endogenous investments are computationally demanding when optimizing investment decision as well as reducing operational cost for multiple years simultaneously. A common way to reduce computation time is to optimize the dispatch decision only for a limited number of representation time slices/blocks instead of modelling every hour of the year. The 8760 hours is then represented by a set of time blocks or representative hours that capture changes in seasonal, weekly and daily demand pattern as well as wind and solar availability to reduce the computational burden.

Each season has been divided into blocks based on the RE generation profile for increasing the granularity and precision of the study. The annual hourly time series profiles of projected regional load, Regional Solar and wind generation profiles are aggregated into Blocks for each of the five seasons.

The aggregation of hours of the day into time blocks in the model is shown pictorially in **Exhibit 5.2** below:

Exhibit 5.2

		Mapping of daily Hours to LT blocks(50 Blocks/yr theme)																										
		H0	H1	H2	H3	H4	H5	H6	H7	H8	H9	H10	H11	H12	H13	H14	H15	H16	H17	H18	H19	H20	H21	H22	H23			
Peak Load	B5																			5	5	5						
Solar Peak	B4																			4	4	4	4					
Rising/Decreasing Solar	B3																			3	3	3	3					
Very less Solar	B2																			2	2	2	2					
Non-Solar off - Peak Load	B1	1	1	1	1	1	1																			1	1	1
		PEAK Day od Season/Stage																										
Peak Load	B10																			10	10	10						
Solar Peak	B9																			9	9	9	9					
Rising/Decreasing Solar	B8																			8	8	8	8					
Very less Solar	B7																			7	7	7	7					
Non-Solar off - Peak Load	B6	6	6	6	6	6	6																			6	6	6
		Non-PEAK Day od Season/Stage																										

The time aggregation technique of aggregating hourly data into Time Blocks helps in reducing simulation time that the model takes while capturing Seasonal peak demand for each region. The number of time blocks considered is based on the system and Resource complexity while achieving as much granularity as possible in time series data as the system permits.

5.6.4 Reserve capacity

As stipulated by National Electricity Policy 2005, 5% Spinning Reserve is to be provided. This reserve capacity has been maintained while carrying out the Generation Planning studies.

5.6.5 Retirement of Thermal capacity

Information was compiled in respect of old thermal power plants which have already retired and plants likely to be considered for retirement in future. Decommissioning of coal-based capacity due to lack of plans for FGD installation also has been considered while carrying out the generation expansion studies. A coal-based capacity totaling to 4629 MW (list of plants is enclosed at **Annexure 5.2**) is considered for likely retirement during the study period of FY 2022-27. No coal or Gas-based capacity has been considered for retirement during the period of FY 2027-32.

5.6.6 Base Capacity considered for the year (2021-22) as on 31.03.2022

All India installed capacity of 398,986 MW (excluding 510 MW Oil based capacity) as on 31st March 2022 is considered as a base installed capacity for the study period 2022-32.

The region wise and Resource wise breakup of the same is outlined in the **Table 5.3** below:

Table 5.3
Region-wise Installed capacity as on 31.03.2022

(All Figures in MW)

Resource	Northern	Western	Southern	Eastern	N- Eastern	All India	Percentage of Total IC
Hydro#	19576	5552	9734	5088	2027	41977	10.5%
PSP	0	1840	2006	900	0	4746	1.2%
Small Hydro	1680	646	1899	337	286	4848	1.2%
Solar PV	17791	13113	21990	931	171	53996	13.5%
Wind	4327	16742	19289	0	0	40358	10.1%
Biomass	3273	3148	3733	512	16	10682	2.7%
Nuclear	1620	1840	3320	0	0	6780	1.7%
Coal+ Lignite	45879	85586	42598	35887	750	210700	52.8%
Gas	5781	10806	6492	100	1720	24899	6.2%
Region-wise Installed Capacity	99927	139273	111061	43755	4970	398,986	

#Excluding 2136 MW of Hydro imports from neighboring countries and 510 MW Diesel based capacity.

5.6.7 Planned/Under construction Capacity for the period FY 2022-27 & 2027-32

The fuel wise capacity which is under construction or in advance stages of development that are likely to be commissioned during the study period is summarized in Table below. The fuel wise list of under-construction projects (for likely benefits during 2022-23 to 2026-27 and 2027-28 to 2031-32) is given in **Annexure 5.3**.

Table 5.4
Type wise Under Construction/Planned Capacity for FY 2022-27 & 2027-32
(All Figures in MW)

Year	Hydro	PSP	Solar [#]	Wind [#]	Nuclear	Coal + Lignite	Gas	Biomass [§]	TOTAL	Hydro Imports
2022-27	10,903	1580	92,580	25,000	7,000	25,580	370	2318	165,331	3,720
2027-32	0	0	0	0	8,700*	0	0	1500	10200	0
TOTAL (2022-32)	10903	1580	92,580	25,000	15,700	25,580	370	3818	175,531	3,720

This is in line with an assumption of a planned capacity of 117.58 GW of Solar and Wind as per information furnished by SECI/MNRE.

*Nuclear projects of 1700 MW are under construction while projects totaling to 7000 MW are in principle approval stage whose construction is yet to begin.

§ Assumed Planned Capacity of Biomass

5.6.8 Hydro based Imports

The electricity hydro imports from neighboring countries till 2021-22 are 2,136 MW and for the period of 2022-27 are likely to be 3,720 MW. The list of these projects is placed at **Annexure 5.4**. Hydro imports from neighboring countries considered for the studies during 2022-32 is given in the **Table 5.5** below:

Table 5.5
Hydro based imports during 2022-27 & 2027-32 (IN MW)

	Nepal	Bhutan	Total
Existing till 2021-22	0	2136	2136
2022-27	900	2820	3720
2027-32	NIL		
Total Hydro based Imports till 2032	900	4956	5856

5.6.9 Investment options considered for selection by model

- Coal based super critical plants at pit head locations have been considered as investment options for the study period.
- Location specific hydro and PSP projects which have been concurred by CEA or are under S&I stage have been considered as investment options for the studies.
- No Gas based plants have been considered as investment options for the studies.
- No additional Nuclear based plants have been considered as investment options for the studies apart from the plants which have been accorded administrative approval and financial sanctions.

- Based on region wise RE potential capacity data received from MNRE, regions wise PV and Wind based investment option capacity has been taken as input for the studies. The potential has been worked out based on state level potential furnished by MNRE.
- Region wise BESS investment options (5-hour storage) have been considered in the studies for the period of 2022-23 to 2031-32. The cost of battery energy storage system includes cost of battery, inverter, Battery and Energy Management Systems and other costs (cabling and installation costs). Also, the capital cost of the battery has been increased to account for the constraint of 90% depth of discharge. A custom duty of 22% on the imported cost of Battery pack and GST of 18% on the cost of Battery system has been considered to arrive at the total cost of the Battery Storage system.

5.6.10 Inter-Regional Transmission Capacity

The inter-regional transmission capacity likely to be installed by end of FY 2021-22 according to National Electricity Plan Vol II (Transmission) (for the period 2017-22) has been considered for the planning studies. The details of the same are given in table 5.6 below:

Table 5.6
Inter-Regional Transmission (Transfer) Capacity in FY 2021-22

(All Figures in MW)

From Node/To node	NR	WR	SR	ER	NER
NR	-	26864	-	16144	3000
WR	26864	-	9328	24178	-
SR	-	9328	-	13118	-
ER	16114	24178	13118	-	2410
NER	3000	-	-	2410	-

Additionally, candidate lines between the regions have also been considered. The capital cost of a candidate inter regional transmission links is assumed to be Rs 10,163/MW-km and for Lines to and from NER it is assumed twice.

5.6.11 Fuel constraint

Due to the unavailability of natural gas and high price of imported RLNG, fuel restriction for gas-based plants has been considered and fuel availability has been limited to present supply of the domestic natural gas. Also, due to seasonal availability of Biomass, fuel restriction for the Biomass has been considered.

5.7 RESULTS OF GENERATION EXPANSION PLANNING STUDIES FOR THE PERIOD 2022- 27 AND 2027-32

5.7.1 Base Case

The studies were carried out to assess the source wise generation capacity addition requirement to meet the projected demand during the year 2026-27 and 2031-32 with the assumptions mentioned above. The region wise and Resource wise likely installed capacity by 2026-27 and 2031-32 from the study results are shown in the Tables and exhibits given below.

Table 5.7
Region-wise likely Installed capacity by the end of 2026-27

(All Figures in MW)

Resource	Northern	Western	Southern	Eastern	N-Eastern	All India	Percentage of Total IC
Hydro#	25791	5952	10794	6245	4147	52929	8.5%
PSP	1000	2320	2586	900	0	6806	1.1%
Small Hydro	1680	646	1899	337	286	4848	0.8%
Solar PV	87171	49813	47990	931	171	186076	29.9%
Wind	12327	31242	37289	0	0	80858	13.0%
Biomass	3984	3831	4543	623	19	13000	2.1%
Nuclear	3720	3240	6820			13780	2.2%
Coal+ Lignite	52420	87048	51348	47767	750	239333	38.4%
Gas	5781	10806	6862	100	1720	25269	4.1%
Region-wise Installed Capacity	193874	194898	170131	56903	7093	622899	100.00%

Excluding 5856 MW of Hydro Imports from Nepal and Bhutan

Exhibit 5.3

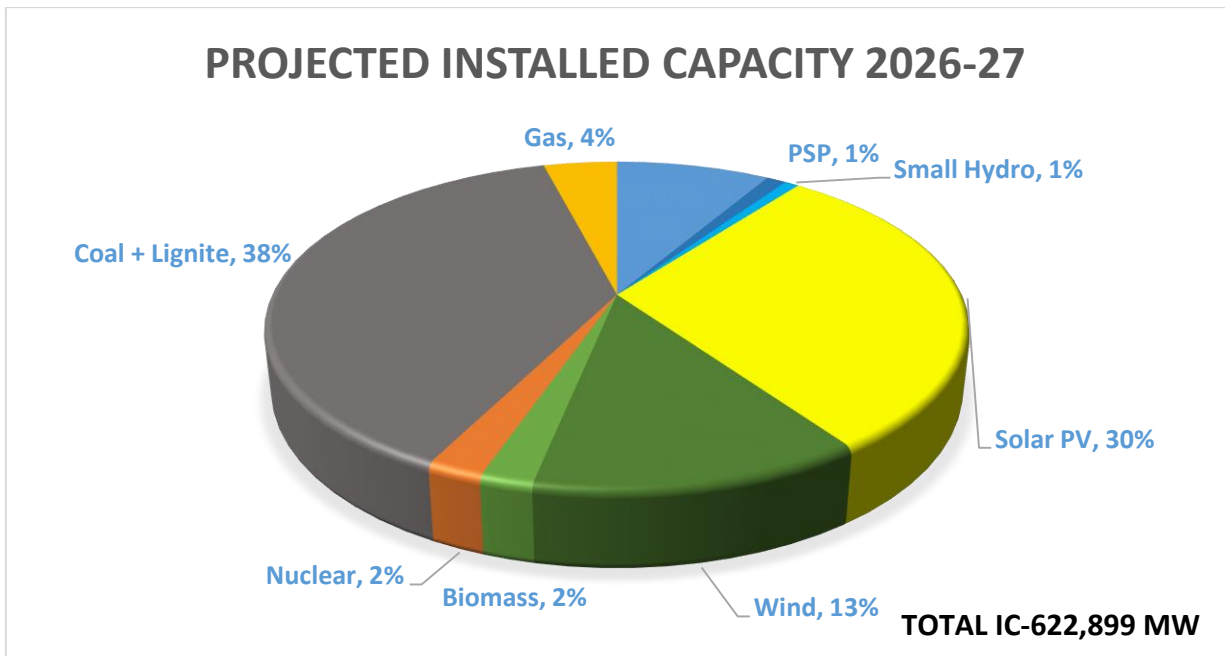


Table 5.8
Projected All India Installed capacity by the end of 2031-32

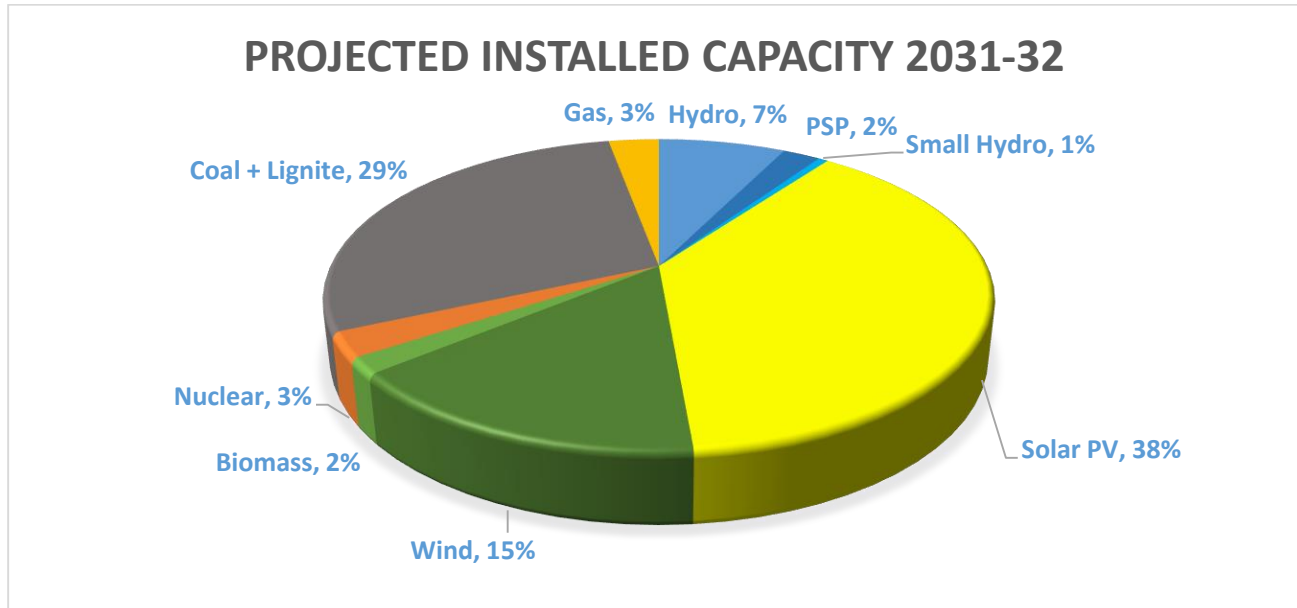
(All Figures in MW)

Resource	Installed Capacity (MW)	Percentage (%)
Hydro [#]	63,816	7.4%
PSP	18,826	2.2%
Small Hydro	4,848	0.6%
Solar PV	3,33,476	38.5%
Wind	1,33,958	15.5%
Biomass	14,500	1.7%
Nuclear	22,480	2.6%
Coal + Lignite	2,48,767	28.7%
Gas	25,270	2.9%
Total	8,65,941	100.00%
BESS*	51,555	

Excluding 5856 MW of Hydro Imports from Nepal and Bhutan

*5-hour Storage; Battery storage is not included in Installed Capacity

Exhibit 5.4



TOTAL IC- 865,941 MW

DRAFT

Table 5.9a
Capacity addition required during 2022-27 and 2031-32

(All figures in MW)

	Hydro	PSP	Solar	Wind	Nuclear	Coal+ Lignite	Gas	Biomass	TOTAL	BESS
Under Construction (2022-27)(A)	10,903	1580	92,580	25,000	7,000	25,580	370	2318 [#]	165,331	0
Additional Capacity Requirement (2022-27)(B)	48	480	39500	15500	0	7682	0	0	63210	0
Total Capacity addition (2022-27) C=(A+B)	10,951	2,060	132,080	40,500	7,000	33,262	370	2318	228541	0
Under Construction (2027-32)(C)	0	0	0	0	8700 [*]	0	0	1500 [#]	10200 [*]	-
Additional Capacity Requirement (2027-32)(D)	10888	12020	147400	53100	0	9434	0	0	232842	51555
Total Net Capacity addition (2027-32)(C+D)	10888	12020	147400	53100	8700	9434	0	1500	243042	51555

*Nuclear projects of 1700 MW are under construction while projects totaling to 7000 MW are in principle approval stage whose construction is yet to begin but considered as under construction during the year 2027-32 for studies.

Assumed Planned Capacity of Biomass

Table 5.9b
Region wise details of Additional Capacity addition required during 2022-27 and 2027-32(Apart from capacity already under-construction)

(All figures in MW)

Period	Region	Hydro	PSP	Solar	Wind	Coal+ Lignite	Total	BESS*
Additional capacity addition required (2022-27)	NR	48		19500	4000	1000	24548	0
	WR	0	480	4000	2000	1762	8242	0
	SR	0	0	16000	9500	0	25500	0
	ER	0	0			4920	4920	0
	NER	0				0	0	0
	Total		48	480	39500	15500	7682	63210
Additional capacity addition required (2027-32)	NR	2826	0	71500	15000	2200	91526	41266
	WR	0	960	13900	3600	2758	21218	0
	SR	0	11060	62000	34500	496	108056	10289
	ER	520	0	0	0	3980	4500	0
	NER	7542	0	0	0	0	7542	0
	Total		10888	12020	147400	53100	9434	232842

*5-Hour BESS System

Analysis of Base Case Result

- As is seen from the table, the likely share of thermal IC reduces to 42.5 % of the total installed capacity in 2026-27 as compared to 59 % in 2021-22 while the RE based IC in 2026-27 (including Large Hydro) increases to 55.4% of the total installed capacity as compared to 39.3 % in 2021-22.
- To meet the electricity demand and electrical energy requirement in 2026-27 additional capacity from PV, Wind and PSP may be required apart from the capacity which is already under construction.
- Likely PSS based installed capacity of 6.8 GW in 2026-27 may fulfil the storage requirement of the grid by 2026-27 to meet the peak and energy requirements in 2026-27. However, Battery energy storage requirements emerge from the year 2027-28 onwards and 5-hour BESS storage of 257.77 GWh is required along with 18.8 GW of PSS for the year 2031-32.
- It has been analyzed that in case of BESS Resource the model chooses to invest preferably in NR region as compared to other regions (80% of the total BESS Storage required in 2031-32 is seen to be required in NR). Due to the fact that historically NR peak occurs during the evening hours. Therefore, BESS Resource is found to be most cost effective and optimally utilized if installed locally in the NR region.
- It is seen that many PSP plants are likely to yield benefits during the period 2027-32 in the Southern region, thereby making it a cost-effective storage alternative there and thus reducing the need of additional Battery storage in SR for the said period.

5.8 SCENARIOS CONSIDERED FOR GENERATION EXPANSION PLANNING DURING THE YEAR 2026-27

Studies were also carried out to assess the capacity addition requirement to meet the projected demand in the year 2026-27 in the following scenarios:

1. **Delayed nuclear capacity addition**
2. **Delayed hydro capacity addition scenario**
3. **Conservative Scenario (Based on historical trend of capacity addition)**
4. **High demand scenario (5% increase in Peak and Energy demand).**

These scenarios and the resultant likely Installed Capacity have been outlined in detail below:

5.8.1 SCENARIO 1- Delayed nuclear capacity addition

A scenario has been studied wherein the Nuclear based capacity addition for the years 2022-23 to 2031-32 is delayed/deferred by 2-3 years. The planned capacity addition of 7000 MW during 2022-23 to 2026-27 is reduced to 3600 MW in this scenario.

The likely resultant installed capacity for the year 2026-27 and 2031-32 in this scenario is as given in **Table 5.10**.

As can be seen, in this scenario due to lesser Nuclear based generation available, the required Coal based installed capacity increases to 241.5 GW in 2026-27 and 250.2 GW in 2031-32 when compared to base case value of 239 GW in 2026-27 and 248.7 in 2031-32 to cater to the Electricity Demand.

5.8.2 SCENARIO 2- Delayed hydro capacity addition scenario

A scenario has been studied wherein the upcoming hydro, PSP based projects likely to yield benefit during 2022-27 are deferred by 2 years as envisaged in base case. The likely resultant installed capacity for the year 2026-27 and 2031-32 in this scenario is given in **Table 5.10**.

In this scenario, in 2026-27 the Hydro and PSP based installed capacity decreases to 49.7 GW and 6.2 GW respectively as compared to 52.9GW and 6.8 GW in base case, owing to which in order to meet the electricity demand, the required coal based capacity increases from 239.3GW (in base case) to 243 GW. Additionally, in 2031-32, the Hydro and PSP based installed capacity decreases to 57.7 GW and 13.2 GW respectively as compared to 63.8 GW and 18.8 GW in base case, owing to which in order to meet the electricity demand, the required coal based capacity increases from 248.7 GW (in base case) to 250.6 GW.

5.8.3 Scenario 3- Conservative Scenario (Based on historical trend of capacity addition)

A scenario has been developed wherein the upcoming capacity addition from different fuel sources likely to yield benefit during 2022-2032 are deferred based on historical trends of construction time for different technologies.

The likely installed capacity for the year 2026-27 and 2031-32 is given in Table 5.10.

It is seen in this scenario that the coal based installed capacity in 2026-27 increases to 241GW from 239GW in base case scenario and in 2031-32, it increases to 259.6 GW from 248.7 GW in base case scenario.

5.8.4 SCENARIO 4- High demand scenario (5% increase in Peak and Energy demand).

A scenario has been studied where in an increase of 5% in both the estimated peak demand as well as energy Requirement for the years 2026-27 has been considered. The likely installed capacity in this scenario is given in **Table 5.10**.

It can be seen that increase in electrical demand by 5% in 2026-27, entails an increase in capacity addition requirement from Coal by around 6 GW and an increase in Storage Capacity both from PSP and BESS(5-hour) by 1.2 GW and 5.2 GW respectively when compared to base case. Also, in 2031-32 an increase in capacity addition requirement from Coal by around 3.4 GW and an increase in Storage Capacity from BESS(5-hour) by 15 GW when compared to base case is seen.

The likely installed capacity in this scenario is given in **Table 5.10**.

Results of **different scenarios** have been summarized in the table 5.10 below.

Table 5.10a
LIKELY INSTALLED CAPACITY BY END OF 2026-27 IN DIFFERENT SCENARIOS

(All figures in GW)

Scenario	Base Case	Delayed Nuclear	Delayed Hydro	Conservative Scenario	High Demand (5%)
Hydro *	52.9	53.1	49.7	47.2	53.1
PSP	6.8	7.0	6.2	6.2	8.0
Small Hydro	4.8	4.8	4.8	4.8	4.8
Solar	186.1	186.1	186.1	148	186.1
Wind	80.9	80.9	80.9	57.5	80.9
Biomass	13.0	13.0	13.0	13.0	13.0
Nuclear	13.8	10.4	13.8	10.1	13.8
Coal + Lignite	239.3	241.6	243.1	241.3	245.1
Gas	25.3	25.3	25.3	25.3	25.3
Total	622.9	622.2	622.9	553.4	630.1
Battery Energy Storage System (5-Hour)	0	0	0	9.0	5.2

*Excl. Hydro imports from neighboring countries

It is observed that the range of coal capacity required in the year 2026-27 varies from 239 GW in Base case to around 245 GW in Higher Demand scenario (5% increase in Peak and Energy requirement). Amongst all scenarios, the BESS capacity is required in 2026-27 only in the high demand scenario and in the conservative scenario.

Table 5.10b
LIKELY INSTALLED CAPACITY BY END OF 2031-32 IN DIFFERENT SCENARIOS

(All figures in GW)

Scenario	Base Case	Delayed Nuclear	Delayed Hydro	Conservative Scenario	High Demand (5%)
Hydro *	63.8	63.8	63.8	58.0	74.7
PSP	18.8	18.8	13.2	14.5	18.8
Small Hydro	4.8	4.8	4.8	4.8	4.8
Solar	333.4	333.4	333.4	299.4	333.4
Wind	133.9	133.9	133.9	90	134.2
Biomass	14.5	14.5	14.5	14.5	14.5
Nuclear	22.4	21.1	22.4	15.5	22.4
Coal + Lignite	248.7	250.2	250.6	259.6	252.1
Gas	25.3	25.3	25.3	25.3	25.3
Total	865.6	865.8	861.9	781.6	880.2
Battery Energy Storage System (5-Hour)	51.5	51.2	60.0	84.1	67.2

*Excl. Hydro imports from neighboring countries

It is observed that the range of coal capacity required in the year 2031-32 varies from 248.7 GW in Base case to around 259.6 GW in Conservative scenario while the BESS capacity varies from 51.2 GW in delayed Nuclear scenario to 84.1 GW in the conservative scenario.

5.8.6 Observations based on Scenario Analysis

The likely coal based and BESS installed capacity by end of 2026-27 and 2031-32 in different scenarios is shown in Exhibit 5.5 below :-

Exhibit 5.5a

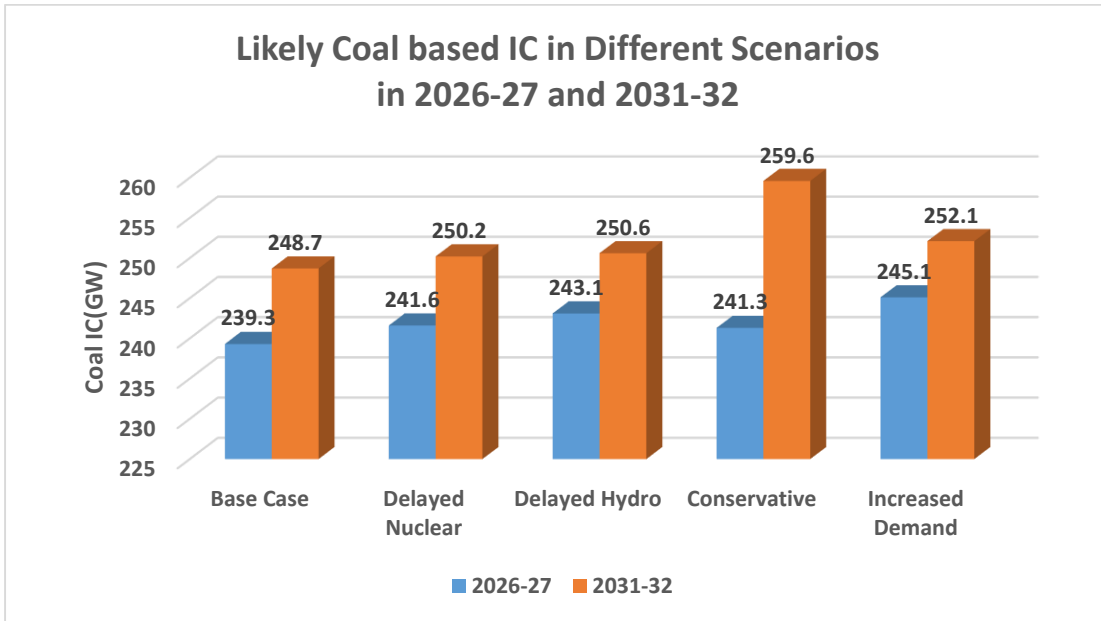
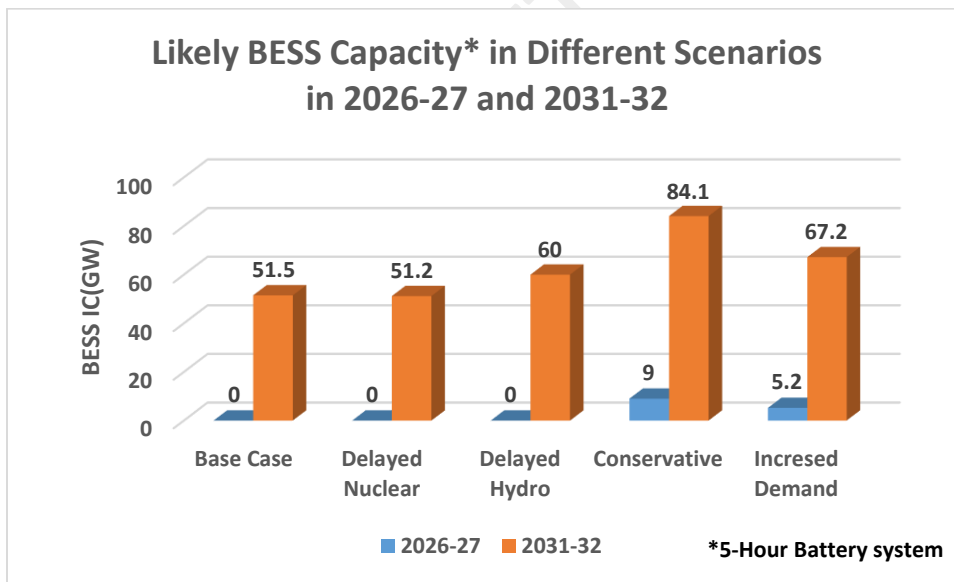


Exhibit 5.5b



- From scenario analysis, it is seen that apart from under construction coal based capacity of 25GW, the additional coal based capacity required till 2031-32 may vary from 17GW to around 28 GW. Additionally, it is seen that the BESS (5-hour) requirement in 2031-32 is varying from 51.5GW to 84GW.

- When the Peak demand and energy requirement increases, both the coal based capacity and storage requirement (PSS and BESS) increases along with marginal increase in Hydro based capacity.

- In the event of delay in achievement of Hydro based plants which are in concurred/under construction stage, there is additional requirement of coal of around 4 GW in capacity mix in 2026-27.
- In the event of non-availability of the base load nuclear capacity the model opts for cheaper coal candidates available to provide base load support.

5.9 SHORT TERM STUDIES - (HOURLY GENERATION DISPATCH)

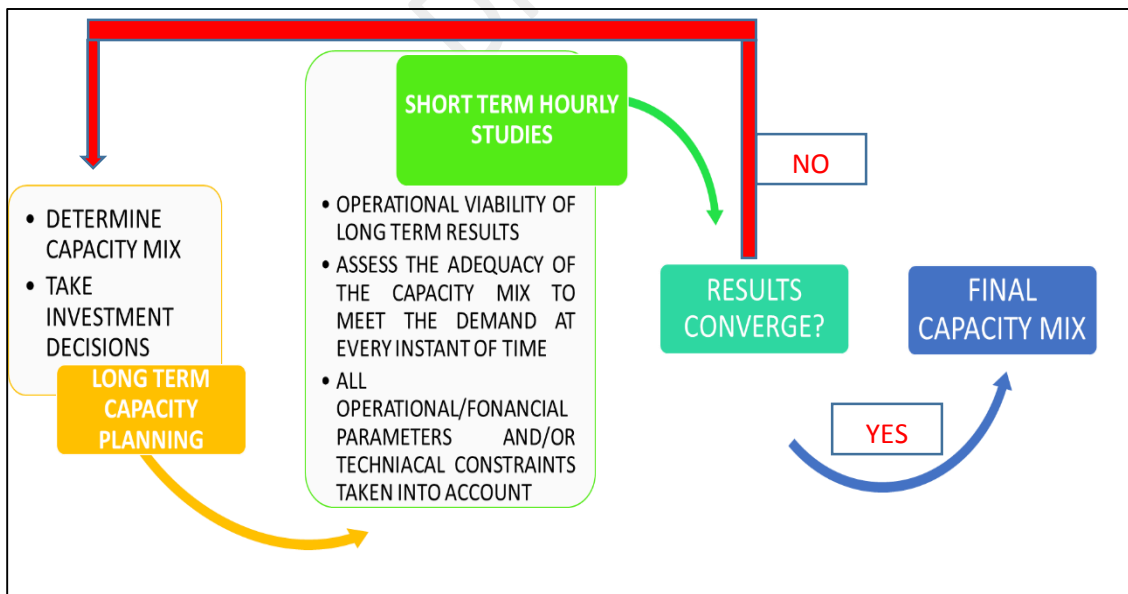
Investing in power sector infrastructure requires long lead times, and – given the long life of resulting projects – future investment options are influenced by investments that are made today. Avoiding near-term inefficiencies due to a poorly specified long-term transition plan requires a more integrated approach, which moves from long-term through short-term planning steps, and establishes clear, internally consistent feedback loops.

Production cost models or the short-term studies help to validate results from long-term generation expansion models and complement the long-term results in overcoming their internal limitation in the time resolution.

A top-down approach of planning and assessments is quite logical such that the process would move from high-scope planning (time horizon) to high-detail analysis.

The **Exhibit 5.6** below represents the sequence of steps followed in Generation planning process.

Exhibit 5.6



To begin with, long-term generation expansion planning defines and proposes a future capacity mix. Having established that mix in the respective years, that capacity mix is used to assess optimal

dispatch, which in turn is used in hourly/sub hourly analysis of the system to ascertain stability and/or to find weaknesses, if any, in system operation.

The short-term view of system encompasses the following aspects of power system operation during the planning process: -

- Hourly/ sub-hourly time steps
- Unit commitment decisions
- Ramping Constraints
- Weather based Hydro inflows
- Technical Constraints like Minimum Technical load of Coal based power plants
- Start up and shut down costs.

5.9.1 Short Term Dispatch studies for the year 2026-27

All the operational/financial parameters and technical characteristics of the units have been considered for the short-term studies to arrive at the least cost and optimum hourly generation dispatch from the projected capacity for all 365 days (8760 hours) throughout the year 2026-27.

Based on the hourly dispatch studies it was found that the capacity mix obtained from Long term studies consisting of 239.3 GW of Coal and Lignite based capacity, 13.8 GW of Nuclear and around 6.8 GW of PSP capacity is capable of meeting India’s electricity demand reliably (i.e., every hour of the year in each of the five regions) with 337.7 GW of RE based installed capacity (comprising of 52.9 GW of Large Hydro, 186 GW from PV, 80.9 GW form Wind, 13 GW from Biomass and 4.9 GW from SHP) in the year 2026-27. This is in line with the target of 500 GW of Non fossil fuel-based capacity by the year 2029-30. Given below is the likely source wise generation in the year 2026-27: -

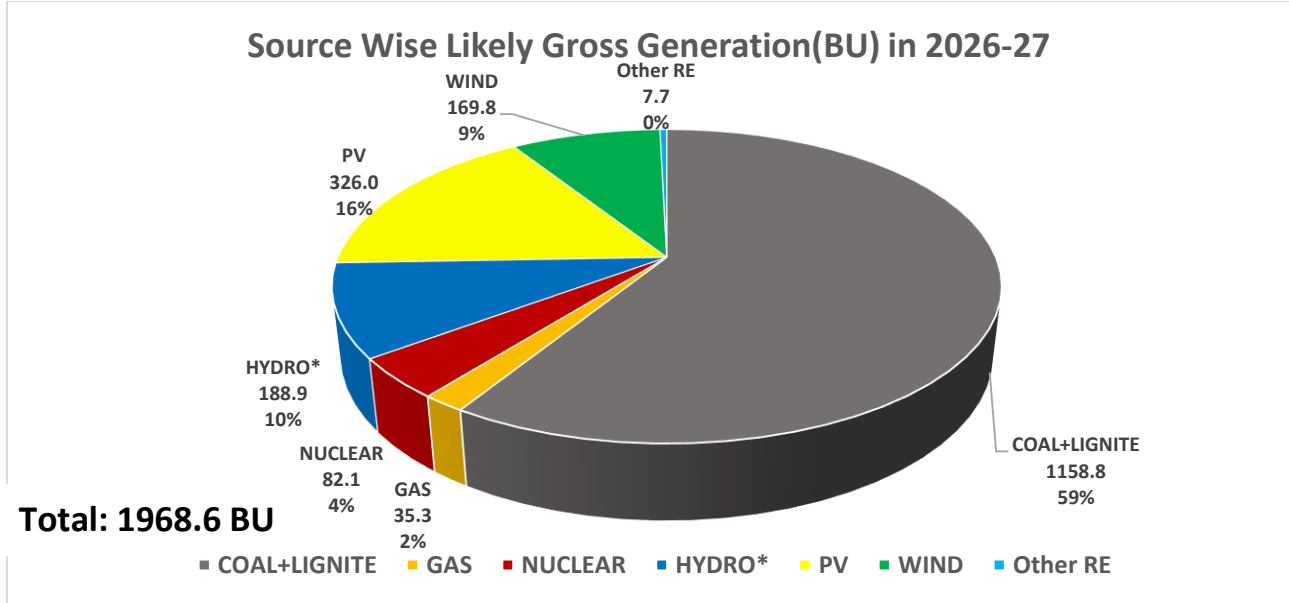
Table 5.11

Source	Gross Generation (BU)	Percentage (%)
COAL+ LIGNITE	1158.8	59%
GAS	35.3	2%
NUCL	82.1	4%
HYDRO[#]	188.9	10%
PV	326.0	17%
Wind Power	169.8	9%
Other RE	7.7	0.4%

Total	1968.6	100%
PSP	17.37	

including Generation from Hydro based imports

Exhibit 5.7



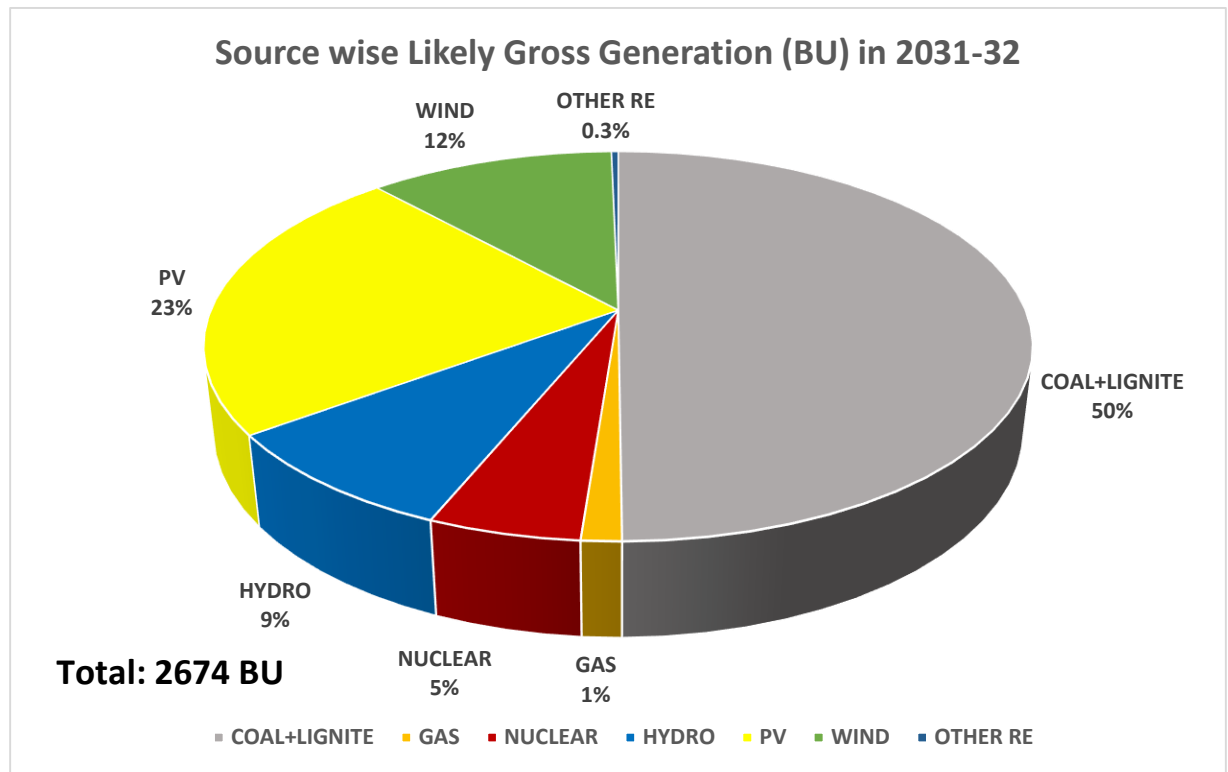
Source wise likely generation in 2031-32 is as follows:-

Table 5.12

SOURCE	Gross Generation (BU)	Percentage (%)
COAL+LIGNITE	1333.8	49.9%
GAS	35.4	1.3%
NUCLEAR	134.3	5.0%
HYDRO#	231.8	8.7%
PV	624.4	23.4%
WIND	305.7	11.4%
OTHER RE	8.6	0.3%
TOTAL	2674.0	100.0%
BS	92.3	
PSS	50.0	

including generation from Hydro Based Import

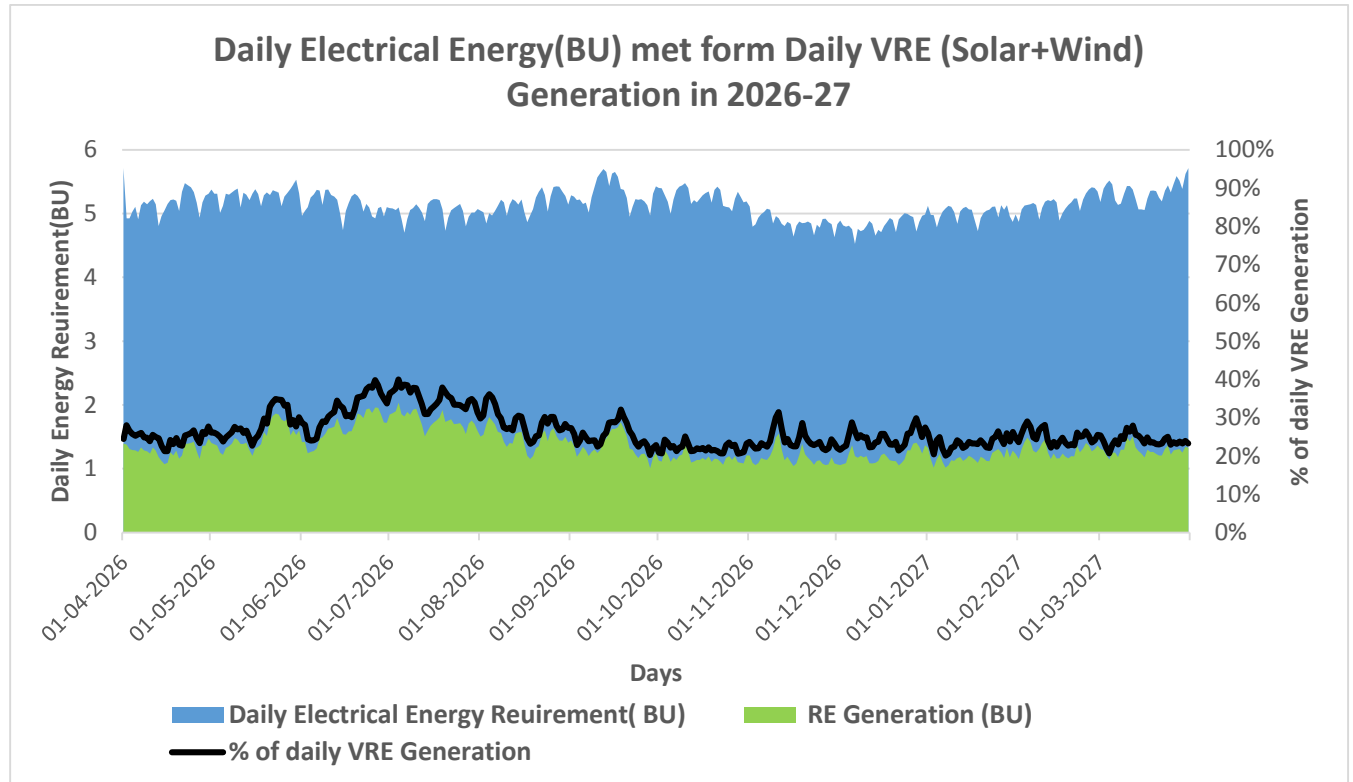
Exhibit 5.8



5.9.1.1 Daily Variation in Demand and VRE Absorption

The **Exhibit 5.9** given below depicts the variation of daily electrical energy requirement and daily VRE generation (solar and wind only) along with the percentage of daily electrical energy requirement met from renewable sources (solar and wind). It may be seen that demand met by VRE generation on few days is as high as 40%.

Exhibit 5.9



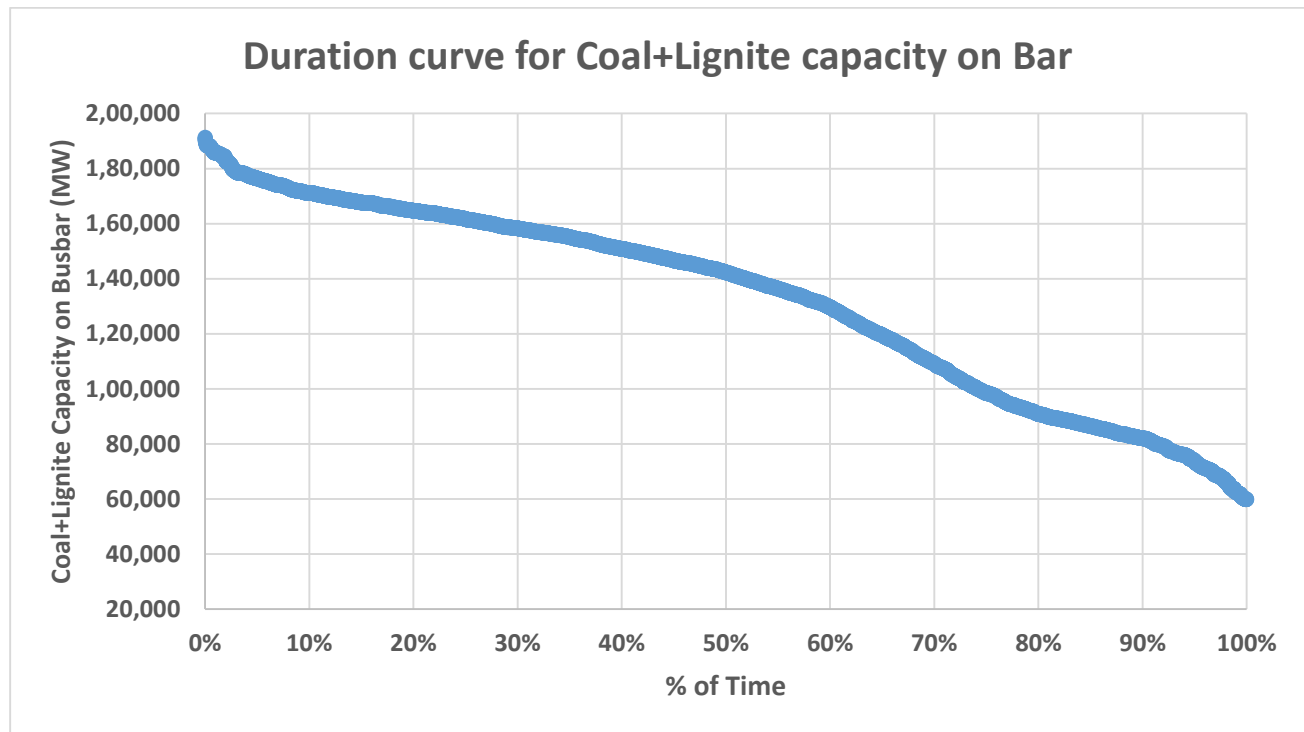
5.9.1.2 Key Findings based on short-term dispatch studies for the year 2026-27

Some of the salient outcomes of the short term dispatch studies are given below:

- Monte Carlo based simulations on hourly level were run to determine the reliability indices for the Long term results of capacity mix for the year 2026-27 as given in the Table 5.7 above. The normative values of Forced outages and planned outages for the generators were taken based on either historical averages or characteristics of technologies while carrying out the Monte Carlo simulations. It has been found out that the base case IC for the year 2026-27 meets the reliability criteria of LOLP of 0.2% and ENS of 0.05%.
- Energy storage technologies like PSP help in diurnal grid balancing during high RE months. Storage technologies charge during the daytime (coincident with solar generation) and discharge during the morning and evening peak periods (4-6 hours total each day). They also help to meet steep system ramps.
- The contribution of Renewable energy based generation(excluding Large Hydro) towards the total generation in 2026-27 is likely to increase to around 26.4 % in 2026-27 from 11% in the year 2021-22.
- It has been observed that about 3.48 % of RE based generation may not be absorbed during the year 2026-27. If peak demand shifts in afternoon hours from evening then this value may further reduce.

- The average PLF of the total Installed coal capacity of 239.3 GW was found to be about 55.28% in 2026-27.
- The maximum coal capacity (Gross) of about 190 GW was observed in the month of October.
- Coal based capacity of about 123.4 GW is expected to run at a high PLF of more than 70% while a capacity of about 53.07 GW is expected to run at a low PLF of less than 30% as shown in **Exhibit 5.10**

Exhibit 5.10



5.9.2 Short term dispatch studies for a few critical days during the year 2026-27

Due to annual/ seasonal variability of VRE resources i.e., Wind as well as Hydro generation and to account for the variation in Solar Insolation in different regions of the country around the year, changes in the shape of the demand curve over the year, a few critical days were identified in a year based on the historical hourly Demand profiles and VRE generation data. The Resource wise generation patterns for the country (while honoring the inter-regional transmission constraints) were studied in detail for such critical days with the purpose of ascertaining if the power system with the given capacity mix in the year 2026-27 is stable and resilient to meet the projected system demand at every instance of time.

The details of typical days identified for the short-term studies are given in **Table 5.13**.

Table 5.13

Critical Days identified during the year 2026-27

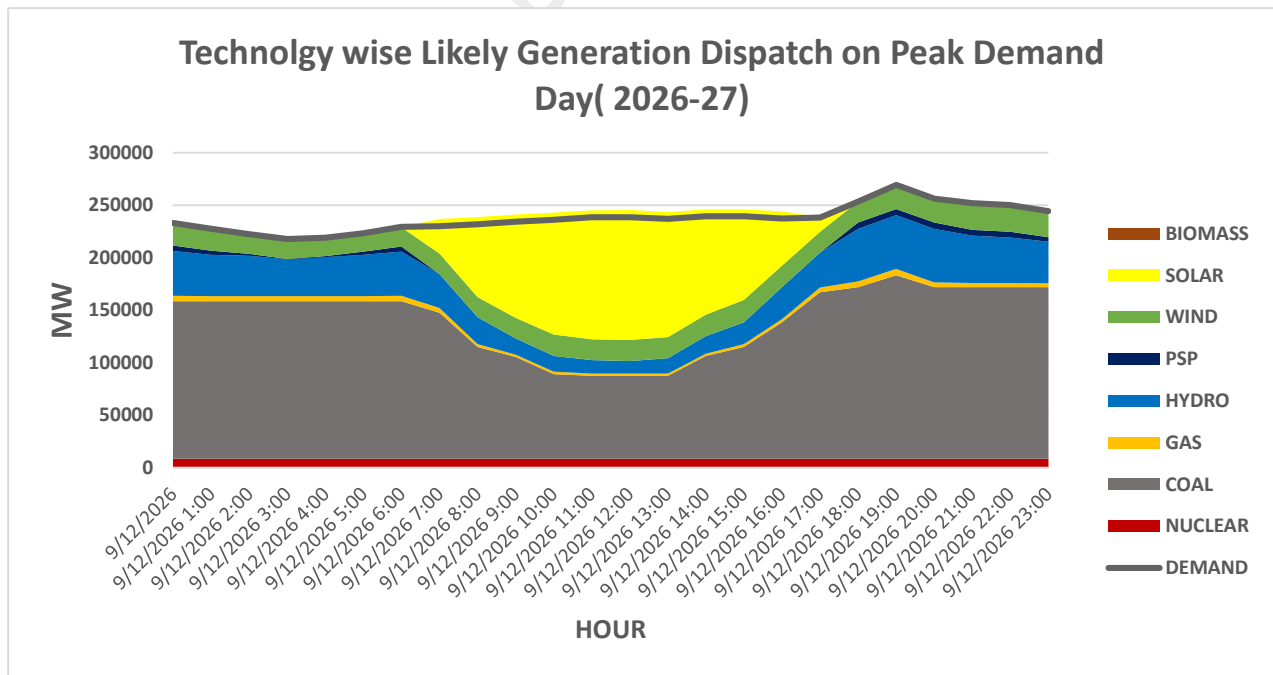
Sl. No.	Scenario	Month
1	Peak Demand Day	September
2	Maximum VRE (Wind+ Solar) generation day	June
3	Maximum Solar generation day	March
4	Minimum Solar generation day	July
5	Maximum Energy Demand Day	March
5	Minimum Energy demand day	December
6	Minimum VRE (Wind+ Solar) generation day	January
7	Maximum Variation in demand day	December
8	Maximum Variation in Net demand day	October

5.9.2.1 Peak Demand Day

One of the most critical days from power planning perspective is the peak demand day and it must be ensured that there would be adequate supply for meeting the peak demand whenever it occurs. This demonstrates the capability of the system for meeting the peak demand on other days as well. From the likely hourly demand profiles of 2026-27, it has been observed that the peak demand of 272 GW in the country occurs in the month of September.

Hourly generation dispatch from all the resources for the peak day is shown in the **Exhibit 5.11**

Exhibit 5.11



It has been observed that on this day when the peak demand occurs, the electricity peak and energy demand is likely to be fully met with the generation capacity mix obtained from the long-term studies. Further, it is seen that online coal capacity is running at 55% minimum technical load (MTL) during the hours when full solar generation is available. The Storage is getting charged during the period when excess solar generation is available and dispatched during non-solar hours. However, RE generation could not be fully absorbed due to shape of load curve, minimum technical loading of the coal and gas plants etc. even when wind Capacity Utilization Factor (CUF) on the day is 24.08% and solar CUF is 17.73%. The Gross PLF of the coal-based capacity is likely to be 59.65 % on the day.

The study of short-term hourly dispatch for other critical days as given in Table above shows that the system is resilient and stable to meet the demand of such days with the capacity mix obtained from the Long-Term studies.

5.9.2. PLF of Coal based Capacity in 2026-27 and 2031-32

Table 5.14
Energy Generated from coal & Lignite and Average PLF of coal-based stations

Year	Likely Coal+ Lignite Based Generation (Gross) (BU)	Likely PLF of Coal Based Plants (%)
2026-27	1159	55.28
2031-32	1334	61.21

5.10 CONCLUSIONS

- The projected All India peak electricity demand and electrical energy requirement is 272 GW and 1874 BU for the year 2026-27 and 363 GW and 2538 BU for the year 2031-32 respectively as per the preliminary estimates of Demand projections.
- The capacity addition of 228,541 MW comprising of 40,632 MW of Conventional capacity addition (Coal-33262 MW, Nuclear-7,000MW, Gas-370MW) and 187,909 MW of Renewable based Capacity Addition (Large Hydro-10,951 MW, Solar-132,080, Wind-40,500 MW, Biomass-2318 MW, PSP-2060 MW) is required during 2022-27 to meet the peak electricity demand and energy requirement for the year 2026-27.
- Based on generation planning studies carried out for the period of 2022-27, the likely Installed Capacity for the year 2026-27 is 622,899 MW comprising of 278,382 MW of Conventional capacity addition (Coal-239,333 MW, Gas-25,269 MW, Nuclear-13,780MW) and 344,517 MW of

Renewable based Capacity Addition (Large Hydro-52,929 MW, Solar-186,076 MW Wind-80,858 MW, Small Hydro-4848MW, Biomass-13,000MW, PSP-6806MW)

- The capacity addition of 243,042MW comprising of 18,134 MW of Conventional capacity addition (Coal-9434 MW, Nuclear-8700 MW) and 223,408 MW of Renewable based Capacity Addition (Large Hydro-10,888 MW, Solar-147400, Wind-53100MW, Biomass-1500 MW, PSP-12020MW) excluding 5856 MW of likely Hydro based Imports, is required during 2027-32 to meet the peak electricity demand and energy requirement for the year 2031-32.
- Based on generation planning studies carried out for the period of 2027-32, the likely Installed Capacity for the year 2027-32 is 865941 MW comprising of 296517 MW of Conventional capacity addition (Coal-248767 MW, Gas-25270MW, Nuclear-22,480MW) and 569424 MW of Renewable based Capacity Addition (Large Hydro-63,816 MW, Solar-333,476MW, Wind-133,958MW, Small Hydro-4848MW, Biomass-14,500 MW, PSP-18826MW; excluding 5856 MW of likely Hydro based Imports) along with 5-hour BESS capacity of 51.55 GW.
- The likely installed capacity for the year 2026-27 is in line with the target of the country to achieve a non-fossil fuel based installed capacity of 500 GW by the year 2029-30.
- It is seen that apart from under construction coal based capacity of 25GW, the additional coal based capacity required till 2031-32 may vary from 17 GW to around 28 GW. It is also seen that the BESS (5-hour) requirement in 2031-32 is varying from 51 GW to 84GW.
- Short term studies carried out for the year 2026-27 on an hourly basis suggest that with the aforementioned capacity mix, the hourly demand will be met on each of the 365 days reliably while honoring various technical system constraints. Dispatch modeling validates that the optimal resource mix can meet demand in every hour of the year i.e. there is no loss of load, even during days when the system is stressed, such as days of peak load, highest net load, highest RE variability, etc.
- A generation of 1968 BU comprising of coal based -1158.8 BU, Gas based-35 BU, Nuclear based- 82 BU, Large Hydro based- 189 BU (including generation from Hydro imports), PV based-326 BU, Wind based- 170 BU and SHP based-8 BU, is projected during the year 2026-27 based on the generation planning studies to meet the projected hourly demand.
- Based on monte carlo based simulations run on hourly level, it has been found out that the IC for the year 2026-27 as given in the table above meets the reliability criteria of LOLP of 0.2 % and ENS of 0.05% as per the globally accepted planning norms.
- The average PLF of the total Installed coal capacity of 239.3 GW was found to be about 55% in 2026-27. The average PLF of the total Installed coal capacity of 248.9 GW was found to be about 62 % in 2031-32.
- Several scenarios viz. Delayed Nuclear capacity addition, Delayed Hydro based capacity addition, Higher Demand requirement (Peak demand and energy requirement increases by 5%) were studied to assess the capacity addition requirement to meet the projected demand in the year 2026-27 corresponding to different plausible situations considered in the respective scenario

Annexure-5.1

Region wise Wind & Solar CUF considered

NODE	NR	WR	SR	ER	NER	ALL INDIA
Solar CUF	22.21%	23.47%	23.74%	21.55%	20.02%	22.20%
WIND(onshore) CUF	24.36%	27.16%	23.93%	-	-	25.15%

TRANSMISSION PARAMETERS

For carrying out the long-term generation expansion studies on regional basis, five Nodes have been created with inter regional Transmission links between them for Inter regional power transfer. The following values have been assumed for the inter-regional transmission links: -

Capital Cost of New Transmission Line *	Rs 10,163 /MW-km
Actual transfer capacity of lines (assumed to be SIL)	~50% of installed Capacity
Line Voltage	400 KV

*For Lines to and From NER it is assumed 2 times of the above cost

FINANCIAL PARAMETERS

Following cost parameters have been assumed in the year 2021-2022:

Resource	Capex* (in ₹/MW)	O&M Fixed Cost (in ₹/MW)	Construction Time (in years)	Amortization/Life time (in years)
Coal	8.34 Cr	19.54 Lakh	4	25
Nuclear	12 Cr	20 Lakh	6	30
Hydro~	6 Cr to 20 Cr	2.5% of Capex	5 to 8	40
Solar ¹	4.5 Cr to 4.1 Cr	1 % of Capex	0.5	25
Wind(Onshore)	6 Cr	1% of Capex	1.5	25
Wind(Offshore) ⁵	16.59 Cr to 13.69 Cr	1% of Capex	1.5	25
Biomass	9 Cr	2% of Capex	3	20
Pumped Storage	3 Cr to 8 Cr	5 % of Capex	7	40
Battery Energy Storage [@]	9.3 Cr to 5.24 Cr	1 % of Capex	0.5	14
Inter -Regional transmission Line Cost	10,163 /MW/Km	-	1	25

* All the Capex figures are on actual basis at the cost level of 2021-22 i.e., inflation is not considered while calculating capex.

~ The Capex values of Hydro and PSS candidates are considered as per the project cost details furnished by the respective developers for state and private sector plants and as per RCEs done periodically by CEA for central sector plants. A benefit in the total Capex of the project equivalent to infrastructure development cost as per the data furnished by the project developer has been considered based on revised Hydro policy guideline as per MoP order no. 23/03/2016-R&R.

! Solar Cost is assumed to reduce from Rs 4.5 Cr in 2021-22 to Rs 4.1 Cr in 2029-30 beyond which its assumed to be the same for next two years.

\$Off-shore wind has been considered as investment option from 2027-28 onwards with cost trajectory reducing from 16.59 Cr/MW in 2027-28 to 13.69 Cr/MW in 2031-32.

@Battery Energy Storage System Cost (5-hour storage) is assumed to reduce from Rs 9.3 Cr/MW in 2021-22 to Rs 6.99 Cr/MW in 2024-25 and then to Rs 5.24 Cr/MW in 2029-30 beyond which its assumed to be the same for next two years. A custom duty of 22% on the Battery pack cost and GST of 18% on the total Battery system cost has been considered in the studies.

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Annexure 5.2

LIST OF COAL BASED PLANTS FOR LIKELY RETIREMENT DURING 2022-23 TO 2026-27

(All Figures in MW)

S.NO	NAME OF PROJECT	STATE	SECTOR	ORGANISATION	TOTAL CAPACITY (MW)
1	KOTA TPS UNIT 1-4	RAJASTHAN	STATE SECTOR	RRVUNL	2*110+2*210=640
2	HARDUAGANJ TPS UNIT 7	UTTAR PRADESH	STATE SECTOR	UPRVUNL	105
3	KORBA-WEST TPS UNIT 1-4	CHHATTISGARH	STATE SECTOR	CSPGCL	4*210=840
4	GEPL TPP PH-I UNIT 1,2	MAHARASHTRA	PRIVATE SECTOR	GEPL	2*60=120
5	DR. N. TATA RAO TPS UNIT 1-6	ANDHRA PRADESH	STATE SECTOR	APGENCO	6*210=1260
6	THOOTHUKUDI TPS UNIT 1-3	TAMIL NADU	STATE SECTOR	TANGEDCO	3*210=630
7	BANDEL TPS UNIT 2,5	WEST BENGAL	STATE SECTOR	WBPDC	1*60+1*210=270
8	TITAGARH TPS UNIT 1-4	WEST BENGAL	PRIVATE SECTOR	CESC	4*60=240
9	DURGAPUR TPS UNIT 4	WEST BENGAL	CENTRAL SECTOR	DVC	210
10	PARICHHA TPS UNIT 1,2	UTTAR PARDESH	STATE SECTOR	UPRVUNL	2*110=220
11	OBRA TPS	UTTAR PARDESH	STATE SECTOR	UPRVUNL	94
TOTAL					4629

Annexure 5.3

LIST OF UNDER CONSTRUCTION THERMAL PLANTS FOR LIKELY BENEFITS DURING 2022-23 TO 2026-27

(All Figures in MW)

S.NO.	NAME OF PROJECT	STATE	SECTOR	ORGANISATION	TOTAL CAPACITY (MW)
1	SRI DAMODARAM TPS ST-II	ANDHRA PRADESH	STATE	APGENCO	800
2	NORTH CHENNAI TPP ST-III	TAMIL NADU	STATE	TANGEDCO	800
3	YELAHANKA CCPP-GAS	KARNATAKA	STATE	KPCL	370
4	DR. NARLA TATA RAO TPS ST-V	ANDHRA PRADESH	STATE	APGENCO	800
5	GHATAMPUR TPP/ NLC JV U-1,2,3	UTTAR PRADESH	CENTRAL	JV OF NLC & UPRVUNL	3*660=1980
6	KHURJA SCTPP UNIT 1,2	UTTAR PRADESH	CENTRAL	THDC	2*660=1320
7	JAWAHARPUR STPP/ UPRVUNL UNIT 1,2	UTTAR PRADESH	STATE	UPRVUNL	2*660=1320
8	OBRA-C STPP/ UPRVUNL UNIT 1,2	UTTAR PRADESH	STATE	UPRVUNL	2*660=1320
9	PANKI TPS EXTN	UTTAR PRADESH	STATE	UPRVUNL	660
10	BHUSAWAL STPP UNIT 1	MAHARASHTRA	STATE	MAHAGENCO	660
11	ENNORE SCTPP / TANGEDCO U-1,2	TAMIL NADU	STATE	TANGEDCO	2*660=1320
12	UDANGUDI STPP UNIT 1,2	TAMIL NADU	STATE	TANGEDCO	2*660=1320
13	TELANGANA PH-I/NTPC U-1,2	TELANGANA	CENTRAL	NTPC	2*800=1600
14	YADADRI TPS UNIT 1-5	TELANGANA	STATE	TSGENCO	5*800=4000
15	BARH STPP-I /NTPC U-2,3	BIHAR	CENTRAL	NTPC	2*660=1320
16	BUXAR TPP UNIT 1,2	BIHAR	CENTRAL	SJVNL	2*660=1320
17	NORTH KARANPURA TPP/ NTPC U-1,2,3	JHARKHAND	CENTRAL	NTPC	3*660=1980
18	PATRATU STPP UNIT 1-3	JHARKHAND	CENTRAL	JV OF NTPC & JHARKHAND BIDYUT VITRAN NIGAM LTD.	3*800=2400
19	SAGARDIGHI THERMAL POWER PLANT PH-III	WEST BENGAL	STATE	WBPDCL	660
TOTAL					25950 MW

*Rourkela TPP-II Expansion (250 MW) is a captive power project and is not to be added in Under Construction list, hence not being monitored by CEA.

Annexure 5.3 (Continued)

LIST OF UNDER CONSTRUCTION HYDRO PLANTS (EXCLUDING PSP) FOR LIKELY BENEFITS DURING 2022-23 TO 2026-27

(All Figures in MW)

S.NO.	NAME OF PROJECT	STATE	SECTOR	ORGANISATION	TOTAL CAPACITY (MW)
1	VYASI UNIT 1,2	UTTARAKHAND	STATE	UJVNL	2*60=120
2	NAITWAR MORI UNIT 1,2	UTTARAKHAND	CENTRAL	SJVNL	2*30=60
3	PALLIVASAL XT UNIT 1,2	KERALA	STATE	KSEB	2*30=60
4	PARBATI ST. II UNIT 1-4	HIMACHAL PRADESH	CENTRAL	NHPC	4*200=800
5	SUBANSIRI LOWER UNIT 1-8	ARUNACHAL PRADESH	CENTRAL	NHPC	8*250=2000
6	THOTTIYAR UNIT 1,2	KERALA	STATE	KSEB	1*30+1*10=40
7	TIDONG-I UNIT 1,2	HIMACHAL PRADESH	PRIVATE	M/S STATKRAFT INDIA PVT. LTD.	2*50=100
8	PARNAI UNIT 1-3	JAMMU & KASHMIR	STATE	JKSDPC	3*12.5=37.5
9	TAPOVAN VISHNUGAD UNIT 1-4	UTTARAKHAND	CENTRAL	NTPC	4*130=520
10	TEESTA- VI UNIT 1-4	WEST BENGAL	CENTRAL	NHPC	4*125=500
11	UHL-III UNIT 1-3	HIMACHAL PRADESH	STATE	BVPCL	3*33.33=100
12	KIRU UNIT 1-4	JAMMU & KASHMIR	CENTRAL	CVPPL	4*156=624
13	LOWER KOPILI UNIT 1-5	ASSAM	STATE	APGCL	2*55+1*5+2*2.5=120
14	POLAVARAM UNIT 1-12	ANDHRA PRADESH	STATE	POLAVARAM PROJECT AUTHORITY	12*80=960
15	RAMMAM - III UNIT 1-3	WEST BENGAL	CENTRAL	NTPC	3*40=120
16	RANGIT-IV UNIT 1-3	SIKKIM	CENTRAL	NHPC	3*40=120
17	SHAHPURKANDI UNIT 1-7	PUNJAB	STATE	PSPCL	6*33+1*8=206
18	SHONGTONG KARCHAM UNIT 1-3	HIMACHAL PRADESH	STATE	HPPCL	3*150=450
19	VISHNUGAD PIPALKOTI UNIT 1-4	UTTARAKHAND	CENTRAL	THDC	4*111=444
20	DHAULASIDH U1,2	HIMACHAL PRADESH	CENTRAL	SJVNL	2*33=66
21	KUTEHR UNIT 1-3	HIMACHAL PRADESH	PRIVATE	JSW ENERGY LTD	3*80=240
22	LUHRI STAGE-I UNIT 1-4	HIMACHAL PRADESH	CENTRAL	SJVNL	2*80+2*25=210
23	PAKAL DUL UNIT 1-4	JAMMU & KASHMIR	CENTRAL	CVPPL	4*250=1000
24	RATLE UNIT 1-5	JAMMU & KASHMIR	CENTRAL	RHEPPL/NHPC	4*205+1*30=850
25	BHASMAY UNIT 1-3	SIKKIM	PRIVATE	GATI INFRASTRUCTURE	3*17=51

26	MAHESHWAR UNIT 1-10	MADHYA PRADESH	PRIVATE	SMHPCL	10*40=400
27	PHATA BYUNG UNIT 1,2	UTTARAKHAND	PRIVATE	LANCO	2*38=76
28	RANGIT-II UNIT 1,2	SIKKIM	PRIVATE	SIKKIM HYDRO POWER VENTURES LIMITED	2*33=66
29	TANGNU ROMAI- I UNIT 1,2	HIMACHAL PRADESH	PRIVATE	TRPG	2*22=44
30	LOWER KALNAI UNIT 1,2	JAMMU AND KASHMIR	STATE	JKSPDC	2*24=48
31	LATA TAPOVAN UNIT 1-3	UTTARAKHAND	CENTRAL	NTPC	3*57=171
32	PANAN UNIT 1-4	SIKKIM	PRIVATE	HIMGIRI HYDRO ENERGY PVT. LTD.	4*75=300
TOTAL					10903

LIST OF UNDER CONSTRUCTION PUMPED STORAGE PLANT FOR LIKELY BENEFITS DURING 2022-23 TO 2026-27

(All Figures in MW)

S.NO.	NAME OF PROJECT	STATE	SECTOR	ORGANISATION	TOTAL CAPACITY (MW)
1	TEHRI UNIT 1-4	UTTARAKHAND	CENTRAL	THDC	4*250=1000
2	KUNDAH UNIT 1-4	TAMIL NADU	STATE	TANGEDCO	4*125=500
3	KOYNA LEFT BANK UNIT 1,2	MAHARASHTRA	STATE	WRD	2*40=80
TOTAL					1580

LIST OF UNDER CONSTRUCTION NUCLEAR PLANTS FOR LIKELY BENEFITS DURING 2022-23 TO 2026-27

(All Figures in MW)

S.NO.	NAME OF GENERATOR	DEVELOPER	STATE	INSTALLED CAPACITY (MW)
1	KAKRAPARA A.P.S. UNIT 3,4	NPCIL	GUJARAT	2*700=1400
2	KUDANKULAM UNIT 3,4,5	NPCIL	TAMILNADU	3*1000=3000
3	PFBR NEW UNIT 1	BHAVINI	TAMILNADU	500
4	RAJASTHAN A.P.S. UNIT 7-8	NPCIL	RAJASTHAN	2*700=1400
5	GORAKHPUR UNIT 1	NPCIL	HARYANA	700
TOTAL				7000

LIST OF UNDER CONSTRUCTION NUCLEAR PLANTS FOR LIKELY BENEFITS DURING 2027-28 TO 2031-32

(All Figures in MW)

S.NO.	NAME OF GENERATOR	DEVELOPER	STATE	INSTALLED CAPACITY (MW)
1	KUDANKULAM UNIT 6	NPCIL	TAMILNADU	1000
2	GORAKHPUR UNIT 2	NPCIL	HARYANA	700



3	GORAKHPUR UNIT 3,4*	NPCIL	HARYANA	2*700=1400
4	KAIGA A.P.S. UNIT 5,6*	NPCIL	KARNATAKA	2*700=1400
5	CHUTKA UNIT 1,2*	NPCIL	MADHYA PRADESH	2*700=1400
6	MAHI BANSWARA RAJASTHAN ATOMIC POWER PROJECT UNIT 1,2,3,4 *	NPCIL	RAJASTHAN	4*700=2800
TOTAL				8700

* Accorded Administrative Approval and Financial Sanction

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Annexure-5.4**List of Hydro Based Imports from neighbouring countries during 2022-23 to 2026-27****(All Figures in MW)**

S.NO	PLANT NAME	COMMISSIONING YEAR	CAPACITY (IN MW)
1	PUNATSANGCHHU 1	2024-25	1200
2	PUNATSANGCHHU 2	2024-25	1020
3	KHOLONGCHU	2024-25	600
4	ARUN-III	2024-25	900
TOTAL			3720

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CHAPTER 6

RENEWABLE ENERGY SOURCES IN INDIA

6.0 INTRODUCTION

To promote human welfare with social and economic development, the supply of electricity needs to be secure and have a low impact on the environment to achieve sustainable development. Renewable energy plays a key role in achieving the set objectives, especially in mitigating climate change.

Renewable energies sources are clean, inexhaustible and due to technological innovation becoming competitive with the fossil fuel-based sources. Renewable energy sources are vital for combating climate change and limiting its devastating effects. The global average temperature has risen by an average 1.09 °C from the 1850-1900 (IPCC report) which clearly indicates that some necessary steps have to be taken at the earliest to keep global temperature in permissible limits. Keeping this in mind Renewable energies received important backing from the international community through the Paris Accord signed at the UNFCCC Summit held in December 2015.

The Paris Agreement's central aim is to strengthen the global response to the threat of climate change by keeping a global temperature rise this century well below 2 degrees Celsius above pre-industrial levels and to pursue efforts to limit the temperature increase even further to 1.5 degrees Celsius. The Paris Agreement requires all Parties to put forward their best efforts through "nationally determined contributions" (NDCs) and to strengthen these efforts in the years ahead.

India's nationally determined contributions (NDCs) consists of a goal to achieve 40% of installed capacity from non-fossil fuels. India has been fully committed to moving towards cleaner investments and has set an ambitious target of 500 GW of non-fossil fuel capacity by year 2030.

This chapter detailed the of status of Renewable energy in India, major Renewable Energy sources and its potential, new emerging technologies, challenges associated with the integration of renewable energy sources with the grid and how we can deal with these challenges.

6.1 PRESENT STATUS OF RENEWABLE ENERGY IN THE COUNTRY

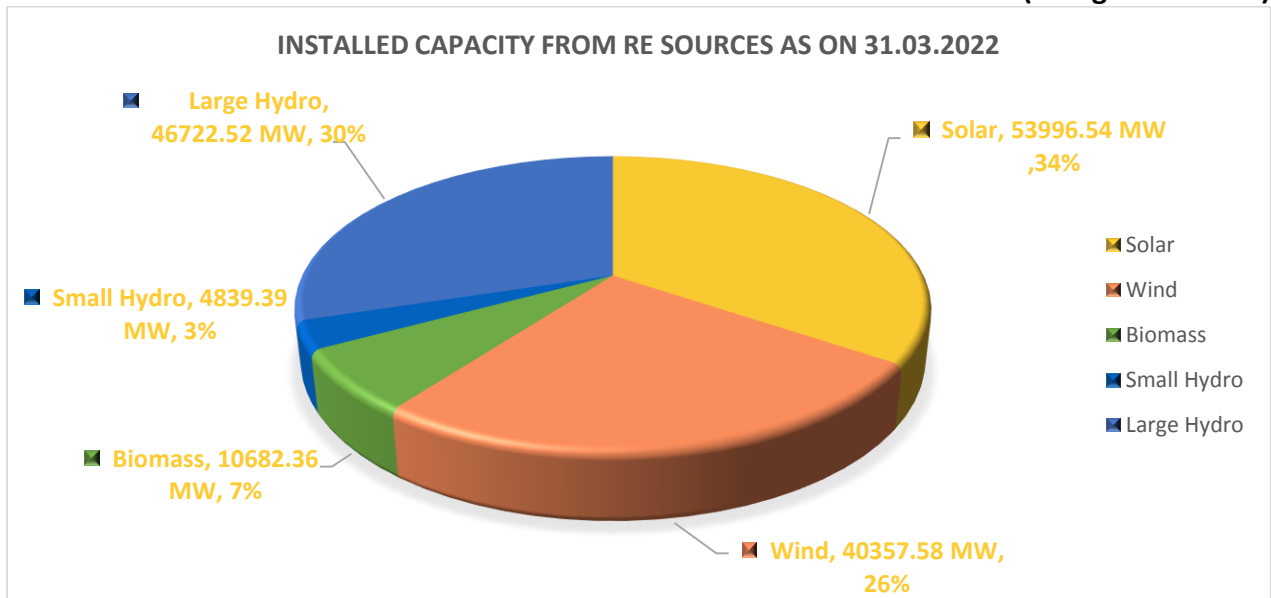
India is endowed with large renewable energy potential consisting of solar, wind, large hydro, small hydro, biomass and other renewable energy sources. As per Hydro policy, 2019 notified on 08.03.2019 Large Hydro power projects (LHPs, i.e., >25 MW) are declared as Renewable Energy source. India has achieved a cumulative installed renewable energy capacity (including large hydro) of 156607.90 MW as on 31.03.2022 as shown in **Table 6.1** and share of each RE source is shown in **Exhibit 6.1**. State wise installed capacity of Renewable energy sources as on 31.03.2022 is attached in **Annexure-6.1**.

Table 6.1
Installed Capacity of Grid-connected Renewable Power Plants
(As on 31.03.2022)

Renewable Energy Source	Installed capacity (MW)
Large Hydro (including PSP)	46722.52
Solar	53996.54
Wind	40357.58
Bio-Power & Waste Power	10682.36
Small Hydro	4848.9
Total	156607.90

Exhibit 6.1

(All figures in MW)



Share of installed capacity of Renewable energy sources in total installed capacity and share of electricity generation from RE sources in total electricity is increasing continuously which is shown in **Table 6.2**

Table 6.2
India's RE Sector at a Glance

Year	Installed RE Capacity (in MW)	% Share of RE in total Installed Capacity	Generation from Renewable Sources (in BU)	Total Generation from all sources (in BU)	% Share of RE in Generation
2017-18	114315.8	33.23	227.95	1308.14	17.43
2018-19	123040.9	34.55	261.65	1376.1	19.01
2019-20	132726.9	35.86	294.09	1389.1	21.17
2020-21	140643	36.80	297.55	1381.86	21.53
2021-22	156607.90	39.00	321.02	1491.9	21.54

6.2 OVERVIEW OF RENEWABLE ENERGY TECHNOLOGIES

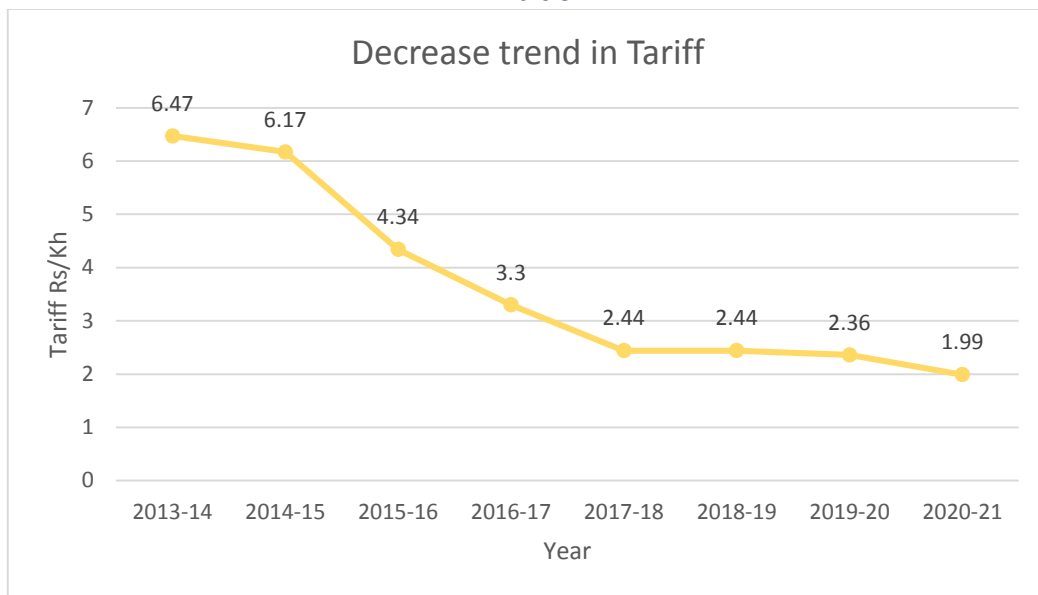
6.2.1 Solar energy

India is endowed with vast solar energy potential. About 5,000 trillion kWh per year energy is incident over India's land area with most parts receiving 4-7 kWh per sq. m per day. Solar also provides the ability to generate power on a distributed basis and enables rapid capacity addition with short lead times. From an energy security perspective, solar is the most secure of all sources, since it is abundantly available.

There has been a visible impact of solar energy in the Indian energy scenario during the last few years. Solar energy based decentralized and distributed applications have benefited millions of people in Indian villages by meeting their cooking, lighting and other energy needs in an environment friendly manner. Solar energy sector in India has emerged as a significant player in the grid connected power generation capacity over the years. It supports the government agenda of sustainable growth, while, emerging as an integral part of the solution to meet the nation's energy needs and an essential player for energy security. With technological improvements, economy of scale and reduction in solar cell/ module prices solar tariff in India is now competitive and has achieved grid parity.

India have witnessed a steep decline in solar tariffs from Rs. 6.47/ kWh in 2013-14 to Rs. 1.99/kWh in December, 2020 as shown in **Exhibit 6.2**

Exhibit 6.2



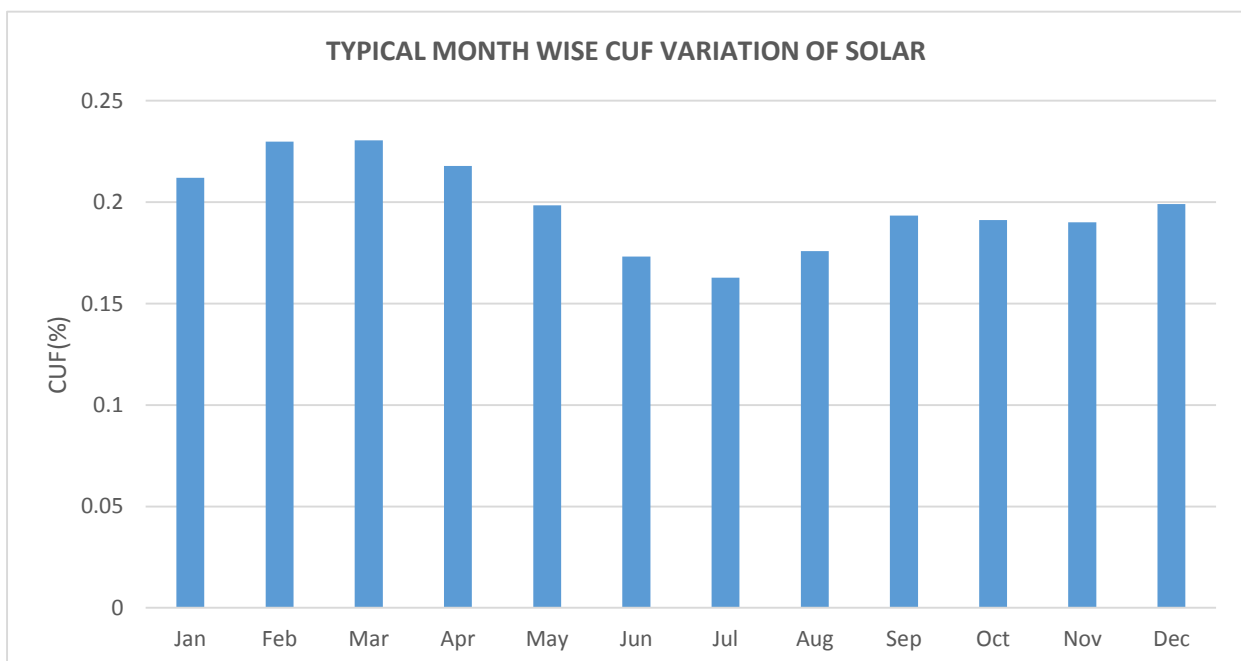
(Source: Ministry of New and Renewable Energy, India)

6.2.1.1 Solar Energy Potential in India:

National Institute of Solar Energy (NISE) has assessed the Country’s solar potential of about 748 GW assuming 3% of the waste land area to be covered by Solar PV modules. State-wise estimated solar energy potential is shown in **Annexure-6.2**

A typical normalized monthly generation profile of a solar is shown in the **Exhibit 6.3**.

Exhibit 6.3



As shown from **Exhibit 6.2**, Average solar generation is maximum in the month of Feb-March

Season Wise Daily Variation of normalized solar profile for different regions is shown in **Exhibit 6.4 (a) to (e)**

Exhibit 6.4 (a)

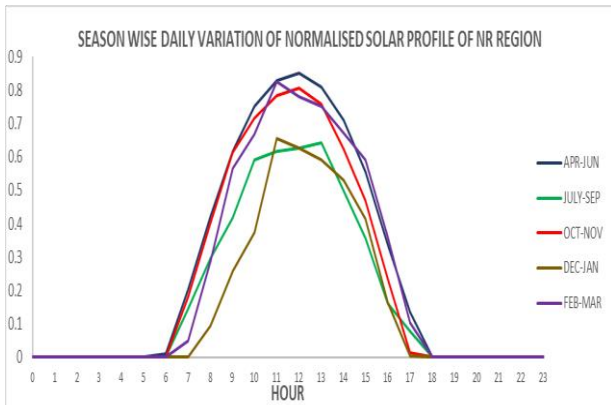


Exhibit 6.4 (b)

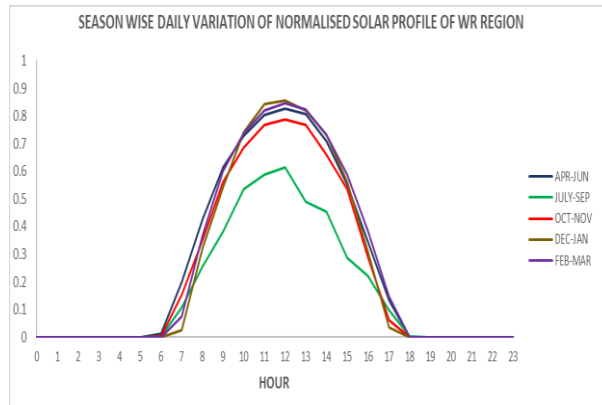


Exhibit 6.4 (c)

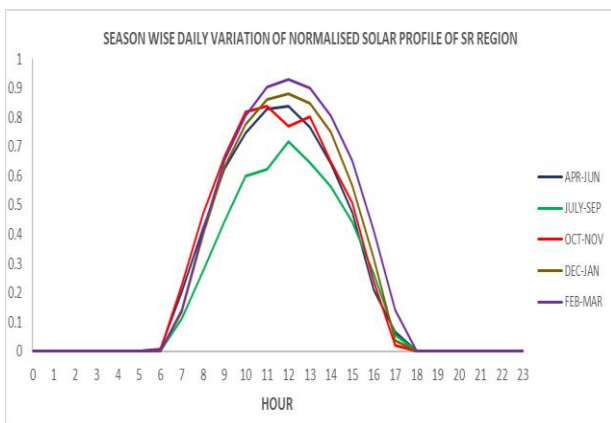


Exhibit 6.4 (d)

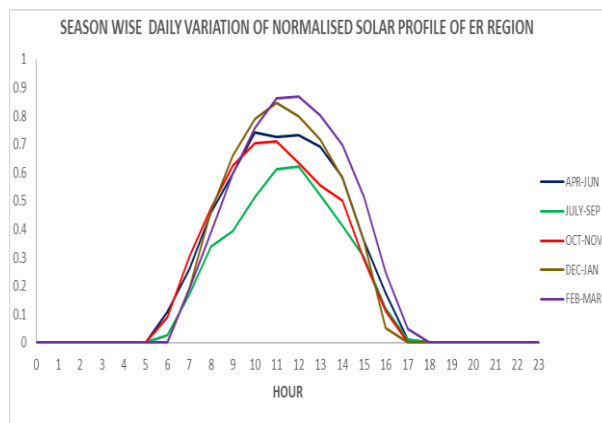
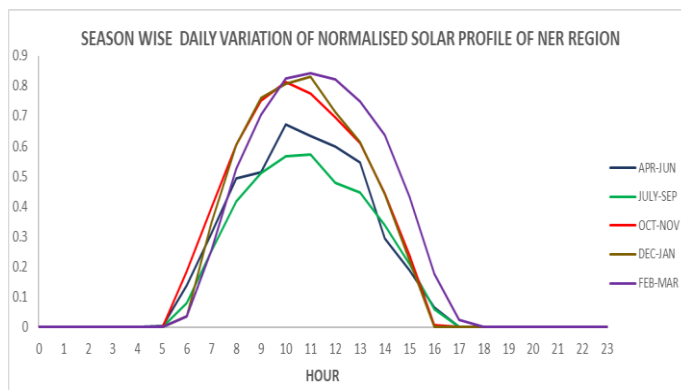


Exhibit 6.4 (e)



6.2.1.2 Status of Grid Connected Solar:

As on 31.03.2022, India has achieved 5th rank in the world in solar power deployment. In solar power, capacity has increased by more than 20.77 times in the last five years from 2.6 GW in March 2014 to 54 GW in March 2022.

Year wise achievement of Grid connected solar power Project is shown in **Table 6.3:**

Table 6.3
Year-wise Grid Connected Solar power in the Country

S.NO	YEAR	CAPACITY ADDED DURING F.Y (MW)	CUMULATIVE CAPACITY (MW)
1	2017-18	9362.63	21651.48
2	2018-19	6529.20	28180.68
3	2019-20	6447.14	34627.82
4	2020-21	5757.55	40085.37
5	2021-22	13911.17	53996.54

6.2.2 Wind energy:

India's wind energy sector is led by indigenous wind power industry and has shown consistent progress. The expansion of the wind industry has resulted in a strong ecosystem, project operation capabilities and manufacturing base of about 10,000 MW per annum (as per MNRE). The country currently has the fourth highest wind installed capacity in the world with total installed capacity of 40.357 GW as on 31.03.2022

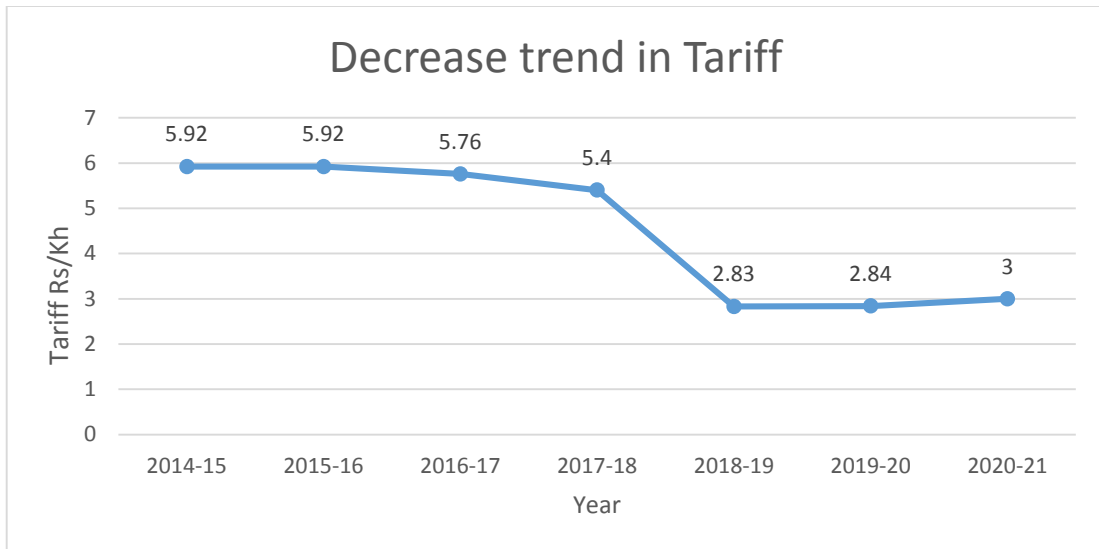
The Government is promoting wind power projects in entire country through private sector investment by providing various fiscal and financial incentives such as Accelerated Depreciation benefit; concessional custom duty exemption on certain components of wind electric generators. Besides, Generation Based Incentive (GBI) Scheme was available for the wind projects commissioned before 31 March 2017.

In addition to fiscal and other incentives as stated above, following steps also have been taken to promote installation of wind capacity in the country:

- Technical support including wind resource assessment and identification of potential sites through the National Institute of Wind Energy, Chennai.
- Issued Guidelines for Tariff Based Competitive Bidding Process for Procurement of Power from Grid Connected Wind Power Projects with an objective to provide a framework for procurement of wind power through a transparent process of bidding including standardization of the process and defining of roles and responsibilities of various stakeholders. These Guidelines aim to enable the Distribution Licensees to procure wind power at competitive rates in a cost-effective manner.

India have witnessed a steep decline in wind tariffs from Rs. 5.92/ kWh in 2014-15 to Rs. 3/kWh in December, 2020 as shown in **Exhibit 6.5**

Exhibit 6.5



(Source: Ministry of New and Renewable Energy, India)

Wind Energy Potential in India:

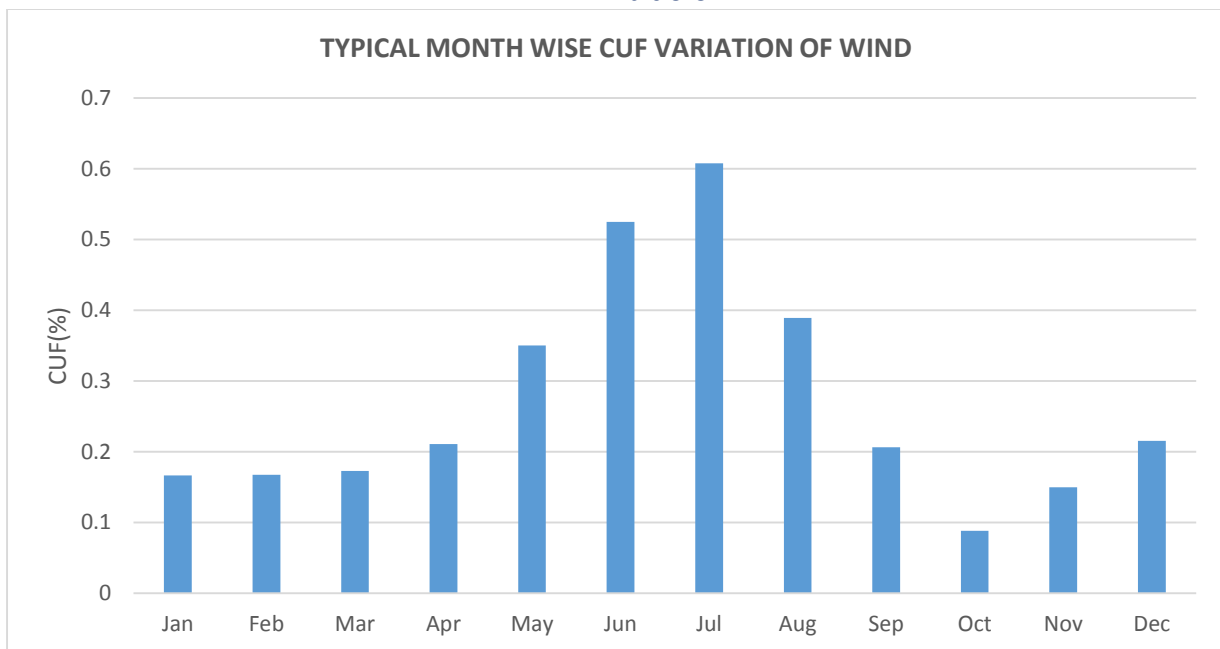
Wind is an intermittent and site-specific resource of energy and therefore, an extensive Wind Resource Assessment is essential for the selection of potential sites. The Government, through National Institute of Wind Energy (NIWE), has installed over 800 wind-monitoring stations all over country and issued wind potential maps at 50m, 80m, 100m and 120m above ground level. The recent assessment indicates a gross wind power potential of 302 GW in the country at 100 meter and 695.50 GW at 120 meter above ground level. Most of this potential exists in seven windy States as shown in **Annexure-6.2**.

GENERATION PROFILE OF WIND:

Wind energy is subjected to daily and seasonal weather patterns. Changes in wind generation occur slowly during the course of hours during approaching storm. This is different from the solar generation where changes occur rapidly and variation may be from second to second due to cloud cover.

A typical normalized monthly generation profile of a wind is shown in the **Exhibit 6.6**.

Exhibit 6.6



As it can be seen from **Exhibit 6.6** that wind generation is usually more in the period May to Aug. which coincide with the monsoon period in India.

Season Wise Daily Variation of normalized wind profile for different regions is shown in **Exhibit 6.7 (a) to (c)**

Exhibit 6.7 (a)

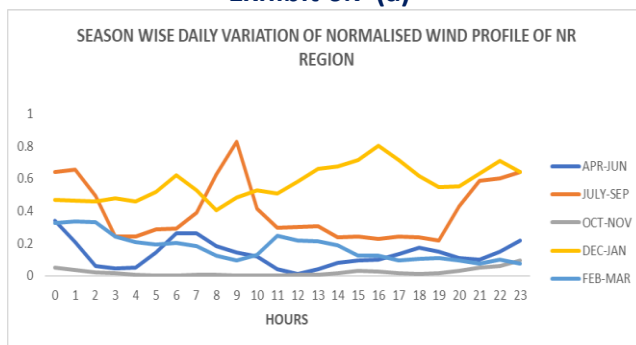


Exhibit 6.7 (b)

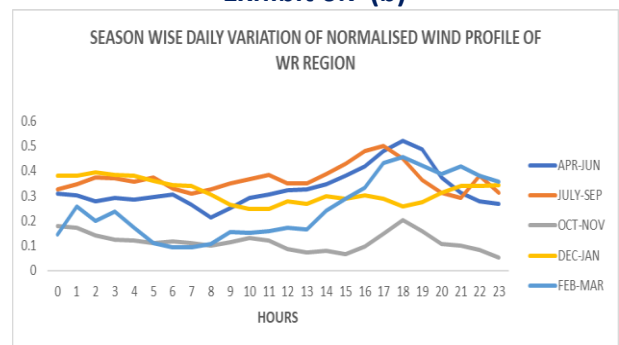
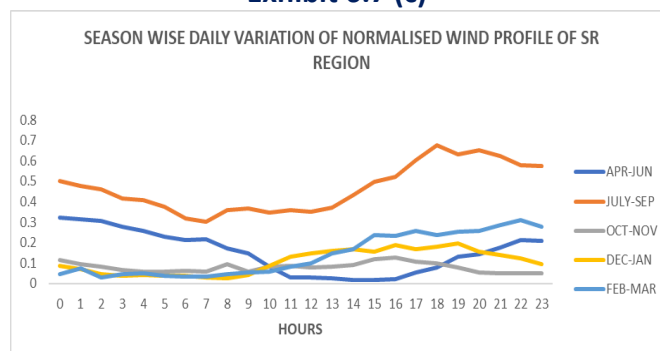


Exhibit 6.7 (c)



6.2.3 Large Hydro:

The inherent benefits of hydroelectric power, whether in terms of technical, economic and environmental benefits, make it an important contributor to the future energy mix, particularly in the developing countries like India. India has an ever-intensifying need for power and water supplies and have large hydro potential to be harness.

While development of all the remaining hydroelectric potential could not hope to cover total future demand for electricity, implementation of even half of this potential could thus have enormous environmental benefits in terms of avoided generation by fossil fuels.

As the impacts of climate change become evident globally, governments are increasingly looking for ways to reduce their greenhouse gas emissions. For countries seeking to reduce or install no-carbon generation options, hydropower projects can be one of the reliable options to achieve carbon neutral economy. Hydropower projects are clean, renewable energy and the schemes are generally integrated within multipurpose development schemes like construction of dam, secure water supply, irrigation for food production and flood control, and societal benefits such as increased recreational opportunities, improved navigation, the development of fisheries, cottage industries, etc. This is not the case for any other source of energy.

It has the lowest operating costs and longest plant life, compared with other large scale generating options. Once the initial investment has been made in the necessary civil works, the plant life can be extended economically by periodic maintenance at minimal cost and replacement of electromechanical equipment (replacement of turbine runners, rewinding of generators, etc. - in some cases the addition of new generating units). Typically, a hydro plant in service for 40-50 years can have its operating life doubled.

Electrical System Benefits

Hydropower, as an energy supply, provides unique benefits to an electrical system. Firstly, when stored in large quantities in the reservoir behind a dam, it is immediately available for use when required. Secondly, the energy source can be rapidly adjusted to meet demand instantaneously. These benefits are a part of large number of benefits which include:

- **Black start capability** - the ability to start generation without any external source of power. This service allows system operators to provide auxiliary power to more complex generation sources that could take long time to restart. Systems with hydroelectric generation are able to restore service more rapidly than those dependent solely on thermal generation.
- **Regulation and frequency response** - the ability to meet small fluctuations in power system. When a system is unable to respond properly to load changes its frequency changes, resulting not just in a loss of power, but potential damage to electrical equipment connected to the system. Hydropower's fast response characteristic makes it especially valuable in load-frequency control.
- **Spinning reserve** - the ability to run at zero load while synchronized to the electric system. When loads increase, additional power can be loaded rapidly into the system to meet

demand. Hydropower can provide this service while not consuming additional fuel, thereby assuring minimal emissions.

- **Non-spinning reserve** - the ability to enter generation into an electrical system from a source not on line. While other energy sources can also provide non-spinning reserve, hydropower's quick start capability is unparalleled, taking just a few minutes, compared with other sources.
- **Voltage support** - the ability to control reactive power to maintain stable voltage profiles in transmission network, thereby assuring that power flows from generation to load.

Providing Stability to Power Grid and support for Integration of variable Renewable Energy Sources

The power system operation stability requires the system to minimize fluctuations between demand and supply. This encompasses, for example, short term reserves (generation, storage, demand response) to cover potential incidents which decrease power supply to the system, or to respond to short-term variations in demand and generation. Hydropower therefore provides an ideal solution for the challenges of a transitioning power system.

Hydropower brings a strong contribution to flexibility in the power system by filling the gap between supply and demand that has been induced by the non-dispatchable variability of RES. The storage capabilities of many hydropower plants make them a perfect instrument for optimizing the use of variable RES over shorter and longer periods, thus facilitating the integration of variable RES into the power system and providing a key tool to maintain a stable and balanced grid.

Hydropower also provides a number of ancillary services which are needed in order to manage a transmission system in a way that secures system stability and security of supply. Moreover, during power system restoration, such as in the case of an extreme event (e.g., blackout), auxiliary loads of conventional thermal and nuclear power plants need external power source, which can be provided quickly by hydropower.

Hydropower plants with reservoirs reduce the dependency on the variability of the natural inflow and enable adjustments of power generation to the variability in demand. These plants are operated on a scheduled basis taking into account data regarding water flow forecast and consumption patterns. They are commonly used for intense load following and to meet peak demand. The generation of peak-load energy from reservoir type hydropower plants allows the optimization of base-load power generation from other less flexible electricity sources, such as nuclear and thermal power plants.

Hydro-Electric Potential:

India has considerable hydro power potential, which can play a key role in reducing the carbon footprint of the Indian power sector. For assessment of the hydroelectric potential in the country, Central Electricity Authority carried out a Reassessment study in various river basins during the period 1978-87. As per these studies, total hydropower potential in the country was assessed, as 84,044 MW (at 60% load factor) from a total number of 845 identified hydroelectric schemes which when fully developed would result in an installed capacity of about 1,48,701 MW. From

these potential hydroelectric schemes above 25 MW installed capacity works out to be 1, 45,320 MW from a total of 592 H.E. Schemes on the basis of probable average load factor. The total energy potential is assessed as 600 billion units per year.

As on 31th March 2022, Hydro Electric Schemes (above 25 MW capacity) have a total installed capacity of 46,722.52 MW including Pumped storage schemes (PSS) capacity of 4,745.6 MW. Summary of the status of Hydro Electric Potential development in the country is indicated in **Table 6.4**

Table: 6.4
Summary of the status of Hydro Electric Potential (As on 31.03.2022)

	Conventional			Pumped Storage		
	Nos	Capacity (MW)	(%)	Nos	Capacity (MW)	(%)
Total Potential	592	145320		63	96529.6	
Schemes under Operation	203	41976.90	28.75	8	4745.6	4.92
Schemes under Construction	24	9747.50	6.71	2	1500	1.55
Schemes in which construction is held up	8	1156.00	0.80	1	80	0.08
DPRs Concurred by CEA & yet to be taken up for construction	29	22268	15.32	2	2200	2.28
DPRs under Examination by CEA	2	756	0.52	-	-	
DPRs returned by CEA for resubmission	25	7777.1	5.35	-	-	
Under S & I for preparation of DPRs	14	4295	2.96	17	16770	17.37
Schemes under S&I- Held up	61	14069	9.68	1	660	0.68
Total Developed/ Under Development	203/ 163	41976.90 / 60068.6	28.89/ 41.34	8/ 23	4745.6/ 21210	4.92/ 21.97

6.2.4 Small Hydro:

In India, hydro power plants of 25MW or below capacity are classified as small hydro, which have further been classified into micro (100kW or below), mini (101kW-2MW) and small hydro (2-25MW) segments. Hydro Power was being looked after by Ministry of Power prior to 1989 mainly with the help of State Electricity Boards. In 1989, plant capacity up to 3MW and below was transferred to the Ministry of New and Renewable Energy (MNRE) and as such 63 MW aggregate installed capacity of 3MW and below hydro projects came within the jurisdiction of MNRE. Many initiatives were taken by Government of India since then for the promotion of small hydro which

included implementation of a UNDP-GEF assisted Technical Assistance project entitled “Optimizing Development of Small Hydro Resources in Hilly Regions of India” and India-Renewable Resources Development Project with IDA credit line having inter alia small hydro development component with target of 100MW canal based small hydro power projects through private sector participation. Subsequently plant capacity up to 25MW and below was entrusted with the MNRE in November 1999.

The installed capacity of Small Hydro power in the country as on 31.03.2022 is 4848.90 MW.

Small Hydro Potential in India:

The estimated potential of 21135.37 MW from 7135 sites for power generation in the country from small / mini hydel projects is assessed by the Alternate Hydro Energy Centre (AHEC) of IIT Roorkee in its Small Hydro Database of July 2016. The hilly States of India mainly Arunachal Pradesh, Himachal Pradesh, Jammu & Kashmir and Uttarakhand, and constitute around half of this potential. Other potential States are Maharashtra, Chhattisgarh, Karnataka and Kerala. Focused attention is given towards these States through close interaction, monitoring of projects and reviewing policy environment to attract private sector investments. The state wise location of identified SHP sites are given - Andhra Pradesh, Arunachal Pradesh, Assam, Bihar, Chhattisgarh, Goa, Gujarat, Haryana, Himachal Pradesh, Jammu & Kashmir, Jharkhand, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Manipur, Meghalaya, Mizoram, Nagaland, Orissa, Punjab, Rajasthan, Sikkim, Tamil Nadu, Tripura, Uttar Pradesh, Uttarakhand, West Bengal.

State-wise estimated small Hydro potential is shown in **Annexure-6.2**

6.2.5 Biomass/Bagasse:

Biomass has always been an important energy source for the country considering the benefits it offers. It is renewable, widely available, carbon neutral and has the potential to provide significant employment in the rural areas. Biomass is also capable of providing firm energy. Ministry of New and Renewable Energy has realised the potential and role of biomass energy in the Indian context and hence has initiated a number of programmes for promotion of efficient technologies for its use in various sectors of the economy to ensure derivation of maximum benefits. For efficient utilization of biomass, bagasse-based cogeneration in sugar mills and biomass power generation have been taken up under biomass power and cogeneration programme.

Biomass power & cogeneration programme is implemented with the main objective of promoting technologies for optimum use of country’s biomass resources for grid power generation. Biomass materials used for power generation include bagasse, rice husk, straw, cotton stalk, coconut shells, soya husk, de-oiled cakes, coffee waste, jute wastes, groundnut shells, saw dust etc.

As on 31.03.2022, a total capacity of 10682.36 MW has been installed in Biomass Power and Cogeneration Sector which includes 476.75 MW of Waste to power, 10205.61 MW of Biomass (Bagasse and Non-Bagasse) Cogeneration.

Potential:

As per a recent study sponsored by MNRE, the current availability of biomass in India is estimated at about 750 million metric tonnes per year. The Study indicated estimated surplus biomass availability at about 230 million metric tonnes per annum covering agricultural residues corresponding to a potential of about 28 GW. Apart from this about 14 GW additional power can be generated through bagasse-based cogeneration in the country's 550 Sugar mills, if these sugar mills adopt technically and economically optimal levels of cogeneration for extracting power from the bagasse produced by them.

Technology:

I. Combustion

The thermo-chemical processes for conversion of biomass to useful products involve combustion, gasification or pyrolysis. The most commonly used route is combustion. The advantage is that the technology used is similar to that of a thermal plant based on coal, except for the boiler. The cycle used is the conventional Rankine cycle with biomass being burnt in high-pressure boiler to generate steam and operating a turbine with the generated steam. The exhaust of the steam turbine can either be fully condensed to produce power, or used partly or fully for another useful heating activity. The latter mode is called cogeneration. In India, cogeneration route finds application mainly in industries.

II. Cogeneration in Sugar and Mills

Sugar industry has been traditionally practicing cogeneration by using bagasse as a fuel. With the advancement in the technology for generation and utilization of steam at high temperature and pressure, sugar industry can produce electricity and steam for their own requirements. It can also produce significant surplus electricity for sale to the grid using same quantity of bagasse. For example, if steam generation temperature/pressure is raised from 400°C/33 bar to 485°C/66 bar, more than 80 kWh of additional electricity can be produced for each ton of cane crushed. The sale of surplus power generated through optimum cogeneration would help a sugar mill to improve its viability, apart from adding to the power generation capacity of the country.

6.3 NEW AREAS IN RENEWABLE ENERGY:

6.3.1 Waste to Energy:

The increasing industrialization, urbanization and changes in the pattern of life, which accompany the process of economic growth, give rise to generation of increasing quantities of wastes leading to increased threats to the environment. In recent years, technologies have been developed that not only help in generating substantial quantity of decentralized energy but also in reducing the quantity of waste for its safe disposal.

Government of India is promoting all the technology options available for setting up projects for recovery of energy in the form of Biogas/Bio CNG/Electricity from agricultural, Industrial and urban wastes of renewable nature such as municipal solid wastes, vegetable and other market wastes, slaughterhouse waste, agricultural residues and industrial/STP wastes & effluents.

The total estimated energy generation potential from **urban and industrial** organic waste in India is approximately 5690 MW.

Types of Waste

There are different types of waste which are generated from our daily or industrial activities such as organic waste, e-waste, hazardous waste, inert waste etc. Organic waste refers to waste which degrades or broken down by microorganisms over time. All organic wastes are essentially carbon based compounds; though they may be diverse in nature and have different degradation rate. Organic waste has significant portion in overall waste generation in industrial/urban/ agricultural sector and therefore it can be used for energy generation.

The organic fraction of waste can be further classified as non-biodegradable and biodegradable organic waste

i) Biodegradable waste consists of organics that can be utilized for food by naturally occurring micro- organisms within a reasonable length of time. The biodegradable organic comprise of agro residue, food processing rejections, municipal solid waste (food waste, leaves from garden waste, paper, cloths/ rags etc.), waste from poultry farms, cattle farm slaughter houses, dairy, sugar, distillery, paper, oil extraction plant, starch processing and leather industries.

ii) Non-Biodegradable organic materials are organics resistant to biological degradation or have a very low degradation rate.

Technologies available:

Waste-to-Energy (WTE) technologies to recover the energy from the waste in the form of Electricity and Biogas/Syngas are given as below:

i) Biomethanation: Biomethanation is anaerobic digestion of organic materials which is converted into biogas. Anaerobic digestion (AD) is a bacterial fermentation process that operates without free oxygen and results in a biogas containing mostly methane (60%), carbon dioxide (40%) and other gases. Biomethanation has dual benefits. It gives biogas as well as manure as end product.

This technology can be conveniently employed in a decentralized manner for biodegradation of segregated organic wet wastes such as wastes from kitchens, canteens, institutions, hotels, and slaughter houses and vegetables markets.

The biogas generated from Biomethanation process can be burned directly in a gas boiler/burner to produce heat for thermal application industries and cooking or burnt in a gas engine to produce electricity. Alternatively, the biogas can be cleaned to remove the carbon dioxide and other substances, to produce Bio CNG. This can be injected into the national gas grid to be used in the same way as natural gas, or used as a vehicle fuel.

By using Biomethanation process, 20-25kgs of Cattle dung can generate about 1m³ of biogas and further 1m³ of Biogas has potential to generate 2 units of electricity or 0.4kgs of Bio CNG.

ii) Incineration: Incineration technology is complete combustion of waste (Municipal Solid Waste or Refuse derived fuel) with the recovery of heat to produce steam that in turn produces power through steam turbines.

The flue gases produced in the boilers have to be treated by an elaborate air pollution control system. The resultant ash from incineration of solid waste can be used as construction material after necessary processing while the residue can be safely disposed of in a landfill.

This technology is well established technology and has been deployed in many projects successfully at commercial level in India to treat solid wastes like Municipal Solid Waste and Industrial solid Waste etc. and generate electricity.

iii) Gasification: Gasification is a process that uses high temperatures (500-1800 degree Celsius) in the presence of limited amounts of oxygen to decompose materials to produce synthetic gas (a mixture of carbon monoxide (CO) and hydrogen (H₂)). Biomass, agro-residues, Segregated Municipal Solid Waste and Refuse Derived pellets are used in the gasifiers to produce Syngas. This gas further can be used for thermal or power generation purposes

The purpose of gasification of waste is to generate power more efficiently at lower power level (< 2MW) and also to minimize emissions and hence it is an attractive alternative for the thermal treatment of solid waste.

iv) Pyrolysis: Pyrolysis uses heat to break down combustible materials in the absence of oxygen, producing a mixture of combustible gases (primarily methane, complex hydrocarbons, hydrogen, and carbon monoxide), liquids and solid residues. The products of pyrolysis process are: (i) a gas mixture; (ii) a liquid (bio-oil/tar); (iii) a solid residue (carbon black). The gas generated by either of these processes can be used in boilers to provide heat, or it can be cleaned up and used in combustion turbine generators. The purpose of pyrolysis of waste is to minimize emissions and to maximize the gain.

6.3.2 Off-shore wind

Out of the total estimated potential more than 95% of commercially exploitable wind resources are concentrated in seven states (Andhra Pradesh, Gujarat, Karnataka, Madhya Pradesh, Maharashtra, Rajasthan and Tamil Nadu). The precious land resources required for onshore wind projects are gradually becoming a major constraint. With exhaustion of best windy sites, we expect upward movements of market determined tariffs for onshore wind energy in future.

Offshore wind power offers a plausible alternative in such a scenario. Absence of any obstruction in the sea offers much better quality of wind and its conversion to electrical energy. Offshore wind turbines are much larger in size (in range of 5 to 10 MW per turbine) as against 2-3 MW of an onshore wind turbine. While, the cost per MW for offshore turbines are higher because of stronger structures and foundations needed in marine environment, the desirable tariffs can be achieved on account of higher efficiencies of these turbines after development of the eco system.

Off Shore wind Potential in India:

Based on the preliminary assessment from satellite data and data available from other sources eight zones each in Gujarat and Tamil Nadu have been identified as potential offshore zones for exploitation of offshore wind energy. Initial assessment by NIWE within the identified zones

suggests 36 GW of offshore wind energy potential exists off the coast of Gujarat only. Further, nearly 35 GW of offshore wind energy potential exists off the Tamil Nadu coast.

The offshore wind energy potential estimation carried out through satellite data needs to be validated through actual ground measurements in order to make the data bankable. Government of India has decided to launch a measurement campaign deploying Light Detection and Ranging (LiDAR's) at the identified zones off the coast of Gujarat and Tamil Nadu. One LiDAR was commissioned in November 2017 for Offshore Wind Resource assessment in identified zone-B off the coast of Gujarat nearly 25 km away from the port of Pipavav. Two years data collected from the deployed LiDAR has been analysed and the report is published at NIWE's website.

In addition to the wind data, the viability of offshore wind projects also largely depends on the condition of site in terms of oceanographic data, geophysical and geotechnical data. Government of India has planned to carry out the required study in this regard through NIWE and provide the basic data to the stakeholders before commencement of the bidding so as to mitigate the risks. Geophysical Survey for 365 Sq. km (Gujarat) for 1.0 GW project capacity in Gujarat has been completed.

6.4 Estimated renewable energy Installed Capacity by 2026-27 and 2031-32

With support of government policies, the declining cost of many RE technologies, an increase of energy demand and with more focus on sustainable development there is continuous increase in capacity of RE sources over the last years and in future as well renewable energy will play a much bigger role in optimal energy mix of the country. As per the modelling studies carried which is detailed in Chapter 5, it has been estimated that renewable energy installed capacity is likely to be 3,44,517 MW by 2026-27. The contribution of the major renewable energy sources to reach an installed capacity of 3,44,517 MW by 2026-27 and 5,69,425 MW by 2031-32 is shown in **Table 6.5**.

Table 6.5
Estimated contribution of the major Renewable Energy Sources

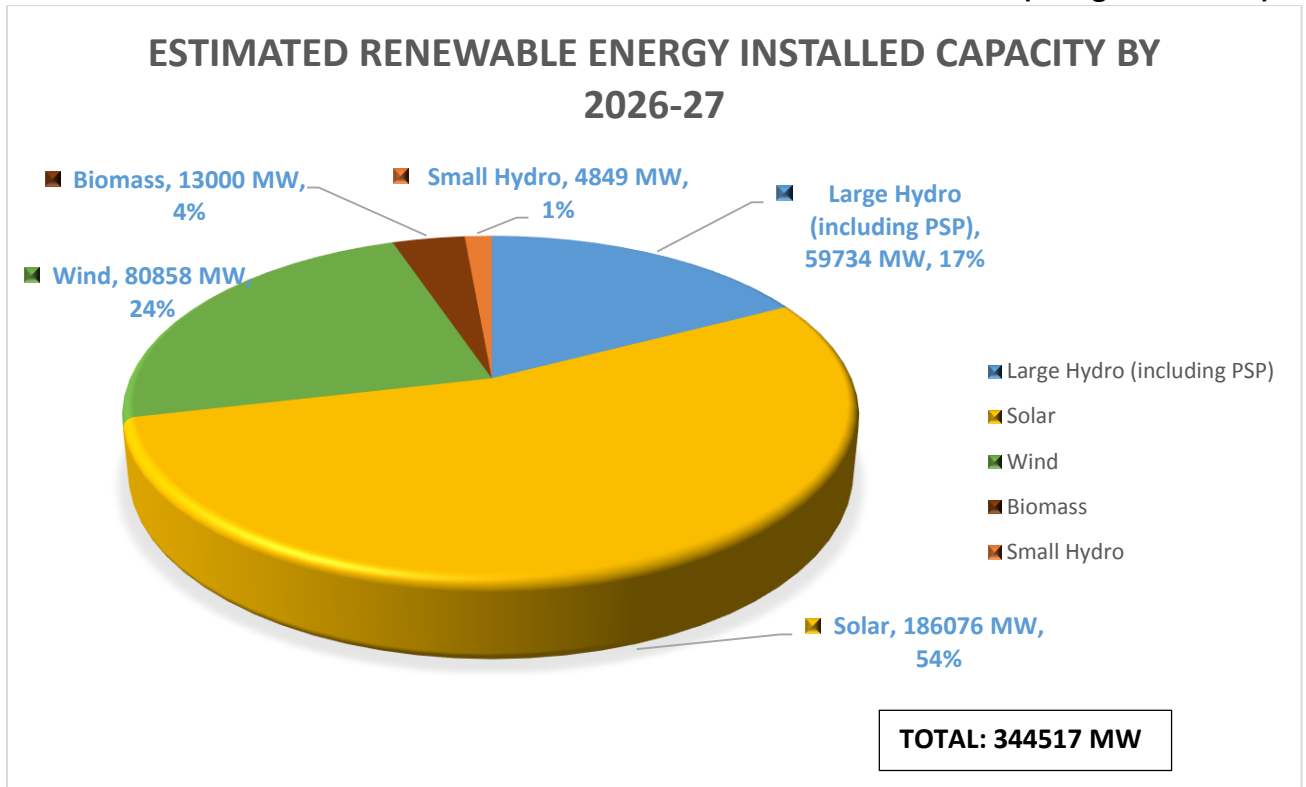
(All figures in MW)

Sl. No.	Renewable Energy Source	Estimated Installed Capacity by 2026-27	Estimated Installed Capacity by 2031-32
1.	Large Hydro (including PSP)	59735	82642
2.	Solar	186076	333476
3.	Wind	80858	133958
4.	Biomass	13000	14500
5.	Small Hydro	4849	4849
Total		344518	569425

Type-wise renewable energy installed capacity on All India basis by 2026-27 is shown in **Exhibit 6.8**.

Exhibit 6.8

(All figures in MW)



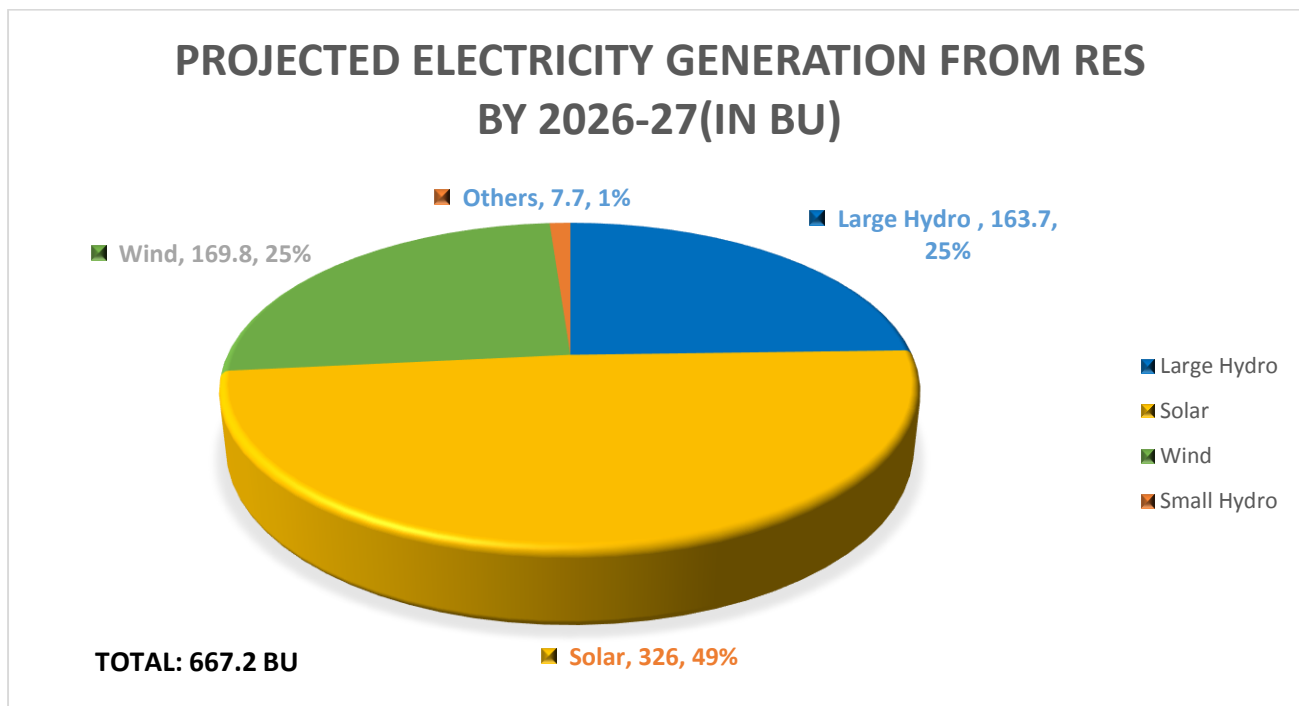
6.5 PROJECTION OF RENEWABLE ENERGY GENERATION

Based on the projections of capacity addition targets from Renewable Energy Sources by the year 2026-27 and considering an RES capacity addition of 2,24,908 MW during the period 2027-32, expected electricity generation from various renewable energy sources has been estimated and is given in **Table 6.6** and **Exhibit 6.9**. It can be seen that contribution of RES will be around 35.6% of the total energy of the country in the year 2026-27 and 45.09% by 2031-32.

Table 6.6
Estimated Electricity Generation from RES in years 2026-27 and 2031-32

Year	Installed capacity of RES (MW)	Expected Generation in (BU)					Contribution of RES to Total Energy Demand (%)
		Large Hydro	Solar	Wind	Others	Total	
2026-27	3,44,517	163.7	326	169.8	7.7	667.2	35.60
2031-32	5,69,425	206.6	624.4	305.7	7.7	1144.4	45.09

Exhibit 6.9



6.6 MAJOR ONGOING SCHEMES AND POLICIES RELATED TO RENEWABLE ENERGY SOURCES

6.6.1 National Solar Mission

National Solar Mission (NSM) was launched on 11th January, 2010. NSM is a major initiative of the Government of India with active participation from States to promote ecological sustainable growth while addressing India's energy security challenges. It will also constitute a major contribution by India to the global effort to meet the challenges of climate change. The Mission's objective is to establish India as a global leader in solar energy by creating the policy conditions for solar technology diffusion across the country as quickly as possible. The Mission targets installing 100 GW grid-connected solar power plants by the year 2022. This is in line with India's Intended Nationally Determined Contributions (INDCs) target to achieve about 40 percent cumulative electric power installed capacity from non-fossil fuel based energy resources and to reduce the emission intensity of its GDP by 33 to 35 percent from 2005 level by 2030.

In order to achieve the above target, Government of India have launched various schemes to encourage generation of solar power in the country like Solar Park Scheme, VGF Schemes, CPSU Scheme, Defence Scheme, Canal bank & Canal top Scheme, Bundling Scheme, Grid Connected Solar Rooftop Scheme etc.

6.6.2 International solar alliance

The International Solar Alliance (ISA) is a treaty based inter-governmental organization working to create a global market system to tap the benefits of solar power and promote clean energy applications. The Paris Declaration that established the ISA states that the countries share the collective ambition to undertake innovative and concerted efforts to reduce the cost of finance and technology for deployment of solar generation assets. The ISA aims to pave the way for future solar generation, storage and technologies for Member countries' needs by mobilising over USD 1000 billion by 2030. Achievement of ISA's objectives will also strengthen the climate action in member countries, helping them fulfil the commitments expressed in their Nationally Determined Contributions (NDCs).

The ISA plays a four-fold role in establishing a global solar market: it is an accelerator, an enabler, an incubator, and a facilitator.

ISA's vision to enable One World, One Sun, One Grid (OSOWOG): The concept is to interconnect generators and loads across continents with an international power transmission grid. A tripartite Memorandum of Understanding (MoU) between the International Solar Alliance (ISA), the Government of India, and the World Bank was signed on September 8th, 2020 to implement the OSOWOG initiative. Currently, a long-term vision, implementation plan, road map and institutional framework is being developed by the ISA, which will implement this project. A consultant has been selected to undertake a study for evaluating the feasibility and implementation of the global OSOWOG project.

6.6.3 Pradhan Mantri Kisan Urja Suraksha Evam Utthan Mahabhiyan (PM KUSUM)

PM-KUSUM scheme is one of the largest initiatives in the world to provide clean energy to more than 3.5 million farmers by solarising their agriculture pumps. PM-KUSUM scheme aims to install grid connected ground mounted solar power plants (up to 2 MW) aggregating to a total capacity of 10 GW under Component A; install 20 Lakh standalone solar pumps under Component B; and solarize 15 Lakh grid connected agricultural pumps under Component C. All components combined would support installation of additional solar capacity of 30.80 GW.

6.6.4 Green Energy Corridors

To facilitate evacuation of electricity from RE projects, Green Energy Corridor scheme was launched in 2015 for setting up of transmission and evacuation infrastructure. The Inter-State Transmission System (ISTS) component consisting of 3200ckm transmission lines and 17,000 MVA substations has been completed in March 2020. The Intra-State Transmission System (InSTS) component has been sanctioned to eight RE rich states of Tamil Nadu, Rajasthan, Karnataka, Andhra Pradesh, Maharashtra, Gujarat, Himachal Pradesh and Madhya Pradesh for evacuation of over 20,000 MW of renewable power.

6.6.5 National Wind-Solar Hybrid Policy:

Government of India issued National Wind-Solar Hybrid Policy on 14th May, 2018. The main objective of the policy is to provide a framework for promotion of large-scale grid connected wind-solar PV hybrid systems for optimal and efficient utilization of wind and solar resources, transmission infrastructure and land. The wind-solar PV hybrid systems will help in reducing the

variability in renewable power generation and achieving better grid stability. The policy also aims to encourage new technologies, methods and way-outs involving combined operation of wind and solar PV plants.

The Major Highlights of the Policy are as under:

- A wind-solar plant will be recognized as hybrid plant if the rated power capacity of one resource is at least 25% of the rated power capacity of other resource.
- Both AC and DC integration of wind-solar hybrid project are allowed.
- The power procured from the hybrid project may be used for fulfilment of solar RPO and non-solar RPO in the proportion of rated capacity of solar and wind power in the hybrid plant respectively.
- Existing wind or solar power projects, willing to install solar PV plant or Wind Turbine Generators (WTGs) respectively, to avail benefit of hybrid project, may be allowed.
- All fiscal and financial incentives available to wind and solar power projects will also be made available to hybrid projects.
- The Central Electricity Authority (CEA) and Central Electricity Regulatory Commission (CERC) shall formulate necessary standards and regulations including metering methodology and standards, forecasting and scheduling regulations, REC mechanism, grant of connectivity and sharing of transmission lines, etc., for wind-solar hybrid systems.
- Storage may be added to the hybrid project to ensure availability of firm power for a particular period.

6.6.6 National Offshore Wind Energy Policy, 2015

Under the policy, the Ministry of New & Renewable Energy (MNRE) has been authorized as the nodal Ministry for the use of offshore area within the Exclusive Economic Zone (EEZ) of the country and the National Institute of Wind Energy (NIWE) has been authorized as the nodal agency for development of offshore wind energy in the country and to carry out the allocation of offshore wind energy blocks, coordination and allied functions with related ministries and agencies. It would pave the way for offshore wind energy development including setting up of offshore wind power projects and research and development activities, in waters, in or adjacent to the country, up to the seaward distance of 200 nautical miles (EEZ of the country) from the base line. Preliminary assessments along the 7,600 km long Indian coastline have indicated prospects of development of offshore wind power. With the introduction of the National Offshore Wind Energy Policy, the Government is attempting to replicate the success of the onshore wind power development in the area of offshore wind power development.

The scheme would be applicable throughout the country depending upon the offshore wind potential availability.

6.6.7 Hydro Policy Notification, 2019

Hydro Policy, 2019 was notified by Govt. of India on 08.03.2019. The salient features of the policy are given below:

- **Declaring Large Hydro Power Projects (LHPs, i.e., >25 MW) AS Renewable Energy Source.** However, LHPs would not automatically be eligible for any differential treatment for statutory clearances such as Forest clearances, environmental clearance, National Board for Wildlife clearance, related impact Assessment and carrying capacity study, etc., available to Small Hydropower Projects (SHPS), i.e., projects capacity up to 25 MW.
- **Hydro Purchase Obligation (HPO) as a separate entity within non-solar Renewable Purchase,** The HPO shall cover all LHPs commissioned after this notification as well as untied capacity (i.e., without PPA) of the commissioned projects. This HPO will be within the existing Non-Solar RPO after increasing the percentage assigned to it so that existing Non-Solar RPO for other renewable sources remain unaffected by the introduction of this HPO. Necessary amendments will be introduced in the Tariff Policy and Tariff Regulations to operationalize HPO.
- **Tariff rationalization measures to bring down hydropower tariff:** Tariff rationalization measures including providing flexibility to the developers to determine tariff by back loading of tariff after increasing project life to 40 years, increasing debt repayment period to 18 years and introducing escalating tariff of 2%;
- Budgetary support for funding flood moderation component of hydropower projects on case-to-case basis; and
- Budgetary support for funding cost of enabling infrastructure i.e., roads and bridges on case-to-case basis as per actual, limited to Rs. 1.5 crore per MW for up to 200 MW projects and Rs. 1.0 crore per MW for above 200 MW projects.

6.6.8 Renewable Purchase Obligation (RPO) Trajectory notified by order on 29th January, 2021

- On 8th March 2019, the government had issued an order detailing various policy measures to promote hydropower sector in India inter-alia declaring large hydropower projects including pumped storage projects having capacity of more than 25 MW (LHPs) which come into commercial operation after 08.03.2019 as RE source and to specify Hydropower Purchase Obligation (HPO) within Non-Solar RPO.
- In compliance of the above decision and with the objective to add 30000 MW of Hydropower capacity by the year 2029-30, Ministry of Power has prepared a revised Trajectory of RPO including long term trajectory for HPO considering the LHPs commissioned after 8th March, 2019
- In super-session of orders dated 22nd July 2016 and 14th June 2018, Ministry of Power hereby specifies the following RPO Trajectory:

Year	Solar RPO	Non-Solar RPO			Total RPO
		HPO	Other Non-Solar RPO	Total Non-Solar RPO	
2019-20	7.25 %	-	10.25 %	10.25%	17.50 %
2020-21	8.75 %	-	10.25 %	10.25%	19 %
2021-22	10.50 %	0.18 %	10.50 %	10.68 %	21.18 %
2022-23	To be specified later	0.35 %	To be specified later	To be specified later	To be specified later
2023-24		0.66 %			
2024-25		1.08 %			
2025-26		1.48 %			
2026-27		1.80 %			
2027-28		2.15 %			
2028-29		2.51 %			
2029-30		2.82 %			

- RPO will be calculated in energy terms as a percentage of total consumption of electricity excluding consumption met from hydro sources (LHPs).
- HPO benefits may be met from the power procured from eligible LHPs commissioned on and after 8.8.2019 and up to 31.03.2030 in respect of 70 % of the total generated capacity for the period of 12 years from the date of commissioning. Free power is to be provided as per agreement with the state government and that provided for Local Area Development Fund (LADF), shall not be included within this limit of 70% of the total generated capacity.
- HPO liability of the State/Discom could be met out of the free power being provided to the State from LHPs commissioned after 08.03.2019 as per agreement at that point of time excluding the contribution towards LADF if consumed within the State/Discom. Free power (not that contributed for Local Area Development) only to extent of HPO liability of the State/Discom, shall be eligible for HPO benefit.
- In case the free power, as above, is insufficient to meet the HPO obligations, then the state would have to buy the additional hydro power to meet its HPO obligations or may have to buy the corresponding amount of Hydro Energy Certificate to meet the non-solar hydro renewable purchase obligations.
- The Hydro Energy Certificate mechanism under regulation to be developed by CERC to facilitate compliance of HPO obligation, would have a capping price of RS 5.50/Unit of electrical energy w.e.f 8th March 2019 to 31st March, 2021 and with annual escalation @5 % thereafter for purposes of ensuring HPO compliance.
- The above HPO trajectory shall be tried up on an annual basis depending on the revised commissioning schedule of Hydro projects. The HPO Trajectory for the period between 2020-21 and 2039-40 shall be notified subsequently.
- Hydro power imported from outside India shall not be considered for HPO.

- On achievement of HPO Compliance to the extent of 85% and above, remaining shortfall, if any, can be met by excess solar or other non-solar energy consumed beyond specified Solar RPO or other Non-Solar RPO of that particular year.
- SERCs may consider to notify RPO Trajectory including HPO for their respective states in line with aforesaid RPO trajectory. Moreover, CERC may consider to devise mechanism similar to Renewable Energy Certificate (REC) mechanism to facilitate fulfilment of HPO.

6.7 SPECIAL MEASURES TO PROMOTE GROWTH OF RENEWABLE ENERGY

6.7.1 Ensuring Round-the-Clock-Power (RTC) from the RE Power Projects

In order to overcome the issues of intermittency and low-capacity utilization of transmission infrastructure, the mechanism of 'bundling' has been brought out by Government of India. To ensure uninterrupted firm power round-the-clock, RE is bundled with power from other sources or combined storage. Such bundled power is supplied to the distribution company (DISCOM) thereby obviating the need for DISCOMs to balance power.

6.7.2 Renewable Energy Hybrid Projects

Solar and Wind power being variable in nature pose challenges to provide a stable supply. However, in India solar and wind resources are complementary to each other as wind is stronger during evening and night, when there is limited input from solar power. Hybridization of these two technologies reduces the variability and optimizes the utilization of land and transmission systems. Capacities of 1,440 MW of wind-solar hybrid projects are under implementation in the states of Rajasthan and Tamil Nadu.

6.7.3 Solar Cities

At least one city, (either the state capital city or a well-known tourist destination) in each of the states of India is being developed as a solar city. All electricity needs of the city will be fully met from RE sources, primarily from solar energy. All houses in the solar city will have roof-top solar energy plants. Every Solar city will also have solar street lights and waste to energy plants among others. The balance of energy needs will be met by ground mounted Solar Plants.

The Solar City programme aims:

- To enable and empower Urban Local Governments to address energy challenges at City - level.
- To provide a framework and support to prepare a Master Plan including assessment of current energy situation, future demand and action plans.
- To build capacity in the Urban Local Bodies and create awareness among all sections of civil society.
- To involve various stakeholders in the planning process.
- To oversee the implementation of sustainable energy options through public - private partnerships.

6.7.4 Renewable Purchase Obligations (RPO)

Uniform Renewable Purchase Obligations (RPO) have been introduced wherein all electricity distribution licensees have to consume a specified minimum quantity of their total requirements from Renewable Energy Sources.

6.7.5 Waiver of Inter State Transmission System Charges

- Inter State Transmission System (ISTS) charges on transmission of electricity generated from solar and wind power projects have been waived for projects to be commissioned up to 30.06.2025.
- Waiver of total Inter State Transmission System charges shall also be allowed for Hydro Pumped Storage Plant (PSP) and Battery Energy Storage systems (BESS) projects to be commissioned up to 30.06.2025, if following conditions are met:
 - i. At least 70% of the annual electricity requirement for pumping of water in the Hydro Pumped storage plant is met by use of electricity generated from solar and/or wind power plants
 - ii. At least 70% of the annual electricity requirement for pumping of water in the Battery energy storage plant is met by use of electricity generated from solar and/or wind power plants
- The Inter State Transmission System (ISTS) charges for power generated/supplied from such Hydro PSP and such BESS shall be levied gradually: 25% of the STOA charges of initial 5 years of operation, then charges can be gradually increased in steps of 25% after every 3rd year to reach to STOA charges from 12th year onwards. This may be aligned with gradual reduction in tariff and payment of debt.
- Waiver of Transmission charges shall be allowed for trading of electricity generated/supplied from Solar, Wind, PSP, BESS in Green Term Ahead Market (GTAM) and Green Day Ahead Market (GDAM) TILL 30TH June, 2023. This arrangement may be reviewed on annual basis depending upon the future development in the power market.

6.7.6 ENHANCING DOMESTIC MANUFACTURING CAPACITY

In compliance of the Atma Nirbhar call given by the Hon'ble Prime Minister and the call "To be Vocal for Local" several steps were taken to enhance domestic manufacture of RE machinery, components and equipment. While sufficient manufacturing capacity in wind power exists in the country, the present installed capacity for manufacturing of solar cells in the country is around 2.5 GW, while the functional capacity of solar modules is around 9-10 GW, whereas the annual requirement for the next 10 years is around 30 GW, necessitating imports. In order to enhance the domestic manufacturing capacity, Government of India has been consistently bringing out policies to support domestic PV manufacturing. Some of the initiatives are:

- Government of India has created a captive market of more than 36 GW over the next 2 to 3 years for domestic producers by making deployment of domestic cells and modules mandatory in schemes such as PM-KUSUM, Solar Rooftops and CPSU schemes.

- Further the procurement of RE sector-related goods by Public Sector Enterprises has to be from domestic sources only.
- A Performance Linked Incentive (PLI) scheme has been approved by the Government for encouraging the production of high efficiency solar modules.
- In order to protect domestic manufacturers from cheap imports, a Safeguard Duty has been imposed on import of solar cells and modules.
- To hand-hold and facilitate investors for setting up manufacturing plants in India, a Project Development Cell (PDC) has been set up.
- In order to give a long-term visibility to investors, Government has announced an advance trajectory of Basic Customs Duty (BCD) on solar cells & modules. Further, the BCD rates on solar inverters and solar lanterns/lamps have been increased.

6.8 CHALLENGES WITH INTEGRATION OF SOLAR AND WIND POWER WITH THE GRID

Intermittency: Intermittency consists of two distinct aspects:

- **Temporal variability:** Temporal variability of Solar and Wind generation makes the supply uncorrelated with demand pattern, thus creating system management related challenges for operators.
- **Output uncertainty:** Uncertainty of output from Solar and Wind plants creates scheduling-related challenges as RE generation forecasts deviate at real time of operation.

Integration with grid: The existing power system structure can handle certain quantum of variability and uncertainty from demand and unit outage using controllable reserve (e.g., thermal power plants). An adjustment of the system operation protocol can only support up to a certain level of Solar and Wind penetration. With large-scale introduction of generation uncertainty and variability, operational adjustment alone is not enough and significant investment planning is required.

Resource Location: Location specificity of Solar and Wind resources is one of the major planning related challenges. In India, geographical distribution of solar and wind resources are not uniform or spatially correlated with demand and are situated far away from load centres often create transmission related challenges. Solar potential is high in western states while wind potential is high in western and southern coastal areas. High capacity of inter-state and inter-regional transmission is therefore needed to evacuate Solar and Wind power to deficit areas.

6.9 WAYS TO ADDRESS THE CHALLENGES OF INTEGRATION OF SOLAR AND WIND POWER WITH GRID

Hybrid of Solar and Wind Energy: An increasingly popular solution is a simple balancing approach in which the production of intermittent renewables such as wind and solar are monitored and intermixed so as to utilise the available energy from both sources at a given time.

The approach allows the maximum possible power to be delivered by combining dominating and non-dominating resources all of the time – and mitigates the intermittency of individual resources.

Energy Storage: Energy storage is a vital tool for accomplishing the seemingly impossible task of matching the grid electricity supply to the demand on a second-by-second basis. Storage plays a critical role in frequency regulation and in maintaining the stability and safety of the grid. It enables excess energy to be stored for consumption at a more convenient time. It provides a buffer source for use in case of emergencies. Together these four functions ensure the essential grid system resilience.

Energy storage methods include not only electrochemical batteries, but also hydraulic (pumped) storage, mechanical storage (flywheels), thermal storage, compressed air storage, storage in an electric field (capacitors) and other methods.

Various Energy Storage system are described in Chapter 10.

Flexibility Associated with Conventional Generating Units

To accommodate the variability and uncertainty of generation from RES, the conventional generating plants must be flexible. The flexibility of generating station refers to its ability (i) to cycle on and off including its lead time required; (ii) the ramping rate at which it can vary the generation; and (iii) maximum and minimum output while it is in operation.

In terms of flexibility, hydro plants, pumped storage plants, open and combined cycle gas turbine, gas engines etc. are very suitable. In many countries, thermal stations are extensively used for cycling as well as ramping.

Transmission Strengthening

In India, Green Energy Corridors for evacuation of power from the regions having high concentration of RES is in the process of implementation.

Advanced Forecasting

Wind and solar power forecasting can help reduce the uncertainty of variable renewable generation. Better forecasting helps grid operators to commit or de-commit generators in accommodating changes in wind and solar generation more efficiently and prepare for extreme events in which renewable generation is unusually high or low. Forecasts can help reduce the amount of fast response operating reserves needed for the system, thereby reducing costs of balancing the system.

Demand Response

Demand side management measures encourage the customers to maximize the use of variable renewable energy sources while the supply is naturally high. For example, when wind and solar PV are producing more than the demand, demand response can incentivize consumers to use

more power during that time through appropriate price signals of low rates, thus helping shift the load and ensuring better utilization of generation resources. The change in load may occur automatically in response to time of use or dynamic rates or due to the direct control by the grid operator or due to participation of demand response in wholesale, ancillary or capital market. To have effective demand response, smart-grid technologies involving smart meters, communication and other methods are used. Electric vehicle “smart charging” is based on V2G and G2V concept where electric vehicle can become an integral part of the grid and are charged or discharged in response to external signals or dynamic prices.

Promotion of Off-grid renewable sector as it is much more competitive with conventional power as it avoids investment in transmission to remote location. E.g., Rice Husk gasifiers-based electricity generation is one such model.

6.10 CONCLUSIONS

Renewables sector in India is set to expand and supply electricity to an increasingly large number of people. From public transport to infrastructure for industry and societal development, renewable energy and the technological capability to store power for on-demand usage creates a new dynamic within the country to further explore green opportunities for the future. With the ambitious plan country can accomplish the dual goal of economic development and green-energy production, which is certainly within the realms of possibility.

The Government of India has taken several initiatives to promote a healthy environment for the growth of renewable products manufacturing sector in the country.

Measures should be taken to attract private investors and more funds should be allocated to support research and innovation activities in this sector so that technologies which are in nascent stage should become reality in future.

Annexure-6.1

STATE-WISE INSTALLED CAPACITY OF GRID INTERACTIVE RENEWABLE POWER (AS ON 31.03.2022)

Sl. No.	STATES/UT	RENEWABLE		
		HYDRO	RES(MNRE)	RES TOTAL
1	CHANDIGARH	101.71	55.17	156.87727
2	DELHI	723.09	270.12	993.21436
3	HARYANA	2324.62	1242.13	3566.75274
4	HIMACHAL PRADESH	3248.88	1040.47	4289.349862
5	JAMMU AND KASHMIR	2321.88	239.05	2560.932404
6	PUNJAB	3818.28	1767.82	5586.098754
7	RAJASTHAN	1941.93	17040.62	18982.5484
8	UTTAR PRADESH	3424.03	4483.52	7907.552272
9	UTTRAKHAND	1975.89	931.80	2907.690106
	NORTHERN-REGION UNALLOCATED	751.45	0.00	751.453828
1	CHHATTISGARH	233.00	233.00	869.08
2	GUJARAT	772.00	772.00	16587.90
3	MADHYA PRADESH	3223.66	3223.66	5468.88
4	MAHARASHTRA	3331.84	3331.84	10657.08
5	GOA	2.00	2.00	20.34
6	DAMAN AND DIU	0.00	0.00	40.72
7	DADAR AND NAGAR HAVELI	0.00	0.00	5.46
	WESTERN-REGION UNALLOCATED	0.00	0.00	0.00
1	ANDHRA PRADESH	1673.60	9211.56	10885.16
2	TELANGANA	2479.93	4959.19	7439.12
3	KARNATAKA	3631.60	15904.59	19536.19
4	KERALA	1856.50	670.70	2527.2
5	TAMIL NADU	2178.20	16148.61	18326.81
6	PUDUCHERRY	0.00	13.69	13.69
	SOUTHERN-REGION UNALLOCATED	0.00	0.00	0.00
1	DAMODAR VALLEY CORPORATION	186.20	0.00	186.1999
2	BIHAR	110.00	387.35	497.3489
3	JHARKHAND	191.00	97.14	288.139
4	ODISHA	2163.22	617.09	2780.3101
5	SIKKIM	633.00	56.79	689.7878
6	WEST BENGAL	1396.00	586.95	1982.949
	EASTERN-REGION UNALLOCATED	85.01	0.00	85.0053
1	ARUNACHAL PRADESH	544.55	142.34	686.885
2	ASSAM	522.08	154.05	676.13

3	MANIPUR	95.34	17.70	113.04
4	MEGHALAYA	409.27	50.48	459.75
5	MIZORAM	97.94	44.37	142.31
6	NAGALAND	66.33	33.71	100.04
7	TRIPURA	68.49	30.90	99.39
	NORTH EASTERN REGION UNALLOCATED	140.00	0.00	140
1	ANDAMAN AND NICOBAR	0.00	34.74	34.74
2	LAKSHADWEEP	0.00	3.27	3.27
	ALL INDIA	46722.52	109885.38	156607.895

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Annexure-6.2

STATE-WISE ESTIMATED SOLAR POWER POTENTIAL IN THE COUNTRY

SL. NO.	STATE/UT	SOLAR POTENTIAL (GWP) #
1	ANDHRA PRADESH	38.44
2	ARUNACHAL PRADESH	8.65
3	ASSAM	13.76
4	BIHAR	11.20
5	CHHATTISGARH	18.27
6	DELHI	2.05
7	GOA	0.88
8	GUJARAT	35.77
9	HARYANA	4.56
10	HIMACHAL PRADESH	33.84
11	JAMMU & KASHMIR	111.05
12	JHARKHAND	18.18
13	KARNATAKA	24.70
14	KERALA	6.11
15	MADHYA PRADESH	61.66
16	MAHARASHTRA	64.32
17	MANIPUR	10.63
18	MEGHALAYA	5.86
19	MIZORAM	9.09
20	NAGALAND	7.29
21	ODISHA	25.78
22	PUNJAB	2.81
23	RAJASTHAN	142.31
24	SIKKIM	4.94
25	TAMIL NADU	17.67
26	TELENGANA	20.41
27	TRIPURA	2.08
28	UTTAR PRADESH	22.83
29	UTTRAKHAND	16.80
30	WEST BENGAL	6.26
31	UTS	0.79
TOTAL		748.98

(Source: Ministry of New and Renewable Energy, India)

Assessed by National Institute of Solar Energy

STATE-WISE ESTIMATED WIND POWER POTENTIAL IN THE COUNTRY

S.NO.	STATE	WIND POWER POTENTIAL AT 100 MTR AGL IN GW	WIND POWER POTENTIAL AT 120 MTR AGL (GW)
1	ANDHRA PRADESH	44.23	74.90
2	GUJARAT	84.43	142.56
3	KARNATAKA	55.86	124.15
4	MADHYA PRADESH	10.48	15.40
5	MAHARASHTRA	45.39	98.21
6	RAJASTHAN	18.77	127.75
7	TAMIL NADU	33.80	68.75
	TOTAL (7 WINDY STATES)	292.97	651.72
	OTHER STATES	9.28	43.78
	ALL INDIA TOTAL	302.25	695.50

(Source: Ministry of New and Renewable Energy, India)

STATE-WISE ESTIMATED SMALL HYDRO POWER POTENTIAL IN THE COUNTRY

SL. NO.	STATE/UT	POTENTIAL (MW) #
1	ANDHRA PRADESH	409.32
2	ARUNACHAL PRADESH	2064.92
3	ASSAM	201.99
4	BIHAR	526.98
5	CHHATTISGARH	1098.2
6	GOA	4.7
7	GUJARAT	201.97
8	HARYANA	107.4
9	HIMACHAL PRADESH	3460.34
10	UT OF JAMMU & KASHMIR	1311.79
11	UT OF LADAKH	395.65
12	JHARKHAND	227.96
13	KARNATAKA	3726.49
14	KERALA	647.15
15	MADHYA PRADESH	820.44
16	MAHARASHTRA	786.46
17	MANIPUR	99.95
18	MEGHALAYA	230.05
19	MIZORAM	168.9
20	NAGALAND	182.18
21	ODISHA	286.22
22	PUNJAB	578.28
23	RAJASTHAN	51.67
24	SIKKIM	266.64
25	TAMIL NADU	604.46
26	TELENGANA	102.25

27	TRIPURA	46.86
28	UT OF A & N ISLANDS	7.27
29	UTTAR PRADESH	460.75
30	UTTARAKHAND	1664.31
31	WEST BENGAL	392.06
	TOTAL	21133.62

(Source: Ministry of New and Renewable Energy, India)

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CHAPTER 7

FUEL REQUIREMENT

7.0 INTRODUCTION

Fuel is the key input required to be tied up before implementation and operation of a thermal power plant. In the changed scenario with growing concern on environment, Government has given emphasis on Renewable Energy projects. However, the country's reliance on coal-based generation cannot be overlooked. An important aspect which, therefore, needs to be addressed is the availability of adequate coal for generation of power. In order to optimize coal usage, Government is committed to super critical/ ultra-super critical technology which is much more efficient and results into reduction in usage of coal. The timely availability of all the key inputs including fuel would ensure timely completion of a project and would, therefore, avert detrimental implications of cost and time overruns in case the power project is delayed.

This Chapter broadly deals with review of fuel availability during 2017-22, detailed plan for 2022-27 and perspective plan for 2027-32 as well as critical issues which need to be addressed and constraints being experienced in the coal sector. This would give a broad picture to all the associated stakeholders to enable them to take advance action and plan their production targets.

7.1 COAL SUPPLY SCENARIO

7.1.1 Background

Coal is the mainstay of India's energy sector. The All India Installed Capacity of the country is about 399,497 MW, as on 31.03.2022, out of which about 204,080 MW (51.1%) is coal based. Once the power station is commissioned, the biggest challenge is to operate the station at a high plant load factor (PLF), which is a measure of the output of a power plant compared to the maximum output it could produce. Higher plant load factor usually means more output and a lower cost per unit of electricity generation. Performance of the power plant is measured on the basis of PLF and Station Heat Rate (SHR). However, the Plant Load Factor (PLF) of the coal-based power stations in the country has been decreasing steadily over the years. The PLF has varied from 60.5 % in 2017-18, 60.9 % in 2018-19, 55.9% in 2019-20, 54.6% in 2020-21 and 58.8 % during 2021-22.

7.1.2 NEW COAL DISTRIBUTION POLICY (NCDP)

The Government introduced the New Coal Distribution Policy (NCDP), effective from 1st April 2009, which assured supplies at pre-determined prices to some categories of consumers and reintroduced e-auction to encourage a vibrant market for the commodity. The main features of the Policy are:

- 100% normative requirement of coal would be considered for supply to Power Utilities.
- Supply of coal through commercially enforceable Fuel Supply Agreements (FSAs) at notified prices by Coal India Limited (CIL).
- 10% of annual production of CIL to be offered through e-auction for consumers who are not able to source coal through available institutional mechanism.
- FSAs to indicate Annual Contracted Quantity (ACQ) of coal to Power Utilities by coal companies during entire year. Incentive and penalty clauses incorporated in FSAs.

Signing of Fuel Supply Agreement (FSA)

FSAs were signed for supply with a trigger value of 90% of the Annual Contracted Quantity (ACQ) for the thermal power plants commissioned before 31st March 2009. Subsequently, Cabinet Committee of Economic Affairs (CCEA) in June, 2013 directed CIL to sign FSAs for a total capacity of about 78,000 MW, which were likely to be commissioned by 31.03.2015. Out of 78000 MW, around 9,840 MW were having erstwhile tapering linkages. Taking into account the overall domestic availability and the likely actual requirements of these power plants, FSA's were signed for supply of domestic coal quantity of 65%,65%,67% and 75% of ACQ for the years 2013-14,2014-15,2015-16 &2016-17 respectively for power plants having normal coal linkages. However, actual coal supplies were commensurate to long term PPA's.

7.1.3 Scheme for Harnessing and Allocating Koyala (Coal) Transparently in India (SHAKTI)

Ministry of Coal vide letter dated 22.05.2017 issued the SHAKTI Policy for allocation of coal to power plants of Central, State and Private Sector. Subsequently, Ministry of Coal on 25.03.2019 issued certain amendments to the SHAKTI Policy after CCEA approval based on the recommendations of Group of Ministers (GoM), which examined the specific recommendations of High-Level Empowered Committee (HLEC) constituted to address the issues of stressed thermal power projects.

Developments under various provisions of SHAKTI Policy are as follows:

- (a) **Para B (i):** Coal linkages to Central Government and State Government generating companies would be granted based on recommendations by Ministry of Power.

Since the launch of SHAKTI Policy, under para B (i), SLC (LT) has accorded coal linkage to 23 nos. of Thermal Power Projects totalling to 25,340 MW capacity.

- (b) **Para B(ii):** Coal linkages may be granted on notified price on auction basis for power producers/IPPs having already concluded long term PPAs based on domestic coal. Power Producers shall bid for discount on tariff.

Till date, four rounds of auction for coal linkage under SHAKTI B(ii) have been held under which a total of 40.99 MT of coal (G13 grade equivalent) have been allocated to 17 nos.

of TPPs having installed capacity of 11,934 MW and long term PPA capacity of 9,204.6 MW.

- (c) **Para B(iii):** Future coal linkages may be granted on auction basis (bid for premium above the notified price) for power producers/IPPs without PPAs that are either commissioned or to be commissioned. Coal drawl will be permitted only against valid long term and medium term PPAs, which the successful bidder shall be required to procure and submit within two (2) years of completion of auction process.

Till date, around 7.15 MT of coal (G13 grade equivalent) have been awarded by CIL to 7 nos. of TPPs, having installed capacity of 5995 MW and non-PPA capacity of 3774.94 MW.

- (d) **Para B(iv):** Coal linkage may be earmarked to the states for fresh PPAs, by pre declaring the availability of coal linkage. States may indicate these linkages to Discoms and based on linkages, undertake tariff based competitive bidding for long term and medium-term procurement.

Till date, coal linkages have been allocated by CIL to States of Gujarat, Uttar Pradesh and Madhya Pradesh for 3915 MW, 1600 MW and 3000 MW capacity of power respectively, to be raised through tariff based competitive bidding.

- (e) **Para B(v):** Power requirement of Group of States can be aggregated and procurement of power on tariff-based bidding shall be made by a designated agency.

PFC Consulting Ltd. (PFCCCL) (a wholly owned subsidiary of PFC) is the designated agency. 10 MT of coal has been earmarked by CIL for this purpose.

- (f) **Para B (viii) (a):** Linkage would be given on auction basis to power plants for their non-PPA capacity, under B (iii) and B (iv) of SHAKTI Policy for a period of minimum 3 months up to a maximum of 1 year, for trading power in Short Term through Discovery of Efficient Energy Price (DEEP) Portal and in Day Ahead Market (DAM) through Power Exchanges.

Till date, under SHAKTI B (viii) (a) covering para B (iii) of SHAKTI Policy, around 7.3 MTs of coal (G-13 grade equivalent) have been allocated to various private power plants in auctions held for seven quarters viz. Apr-June'2020 to Oct-Dec'2021.

7.1.4 Coal Stocking Norms:

7.1.4.1 Earlier Coal Stocking Norms of CEA:

The earlier norms for number of days of coal stock to be maintained by power stations was based on the distance of the power plant from the mine-head as per details given in **Table 7.1**.

Table 7.1
Earlier Coal stocking norms for power stations

Distance of Power Plant	Number of Days of Stock
Pit-head Station	15
Upto 500 kms from coal mine	20
Upto 1,000 kms from coal mine	25
Beyond 1,000 kms from coal mine	30

Critical / Super critical stock at power plants

Earlier, the coal stock position at coal based thermal power plants in the country having coal linkages with CIL/ Singareni Collieries Company Limited (SCCL) were being monitored by CEA on a daily basis. The coal stock at power plants was categorised as critical and super critical based on number of days of stock available at the plant, so that coal supply to such power plants could be augmented on priority.

7.1.4.2 Revised Coal Stocking Norms of CEA:

CEA has revised the coal stocking norms w.e.f 6th December 2021. As per the revised norms, daily coal requirement for both Pithead and Non-Pithead plants would be estimated @85% PLF and number of days for which stock needs to be maintained would vary from 12 to 17 days for Pithead plants and 20 to 26 days for Non-Pithead plants with month-wise variation based on coal despatch/coal consumption pattern during the year as detailed below in Table 7.2.

Table 7.2

Plant	Q1			Q2			Q3			Q4		
	April	May	June	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
Pithead	17	17	17	14	13	12	13	14	15	16	17	17
Non-pithead	26	26	26	22	21	20	21	22	23	24	26	26

The Gencos would be graded in three zones. Grading of a Genco/Independent Power Producers (IPP) into red, yellow and green zone will be done on monthly basis based on the average coal stock maintained by the plant during previous month and its outstanding dues with coal companies. Gencos/IPPs in Green Zone will be given highest priority followed by Yellow and the least priority to Red Zone- in terms of rakes loading and supply of coal.

Further, in the event that availability by any power plant is less than the Normative Availability (as per prevailing regulatory norms of Central Electricity Regulatory Commission (CERC)/ State Electricity Regulatory Commission (SERC) - as applicable) due to less coal stock maintained by the plant, the penalty will be levied on defaulter Gencos/IPPs as per the revised norms.

Revised criteria for identifying critical coal stock

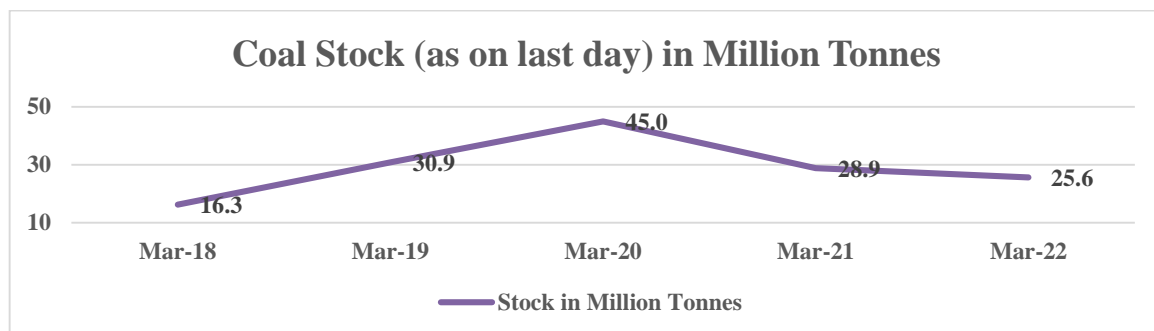
At present, all coal based thermal power stations in the country are being monitored on daily basis and daily coal stock report is published on National Power Portal (NPP) (npp.gov.in).

The coal stocking norms issued on 06.12.2021 provides for the criteria for identifying plants having critical coal stock. It has been decided to adopt a uniform criteria for both pithead and non-pithead plants and to do away with the category of plants having critical and super critical coal stock.

The plants having stock of less than 25% of the mandated coal stock as per the revised norms is being identified as having critical coal stock.

The details of coal stock available at the power plants as on last day of financial year since 2017-18 and as on 31.03.2022 is given at **Exhibit 7.1**

Exhibit 7.1



During the year 2020-21, the coal stock at the power plants has reached the highest level of about 51.7 MTon 06.05.2020, whereas it reached the lowest of 7.23 MT as on 08.10.2021 during FY 2021-22.

7.1.5 Import of coal

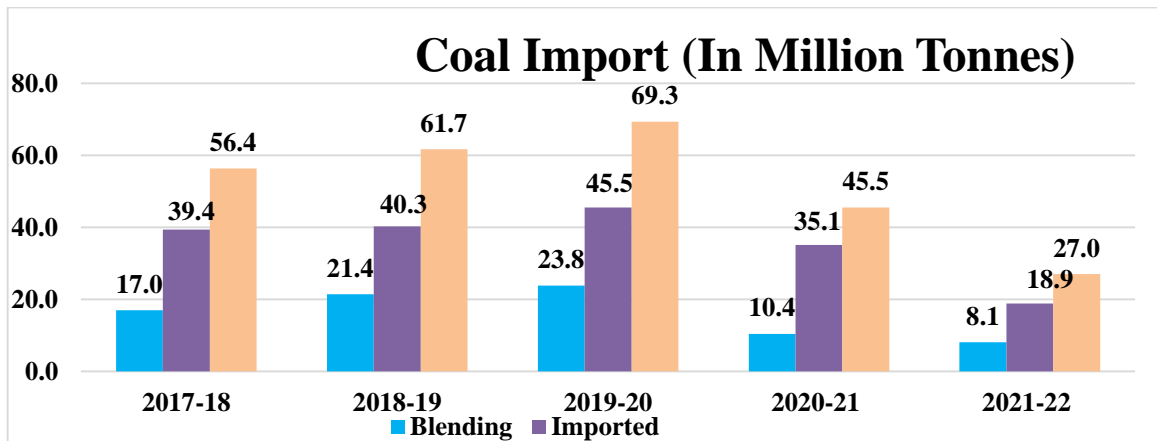
In the past, Power Utilities were advised to import coal to maintain the stipulations of the then Ministry of Environment & Forest regarding use of coal of less than 34% ash content and to supplement the inadequate availability of coal from indigenous sources. Further, with the commissioning of power plants designed for use of imported coal as fuel, power utilities imported coal to meet the requirement of fuel for these power plants. The details of coal imported by power utilities since 2017-18 are furnished in **Table 7.3 and Exhibit 7.2**.

Table 7.3

Details of coal imported by power utilities

Year	Requirement for Imported Coal based Plants (MT)	Coal Import for		
		Blending (MT)	Imported based power plants (MT)	Total(MT)
2017-18	46.0	17.0	39.4	56.4
2018-19	46.0	21.4	40.3	61.7
2019-20	47.0	23.8	45.5	69.2
2020-21	45.0	10.4	35.1	45.5
2021-22	45.3	8.1	18.9	27.0

Exhibit 7.2



7.1.5.1 Import Substitution: -

1. Power Utilities have been importing coal in view of their cost economics. During 2020-21, with the increased availability of domestic coal, Govt. of India advised the power plants to make best efforts to substitute imported coal used for blending with domestic coal. With the concerted efforts of all the stakeholders, viz. MoP, CEA, MoC, coal companies, power plants, etc., the coal imported for blending purpose has reduced by about 56% in 2020-21 as compared to 2019-20. CIL vide Notice no. 178 dated 06.05.2020 had informed the decision to offer coal to TPPs under import substitution considering sufficient availability of coal with CIL subsidiaries for power plants. Subsequently, CIL vide letter dated 13.04.2021 informed the decision to continue supply of coal to power plants under import substitution mechanism for FY 2021-22 also.

Accordingly, CIL vide letter dated 23.04.2021 had offered about 17 MT domestic coal in lieu of import substitution.

2. However, during the second quarter of the FY 2021-22, due to bottlenecks in supply of coal to TPPs in monsoons and less production by CIL mines, the coal stock available with the TPPs depleted. Further, coal companies prioritized coal supplies under FSA to their linked power plants and to plants having critical / supercritical coal stock. Since coal is offered on as is where basis under import substitution, the supply of coal to TPPs was affected.
3. Considering less coal stock in TPPs during 2021-22 and supply pattern from domestic sources, Ministry of Power vide letter No. FU-21/2020-FSC CN:253974 dated 28.04.2022 has issued an advisory regarding import of coal for blending purpose for the period 2022-23. As per the advisory, the requirement of imported coal for blending purpose during 2022-23 has been estimated at 10% of coal requirement at 85% availability for State Gencos and IPPs. NTPC and DVC have been advised to import 20 Million Tonnes (MT) and 3 MT respectively for blending in FY 2022-23. State Gencos and IPPs DVC have been advised to import 22.1 Million Tonnes (MT) and 15.9 MT respectively for blending in FY 2022-23.

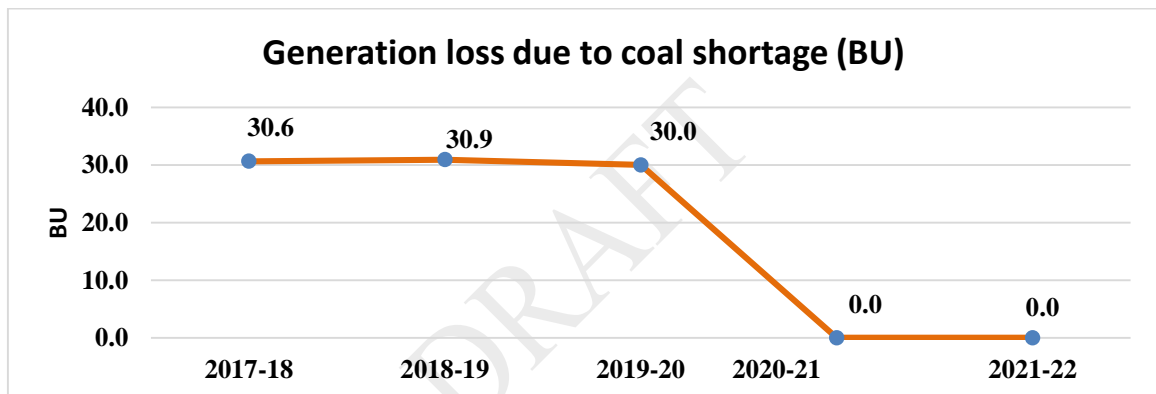
7.1.6 Generation loss due to coal shortage

The loss of generation due to shortage of coal as reported by power utilities during 2017-18 to 2020-21 and 2021-22 is given in **Table 7.4 and Exhibit 7.3.**

Table 7.4
Generation loss due to coal shortage

Year	Generation loss due to coal shortage (BU)
2017-18	30.6
2018-19	30.9
2019-20	30.0
2020-21	0.0
2021-22	0.0

Exhibit 7.3



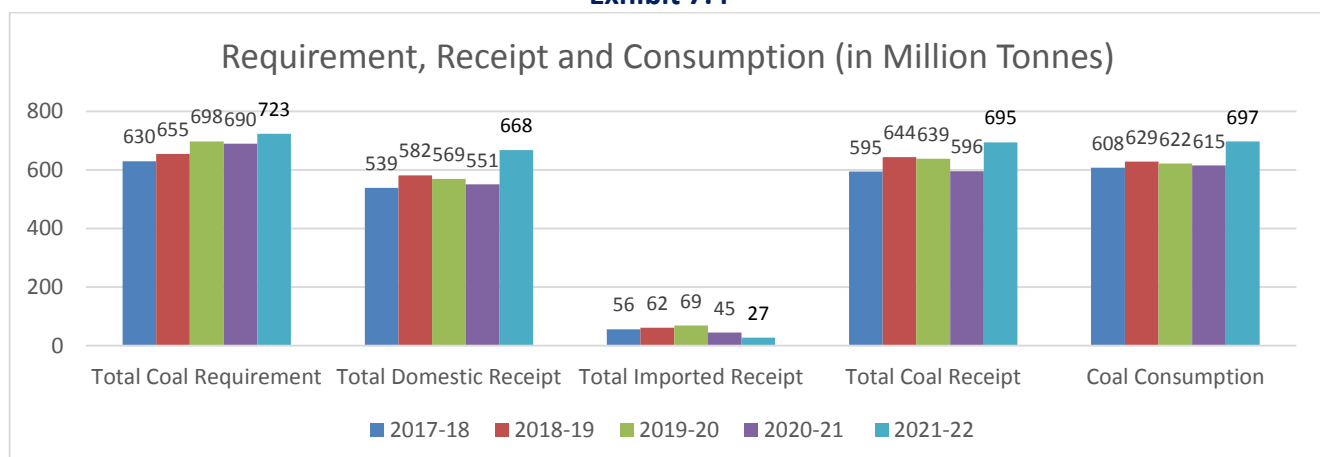
7.2 COAL DEMAND AND SUPPLY

7.2.1 Estimated coal requirement, source-wise actual receipt and coal consumption from 2017-18 are given at Table 7.5 and Exhibit 7.4.

Table 7.5
Estimated Requirement, Receipt and Consumption

Source	2017-18	2018-19	2019-20	2020-21	2021-22
Requirement (Million Tonnes)					
Domestic Coal Requirement	584	609	651	645	678
Imported Coal Requirement	46	46	47	45	45
Total Coal Requirement	630	655	698	690	723
Actual Receipt (Million Tonnes)					
CIL Receipt	416.0	457.4	438.5	422.5	501.5
SCCL Receipt	52.1	55.9	54.3	43.2	55.9
Captive	31.6	40.1	43.5	50.1	71.0
e-Auction	39.0	28.7	33.1	35.0	39.3
Total Domestic Receipt	538.6	582.1	569.5	550.8	667.6
Imported (Blending)	17.0	21.4	23.8	10.4	8.1
Imported (Imported coal plants)	39.4	40.3	45.5	35.1	18.9
Total Imported Receipt	56.4	61.7	69.2	45.5	27.0
Total Coal Receipt	595.0	643.7	638.7	596.3	694.6
Consumption (Million Tonnes)					
Domestic Coal Based Plants	568.1	588.4	577.3	579.1	678.8
Imported Coal Based Plants	39.9	40.5	44.9	36.3	18.5
Total Coal Consumption (Domestic + Imported)	608	628.9	622.2	615.4	697.3

Exhibit 7.4



7.2.2 Comparison Coal Supply Position during 2020-21 and 2021-22:

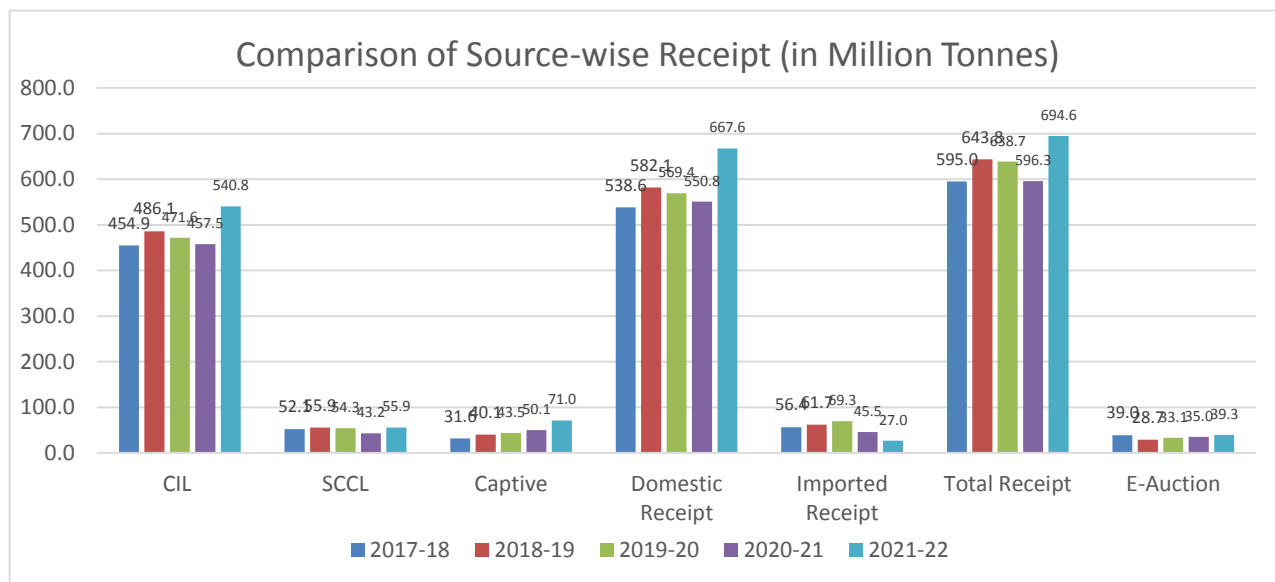
The details of source-wise program and receipt of coal by power plants during 2020-21 and 2021-22 are given in **Table 7.6** and **Exhibit 7.5**.

Table 7.6
Source-wise program and receipt of coal

Period	2020-21			2021-22		
	Program	Receipt	% of Program	Program	Receipt	% of Program
CIL	526.0	457.5 (*)	87.0%	548.0	540.8	98.7%
SCCL	55.0	43.2	78.5%	56.0	55.9	99.8%
Captive	63.0	50.1	79.5%	74.0	71.0	95.9%
Total (Domestic) (A)	644.0	550.8	85.5%	678.0	667.6	98.5%
E-Auction	-	35.0	-	-	39.3	-
Import (Blending)	-	10.4	-	-	8.1	-
Import (Imported Coal Based)	45.0	35.1	78.1%	45.0	18.9	42.0%
Total (Import) (B)	45.0	45.5	101.2%	45.0	27.0	60.0%
Total (A+B)	689.0	596.3	86.6%	723.0	694.6	96.1%

(*): includes e-Auction coal)

Exhibit 7.5



7.2.3 Coal Demand and Availability Position during the Year 2022-23

For the year 2022-23, coal based gross generation programme of 1080BU has been estimated by CEA. Based on the generation program, the total coal requirement of 788.5 MT has been estimated. The details of coal requirement vis-à-vis likely coal availability during the year 2022-23 are given in **Table 7.7**.

Table 7.7
Coal Requirement and likely availability for the year 2022-23

S.No.	Description	Units	2022-23
1	Coal based generation		
1.1	Gross Coal based generation programme during 2020-21	BU	1080
2	Coal Requirement		
2.1	For plants designed on domestic Coal	MT	759.9
2.2	For plants designed on imported coal	MT	28.6
2.3	Total Coal Requirement	MT	788.5
3	Coal Availability from Indigenous Sources		
3.1	From CIL	MT	565
3.2	From SCCL	MT	57

3.3	From Captive Mines	MT	113
3.4	Total domestic coal availability	MT	735
3.5	Shortfall in domestic coal availability	MT	25
3.6	Requirement of imported coal for blending	MT	17

It is thus observed from the above that power plants on domestic coal may not meet their requirement of coal from domestic sources and may require import of coal for blending.

7.2.4 Coal Demand and Availability Position during the year 2026-27 and 2031-32

Preliminary Exercise has been carried out in CEA for assessing the power requirement of States/UTs considering past growth rates and the increase in Electrical Energy Requirement on account of Power for All Make in India initiatives, reduction in demand on account of DSM and various efficiency improvement measures being under taken by the Government. Accordingly, the total electricity requirement on All India basis has been assessed.

With the likely Renewable Energy Sources (RES) capacity addition, the coal-based generation has been estimated and accordingly provisional coal requirement has been worked out. The estimated generation from coal-based power plants is expected to be around 1133 BU during 2026-27 and about 1303 BU during 2031-32. However, in view of uncertainty associated with VRE Nuclear, Hydro generation, the coal requirement for the year 2026-27 and 2031-32 has been worked out assuming 20% reduction in Hydro, Nuclear and VRE generation due to uncertainty. This is to be compensated by coal-based generation. Accordingly the details of coal requirement for the year 2026-27 and 2031-32 have been worked out and the details are given in **Table 7.8**.

Table 7.8
Coal requirement during the year 2026-27 and 2031-32

S. No	Coal Requirement Calculation	Unit	2026-27	2031-32
1	Coal based generation (gross)	BU	1133	1303
2	Hydro based generation (gross)	BU	196.6	239.6
3	Nuclear based generation (gross)	BU	82.1	134.3
4	Wind Generation(gross)	BU	169.8	305.7
5	Solar Generation(gross)	BU	326	624.4
6	Total VRE(Solar & Wind) +Hydro +Nuclear generation (gross)	BU	774.5	1304
7	20% reduction in Hydro, Nuclear and VRE generation due to uncertainty	BU	154.9	260.8
8	Total coal based generation (SI no 1+SI No 7)	BU	1287.9	1563.8
9	Coal Requirement @0.67kg/kwh+1% transportation loss	MT	871.5	1058.2
10	Imported Coal requirement	MT	40.0	40.0
11	Domestic Coal Requirement	MT	831.5	1018.2

In order to enhance coal availability, multi-dimensional efforts are underway by Coal India Ltd to enhance production of domestic coal. A road map has been prepared by CIL to substantially enhance coal production level to 1 Billion Tonnes (BT) by the year 2023-24. With this programme there would be no shortage in the availability of coal for the power plants during 2026-27 and 2031-32. In addition, coal production from the captive coal blocks allotted to power utilities would also supplement the availability of domestic coal. The Government has also allowed commercial mining and mines have already been allocated through auction to the participating bidders. This would further supplement the supply of domestic coal to the power utilities. Likely coal-based generation and coal requirement during 2021-22, 2026-27 and 2031-32 are shown in **Exhibit 7.6** and **Exhibit 7.7**.

Exhibit 7.6

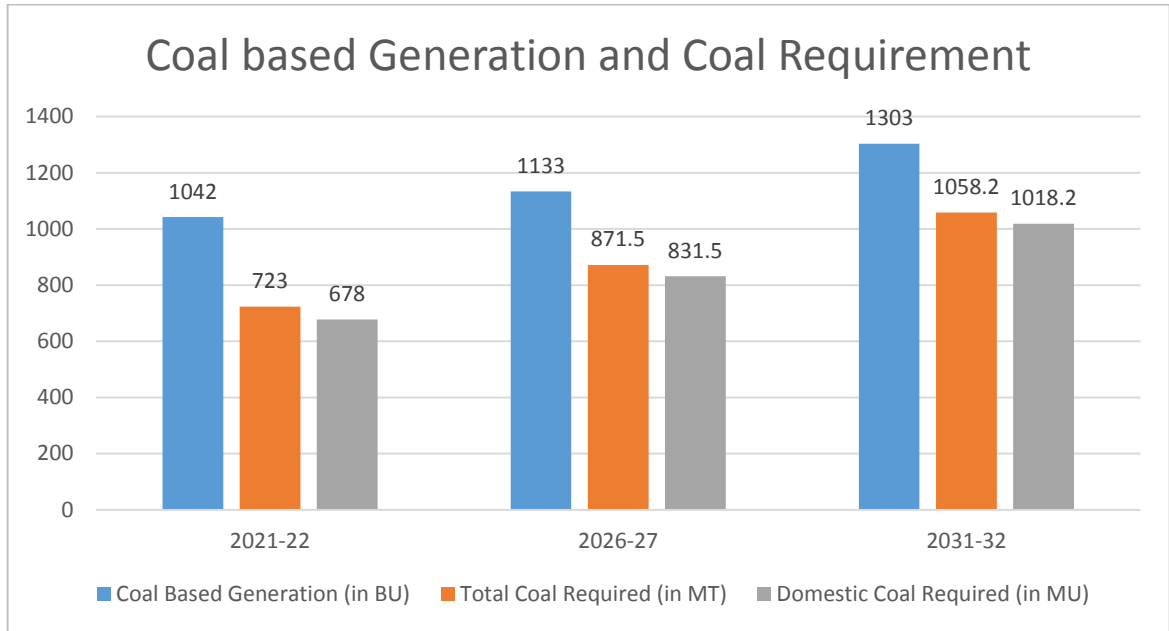
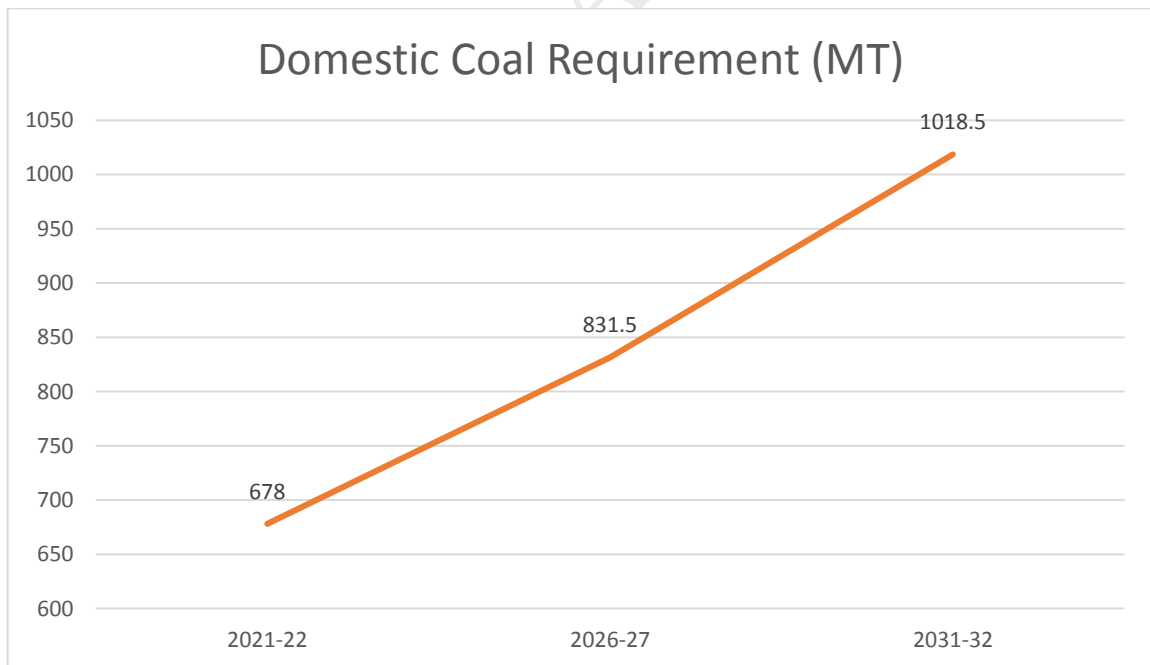


Exhibit 7.7



CONCLUSIONS

The coal requirement for the year 2026-27 and 2031-32 have been worked out. The domestic coal requirement in the year 2026-27 have been estimated as 831.5 Million

Tonnes and in 2031-32 as 1018.2 MT and Imports by plants designed on imported coal to be 40 Million tonnes.

7.3 ISSUES/CONSTRAINTS IN MAKING COAL AVAILABLE TO POWER STATIONS

Timely availability of adequate coal is extremely crucial for maximizing generation from the power plants. In addition to tapping fuel source or organizing its availability, it is also essential to create the infrastructure to facilitate fuel to reach the intended destination. Therefore, development of mines/ ports and requisite transportation facilities commensurate with the completion of the projects is very necessary. The gestation period in the development of mines and even transport facilities are in some cases, longer than the gestation period for setting up of thermal power stations. It is, therefore, imperative for the Power Sector to make its prospective coal requirement, over a long time horizon, known to the Ministry of Coal, Railways and port authorities to enable them to undertake co-ordinated development of coal mines and transport infrastructure with the coming up of thermal power stations.

However, to address the issue of supply of coal to the power plants due to infrastructural constraints etc. there is an Inter-ministerial Sub group in the Ministry of Coal. The Inter-ministerial subgroup constituted by the Infrastructure Constraints Review Committee, is under the Chairmanship of Joint Secretary, Ministry of Coal comprising of representatives from Ministry of Railways, Ministry of Power, Shipping, NITI Aayog CEA, Coal India Limited and NTPC Limited. The subgroup reviews and monitor coal supply and related infrastructural constraints on day-to-day basis for adequate supply of coal to power plants.

7.4 NEW INITIATIVES TAKEN BY THE GOVERNMENT FOR ADDRESSING ISSUES RELATED TO COAL SUPPLY TO THE POWER PLANTS

7.4.1 Rationalization/ Swapping of Coal Linkages

A. For State/Central Gencos (Constitution of a new Inter- Ministerial Task Force - IMTF)

- i. In order to undertake a comprehensive review of existing sources of coal and considering the feasibility of rationalization of these sources to optimize cost of coal transportation, a new Inter-Ministerial Task Force (IMTF) was constituted by Ministry of Coal in June, 2014. CIL also engaged M/s KPMG Advisory Services Private Ltd to assist the Task Force in optimization exercise.
- ii. The new Inter-Ministerial Task Force (IMTF) had recommended a three-step approach for implementation. The recommendations inter-alia included rationalization of linkage sources for 19 power utilities in Stage-I by swapping

linkage coal between different coal companies to optimize distances and maximizing dispatches of coal. As per status of implementation of recommendations of IMTF, Coal India Ltd. executed revised Fuel Supply Agreement (FSA) with 17 power plants in respect of Stage-I rationalization. This had resulted in movement rationalization of 24.6 MT coal with potential annual savings of about Rs. 913 crores.

- iii. The Task Force recommended rationalization of 6 swap sets among power utilities in Stage-II which envisaged swapping of coal between 'imported coal and domestic coal' and 'domestic coal of different power stations among 6 States involving 11 power utilities in Centre /State/ Private Sector. Among the participating companies, 19 swaps were envisaged. Out of these swaps, only 6 swaps (saving 952 Crores) were agreed for implementation. However, with the improved availability of coal for pit head power plants, the swaps agreed for swapping of imported coal with domestic coal for pit head plants was not feasible. However, only one set of swaps has been implemented for movement of rationalization of 1.3 MT coal and potential annual savings of 458 crores of transportation cost.
- iv. With the implementation of Stage-I and Stage-II of recommendations of the IMTF, movement rationalization of 25.9 MT coal has been taken.

B. For IPPs

- i. Ministry of Coal vide OM dated 18th July, 2017 constituted a new "Inter-Ministerial Task Force (IMTF)" to rationalize the linkages of the Independent Power Producers (IPPs). The IMTF was constituted under the Chairmanship of Additional Secretary, Ministry of Coal, with members from Ministry of Coal, Ministry of Power, Ministry of Railways, Ministry of Shipping, CEA, CIL, and SCCL.
- ii. The terms of reference of the IMTF was to undertake a comprehensive review of existing coal sources of IPPs having linkages and consider the feasibility for rationalization of these sources with a view to optimize transportation cost given the various technical constraints. The benefits accrued would be passed on to the DISCOMs/consumers in an objective and transparent manner.
- iii. Based on the recommendation of IMTF, Ministry of Coal vide letter dated 15.05.2018 issued the Methodology for Linkage Rationalization for IPPs. The summary of the methodology is as under:
 - a. Basic objective of the methodology is to reduce the landed cost of coal due to reduction in transportation cost and cost of coal. The reduced landed price of coal would lead to savings, to be reflected in cost of power generated, and these savings shall be passed on to the buyers of power through a transparent and objective mechanism.
 - b. Reduce the distance by which the coal is transported, thus, easing up the Railway infrastructure for gainful utilization for other sectors.

- c. The methodology has considered rationalization only for IPPs having linkages obtained through allotment route. The IPPs having linkages obtained through auction process are not eligible for rationalization under this scheme.

Status:

- i. In the first round of linkage rationalization for IPPs initiated by CIL on 28.08.2018, the linkage of Bajaj Energy Limited (5 plants) has been rationalized for a quantity of 1.605 MT as per the decision taken in the meeting held on 11th March, 2019 by the Apex Committee comprising members from CIL, SCCL, CEA and Railways.
- ii. In the second round of linkage rationalization for IPPs initiated by CIL on 25.08.2020, linkage of seven IPPs (Talwandi Sabo Power Ltd., Nabha Power Ltd., Jhajjar Power Ltd., Bajaj Power, Jhabua Power Ltd., Maithon Power Ltd. and Dhariwal Infrastructure Ltd.) has agreed for rationalization. Nabha Power Ltd. has already signed FSA at the rationalized source (Northern Coalfields Ltd.) in December '21 based on the decision of the Apex Committee on 14.06.2021.

7.4.2 Third Party Sampling

- i. In order to address quality concern of the coal supplied to power plants, it was decided in the meeting dated 28.10.2015 that coal samples shall be collected and prepared by a Single Third-Party Agency appointed by power utilities and coal companies. Accordingly, it was decided by the Ministry of Power and the Ministry of Coal that the power utilities would appoint a Third-Party Sampler (CIMFR) for Third Party Sampling and Analysis of coal at loading-end as well as at unloading-end. Based on the Third-Party Sampling analysis results furnished by CIMFR, credit/debit note are being issued by coal companies to the power plants in case of difference between declared grade of coal and analysed grade of coal.
- ii. Third party sampling has been started by CIMFR at loading as well as unloading ends, which has resulted into lowering of ECR, thus benefiting the end consumers of electricity.
- iii. Subsequently, Ministry of Power vide letter dated 30.03.2021 conveyed the decision that Power Finance Corporation (PFC) shall empanel Third Party Sampling (TPS) Agencies for Power Sector, in addition to CIMFR, and consumers shall be free to take services of any of the empanelled agencies. The Terms of Reference for empanelment for the agency was to be formulated with the following broad guidelines:
 - a. Multiple Agencies should be available.
 - b. Sampling only at loading end with appellate/referee provision.
 - c. Choice of taking services from empanelled agencies shall be of the buyer of coal.
 - d. Review mechanism to review the working of the system.

- iv. MOP, after consultation with the stakeholders including CEA, finalized the Terms of Reference for empanelment of TPS which was forwarded to PFC on 17.08.2021 for taking further necessary action.
- v. PFC has empanelled one firm (M/s Mitra SK Private Limited) as a 'Third Party sampling Agency (TPSA) for collection, preparation and analysis of coal samples at loading end with appellate/referee provision for power sector'.

7.4.3 Flexibility in Utilization of Domestic Coal

- i. The Government, on 04.05.2016, approved the proposal for allowing flexibility in utilization of domestic coal amongst power generating stations to reduce the cost of power generation. Under the scheme, the Annual Contracted Quantity (ACQ) of each individual coal linkage as per Fuel Supply Agreement is to be aggregated as consolidated ACQ for each State and Company owning Central Generating Stations instead of individual generating station. The State/Central Gencos have flexibility to utilize their coal in most efficient and cost-effective manner in their own power plants as well as by transferring coal to other State/Central Gencos Power plants for generation of cheaper power. The methodology provides for utilizing coal amongst State/Central Generating Stations having 4 cases- i) within state ii) one state to another state iii) one state to CGSs & vice versa and iv) within CGSs & other CGSs. The methodology in this regard has been issued by CEA on 08.06.2016.
- ii. Further, the methodology for use of coal transferred by a State to Independent Power Producer (IPP) generating stations has been issued by Ministry of Power, Govt. of India on 20.02.2017. As per the methodology, the State can divert their coal and take equivalent power from IPP generating station, which is selected through an e-bidding process. The guiding principle of the methodology is that the landed cost of power from IPP generating station at the State's periphery should be lower than the variable cost of generation of the State generating station whose power is to be replaced by generation from IPP. The landed cost of power is inclusive of the transmission charges and transmission losses.
- iii. Based on the experience gained, Ministry of power vide letter dated 15.06.2018 has amended clauses related to bid security, performance security coal transportation mode in the methodology for Case-4. Subsequently, Ministry of Power vide letter dated 25.10.2018 has issued 2nd amendment in the methodology allowing moisture correction while reconciliation of coal.

7.4.3.1 Status/ Current Development of the Scheme:

- i. All State/Central gencos have signed supplementary agreement with Coal Companies for aggregation of their ACQ. CIL, on quarterly basis, allocates coal to the plants of State /Central Gencos as per their requirement within their AACQ.
- ii. Based on the methodology issued by MoP on 20.02.2017 for Case-4, Gujarat Urja Vikas Nigam Limited (GUVNL) and Maharashtra State Power Generation Company Limited (MSPGCL) invited bids for supply of power from willing IPPs.

- iii. GMR Chhattisgarh Energy Limited (GCEL) emerged as successful bidder in case of bid invited by GUVNL and was awarded contract to take equivalent power of 500 MW at a tariff of Rs 2.81 per unit for a period of 8 months starting from November 2017 to June 2018. However, power supply started from January 2018. The contract was later extended by GUVNL till November, 2018. Gujarat again invited bids and awarded contract to GCEL for supply of 1000 MW at a tariff of Rs. 3.16 per unit. The Power purchase agreement (PPA) was signed on 21.12.2018 and the contract period was upto June, 2019. However, the supply of power started from January, 2019 and the contract was extended till December, 2019.
- iv. Maharashtra tied up 400 MW (185 MW with Dhariwal Infrastructure Ltd. and 215 MW with Ideal Energy Projects Ltd. for a period of 8 months at a tariff of Rs. 2.76 per unit. The supply of power started by Dhariwal Infrastructure Ltd. from April 2018 and by Bela TPS from May 2018. Maharashtra again tied up 185 MW with Dhariwal Infrastructure Ltd. from November 2019 to October 2020.

7.5 LIGNITE

Lignite reserves in the country have been estimated at around 40.9 Billion Tonnes, most of which is found in the State of Tamil Nadu. About 82 % of the Lignite reserves are located in the State of Tamil Nadu & Pondicherry. At present only a small percentage of the total reserves of lignite have been exploited. There is considerable scope for exploitation of lignite reserves and use of lignite in thermal power stations subject to cost-economics, particularly in the States of Tamil Nadu, Rajasthan and Gujarat having the limitations of transportation of coal to these regions. State-wise distribution of Lignite resources is shown in **Table- 7.9**.

Table 7.9
State-wise Lignite Reserves

State	Total [MT]
Tamil Nadu	33309.53
Rajasthan	4835.29
Gujarat	2722.05
Jammu & Kashmir	27.55
Others (Kerala, West Bengal)	11.44
Total	40905.86

The anticipated Lignite Generation for 2026-27 & 2031-32 are shown in **Table 7.10**.

Table-7.10
Anticipation Lignite generation of 2026-27 & 2031-32

S.No.	Description	2026-27	2031-32
1.1	Gross Lignite based generation (BU)	25.8	30.8

7.6 GAS-BASED POWER PLANTS

7.6.1 INTRODUCTION

Natural Gas is the next generation fossil fuel with less carbon dioxide per joule delivered than either by coal or oil and contains far fewer pollutants than other hydrocarbon fuels. Therefore, the natural gas has emerged as the most preferred fuel due to its inherent environmentally benign nature, easy transportability, ease of use, greater efficiency and cost effectiveness. The development of Natural Gas industry in the country started in 1960s with discovery of gas fields in Assam and Gujarat. After discovery of South Basin fields by ONGC in 1970s, Natural Gas assumed importance. The Exploration activities in India were earlier carried out only by the National Oil Companies (ONGC & OIL) under nomination regime. Later private companies were allowed to enter into exploration through JV with National Oil Companies (NOCs) under Pre-NELP (New Exploration Licensing Policy) regime. Subsequently, 100% foreign participation in exploration was allowed under NELP regime. Later discoveries were made in Gujarat, Krishna Godavari (KG) basin, Cauvery basin, Tripura, Assam etc. Subsequently, Hydrocarbon Exploration and Licensing Policy (HELP) was introduced in March, 2016 for a uniform licensing system to cover all hydrocarbons such as oil, gas, coal bed methane etc. under a single licensing framework coupled with open acreage policy.

The demand of natural gas has sharply increased in the last two decades at the global level. However, the supply of domestic gas in India is not keeping pace with the demand and gas-based power plants are operating at sub-optimal PLF. The power and fertilizer industries emerged as the key demand drivers for natural gas due to the scale of their operations, policy intervention and social impact. In an agrarian economy such as India, the priority has been the production of fertilizers.

7.6.2 BACKGROUND

In India, Natural gas produced from domestic sources is being allocated to different sectors by the Central Government as per policy guidelines issued from time to time. In case of imported gas, the marketers are free to import Liquefied Natural Gas (LNG) and sell the Regasified LNG (RLNG) to customers.

The domestic gas in the country is being supplied mainly from the oil & gas fields located at western and south-eastern areas viz. Hazira basin, Mumbai offshore & KG basin. In addition, North Eastern Region (Assam & Tripura) is also having limited domestic gas production which is being consumed by the localised gas consumers. Import of LNG is being mainly carried out at terminals located on western and southwestern coast viz. Dahej(GJ), Hazira(GJ), Mundra(GJ), Dabhol(MH) and Kochi(KL).

Gas-based generation in India got the impetus when HVJ (Hajira- Vijaypur-Jagdishpur) gas pipeline was commissioned by GAIL in the 80's after discovery of gas in the west coast of India. This led to commissioning of a number of Gas-based Combined Cycle Gas Turbines (CCGTs) along the HVJ pipe line in the Western and Northern part of India. Apart from the major HVJ trunk pipeline, certain regional gas grids, like in KG basin and Kaveri basin also helped in development of some gas-based power generation capacities. Isolated fields are located mainly in parts of Tamil Nadu, Rajasthan and North-Eastern Region.

With the New Exploration Licensing Policy (NELP), gas exploration in India got an impetus and the discovery of gas in Krishna Godavari Dhirubhai 6 (KG-D6) field by Reliance Industries Limited in 2002, was expected to be a turning point in gas production in the country. With the commissioning of East West pipeline by Reliance Gas Infrastructure India Limited, KGD6 gas got infused into the system in early 2009.

With the commencement of production from KGD6 field and the expectation of considerable increase in the volume of production from this field, number of gas-based plants were taken up for implementation in the country even without firm allocation of gas. Before the commencement of production from KGD6 fields, gas-based power plants were operating primarily with the allocated Administrative Price Mechanism (APM) /Non APM/Panna-Mukta-Tapi- Ravva basin gas from nominated fields, but these supplies were short of their requirement. The production from KG D-6 reached its peak of around 60 MMSCMD in March 2010 and thereafter the production has decreased steadily. In view of this decrease in production from KG D-6, MoPNG issued an order in July 2010 to apply pro-rata cuts in supply against firm allocations to all customers on days when the total production is less than signed Gas Sale and Purchase Agreements (GSPAs). The Empowered Group of Ministers (EGoM) in its meeting held on 23rd August, 2013 decided that the incremental production of NELP gas, available during the years 2013-14, 2014-15 & 2015-16 be allocated to power sector after first ensuring the supply of 31.5 Million Metric Standard Cubic Meters per Day (MMSCMD) to fertilizer sector.

Thus, contrary to the expectations, the gradual reduction in production from KG D6 had upset the gas-based capacity addition programme in the country. When the production from KG D6 field fell to 16 MMSCMD in March, 2013, the supplies to power sector got reduced to zero. The gas supply against allocation from KG D6 field to power sector is NIL since March 2013.

7.6.3 PRESENT STATUS

CEA monitors 62 nos. of gas-based power stations, using gas as primary fuel, with a total capacity of about 23845 MW. Out of this, about 20922 MW are connected with gas pipeline grid and the balance 2923 MW are connected with isolated gas fields. The plants connected with isolated gas fields operate on the gas which is available locally and are located in Tamil Nadu, North-East and Rajasthan. Out of total installed capacity of 3,99,497 MW in the country as on 31st March 2022, a capacity of 23845 MW (about 6%)

is from gas-based power plants. However, during 2021-22, generation from gas-based plants was only about 2.4 % of the total generation in the country.

Normative gas requirement to operate the existing power plants having capacity of 23,845 MW at 85% Plant Load Factor (PLF) is about 102 MMSCMD. However, the total domestic gas allocated to power projects is about 85 MMSCMD and average gas supplied to these gas-based power plants during the year 2021-22 was only 22.62 MMSCMD. Out of 22.62 MMSCMD gas, grid connected capacity has received 13.31 MMSCMD and gas-based capacity connected with isolated gas fields received 9.31 MMSCMD gas during the year 2021-22. The PLF achieved by grid connected gas-based capacity is around 12.5% only, whereas, plants connected with isolated field has achieved average PLF of around 51%. Overall PLF of gas-based capacity during the year 2021-22 remained around 17.2%.

7.6.4 Gas supply position to gas-based power plants

The details of plant wise gas-based installed capacity and gas supply position for the year 2021-22 is given at **Annexure 7.1**.

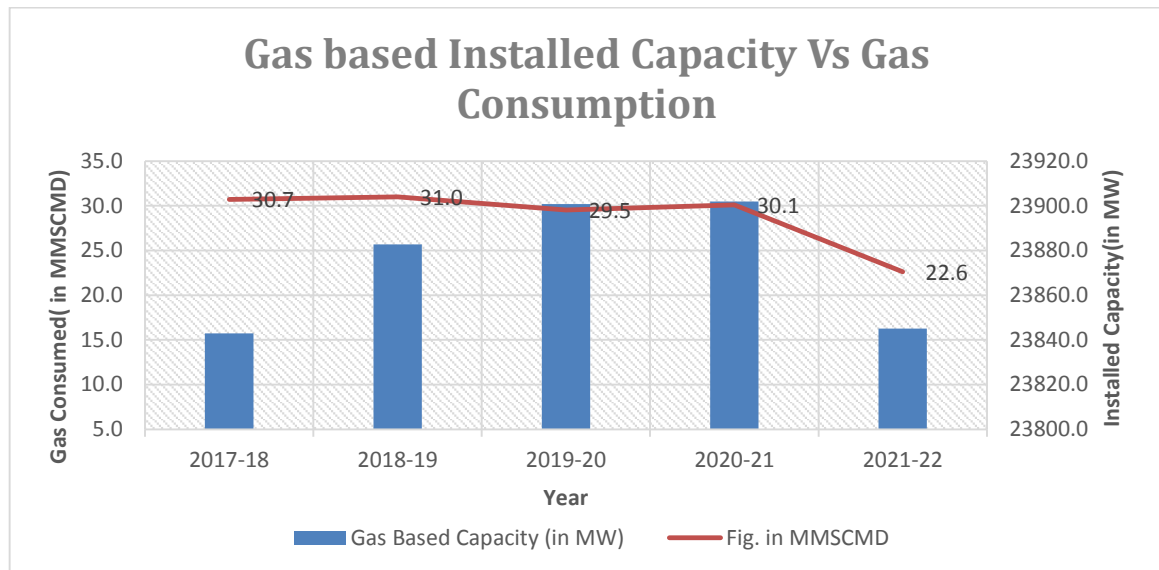
Supply of natural gas to gas-based power plants since 2017-18 is shown in Table 7.11.

Table 7.11
Average Gas Supply and Shortfall

Sl.	Years	Gas-based Capacity at the end of year (MW)	Gas Required* (MMSCMD)	Average Gas Supplied (MMSCMD)	Shortfall (MMSCMD)
1	2	3	4	5	(6)=(4)-(5)
1	2017-18	23842.87	101.5	30.7	70.8
2	2018-19	23882.68	101.8	31.0	70.8
3	2019-20	23900.82	102.0	29.5	72.5
4	2020-21	23901.97	102.0	30.1	71.9
5	2021-22	23845.05	101.5	22.6	78.9

Supply / Consumption of gas to gas-based power plants since 2017-18 is shown at **Exhibit 7.8**

Exhibit 7.8

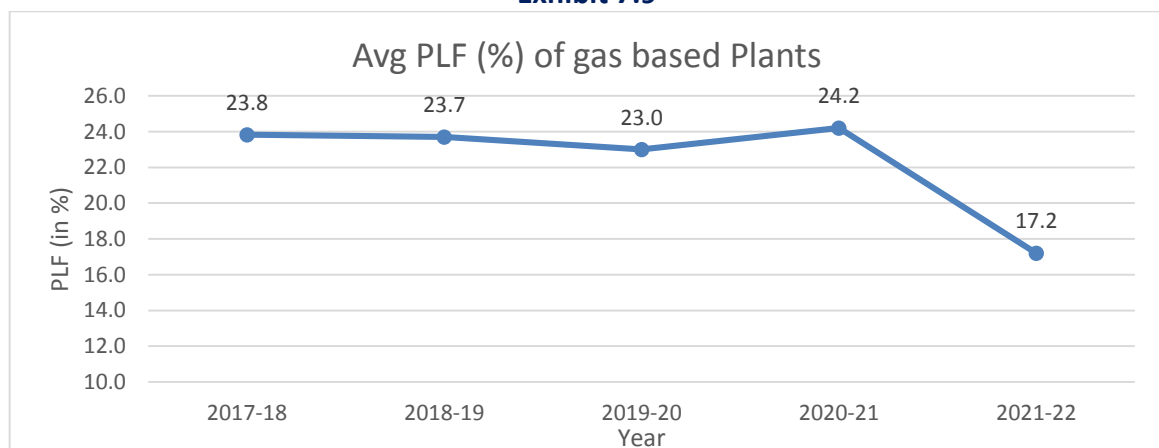


Domestic gas supply to gas-based power plants had reached a peak of 59.3 MMSCMD during 2010-11, thereafter, due to unprecedented reduction in gas supply, the gas supply to gas-based power plants had reduced sharply. The gas supplied to gas-based power plants since 2017-18 to 2020-21 has been almost 30 MMSCMD. However, during the year 2021-22, total gas supplied to gas-based power plants was only 22.62 MMSCMD.

7.6.5 Average PLF of Gas-based capacity

Average PLF of gas-based capacity since 2017-18 is shown in **Exhibit 7.9**. It can be seen that average PLF of gas-based capacity during 2017-18 was around 24% and has decreased to about 17% in the year 2021-22.

Exhibit 7.9

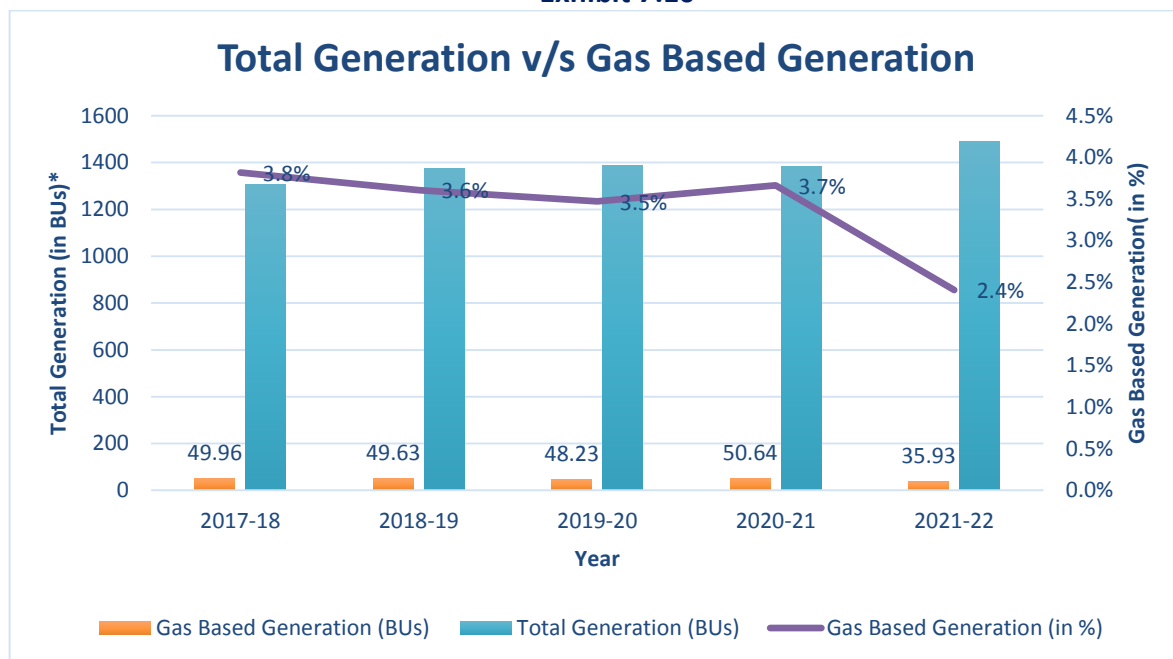


Share of Gas-based Generation in Total Generation

Share of gas-based power generation against total generation from 2017-18 to 2021-22 is shown in **Exhibit 7.10**.

It can be seen that share of gas-based generation since 2017-18 till 2020-21 has been about 3.6%, which has reduced to around 2.4% during 2021-22.

Exhibit 7.10



7.6.6 ADVANTAGES OF GAS-BASED POWER PLANTS

Natural gas-based power generation has many advantages over other conventional energy sources mainly on account of its lesser impact on the environment and better economics. However, despite these advantages, due to shortage of domestic gas, India's energy mix is skewed towards coal compared to other countries, with gas-based generation share in India is only around 2.4% at present.

Gas-based power plants require significantly less land and water in comparison to coal-based power plants of the same capacity. In addition, gas-based plants with quick ramping up/down capability can support the renewable balancing power requirements. This gains importance especially in the context of India's aspiration to rapidly scale up renewable generation. Besides, gas-based capacity will minimize the need for other alternative modes of power generation during peak hours of power shortage such as using diesel generators etc., which are not only costlier but also result in more environmental pollution. It may also be noted that gas-based power generation would reduce carbon emissions, as emissions from gas-based power generation is less as compared to Diesel or coal-based generation. Details are shown in the **Table 7.12**

Table 7.12
CO₂ emission from various fuels

Particulars of the Plant	Gas based	Coal based	Diesel based
Capacity (MW)	1000	1000	1000
Gross Station Heat Rate kcal/kWh	1850	2350	1975
Auxiliary Power Consumption (%)	3%	8.5%	3.5%
Net Station Heat Rate (kcal/kWh)	1907	2568	2047
Fuel emission factor (g CO ₂ /KJ)	49.4	99.6	69
Specific CO ₂ emission (tCO ₂ /MWH)	0.30	0.98	0.59

However, due to acute shortage of domestic gas and higher price of imported natural gas, gas-based power plants are not in a position to run their plants efficiently and help in reduction of environmental pollution.

7.6.7 STEPS taken by Government to overcome shortage of gas

- Policy to grant relaxation, extension & classifications at development & production stage for early monetization of hydrocarbon discoveries.
- Discovered Small Field Policy.
- Formulation of Hydrocarbon Exploration and Licensing Policy (HELP) in March, 2016.
- Policy for marketing freedom for gas produced from Deepwater & Ultra Deepwater areas.
- In order to revive and improve utilization of gas-based capacity in the country, Government of India had sanctioned a scheme for utilization of gas-based power generation capacity for the years 2015-16 and 2016-17. The scheme envisaged supply of imported spot RLNG to the stranded gas-based plants as well as plants receiving domestic gas, selected through a reverse e-bidding process. The scheme also envisaged sacrifices to be made collectively by all stakeholders and support from PSDF (Power System Development Fund). The scheme ended on 31.03.2017.
- The Government of India constituted a High-Level Empowered Committee (HLEC) on 29th July, 2018 to consider issues related to stressed thermal power projects. HLEC, in its report submitted in November 2018 has, inter-alia, recommended that MOP and MOPNG may jointly devise a scheme in line with the earlier e-bid RLNG scheme supported by PSDF in order to revive gas-based power plants. The recommendation of HLEC is under consideration in the Ministry of Power.

7.7 CONCLUSION

1. The scheme for utilisation of gas-based generation capacity introduced by Government of India ended on 31.03.2017. However, it is felt that a long-term policy intervention is required for optimal utilization of gas-based capacity in the country.
2. Large scale renewable capacity addition is being implemented in the country. Such largescale renewable integration is likely to pose a number of challenges to system operations. One of the challenges is to provide support to the grid particularly during the peak hours when solar energy is going down and the load is ramping up. Gas-based power plants can play a vital role in grid stability and provide the much-needed balancing power for integrating renewable sources-based power generation into the grid, particularly in view of their fast ramp up/down capability.
3. The regasification capacity in the country is also a matter of concern for gas-based power plants, particularly those who are connected with RGTIL East-West pipeline. Due to technical constraints like directional flows etc., imported RLNG from west coast cannot be transported to power plants located in the East Coast. Therefore, facility of re-gasification capacity may be suitably created at East Coast also.

Annexure 7.1

FUEL SUPPLY/CONSUMPTION FOR GAS-BASED POWER STATIONS IN THE COUNTRY FOR THE PERIOD 2021-22

S. No	Name of Power Station	Utility	Installed Capacity (MW)	State	Domestic Gas Allotted (MMSCMD)	Gas Consumed (MMSCMD)
(A) CENTRAL SECTOR						
1	NTPC, FARIDABAD CCPP	NTPC	431.59	HARYANA	1.81	0.07
2	NTPC, ANTA CCPP	NTPC	419.33	RAJASTHAN	1.55	0.08
3	NTPC, AURAIYA CCPP	NTPC	663.36	UTTAR PRADESH	2.47	0.25
4	NTPC, DADRI CCPP	NTPC	829.78	UTTAR PRADESH	3.25	0.46
	Sub Total (NR)		2344.06		9.08	0.86
5	NTPC, GANDHAR(JHANORE) CCPP	NTPC	657.39	GUJARAT	3.19	0.27
6	NTPC, KAWAS CCPP	NTPC	656.2	GUJARAT	5.72	0.17
7	RATNAGIRI CCPP	RGPPL	1967.08	MAHARASHTRA	8.50	1.69
	Sub Total (WR)		3280.67		17.41	2.12
8	KATHALGURI	NEEPCO	291	ASSAM	1.40	1.42
9	AGARTALA GT+ST	NEEPCO	135	TRIPURA	0.75	0.71
10	MONARCHAK	NEEPCO	101	TRIPURA	0.50	0.45
11	TRIPURA CCPP	OTPC	726.6	TRIPURA	2.65	2.20
	Sub Total (NER)		1253.60		5.30	4.79
	Total (CS)=A		6878.33		31.79	7.77
(B) STATE SECTOR						
12	I.P.CCPP	IPGCL	270	DELHI	0.95	0.16
13	PRAGATI CCGT-III	Pragati Power Corp. Ltd.	1500	DELHI	2.49	1.72
14	PRAGATI CCPP	Pragati Power Corp. Ltd.	330.4	DELHI	2.05	0.89
15	DHOLPUR CCPP	RRVUNL	330	RAJASTHAN	1.60	0.00
16	RAMGARH	RRVUNL	273.8	RAJASTHAN	1.65	1.27
	Sub Total (NR)		2704.20		8.74	4.05
17	DHUVARAN CCPP	GSECL	594.72	GUJARAT	0.69	0.15
18	HAZIRA CCPP	GSEG	156.1	GUJARAT	0.81	0.02
19	HAZIRA CCPP EXT	GSEG	351	GUJARAT	0.00	0.04
20	PIPAVAV CCPP	GPPC (GSPC-Pipavav Power Comp. Ltd.)	702	GUJARAT	0.00	0.08
21	UTRAN CCPP	GSECL	374	GUJARAT	1.45	0.22
22	URAN CCPP	MAHAGENCO	672	MAHARASHTRA	4.90	1.52



	Sub Total (WR)		2849.82		7.85	2.02
23	GODAVARI (JEGURUPADU)	APEPDCL	235.4	ANDHRA PRADESH	1.31	0.33
24	KARAIKAL CCPP	PPCL	32.5	PUDUCHERRY	0.20	0.17
25	KOVIKALPAL	TANGEDCO	107	TAMIL NADU	0.45	0.17
26	KUTTALAM	TANGEDCO	100	TAMIL NADU	0.45	0.29
27	VALUTHUR CCPP	TANGEDCO	186.2	TAMIL NADU	0.89	0.56
	Sub Total (SR)		661.1		3.30	1.53
28	LAKWA GT	APGCL	97.2	ASSAM	0.50	0.28
29	LAKWA Replacement CCPP	APGCL	69.76	ASSAM	0.40	0.33
30	NAMRUP CCPP + ST	APGCL	162.4	ASSAM	0.66	0.59
31	BARAMURA GT	TSECL	42	TRIPURA	0.40	0.26
32	ROKHIA GT	TSECL	95	TRIPURA	0.50	0.40
	Sub Total (NER)		466.36		2.46	1.86
	Total (SS)=B		6681.48		22.35	9.45
(C) PVT/IPP SECTOR						
33	RITHALA CCPP (NDPL)	Tata Power Delhi Distribution Ltd.	108	DELHI	0.40	0.00
34	GAMA CCPP	Gama Infraprop Pvt. Ltd.	225	UTTARAKHAND	0.00	0.21
35	KASHIPUR CCPP	Sravanthi Energy Pvt. Ltd.	225	UTTARAKHAND	0.00	0.37
	Sub Total (NR)		558		0.40	0.57
36	BARODA CCPP	GIPCL	160	GUJARAT	0.45	0.00
37	ESSAR CCPP	EPL	300	GUJARAT	1.17	0.00
38	PAGUTHAN CCPP	CLP India	655	GUJARAT	1.43	0.00
39	SUGEN CCPP	Torrent Power Ltd.	1147.5	GUJARAT	4.21	2.33
40	UNOSUGEN CCPP	Torrent Power Ltd.	382.5	GUJARAT	0.00	0.70
41	DGEN Mega CCPP	Torrent Power Ltd.	1200	GUJARAT	0.00	0.00
42	TROMBAY CCPP	Tata Power Comp. Ltd.	180	MAHARASHTRA	1.50	0.56
43	MANGAON CCPP	PGPL	388	MAHARASHTRA	0.00	0.00
	Sub Total (WR)		4413		8.76	3.60
44	GAUTAMI CCPP	GVK Energy Ltd.	464	ANDHRA PRADESH	3.82	0.00
45	GMR- KAKINADA	GMR Energy Ltd.	220	ANDHRA PRADESH	0.88	0.00

46	GMR- Rajahmundry	GREL	768	ANDHRA PRADESH	0.00	0.00
47	GODAVARI (SPECTRUM)	Spectrum Power Generation Ltd.	208	ANDHRA PRADESH	1.04	0.14
48	JEGURUPADU CCPP PHASE- II	GVK Energy Ltd.	220	ANDHRA PRADESH	2.22	0.00
49	KONASEEMA CCPP	Konaseema Gas Power Ltd.	445	ANDHRA PRADESH	1.78	0.00
50	KONDAPALLI EXTN CCPP	LANCO Kondapalli Power Pvt. Ltd.	366	ANDHRA PRADESH	1.46	0.00
51	KONDAPALLI ST-3 CCPP	LANCO Kondapalli Power Pvt. Ltd.	742	ANDHRA PRADESH	0.00	0.00
52	KONDAPALLI CCPP	LANCO Kondapalli Power Pvt. Ltd.	368.14	ANDHRA PRADESH	1.82	0.25
53	PEDDAPURAM	Reliance Infra. Ltd.	220	ANDHRA PRADESH	1.09	0.00
54	VEMAGIRI CCPP	GMR Vemagiri Power Generation Ltd.	370	ANDHRA PRADESH	3.12	0.00
55	VIJESWARAN CCPP	APGPCL	272	ANDHRA PRADESH	1.32	0.63
56	PCIL POWER AND HOLDINGS Ltd.	PCIL power and Holdings Ltd.	30	ANDHRA PRADESH	0.12	0.0
57	RVK ENERGY	RVK Eney	28	ANDHRA PRADESH	0.11	0.0
58	SILK ROAD SUGAR	SILK ROAD SUGAR	35	ANDHRA PRADESH	0.10	0.0
59	LVS POWER	LVS POWER	55	ANDHRA PRADESH	0.22	0.0
60	KARUPPUR CCPP	Lanco Tanjore	119.8	TAMIL NADU	0.50	0.16
61	P.NALLUR CCPP	PPN Power Generating Company	330.5	TAMIL NADU	1.50	0.00
62	VALANTARVY CCPP	Pioneer Power Ltd.	52.8	TAMIL NADU	0.38	0.05
Sub Total (SR)			5314.24		21.48	1.23
Total(PVT/IPP)=C			10285.24		30.64	5.40
GRAND TOTAL=A+B+C			23845.05		84.79	22.62

CHAPTER 8

FUND REQUIREMENT

8.0 INTRODUCTION

The generation capacity addition for the period 2022-27 and 2027-32 has been assessed in the Chapters 5. This Chapter estimates total fund requirement corresponding to this capacity addition. The requirement of funds for transmission and distribution will be included in Volume-II of the National Electricity Plan. The requirement of funds assessed in this chapter does not include the funds required for captive power plants and for R&M of existing power plants.

8.1 FUND REQUIREMENT FOR THE PERIOD 2022-2027

8.1.1 A total capacity addition of 40,632 MW from conventional sources (Coal, Gas and Nuclear) and 1,87,909 MW from renewable energy sources (Hydro including SHP, Pumped Storage Plants (PSP), Solar, Wind and Biomass) has been envisaged for the period 2022-2027. The requirement of funds for generation projects for the period 2022-27 has been assessed for the above mentioned capacity addition.

8.1.2 To assess the fund requirement for various types of generation projects, the year-wise phasing of expenditure has been considered in accordance with the base scenario. The estimates of standard cost per MW for the year 2021-22 has been taken as input for various technologies (except Hydro and Nuclear stations) and this has further been escalated thereafter @2.65% per annum (considering 4 year CAGR of WPI for- FY15/16-19/20). The fund requirement of Hydro projects has been considered based on estimated capital cost data and actual expenditure incurred for identified individual projects. Fund requirement for Nuclear capacity addition has been based on estimates provided by NPCIL. The details of assumptions of capital cost per MW and year-wise phasing of expenditure of different categories of generation projects are given in **Annexure 8.1** and **Annexure 8.2** respectively.

8.1.3 Based on the above, the total fund requirement for the period 2022-2027 is estimated to be Rs.14,30,718 Crores, which also includes the likely expenditure during this period for the projects expected to get commissioned during 2027-2032. **Table 8.1** below captures the year-wise details of total estimated fund requirement.

Table 8.1
Total fund requirement for Generation projects during 2022-2027

	(Rs. Crores)					
	2022-23	2023-24	2024-25	2025-26	2026-27	Total
For projects likely to be commissioned during 2022-27	2,93,071	3,14,418	2,14,315	1,83,378	64,266	10,69,448
Advance action for projects likely to be commissioned during 2027-32	7,926	30,410	43,750	57,771	2,21,413	3,61,270
Total	3,00,997	3,44,828	2,58,065	2,41,149	2,85,679	14,30,718

8.1.4 The source-wise estimated fund requirement for the period 2022-2027 (including the likely expenditure during this period for the projects expected to be commissioned during 2027-2032) is given in **Table 8.2**

Table 8.2
Fund requirement for Generation projects (Source-wise) during 2022-2027

	(Rs. Crores)					
	2022-23	2023-24	2024-25	2025-26	2026-27	Total
A. Conventional						
Thermal	68,632	64,417	40,274	37,767	41,611	2,52,701
Nuclear	18,598	30,028	29,013	20,628	30,855	1,29,122
						3,81,823
B. Renewables						
Hydro	15,774	15,000	14,694	15,010	18,587	79,065
PSP	2,104	7,233	9,174	11,506	13,082	43,099
Wind	47,591	59,170	53,938	53,528	61,155	2,75,382
Offshore Wind	0	0	0	0	4,852	4,852
Biomass	4,237	4,868	4,998	5,130	5,266	24,499
Solar	1,44,061	1,64,112	1,05,974	97,580	1,10,271	6,21,998
						10,48,895
C. Total	3,00,997	3,44,828	2,58,065	2,41,149	2,85,679	14,30,718

8.2 FUND REQUIREMENT FOR THE PERIOD 2027-32

8.2.1 The fund requirement for the period 2027-32 has been estimated based on total capacity addition of 2,94,597 MW, consisting of 18,134 MW from conventional energy sources, 2,24,908 MW of renewable energy sources and 51,555 MW of Battery Energy Storage Systems (BESS). with 5 hours storage.

8.2.2 The fund requirement for the period of 2027-32 has been assessed using same principles as that for 2022-27. The total fund requirement for coal based generation, solar, wind, Biomass, PSP and SHP has been arrived based on estimated standard cost per MW for the year 2021-22 with annual escalation @2.65%. The fund requirement of Hydro projects has been considered based on estimated cost data and actual expenditure incurred for identified individual projects. Fund requirement for Nuclear capacity addition has been based on estimates provided by NPCIL. The details of assumptions of capital cost and year-wise phasing of expenditure of different categories of generation projects are given in **Annexure 8.1** and **Annexure 8.2** respectively.

8.2.3 Based on the above, the total fund requirement for the period 2027-2032 has been estimated to be Rs. 17,15,608 Crores. This fund requirement does not include advance action for the projects which may get commissioned after 31.03.2032.

8.2.4 The source-wise fund requirement for the period 2027-2032 is given in **Table 8.3**.

Table 8.3
Fund requirement for Generation projects (mode-wise) during 2027-2032

	(Rs. Crores)					
	2027-28	2028-29	2029-30	2030-31	2031-32	Total
A. Conventional						
Thermal	26,815	12,385	1,693	1,614	1,614	44,121
Nuclear	30,648	20,981	13,293	7,840	2,123	74,885
						1,19,006
B. Renewables						
Hydro	27,209	25,319	19,623	12,258	4,661	89,070
PSP	13,048	9,697	7,303	4,120	1,364	35,532
Wind	68,071	88,889	56,636	43,666	21,822	2,79,084
Offshore Wind	18,957	41,342	44,700	44,136	26,674	1,75,809
Biomass	5,405	3,840	1,664	0	0	10,909
Solar	1,39,423	1,57,380	1,63,616	1,67,952	33,765	6,62,136
						12,52,540
C. BESS	24,870	60,841	79,680	84,124	94,547	3,44,062
D. TOTAL	3,54,446	4,20,674	3,88,208	3,65,710	1,86,570	17,15,608

8.3 SOURCES OF FUNDS

8.3.1 In case of Central Sector projects, generally developers make an equity contribution of 30%. In case of projects developed in State Sector and Private sector, the equity contribution is generally 20% and 25% respectively. Therefore, to arrive at overall requirement of equity and debt, we have assumed an average of 25% equity and 75% debt for overall fund requirement.

8.3.2 Based on the estimation of fund requirement for the period 2022-27 and considering sector-wise equity contribution mentioned in para 8.3.1, it is estimated that developers will be required to infuse equity amount totaling to Rs. 3,57,679 Crores. Further, they will have to arrange for total debt of Rs. 10,73,039 Crores.

8.3.3 Similarly, the equity and debt requirement (excluding fund requirement for advance action for projects during the period beyond 31.03.2032) for the period 2027-2032 have been estimated as Rs. 4,28,902 Crores and Rs. 12,86,706 Crores respectively.

8.3.4 The equity can be arranged from surplus generated from operations, Initial Public Offerings by Listing in Markets, Follow on Public Issues, convertible debentures and monetization of operational assets. Equity markets investments can be directly from the public and also from Mutual funds, Insurance companies' funds etc. NPS has provision of allowing Equity investment. Similarly, provident fund also has provision of certain percentage investments in equity to support investments. As solar capacity includes roof top solar capacity, funding would be available from individuals, companies and the community from their savings. As per NITI Aayog estimates, funds availability for power sector from National Monetization Pipeline is estimated to be Rs. 85,032 Crore over 2022-25.

8.3.5 The sources available for debt funding are scheduled commercial banks, financial institutions like Power Finance Corporation (PFC), Rural Electrification Corporation (REC), Life Insurance Corporation (LIC), commercial banks and Bonds (domestic as well as overseas), External Commercial Borrowings, foreign currency loan from World Bank, ADB, KfW, EXIM Bank and also Buyer's credit from foreign equipment manufacturers.

8.3.6 In respect of nuclear power generation, Government budgetary support may be required for funding equity requirement for future power projects.

8.3.7 IREDA, as Non-Banking Financial Institution is already engaged in promoting, developing and extending financial assistance for setting up projects relating to new and renewable sources of energy. Further, for financing renewable energy projects under various schemes and supporting technologies like Energy Storage, Green Climate Fund may also be a potential source.

Annexure 8.1

Assumptions for estimating capital cost of power projects (Part-a)

I. Cost /MW considered for assessment of fund requirement for the period 2022-2027

Sl.No.	Project type	Capital cost per MW (Rs. Crores)				
		2022-23	2023-24	2024-25	2025-26	2026-27
1	Coal	8.56	8.79	9.02	9.26	9.51
2	Hydro*	-	-	-	-	-
3	PSP	5.13	5.27	5.41	5.55	5.70
4	Nuclear#	-	-	-	-	-
5	Solar	4.57	4.64	4.71	4.77	4.84
6	Wind	6.16	6.32	6.49	6.66	6.84
7	Biomass	9.24	9.48	9.73	9.99	10.26
8	BESS	8.75	8.17	7.56	7.37	7.17

II. Cost (Rs Crore) /MW considered for assessment of fund requirement for the period 2027-2032

Sl.No.	Project type	Capital cost per MW (Rs. Crores)				
		2027-28	2028-29	2029-30	2030-31	2031-32
1	Coal	9.76	10.02	10.28	10.55	10.83
2	Hydro*	-	-	-	-	-
3	PSP	5.85	6	6.16	6.33	6.49
4	Nuclear#	-	-	-	-	-
5	Solar	4.91	4.98	5.05	5.19	5.33
6	Wind	7.02	7.21	7.40	7.59	7.79
7	Biomass	10.53	10.81	11.09	11.39	11.69
8	BESS	6.95	6.71	6.46	6.63	6.81

*The fund requirement of Hydro projects has been considered based on estimated cost data and actual expenditure incurred.

Fund requirement for Nuclear has been based on estimates provided by NPCIL

Annexure 8.2**Assumptions for estimating capital cost of power projects (Part-b)****Phasing of expenditure of generation projects, for the periods 2022-27 and 2027-32**

Type of Generation Project	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Total
Coal	10%	10%	20%	30%	30%	-	-	-	-	100%
Hydro	20%	25%	25%	20%	10%	-	-	-	-	100%
PSP	20%	25%	25%	20%	10%	-	-	-	-	100%
Solar	80%	20%	-	-	-	-	-	-	-	100%
Wind	60%	40%	-	-	-	-	-	-	-	100%
Biomass	30%	40%	30%	-	-	-	-	-	-	100%
SHP	30%	40%	30%	-	-	-	-	-	-	100%
BESS	100%	-	-	-	-	-	-	-	-	100%
Nuclear\$	-	-	-	-	-	-	-	-	-	-

\$ Phasing of Funds for Nuclear has been considered as per estimates provided by NPCIL

Chapter 9 Key Inputs for Power Sector

9.0. Introduction

Material and equipment are the backbone of any capital-intensive sector like the power sector. Technological prowess in electricity generation can only be harnessed when support is available from all the contributing agencies. Timely availability of all key inputs - as per the requirement of the individual power projects, is vital for its successful completion and long-term sustenance. These key inputs include availability of major equipment, key materials including the material for construction and equipment as well as availability of various types of transportation facilities. Infrastructural support such as port facility, rail and road connectivity and erection agencies including civil contractors are of equal important.

- The requirement and availability of following major key inputs has been examined in the report.
- Requirement of Equipment for Thermal, Hydro, Wind & Solar power plants and other RE sources
- Requirement of Key Materials like Cement, Steel and Aluminium
- Transportation including Railways, Roadways, Ports, Inland Waterways, LNG terminals & Gas pipelines
- Land and Water requirement
- Availability of Construction Machinery
- Availability of materials for solar power generation.

9.1. Capacity Addition Plan for the period 2022-27 and 2027-32

The projected Installed Capacity from different energy sources (Thermal- Coal & Gas, Hydro, Nuclear, Renewable – Solar, Wind, Biomass, Small Hydro) in the country at the end of year 2021-22, as considered in the base case of generation planning studies, is given in **Table 9.1**.

Table 9.1

Installed Capacity from different energy sources in 2021-22			
S.No.	Source		Capacity (MW)
1	Coal + Lignite		210700
2	Gas		24899
3	Nuclear		6780
4	Hydro (including small Hydro)		46825
6	Solar		53996
7	Wind		40358
8	Pumped Storage		4746
9	Biomass		10682
	Total		398986

Capacity addition plan for 2022-27 & 2027-32, as estimated in the generation planning studies is as given in **Table 9.2**.

Table 9.2
Capacity addition plan for 2022-27 & 2027-32

S.No.	Source \ Year	Capacity Addition in 2022-27 (MW)	Capacity Addition in 2027-32 (MW)
1	Solar PV	132080	147400
2	Wind Power	40500	53100
3	Coal	33262	9434
4	Hydro*	10951	10888
5	Nuclear	7000	8700
6	Pumped Storage	2060	12020
7	Biomass	2318	1500
8	Gas Power	370	0
	Total (MW)	228541	243042
	Battery Energy Storage System#		51555

*including small Hydro but excluding hydro imports of 5856 MW
#5 Hour Battery energy Storage

It may be noted that 4629 MW of Coal capacity is considered to be retired during the period 2022-27.

9.2. Requirement of Equipment

9.2.1. Thermal Power Plants

9.2.1.1. Main Plant Equipment

The thermal power generation expected in next ten years is around 43 GW. Accordingly, approximately 4.3 GW/year is expected to be added. Boiler, Turbine & Generator (BTG) form a major part of the thermal power plant. The overall BTG manufacturing capability in the country has been estimated to be around 22 to 25 GW/year, as shown in **Table 9.3**.

Table 9.3
BTG manufacturing capability in the country

S.No.	Company	Boilers (MW)	Turbine Generator (MW)
1	BHEL	13500	13500
2	L&T-MHI Power Boiler Pvt Ltd	4000	-
3	L&T MHI Power Turbine Generators Pvt Ltd	-	4000
4	Doosan Power System Pvt Ltd	2200	-
5	GE Power Systems India Pvt Ltd	-	4000
6	Toshiba JSW Power System Pvt Ltd	-	3000
7	Thermax - Babcock & Wilcox	3000	-
	Total	22700	24500

Thus, adequate indigenous manufacturing capacity of main plant equipment is available in the country. However, most manufacturers reportedly do not have requisite orders and have expressed concerns on lack of orders.

9.2.1.2. Balance of Plant (BoP) equipment

Following balance of plant equipment are assessed for requirements:

9.2.1.2.1. Dry Bottom Ash Handling system

In these systems, the bottom ash is air-cooled as it is being removed from the boiler and transported, eliminating the need to use water which leading to substantial saving in water consumption. As this system, does not use any water to handle bottom ash, boasts the following advantages over conventional hydraulic transport systems:

- lesser environmental impact
- Wider and more effective uses of dry bottom ash
- Lower equipment and running costs

Dry Bottom Ash Handling Systems are currently not being manufactured in the country.

9.2.1.2.2. High Concentration Slurry Disposal (HCSD):

High concentration fly ash slurry is the fly ash disposal system that is followed in many coal-based thermal power plant in India. Efforts to reduce the dilution of the slurry will result in energy conservation as well as water conservation. The main advantages of HCSD system are as given below:

1. Water consumption: high concentration ash slurries use up to a factor 12 less water than dilute slurries.
2. No or minimal contamination by water leaking to the environment.
3. Pipeline transportation is safe, silent and reliable without ash spills.
4. Pipeline scaling eliminated.
5. High availability, low parts usage, low maintenance.
6. Substantial energy savings to run system.

HCSD systems have not been fully indigenised with major components like slurry pumps being imported.

9.2.1.2.3. Air Cooled Condensers (ACC):

An air-cooled condenser (ACC) is a direct dry cooling system where steam is condensed inside air-cooled finned tubes. Since these kinds of power plants, which are equipped with ACCs, do not require a large volume of cooling water, the power plants can easily be built in a region where water may not be available, or where its use is restricted or expensive.

ACCs are currently the frontrunners in dry cooling technology for thermal power plants. Design for lower rating ACC's with multi row tube arrangement is available in India, while

BHEL is making efforts to indigenize the design for higher ratings. Efforts are underway to indigenize the components used in ACC like vacuum pumps, raw material for tube bundles, etc. Approx. 5% to 7% of complete ACC is imported.

Hence, in case of certain specialised Balance of Plant equipment there are still some constraints in their indigenous availability as highlighted above.

9.2.1.2.4. Emission Control Equipment

9.2.1.2.4.1. Flue Gas Desulphurisation (FGD)

In order to meet the new emission norms notified by MoEFCC, thermal power plants need to install FGD to control SO_x emissions. While sufficient FGD system suppliers are present, and most of the components used in manufacturing FGDs are indigenously available, there are still some constraints w.r.t the following components.

- Some special materials are imported
 - C276 clad/sheet
 - Titanium Gr2 clad / sheets
 - Alloy 59, Hastelloy C22, Alloy 31
 - Bromo-butyl rubber lining
 - Borosilicate lining
- Some specialised systems involved in FGD
 - Gypsum Dewatering system
 - Slurry recirculating pumps
 - Agitators
 - Mist Eliminator

Although manufacturing capability of 70 to 80% FGD components is available in India, the balance 20 to 30% of FGD components are being imported from other countries. It is estimated that to create a manufacturing capability of these items in India it would take few years.

9.2.1.2.4.2. Selective Catalytic Reduction (SCR)

In order to meet the NO_x emission standards under the new emission norms notified by MoEFCC, thermal power plants need to either implement combustion modification or install SCRs depending upon the stringency of the norms applicable to a particular unit/plant. While sufficient SCR system suppliers are present, and some of the SCR components can be indigenously sourced, there are still some constraints w.r.t major components like Ferritic Stainless Steels, Titanium Oxide (TiO₂) catalyst etc. As per information collected by the subcommittee, M/s BHEL is augmenting its capacity to manufacture the SCR Catalyst to 4,000 MW/year.

9.2.1.3. Construction Machinery

There is a general consensus that no constraint in availability of major construction machinery for power plants. However, contractors usually take on work beyond their capacities and this leads to delay in mobilisation of resources at site. Proper planning of construction schedule and provisioning of resources beforehand can address this problem. The list of major construction equipment required for construction of 660 MW sets is given in **Table 9.4**.

Table 9.4
Major Construction Equipment for 660 MW sets

S.No.	Major Construction Equipment for 660 MW sets
1	Heavy Lift High Reach (HLHR) Crane for Ceiling Girder Erection (600 MT or above capacity)
2	250/270/300 MT Class Crane – 2 Nos.
3	250/270 MT Class Crane
4	135/150 MT Class Crane- 4 Nos.
5	100/120 MT Class Crane - 2 Nos.
6	100/120 MT Class Crane – 2 Nos. Or Tower Crane of 20 MT capacity – 2 Nos.
7	75/80 MT Class Crane – 6 Nos.
8	Induction Heating Machine
9	Strand Jack System

9.2.1.4. Requirement of spare parts and maintenance contracts for existing thermal projects

In the last one decade there has been renewed thrust on renewables and the trend of shift away from fossil fuels to renewables is expected to continue in the coming decades leading to sharp decline in the growth rate of new capacity addition of coal-based power, and gradual movement of OEMs away from manufacturing of thermal capital equipment.

The above situation of spare parts is likely to impact the support for spares and services for coal power plants especially for fast-moving wear parts such as those in Ash Handling Plant (AHP), Coal Handling Plant (CHP) and Coal mills. In the boiler area, the supply of bearings of fans and air-preheaters may be affected. High-grade bearings and boiler tubes may also have limited availability in India. In the Turbine Generator (TG) area, spares for governing system of old generation turbines may impact coal-based generation in the long run.

Therefore, it would be in the interest of the thermal power utilities to anticipate the future spare and maintenance requirements and prepare for reliable operation of their plants accordingly.

9.2.2. Hydro Power Plants

Installation of a Hydro Electric Plant (HEP) involves Hydro-Mechanical, Electro-Mechanical and Civil works. There seem to be sufficient number of companies involved in each of these fields (A list of major suppliers is given in **Annexure-9.1.**). However, it has been noticed that some of the components of the Hydraulic System for Gates of Hydro Power Plants still require full indigenization. Especially the cylinders used in the hydraulic system of the Spillway Gate, Penstock Intake Gate, Silt Excluder Gate and the Power Pack in some cases is being imported from countries like Italy and Germany. Hence, efforts toward indigenization of these components may be accelerated.

While availability of equipment is not the main concern for hydro power development in the country, there are some constraints regarding capability of civil contractors. As civil construction and engineering usually forms a huge part of overall project time and cost of an HEP, this has always remained an area of concern. It has come to the knowledge of the committee that the financial health and competence of Indian civil contractors has eroded over the years due to slow progress on capacity addition of HEPs. This is a sector specific issue and while measures like easing the cash flow to contractors, relaxing qualification requirements etc. are being undertaken, more attention needs to be given to the matter.

In this regard, Ministry of Power's OM on "Measures to Promote Hydro Power Sector" dated 8th March 2019 may be referred (**Annexure A8**).

9.2.3. Wind Power Plants

In India, over 17 wind turbine manufacturers are available with the domestic annual production capacity of around 10,000 MW/year. India has a manufacturing base for most of the major wind components within the country. They supply the components to domestic wind turbine industry and export the components to the global wind turbine market.

The present wind turbine gearbox manufacturing capacity available in the country is more than 6 GW per year which is more than the present annual requirement by wind turbines power plants. Therefore, the present gearbox manufacturing capacity can meet both the existing and future increase in demand, if any. In addition to the main gearbox, the manufacturing capacity for both pitch and yaw drives is also sufficient at more than 10 GW per year.

However, at certain instances, the Gear boxes required for wind turbine power plants are also being imported to India due to issues related to Quality, Cost and Delivery lead time. Hence, more focus on quality and cost effectiveness in this area is required. The report on 'Scaling up Domestic Manufacturing of Wind Turbine Components – A Step towards Atmanirbhar Bharat, Sept 2020' prepared by NIWE may be referred in this regard.

9.2.4. Solar Power Plants

India has made significant progress in indigenous manufacturing of solar power project equipment. However, it seems difficult for the manufacturing capacities of major solar equipment to match up to the country's ambitious solar capacity addition plans. At present the Solar PV Modules manufacturing capacities in India is around 12 GW/year; while for Solar PV Cells, the manufacturing capacity is around 3.0 GW/year and around 5GW/year for solar inverters.

Further, other electrical equipment like String & Central Inverters, Cables, etc. are required for solar PV power plant. While 5 - 6 nos. of String Inverters are required for 1 MW power plant, one central inverter is sufficient for each 2 – 4MW of power plant capacity. Cables required are as follows: String cable, 2800 m/MW, DC Power cable, 3000 m/MW and HV Cable (33kV), 500 m/MW.

9.2.5. Other Renewables

9.2.5.1. Small Hydro

Indigenous capacity for small hydropower equipment manufacturing is in order of 1000 MW annually, since the country has six to seven established manufacturing companies in the field. A list of major manufacturers is given in **Annexure 9.2**. For SHP, most of the raw material is available in India. However, up to 20% components of generators are imported. Control panels and governors are available indigenously.

9.2.5.2. Biomass

All equipment, technology & services supply for these projects can be sourced indigenously.

9.2.6. Availability of Equipment in India - Make in India efforts

Efforts are underway in India to reduce dependence on imports for power plant equipment. At present, many components/systems used in thermal power plants are being imported. Large steam turbine components like High Pressure (HP) and Intermediate Pressure (IP) rotor forgings of 10% Cr Steel are being imported irrespective of weight, while all Low Pressure (LP) Rotors are also being imported. Large diameter Alloy Steel Pipes SA335P22 and Carbon Steel Pipes Sa106GRC of thickness greater than 36 mm are being imported. Further, there is no indigenous supplier for Electrohydraulic Actuators for HP/IP turbine valves, Servo Valves for Turbine Control Valves and Generator Terminal Bushing.

Similarly for other sources, there is dependence on import of certain components which are not manufactured in India from certain generator components to special quality steel parts. In case of renewables, there is large import dependency for solar power plants. The country is largely importing solar cells for the manufacturing of solar modules/panels.

Efforts are underway in Gol through Make in India (MII) initiative to reduce import component in power plant equipment. The Government of India has issued Public Procurement (Preference to Make in India) Order 2017 via Department of Industrial Policy and Promotions (DIPP) and revision thereof (time to time) to promote manufacturing and production of goods and services in India with a view to enhance income and employment. In pursuance of the aforesaid orders of DIPP, Ministry of Power issues order time to time wherein the preference shall be given by all public procuring entities to domestically manufactured products used in the Power Sector.

9.3. Requirement of Key Materials

9.3.1. Cement, Steel, Aluminium

The overall requirement of materials (Cement, Structural Steel, Reinforcement Steel, Stainless Steel and Aluminum) in thousand metric tons as per the capacity addition plan for the period 2022-27 is given in **Table 9.5**. It is estimated that approximately 52.1 million metric tons of material would be required for 2022-27.

Table 9.5
Overall requirement of materials (round off values in thousand MT) in 2022-27

S.No.	Materials (thousand MT)	Coal	Nuclear	Hydro	Solar	Wind	Biomass	Total
1	Cement	6253	1708	12438	2972	4455	1159	28985
2	Structural Steel	2927	798	442	3170	6075	3477	16889
3	Reinforcement Steel	1596	434	1210	-	2835	-	6075
4	Stainless Steel	66	18	-	-	-	-	84
5	Aluminium	17	5	1	-	-	-	23

Similarly based on the perspective plan for the period 2027-32, the material requirement in thousand metric tons is as given in **Table 9.6**. It is estimated that approximately 59 million metric tons of material would be required for 2027-32.

Table 9.6
Overall requirement of materials (round off values in thousand MT) in 2027-32

S.No.	Materials (thousand MT)	Coal	Nuclear	Hydro	Solar	Wind	Biomass	Total
1	Cement	1774	2123	21900	3316	5841	750	35704
2	Structural steel	830	992	779	3538	7965	2250	16354
3	Reinforcement steel	453	539	2130	-	3717	-	6839
4	Stainless steel	19	23	-	-	-	-	42
5	Aluminium	5	6	2	-	-	-	13

The following norms (given in **Table 9.7**, **Table 9.8** and **Table 9.9**) have been used to estimate the key materials required for thermal, nuclear, hydro and renewable power projects.

Table 9.7
Norms for estimation of key materials for Thermal projects

S.No.	Materials (Ton/MW)	Thermal	
		Coal/Lignite	Gas
1	Cement	188	60
2	Structural steel	88	29
3	Reinforcement steel	48	24
4	Stainless steel	2	1
5	Aluminum@	0.5	0.5

Table 9.8
Norms for estimation of key materials for Hydro & Nuclear projects

Inputs for Cement and other materials for nuclear projects have been considered at 130% of the requirement of coal-based projects based as considered in NEP-2015.

S.No.	Materials(Ton/MW)	Nuclear	Hydro
1	Cement	244	956
2	Structural steel	114	34
3	Reinforcement steel	62	93
4	Stainless steel	2.6	-
5	Aluminium@	0.7	0.1

Table 9.9
Norms for estimation of key materials for Renewable projects

S.No.	Material (Ton/MW)	Solar Power Plant	Biomass Power Plant	Wind Power Plant	Small Hydro Power Plant*
1	Cement	20 – 25	500	110	160
2	Steel	21 – 27	1500	220	190
3	Aluminum@	-	-	-	-
4	Copper	1 – 1.25	-	-	-

@: Aluminium is only used in transmission lines employed in power evacuation. The same is excluded here as material usage within power plant boundary has been considered.

*: The figure has been arrived at with the assumption that 30% SHP projects are on canal fall and dam toes which require lesser construction material and 70% SHP projects are in hilly region.

9.3.2. Tubes, Pipes & Thick Boiler Plates for TPS

Table 9.10

Norms for estimation of Tubes, Pipes & Thick Boiler Plates for TPS

Material	For Supercritical Units (in Tons/MW)
Tubes & Pipes	10.62
Thicker Boiler Quality Plates	3.38 / 1.61*

*The value is 3.38 when we consider plates with thickness > 20 mm and the value is 1.61 when we consider plates with thickness > 100 mm as thick boiler plates.

9.3.3. Castings & Forgings for Turbine-Generators (TG) Sets for TPS

Table 9.11

Norms for estimation of Castings and Forgings for TPS

S.No	Equipment	Weight of Casting(MT per set)	Weight of Forging(MT per set)
1.	Turbine (660 MW)	430 – 477	221 – 250
2.	Turbine (800 MW)	380 – 528	220 – 255
3.	Generator	2.5 – 3	102 – 130

9.3.4. Emission Control Equipment for TPS

9.3.4.1. Flue Gas Desulphurisation:

The major requirement (in Metric Tonnes) for a typical FGD system for a 2x500 MW TPS is given in **Table 9.12**. The exact values are dependent on the unit-specific design aspects.

Table 9.12

Major material requirement (MT) for a typical FGD system (2x500 MW)

S. No.	Major Materials	Material Requirement (MT)
i	Cement	25,000
ii	Structural Steel	15,000
iii	Reinforcement steel	5,750 – 6000
iv	Stainless steel & plates	350 – 400
v	Aluminium	50 – 70
vi	Casting and Forgings	200
vii	Casting and Forgings special alloy / Duplex stainless steel	50
viii	Tube & Pipes	600 – 800
ix	BQ Plates	30
x	C276 clad/sheet for absorber	350 – 375
xi	Titanium Gr2 for ducting	300 – 350

Most of the flue gas desulphurisation technology is limestone based. As per the information available with Ministry of Mines, India has limestones reserves of 1,70,749 million tonnes containing more than 38% Cao, and 1640 million tonnes of limestone with CaO content greater than 50%. Production of limestone in the year 2018-19 was 351 million tonnes, with cement industry using almost 95% of the production. Limestone requirement of thermal power sector is expected to increase in the coming years to a peak of around 18 million tonnes when all plants are using FGDs. With existing reserves and production capacity this seems to be an achievable target.

9.3.4.2. Selective Catalytic Reduction (SCR)

Major material requirement of SCR for a 660/800 MW unit in MT/MW is given in **Table 9.13**.

Table 9.13
Major material requirement (MT/MW) of SCR in a typical 660/800 MW plant

S.No.	Items	MT per MW
1	Ferritic Stainless Steel Grade 430	0.280
2	Titanium dioxide (TiO ₂)	0.193
3	Structural Steel	5
4	SA 516 Grade 70	0.3 – 0.5
5	Carbon Steel	1.14 – 1.20

9.3.5. Material requirement for Solar Power Plants

Solar comprises almost 45% of the installed RE capacity. Raw polycrystalline silicon, commonly referred to as polysilicon, is a high-purity form of silicon which serves as an essential material component in the solar photovoltaic (PV) manufacturing industry. It is the primary feedstock material used for the production of solar cells today.

Solar panels are made of tempered glass, also referred to as safety glass/ toughened glass as specific characteristics of tempered glass suitable for the manufacturing of solar PV panels.

With ambitious plans to use renewables, India’s requirement for flexibility in power generation and power ramping is expected to increase in the coming years. Batteries, among other types of storage, are ideally suited to meet these rising flexibility needs. Battery storage, coupled with solar PV, can become one of the most cost-effective ways to produce clean reliable power both on-grid and off-grid.

Table 9.14 present the major material requirement of Solar Photovoltaic power plants.

Table 9.14
Material usage estimate* for Solar PV

S No	Item	Attribute	Unit	Quantity
1.	Solar Cell	Monocrystalline/Poly-crystalline	kg/MW	4350
2.	Tempered ARC Glass	Low iron content, high transmissivity, 3.2/2.5/2 mm thickness with Anti reflective coating	m ² /MW	7500
			Ton/MW	60
3.	Frame parts	Anodized Aluminium, Anodization thickness>15 microns, 2 long pieces, 2 short pieces	km/MW	21
4.	Cell Interconnect	Alloy Sn60Pb40, 0.9mm x 0.23mm	km/MW	750

*Assumptions used for estimation: i) For 1 MW AC Solar Power 1.45 MW DC Power is required; ii) Glass is 75% by weight of the module.

Material requirement of Lithium-Ion Battery is given in **Table 9.15**.

Table 9.15
Material usage estimate for Lithium-Ion Battery

S No	Item	Unit	Quantity
1	Cobalt	kg/MWh	176
2	Lithium	kg/MWh	144
3	Nickel	kg/MWh	475
4	Manganese	kg/MWh	166
5	Graphite	kg/MWh	1109

9.4. Transportation

Transport requirements of the power sector

Transport Exigencies in case of Wind Turbines

Accessibility by roadways/ railways to project sites is imperative for effective installation/ commissioning of power plants and their O&M activities. Location of wind power plants in remote location often creates a problem of transportation of heavy, large sized equipment. One of the primary challenges facing the wind industry is the sheer size and dimensions of wind turbine components that typically require special logistical handling throughout transportation. Once fully constructed, a blade cannot be bent or folded, limiting both the route a truck can take and the radius of turns that it can make, often making elongated routes necessary to avoid urban roadblocks.

While the towers that support wind-turbines extend high into the sky, their width is also a significant factor to consider. Their transportation is often obstructed when the diameter of components is unable to fit under highway overpasses or bridges.

Roadways should be sufficient/ broad enough for the crane movement, transporting the rotor blades of length ranging from 15 m to 70 m by trailers and other heavy construction equipment.

Transportability consideration for Biomass and Small Hydro

As both Biomass and Small Hydro based projects are usually small in size & located in remote/rural areas, their requirement regarding transportability is more about the availability of roads rather than the size of roads/ rail network. Motor able roads are most essential for movement of equipment during construction phase and for transport of labor& fuel during the operational phase. Rail network, if available, can provide a low-cost alternative.

Transportability consideration for Solar

Road and Rail infrastructure is key essential requirements in facilitation of the Solar PV and solar thermal power plant. It is required for the smooth movement of logistic components, and manpower (for installation and maintenance). Especially the connecting roads till the power plant site is to be established for a damage free movement of the goods

Transportability consideration for Hydro Electric Plants (HEPs)

While availability of roads augments the swift completion of large scale HEPs, the weight and dimensions are the real concerns when it comes to transport consideration of HEPs. From the point of view of cargo transportation, there are several Over-dimensional (ODC) and heavy weight equipment in HEP like the Generator Rotor, Rotor Spider, GSU transformer, Penstock valve, Main Inlet Valve, EOT Crane Girder etc. which need clearances.

9.4.1. Ports

Availability of major & minor ports of the country brings about a significant boost to sea trade. It allows the consumers to transport their equipment & materials to distant locations in a secure and relatively inexpensive manner. India has a coastline of about 7500km with close to 200+ ports, including 12 major ports. Around 95% of India's trading by volume and 65% by value is done through maritime transport and hence, play vital role in the country's trade and commerce. Total traffic handled at Indian Ports rose from 885 MTPA in 2010-11 to 1300 MTPA in 2019-20. The 12 Major Indian Ports handled nearly 54 per cent of the total cargo in 2019-20, and have witnessed just about 4% CAGR growth in overall cargo traffic over last 5 years.

Major Ports in India

There are 12 major ports in India with a total capacity of around 1500 million tonnes. The port-wise capacity and their utilization is in **Table 9.16**:-

Table 9.16
Capacity of major ports in India

S. No.	PORTS	State	Capacity (MTPA)	Utilisation
1	SMP, Kolkata (KDS)	West Bengal	27.30	63%
1b	SMP, Kolkata(Haldia)	West Bengal	53.45	87%
2	Paradip	Odisha	259.50	43%
3	Visakhapatnam	Andhra Pradesh	126.89	57%
4	Kamarajar	Tamil Nadu	91.1	35%
5	Chennai	Tamil Nadu	134.60	35%
6	VO, Chidambaranar	Tamil Nadu	95	38%
7	Cochin	Kerala	73.67	46%
8	New Mangalore	Karnataka	112.51	35%
9	Mormugao	Goa	62.5	26%
10	Mumbai	Maharashtra	77.85	78%
11	JNPT	Maharashtra	118.3	58%
12	Deendayal	Gujarat	261.1	47%
	TOTAL		1493.77	47%

SMP: Syama Prasad Mukherjee Port | KDS: Kolkata Dock System | HDC: Haldia Dock Complex
JNPT: Jawaharlal Nehru Port Trust

Major Ports Authority Bill

The Major Ports Authority (MPA) Bill 2020 was enacted as an Act of the parliament in February, 2021. The new act is expected to usher in an era for enhanced administration of Major Ports in India, wherein, the Major Ports will contribute significantly to the economic growth of the country and provide world-class port infrastructure by adopting Landlord Model of development. Under the bill, the Major Ports shall gain autonomy on many key matters including tariffs, development of port assets, master planning of infrastructure within port limits and powers to make regulations for port operations.

Sagarmala Project

In 2015, the Sagarmala programme was approved with the vision to reduce logistics cost for EXIM and domestic trade with minimal infrastructure investment. Aimed at propagating 'Port-led economic growth, the key pillars of the Sagarmala Programme include Port Modernization & New Port Development, Port Connectivity Enhancement, Port-linked Industrialization, Coastal Community Development and Coastal Shipping and IWT.'

Under the Sagarmala Programme, 802 projects at an estimated investment of more than Rs. 5.52 Lac Crore have been identified for implementation up to 2035. Of these, 165 projects (Rs. 86,939 Crore) have been completed and 238 additional projects (Rs. 2.16 Lac Crore) have been awarded and are under implementation.

Pillar wise summary of projects under Sagarmala is given in **Table 9.17**:

Table 9.17
Pillar-wise summary of Sagarmala project

S. No	Project Theme	Total	Completed	Under Implementation
1	Port Modernization	242	74	55
2	Port Connectivity	207	47	80
3	Port Led Industrialization	33	8	22
4	Coastal Community Development	88	18	28
5	Coastal Shipping and IWT	232	18	53
Total		802	165	238

Coal handled at Indian Ports

Sea route is being extensively used for coal transportation. In the year 2019-20, the major ports across the country handled approx. 144 million tonnes of coal. The port wise break-up for the total coal handled (in '000 tonnes) at major ports in India for the year 2019-20 is given in **Table 9.18**:

Table 9.18
Coal handled at Indian Ports (Thousand tonnes)

Ports	Coal (Thousand tonnes)			
	Thermal Coal	Coking Coal	Other Coal	Total
SMP, Kolkata (KDS)	-	286	1614	900
SMP, Kolkata (Haldia)	2359	7680	7532	17571
Paradip	27003	11995	129	39127
Visakhapatnam	821	7552	9749	18122
Kamarajar	19313	953	-	20266
Chennai	-	-	-	0
V.O. Chidambaranar	7190	61	6012	13263
Cochin	-	-	-	0
New Mangalore	-	10	5133	5143
Mormugao	1550	7936	-	9486
Mumbai	2335	-	-	2335
J.N.P.T.	-	-	-	0
Deendayal	16821	1040		17861
TOTAL:	77392	37513	29169	144074

Mechanisation of Ports

Mechanisation of ports is under various stages of implementation by Ministry of Shipping. Mechanisation Status of major ports is given in **Annexure 6**.

9.4.2. Inland Waterways

To promote inland water transport in the country as an economical, environment friendly and supplementary mode of transport to rail and road, 111 inland waterways were declared as national waterways by the National Waterways Act, 2016.

Five national waterways are at advanced stage of development. Their brief status is given below.

- **National Waterway (NW) – 1**

Government is implementing the Jal Marg Vikas Project (JMVP) at an estimated cost of Rs. 5369.18 cr. for capacity augmentation of navigation on National Waterway -1 (NW-1) on the Haldia - Varanasi stretch of Ganga-Bhagirathi- Hooghly River System with the technical and financial assistance of the World Bank. The project is scheduled to be completed in 2022-23. Five locations for Ro-Ro terminals have been identified on the waterway.

- **National Waterway (NW) – 2**

The river Brahmaputra having a length of 891 Km between Bangladesh Border and Sadiya was declared as NW-2 in 1988. The existing infrastructure includes high & low-level jetties at Pandu with railway connectivity, Ro- Ro terminal at Dhubri, 11 floating terminals and Navigational aids. Development has been undertaken with renewed works which include - Cargo & Ro-Ro terminals at Dhubri & Hatsinghimari, Slipway at Pandu.

- **National Waterway (NW) – 3**

West Coast Canal from Kottapuram to Kollam (168 KM) together with Champakara canal (14 Km) and Udyogmandal canal (23 KM) was declared as NW-3 in 1993. The National Waterways Act 2016 included stretch of West Coast Canal from Kottapuram to Kozhikode for a length of 165 km, thereby extending the total length of NW-3 to 370 km. IWAI has constructed nine permanent terminals along the waterway.

- **National Waterway (NW) – 4**

NW-4 was declared in 2008 for the length of 1,078 km comprising of the Kakinada-Puducherry stretch of canals and the Kaluvelly Tank, Bhadrachalam Rajahmundry stretch of river Godavari and Wazirabad Vijayawada stretch of river Krishna in Andhra Pradesh & Tamil Nadu. With the notification of the National Waterways Act 2016, the total length of NW-4 got extended to 2,890 km

- **National Waterway (NW) – 5**

NW-5 will provide connectivity between Paradip/ Dhamra Ports and Kalinganagar Industrial cluster (Pankapal) in Phase I and Mahanadi Coal Field Ltd. (Talcher) in Phase 2.

Out of the remaining 106 national waterways, 23 have been found to be suitable for cargo transportation. Out of the 23 waterways identified for cargo movement, the development activity on the following eight waterways has started.

- i. River Barak (NW-16) in Assam

- ii. River Gandak (NW-37) in Bihar
- iii. Cumberjua (NW-27) in Goa
- iv. Mandovi (NW-68) in Goa
- v. Zuari (NW-111) in Goa
- vi. Alappuzha-Kottayam-Athirampuzha Canal (NW-9) in Kerala
- vii. River Rupnarayan (NW-86) in West Bengal
- viii. Sunderbans (NW-97) in West Bengal

Coal handled by Inland Waterways

The amount of coal being handled by NWs has been increasing at an annualised CAGR of about 17%. The details of transportation of coal (thousand MT) on NWs for FY2018-19, FY 2019-20 and FY 2020-21 (till January 2021) are given in **Table 9.19**: -

Table 9.19
Coal handled by Inland Waterways (thousand metric tonnes)
FY 2018-19

S.No.	National Waterways No.	Total Export	Total Import	Grand Total
1	NW – 10 (Amba River)	155	7997	8152
2	NW-68 (Mandovi River)	-	36	36
3	NW -83 (Rajpuri Creek)	-	37	37
4	NW -85 (Revadanda Creek-Kundalika River System)	-	1060	1060
5	NW – 91(Shastri River-Jaigad Creek System)	161	1474	1635
6	NW-100 (Tapi River)	-	7991	7991
7	NW-111 (Zuari River)	-	51	51
Total (FY 2018-19)				18962

FY 2019-20

S.No.	National Waterways No.	Total Export	Total Import	Grand Total
1	NW-10 (Amba River)	-	11043	11043
2	NW-68 (Mandovi River)	-	402	402
3	NW-85 (Revadanda Creek-Kundalika River System)	-	1188	1188
4	NW-91(Shastri River- Jaigad Creek System)	103	-	103
5	NW -100 (Tapi River)	-	9016	9016
Total (FY 2019-20)				21752

FY 2020-21

S.No.	National Waterways No.	Total Export	Total Import	Grand Total
1	NW-1 (Ganga-Bhagirathi-Hooghly River System)	1586	293	1879
2	NW-2(Brahmaputra River)	-	2	2
3	NW-10 (Amba River)	-	8636	8636
4	NW -68 (Mandovi River)	-	3	3
5	NW -85 (Revadanda Creek –Kundalika River System)	-	420	420
6	NW-91(Shastri River-Jaigad Creek System)	4940	4112	9052
7	NW-100 (Tapi River)	4669	1153	5822
8	NW -111(Zuari River)	-	262	262
Total (FY 2020-21)				26076

9.4.3. Rail Transportation

Indian Railways play a crucial role in development of power sector in India. India’s railway network is the 4th largest in the world totaling to more than 70,000 km. Apart from enabling transportation of fuel (coal, lignite etc.) from the mines to the power plants, railways also provide an alternative route for transportation of heavy equipment over long distances.

Dedicated Freight Corridor

The Dedicated Freight Corridor (DFC) is the most ambitious and biggest ever infrastructure project in the Railways. DFC project is aimed at providing better transportability to Railway’s freight customers. Under DFC, separate high-speed railway lines have been laid over selected routes having high freight traffic.

DFC is aimed to be constructed along the golden quadrilateral routes. The golden quadrilateral route is only 16% of the total length of IR but caters to 52% of passengers and 58% of the freight traffic. The Construction of DFC is in advanced stage. While both Eastern and Western DFCs are targeted to be completed by June 2022, the work for preparation of DPRs for the East Coast, North-South & East-West sub-corridors is underway.

The following DFC corridors are under implementation.

- 1) The Eastern DFC (1856 kms): Ludhiana (Punjab) – Dankuni (West Bengal).
- 2) The Western DFC (1506 kms): New Mumbai (Maharashtra) – Dadri (UP).

Detailed Project Report (DPR) for the following corridors is under preparation.

- 1) East Coast corridor: Kharagpur – Vijayawada
- 2) East-West sub-corridors:

- (i) Bhusaval – Wardhan – Nagpur – Rajkharswan – Kharagpur – Uluberia – Dankuni
 - (ii) Rajkharswan – Kalipahari – Andal
- 3) North – South sub-corridor: Vijayawada – Nagpur – Itarsi

DFC will offer higher transport output in the country with reduced transit time & cost.

Rail Connectivity of Major Ports

Availability of railways near ports enables last mile connectivity for transport of cargo. A number of projects have been undertaken by MoR with private participation, for enhancing the rail connectivity of ports as given in **Table 9.20**.

Table 9.20
Projects undertaken by MoR with private participation for rail connectivity of ports

S.	Project name	State	Implementing Agency - SPV	Kms	Completion	Participating agencies
1	Surendernagar Pipavav (GC)	Guj.	Pipapav Rail Corp Ltd (PRCL)	271	2003	MoR, GPPL, IL&FS, GIC, NIA
2	Hassan Mangalore (GC)	Kar.	Hassan Mangalore Rail Development Corp Ltd (HMRDC)	183	2006	MoR, GoK, KRIDE, New Mangalore port trust, MEL
3	Bharauch Dahej (GC)	Guj.	Bharuch Dahej Rail Co Ltd (BDRCL)	63	2012	RVNL, GMB, Dahej SEZ Ltd, GNFC, AdaniPetronetDahej Port, Hindalco, Jindal Rail Infrastructure, GIDC
4	Krishnapatnam - Venkatachalam – Obulavaripalle (NL)	A.P.	Krishnapatnam Rail Co Ltd (KRCL)	113	July 2019	RVNL, Sagarmala Development Corp Ltd, Krishnapatnam Port Company Ltd, Govt. of A. P, NMDC Ltd, Brahamani Industries
5	Haridaspur Paradip (1996-97) (NL)	Odisha	HaridaspurParadip Railway Co Ltd (HPRCL)	82	Aug 2020	RVNL, GoO, Paradip Port Trus, Essel Mining, JSPL, Rungta Mines Ltd, OMC, MSPL, SAIL, IDCO

Apart from these, currently other railway projects are under implementation by MoR which are significant from coal evacuation point of view.

- 1) A total of 14 projects which are jointly monitored by Ministry of Railways and Ministry of Coal are given in **Annexure 3**.
- 2) There are 51 projects which have been prioritised by Chairman & CEO, Railway Board (CRB) are given in **Annexure 4**.

It is recommended that Capacity augmentation may be explored for the following.

- East Central Railway (ECL) to East Coast Railway (ECoR) - Railway traffic congestion in coal rake movement has been observed in the route ECL to ECoR due to simultaneous coal rake movement towards ports and rake movement in the coal-based power plants under ECoR and in the southern states of the country.
- In the Jabalpur division capacity augmentation may be explored in view of Railway traffic congestion observed in the route for movement of the rakes.

9.4.4. Road Transportation

India has an extensive road network of 1,34,381kms of national highways. Further 14,382kms are under construction at different phases of execution.

Bharatmala Project

In 1998, the Government of India announced the National Highways Development Project (NHDP) comprising of the Golden Quadrilateral and other projects in Phase-I, and North South & East West Corridors in Phase II. The Government of India has entrusted NHAI the responsibility of implementing a greatly expanded National Highways Development Project (adding Phase III to VII) with an investment of about Rs. 2,20,000 Crore. Subsequently, balance works of various phases of balance NHDP has been subsumed under “Bharatmala Pariyojana” Phase-I which includes, developing the road connectivity to Border areas, development of Coastal roads including road connectivity for Non-Major ports, improvement in the efficiency of National Corridors, development of Economic Corridors, Inter Corridors and Feeder Routes along with integration with Sagarmala under proposed Bharatmala Pariyojana.

ODC Movement

ODC movement has been highlighted as a major constraint in the last NEP. A cargo may be over dimensional (ODC) depending on any of its dimensions including length, breadth and height while a cargo with extra weight is classified as Over Weight Cargo (OWC).

MoRTH has institutionalised an online application system in January 2015 for obtaining permission for cargo movement by the transporters. There is a system of online approval and quick fee payment after the details are entered by the transporter. However, at present the system is able to grant the permission online for cargo less than 169 Tons. If the cargo weight is more than 169 Tons or certain distressed bridges are involved, the approval of concerned RO is required through the offline route. It is understood that on completion of Indian Bridge Management System (IBMS), which is under development, the process of online approvals could be expanded. Some necessary conditions for the movement of ODC/OWC as shared by MoRTH are mentioned in **Annexure 5**.

Road Connectivity of Major Ports

Availability of roads near ports provide last mile connectivity to the sea cargo being transported onto land. All the major ports in the country are connected by at least one national highway. List of National Highways near Ports are as given in **Table 9.21**.

Table 9.21
List of National Highways near Ports

S. No.	PORTS	State	NH near Port
1	SMP, Kolkata (KDS + HDC)	West Bengal	12, 115
2	Paradip	Odisha	53
3	Visakhapatnam	Andhra Pradesh	16
4	Kamarajar	Tamil Nadu	16
5	Chennai	Tamil Nadu	716, 32, 48
6	VO Chidambaranar	Tamil Nadu	38, 138
7	Cochin	Kerala	966A, 966B, 66
8	New Mangalore	Karnataka	66
9	Mormugao	Goa	366
10	Mumbai	Maharashtra	48
11	JNPT	Maharashtra	348, 348A
12	Deendayal	Gujarat	141

9.4.5. Natural Gas: LNG Regasification & Gas Pipelines

LNG Regasification

At present the country is having six (6) operational LNG re-gasification terminals operational with capacity to the tune of 42.5 MMTPA. In CY 2020, total imports in India were around 26.4 MMTPA, as per IHS market. Accordingly, average utilization (considering nameplate capacity) of LNG terminals in India is 62%. Further, LNG terminal wise utilization is as given in **Table 9.22**:

Table 9.22
Capacity of RLNG terminals in India

S.No	Location	Owner/operator	Capacity (MMTPA)	Capacity Utilization in CY 2020
1	Dahej (Gujarat)	PLL	17.5	93%
2	Hazira (Gujarat)	SHELL	5	96%
3	Kochi (Kerala)	PLL	5	18%
4	Dhabol (Maharashtra)*	GAIL (KLPL)	5	35%
5	Mundra (Gujarat)	GSPC LNG Ltd	5	11%
6	Ennore (Tamil Nadu)	IOCL	5	43%
Total Capacity (MMTPA)			42.5	62%

*the name plate capacity is 5 MMTPA but in absence of the break-water, the terminal can only operate at 1.7 MMTPA

Data from Annual reports of PLL & IOCL 2019-20, LNG Market Data Sheet: India by IHS Market.

Gas Pipelines

Efficient operation of gas pipelines is important for successful running of Gas based thermal power plants. In recent past, gas power plants have been running at low PLF of around 23%. However, the low PLF is not due to lack of gas pipeline infrastructure, but due to unavailability of cheap sources of natural gas. At present, around 18,161 Km long pipeline is under operation in the country of which 13,560 km is operated by GAIL. Capacity Utilization of Gas Pipelines of GAIL varies from pipeline to pipeline. Average pipeline capacity utilization for GAIL network during FY2020-21 is around 47%.

For further capacity strengthening, around 16,200 km long pipeline network is under construction of which 6,000 kms of pipeline is being executed by GAIL. Efforts are underway to complete the gas grid in time bound manner. State-wise details of existing & under construction gas pipeline are given in **Annexure – 7**

GAIL has connected various power plants with its pipelines across the country. However, due to reasons like non-availability of low-priced gas many gas power plants are stranded / underutilized. Total gas consumed by the gas-based power stations in the country in the year 2019-20 was 30 MMSCMD at a PLF of approx.23% by an installed capacity of approx. 24 GW.

As per PNGRB regulations, 25% of the pipeline capacity is required to be offered on common carrier basis i.e. for capacity for a period of less than one year. The details of available common carrier capacity in various GAIL pipelines is available on GAIL website. Any Shipper including power plants desirous of booking common carrier capacity in GAIL's pipeline can access the open access portal of GAIL. In case of capacity booking requirement with term exceeding one year, the same is undertaken at mutually agreed terms between shipper and transporter.

Status of International pipelines of India

GAIL under the aegis of Government of India has been pursuing the TAPI pipeline project. In this regard, two Govt. level agreements (Inter Governmental Agreement and Gas Pipeline Framework Agreement) have been signed. The FEED studies of the pipeline, survey field works and land acquisition planning have been completed. TPCL (TAPI Pipeline Company Ltd, incorporated in November 2014) has also signed bilateral Pleads of Terms of the Host Government Agreements with Governments of Afghanistan and Pakistan. Typically, such international pipelines take lot of time in fructification.

9.5. Land and Water requirement

9.5.1. Land

The land required for development of a power plant varies with the type of technology used, site geography, size of power plant, location, topology and several other factors. However, for a

typical power plant in each technology the following estimates as given in **Table 9.23** have been considered.

Table 9.23
Land requirement for different technologies

S.No.	Source Type	Land Requirement (Acre/MW)		
		Lower Estimate	Upper Estimate	Median Estimate
1	Thermal ⁺	0.67	1.09	0.88
2	Nuclear [^]	0.20	0.66	0.60
3	Hydro	0.50	10.00	5.00
4	Solar	3.90	4.10	4.00
5	Wind	1.50	2.00	1.75
6	Biomass [*]	5.00	7.00	6.00
7	Small Hydro [#]	1.00	2.47	1.60

+ For pithead plants [^]lower estimate for coastal plants ^{*}includes area for fuel storage [#]varies with whether project is on canal fall/dam toe/hill; excludes area for transmission development

Note: 1 sq. km = 247 acre 1 hectare = 2.47 acre 1 acre = 4047 sq. m

Variation in land requirement is especially high in case of hydroelectric plants, because of the following features that leads to large variations in the design of the plant.

- a) The amount of Submergence involved.
- b) Surface/ Underground Structures involved.
- c) Spread / Concentrated (Dam-Toe) Scheme.
- d) Resettlement and Rehabilitation involved and Compensatory Afforestation (in lieu of Forest Land) involved.

Land Acquisition Issues

Land acquisition has been conventionally fraught with several challenges, which continue to affect major development projects in the country. The major issues regarding land acquisition for power plants are as follows: -

- Lack of proper land records,
- Lack of clarity about the status of occupiers/ encroachers on Govt. land/ Forest Land leading to issues related to compensation
- Right of User (ROU) for Pipelines, Right of Way (ROW) for Transmission lines sometimes face resistance from local people with demands for higher compensation.
- MOEF&CC clearance.
- Wide variation from State to State in cost implications (land premium, cess, lease rent).
- Rehabilitation & Resettlement of the Project Affected Families (PAFs).

Land considerations for Solar Power plants

Land is the most important resource, after Solar Irradiation, for Solar power plant. Due to the advent of high wattage PV modules (450Wp and above) the Land requirement has come down to minimum 20% and has reduced from more than 5 Acre/MW to 4 Acre/MW usable land for large ground mounted Solar PV Power Plants.

However, there are issues pertaining to the availability of land and to the legal issues of land transfer. As of now primarily waste land, arid land and land in the remotest regions of the country with good solar radiation is being utilised for installing large ground mounted solar power plants. Going forward other avenues such as floating, roof-top, & canal-top solar etc. for installing solar PV Modules need to be explored.

Floating Solar PV (FSPV) project comprises solar modules on floating platform which are, anchored or moored and placed on top of the water surface. Floating solar can be deployed on various types of water bodies including industrial water ponds, irrigation or drinking water reservoirs, abandoned quarry lakes, aquaculture ponds, canals, and dams.

Floating Solar PV offers other benefits apart from saving in land-

- i. The cooling effect of water on the installed PV modules helps to reduce thermal losses which increases the efficiency of panels. Plant operators claim higher efficiencies in the range of 5-16% from floating solar power plants compared to land based PV plants.
- ii. While land disputes including multiple owners are much prevalent, it is expected that the water bodies shall have no problem on these accounts. Also, the water evaporation losses tend to be less by as much as 40% and therefore very useful for water stressed areas.

Solar plants installed on rooftops of institution, universities, housing societies and commercial building and canal tops can be utilized at the distribution level.

Water

Water is consumed in power generation from thermal power plant mainly on account of cooling purposes.

Over the years, considerable technology improvements have been made, to reduce water consumption in the stations. The consumptive water requirement which used to be about 7m³/MWh in the past, been optimized by various technological interventions & water conservation practices, and has been brought down to 3.0 m³/ MWh in present day stations. As per the new environmental Regulations issued by MOEF&CC in Dec-2015, all new stations to be installed after 1st January, 2017, shall be required to meet specific water consumption up to maximum of 3.0 m³/ MWh without FGD. These norms are, however, not applicable to the Thermal Power Plants using sea water.

Since, the availability of water is going to be a concern in operation of thermal power projects in the future, efforts need to be made to access the feasibility of adopting air cooled condensers, especially in areas with shortage of water.

Solar

In PV power plants, water is required mainly to clean the modules. The estimated water requirements per MW is 3,000 Litres, for one cleaning cycle. In general, cleaning frequency is 2 times in a month. Thus, water requirement for 1MW plant is ~ 6000 Litres/ month. The water usage varies with respect to the soiling conditions (location dependent), PV module size, frequency of cleaning of PV modules, and cleaning method. Currently, India doesn't have specified norms/ standards to limit the usage of water in solar power plants. However, for modern solar power plants, the PV industry is moving towards dry cleaning with robots thus reducing the water requirement drastically.

9.6. Conclusions & Recommendations

- a. With the thrust of Government on clean energy (Renewable Energies Sources), the conventional fossil-based power plants have to play supporting role. Despite the above development, thermal power plants will continue to play a stabilising role in the electricity grid. Being the oldest and most widely adopted technology, there are little infrastructural challenges in thermal power development. However, for compliance of new environment norms suppliers should continue to explore indigenous sources/alternatives for required materials.
- b. In case of hydro power plants, while equipment availability is not a constraint, there is dearth of competent and resourceful civil contractors in the country to execute the Major Works of hydro power plants. Many of the available Civil Contractors that have wide experience in execution of Hydro Projects are facing a financial crunch. This and other systemic challenges in hydro power (e.g. geological surprises, R&R etc.) need urgent redressal, if hydro-sector has to keep pace with other technologies.
- c. For timely execution of the hydro power projects, it is recommended that the requirement of the construction agencies may be suitably included in the Detailed Project Report (DPR). Further, regarding the difference in estimated material requirement in the initial DPR and that during the actual project execution of hydro power projects, a study may be conducted by relevant agencies in order to reduce this gap.
- d. As brought out in the capacity addition plan, most of the capacity addition is expected to happen in the renewable energy sector. The capacity addition in fossil-based generation is small in comparison to the Renewable Energy Sources. Further, whatever small capacity addition is expected to happen in coal, it is expected to take place in existing TPP hotspot areas. Hence, the infrastructure development for renewable energy projects shall be given due importance in coming years.
- e. In case of thermal power projects, while the BTG equipment market is fully developed, there are new challenges in terms of full indigenisation of FGD and SCR. Further,

special emphasis may be given on indigenous development of Dry Bottom Ash Handling system, High Concentration Slurry Disposal (HCSD) pumps and Air-Cooled Condensers (ACC). ACC becomes increasingly important as the country tries to reduce the water consumption of its thermal power plants.

- f. In recent years, Solar PV deployment has been stepped up in a big way. The trend is expected to continue. However, the country is highly dependent on imported solar cells and wafers for keeping pace with the solar capacity addition targets. More focus shall be given on increasing the production capacity of Indian solar equipment manufacturers.
- g. Transportability is a major concern for wind power projects as the main components (Blade, tower etc) are usually over-dimensional. Adding to the difficulty is the usual remote location of wind power plant sites. Improving last mile connectivity via road and highway development near probable high wind sites can accelerate the pace of wind power capacity addition. Extending the functionality of online over dimensional (ODC)/Over Weight Cargo (OWC) portal would assist in faster movement of all heavy equipment.
- h. Government of India has given special push towards improving transportability of commercial cargo, equipment and materials across sectors. The Bharatmala Pariyojana aims to be the subsequent achievement in road transportation after the Golden Quadrilateral. Similarly, the progress towards developing Dedicated Freight Corridors (DFCs) by the Indian Railways is expected to be a big boost to faster & more economical transportation across long distances.
- i. While all 12 major ports are well connected through national highways, effort are underway to extend similar connectivity to over 200 minor ports along the Indian coast. This along with several other initiative like port mechanisation are encapsulated in the Sagarmala Pariyojana of GoI. Identification of 111 National Waterways by GoI shows the potential of this growing mode of transport.
- j. Gas power plants work on an established conventional technology and are more flexible than coal/ lignite/ nuclear power plants. In this regard, commercial and regulatory bottlenecks in enhancing consumption of natural gas in power sector be taken care of to help gas-based power act as balancing power, together with renewables-based power. Use of combination of domestic gas, imported LNG and APM/Non-APM gas may be examined for optimum pricing of power produced.
- k. Large scale land is required for construction of thermal, nuclear, hydro and renewable power plants. Land acquisition continues to be fraught with challenges. While rehabilitation & resettlement is a major issue for hydro power plants, availability of land records for remote locations and issues like Right of Way & Right of Use need to be resolved in amicable manner.

- I. Water is becoming an increasingly scarce resource. Water usage is comparatively higher in thermal power plants as compared to other sources. Efforts towards adoption of low water use technologies like ACC, HCSD, Dry Bottom Ash systems need to be envisaged. Similarly, in view of the large-scale capacity addition in solar PV, innovations methods like dry-cleaning/ robotic cleaning of panels/modules need to be encouraged with the objective of reducing the water usage.

DRAFT

CHAPTER 10

EMISSIONS FROM POWER SECTOR

10.0 INTRODUCTION

The phenomenal growth in demand for energy is increasingly affecting the natural environment. Human activities now occur on a scale that has started to interfere with complex natural systems. Anthropogenic activities such as energy generation from fossil fuels, industrialization and deforestation have been increasing the atmospheric concentration of Green House Gases (GHGs) above their natural levels resulting in Global climatic change. Excessive concentration of Green House Gases like Carbon di-oxide (CO₂) and Methane (CH₄) and other harmful emissions in the atmosphere has become one of the most critical global environment issues by which human life is gravely threatened.

In most of the developing countries, the major requirement of power is met through thermal power plants. India also depends largely on coal as a major source of energy for producing power and coal may continue to play an important role in producing power in near future. As on 31.03.2022, coal based power generation capacity is around 52.74% of total installed capacity, however during 2021-22 coal based generation was almost 69.8 %of total power generation in country and lignite based power capacity is about 1.65% as on 31.03.2022 of the total installed capacity but generates almost 2.48% of total power generation in country during 2021-22.

Generation of power by use of fossil fuel like coal, oil and gas pollutes the atmosphere in many ways. Emission of particulate matter and generation of fly ash from coal based power stations are local health hazard. Gaseous emissions from fossil fuel based power generation like CO₂, SO_x, NO_x and Mercury etc. affect the local as well as global climate.

10.1 EMISSION FROM THERMAL POWER STATIONS

Fossil fuel-fired power plants burn fossil fuels like coal, lignite, natural gas, diesel etc. to generate steam/ hot air to run turbines generating electricity. The generation of power from combustion of fossil fuels has an impact on Air, Water and Land resulting in degradation of local as well as global environment.

The major types of pollutants emitted from thermal power stations are as follows:

10.1.1 Air Pollution

The following major air pollutants are generated from combustion of fossil fuels by thermal power stations: i) Nitrogen oxide(NO₂) ii) Sulphur di-oxide (SO₂) iii) Green House Gases like CO₂ iv) Suspended Particulate Matter (SPM) v) Mercury Emissions. Traces of Carbon monoxide (CO) is also produced during the process of combustion. The brief description of major pollutants and their effects are detailed below:

10.1.1.1 Nitrogen Oxide

Most of the NO_x is emitted as NO which is oxidised to NO₂ in the atmosphere. All combustion processes at high temperature are sources of NO_x emission. Formation of NO_x may be due to oxidation of nitrogen in the air (thermal NO_x) or due to nitrogen present in the fuel (fuel NO_x). In general, higher the combustion temperature the higher NO_x is produced. Some of NO_x is oxidised to NO₃, an essential ingredient of acid precipitation and fog. There were no existing norms for control of NO_x. However, new norms notified by Ministry of Environment, Forest and Climate Change has stipulated norms for NO_x control, which are discussed later in the chapter.

10.1.1.2 Sulphur Oxide

The combustion of sulphur contained in the fossil fuels, especially coal and oil is the primary source of SO_x. About 97% to 99% of SO_x emitted from combustion sources is in the form of Sulphur Di-oxide which is a critical pollutant, the remainder is mostly SO₃, which in the presence of atmospheric water is transformed into Sulphuric Acid at higher concentrations, produce delirious effects on the respiratory system. The SO_x emissions are controlled by providing tall height stack for dispersion. Higher size units of 500 MW and above were also required to keep space provisions for future installation of Flue Gas de-sulphurisation (FGD) system when required. In specific cases, installation of FGD system has been stipulated by MOE&F while granting environmental clearance. The new norms notified by Ministry of Environment, Forest and Climate Change has stipulated emission norms for SO_x which are discussed later in the chapter.

10.1.1.3 Green House Gases

A number of gases like CO₂, Methane, nitrous oxide(N₂O), Chlorofluorocarbons and water vapour are called Green House Gases. Carbon dioxide is released primarily through the burning of fossil fuels. It is generated by combustion of coal and hydrocarbons. Methane is released through the decomposition of organic matter (marshes, cattle raising, rice flakes etc.) and the use of fossil fuels.

10.1.1.4 Particulate Matter

The terms particulate matter, particulates, particles are used interchangeably and all refer to finely divided solids dispersed in the air through chimney or stack of power stations. Norms have been stipulated by Ministry of Environment, Forest and Climate Change for control of Suspended Particulate Matter and are more stringent for new power plants.

10.1.1.5 Carbon Monoxide

It is a colourless, odourless flammable and toxic gas. It has ability to react with haemoglobin in the blood and reduce the oxygen absorbing capacity of the blood. It is generated by

incomplete combustion of coal and hydrocarbons. The most significant source of CO is automobiles.

10.1.1.6 Mercury Emissions

Emissions of mercury from thermal power stations are a subject of increasing concern because of its toxicity, volatility, persistence, long range transport in the atmosphere. Once released into the environment, mercury contaminates soil, air, surface and ground water. The mercury emitted from coal-fired power plants originates from the mercury present in the coal. Typically, mercury is present in the coal in the tens of parts-per-billion range. Burning of enormous quantity of coal for power generation makes it the largest anthropogenic source of mercury emissions.

10.1.2 Water Pollution

Water pollution refers to contamination of natural water, whereby its further use is impaired. The contamination could be caused by the introduction of organic or inorganic substances in the water or due to change in the temperature of the water.

In thermal power stations the source of water is river, lake, pond or sea from where water is usually taken. There is possibility of water being contaminated from the source itself. Further contamination or pollution could be added by the pollutants of thermal power plant waste as inorganic or organic compounds.

The types of water pollution & its sources are given in **Table 10.1**.

Table 10.1
Types of Water Pollution & its Sources

	Type	Sources
(i)	Thermal pollution	- Discharges from condenser
(ii)	Carryover of ash to water bodies	- Ash pond overflow, ash handling area drainage
(iii)	Acid or alkaline effluents	- DM water treatment plant, chemical storage area & lab
(iv)	Leaching and water percolation	- Ash dumps, ash ponds
(v)	Heavy metals	- Air heater wash, wash water from boiler fire side clearing
(vi)	Toxic substances, high total dissolved solids (TDS) , Phosphates high alkaline, ammonia	- Boiler blowdown
(vii)	sludge and oil	- Drains from fuel oil area, tube oil area, transformer oil off
(viii)	Cyanide and other chemicals	- Radio graphic lab
(ix)	Bacteriological pollution	- Sanitary & domestic waste

The effects of water pollutants are manifold and depend on the type and concentration. Some of these are given below in **Table 10.2**.

Table 10.2
Effects of Water Pollution

	Pollutants	Effects
a	Soluble organic as represented by BOD(Biological Oxygen Demand)	Deplete oxygen in surface water, Fish killing, the growth of undesirable aquatic life and odours Certain organics can be bio-magnified in the aquatic food chain
b	Suspended solid	Decrease water clarity and hinder photosynthesis, form sludge deposits which changes eco-system results.
c	Chloride	Salty taste in water
d	Acidic, alkaline and toxic substances	Cause fish killing also can cause imbalance in stream eco-system
e	Disinfectants Cl ₂ , H ₂ O ₂	Killing of micro-organisms
f	Ionic forms Fe, Ca, Mg, Mn, Cl and SO ₄	Changed water characteristics, staining hardness, salinity

All discharge from thermal power stations to water bodies is made after treatment as per the environmental standards prescribed by MOE&F. Further, ash ponds are High Density Polyethylene (HDPE) lined to prevent leaching etc. Also zero discharge system with no discharge to water body are envisaged at many stations installed up to 31.12.2016 and mandatory zero waste discharge for TPPs installed after 01.01.2017

10.1.3 Fly Ash Generation

Indian coal is of low grade with ash content of the order of 30%-50 % in comparison to imported coals which have low ash content of the order of 10%-15%. Large quantity of ash is thus being generated at coal/lignite based Thermal Power Stations in the country, which not only requires large area of precious land for its disposal but is also one of the sources of pollution of both air and water. To reduce the requirement of land for disposal of fly ash in ash ponds and to address the problem of pollution caused by fly ash, Ministry of Environment, Forests and Climate Change has issued various Notifications on fly ash utilization, first Notification was issued on 14th September, 1999 which was subsequently amended in 2003, 2009 and 2016 vide Notifications dated 27th August, 2003, 3rd November, 2009 and 25th January, 2016 respectively. The Notification of 3rd November, 2009 prescribes targets of Fly Ash utilization in a phased manner for all Coal/Lignite based Thermal Power Stations in the country so as to achieve 100% utilization of fly ash.

The MoEFCC Notification of 25th January, 2016 stipulates mandatory use of flyash based products in all Government schemes or programmes e.g. Pradhan Mantri Gramin Sadak Yojana, Mahatma Gandhi National Rural Employment Guarantee Act, 2005, Swachh Bharat Abhiyan, etc.

The latest MoEFCC notification dated 31.12.2021 stipulates 100 per cent utilisation of fly ash generated by coal or lignite based thermal power plant in an eco-friendly manner namely: (i) Flyash based products viz. bricks, blocks, tiles, fibre cement sheets, pipes, boards, panels; (ii)

Cement manufacturing, ready mix concrete; (iii) Construction of road and fly over embankment, etc. The notification also mandates that if the coal or lignite based thermal power plant has not achieved at least 80 per cent ash (fly ash and bottom ash) utilisation in the first two years of a three years cycle, then an environmental compensation of Rs. 1000 per ton on unutilised ash shall be imposed for non-compliant thermal power plants.

10.1.4 Land Degradation

The thermal power stations are generally located on the non-forest land and do not involve much Resettlement and Rehabilitation problems. However, its effects due to stack emission etc., on flora and fauna, wild life sanctuaries and human life etc. have to be studied for any adverse effects. One of the serious effects of thermal power stations is land requirement for ash disposal and hazardous elements' percolation to ground water through ash disposal in ash ponds.

10.2 STEPS TAKEN BY THERMAL POWER STATIONS TO REDUCE EMISSIONS FROM POWER PLANTS

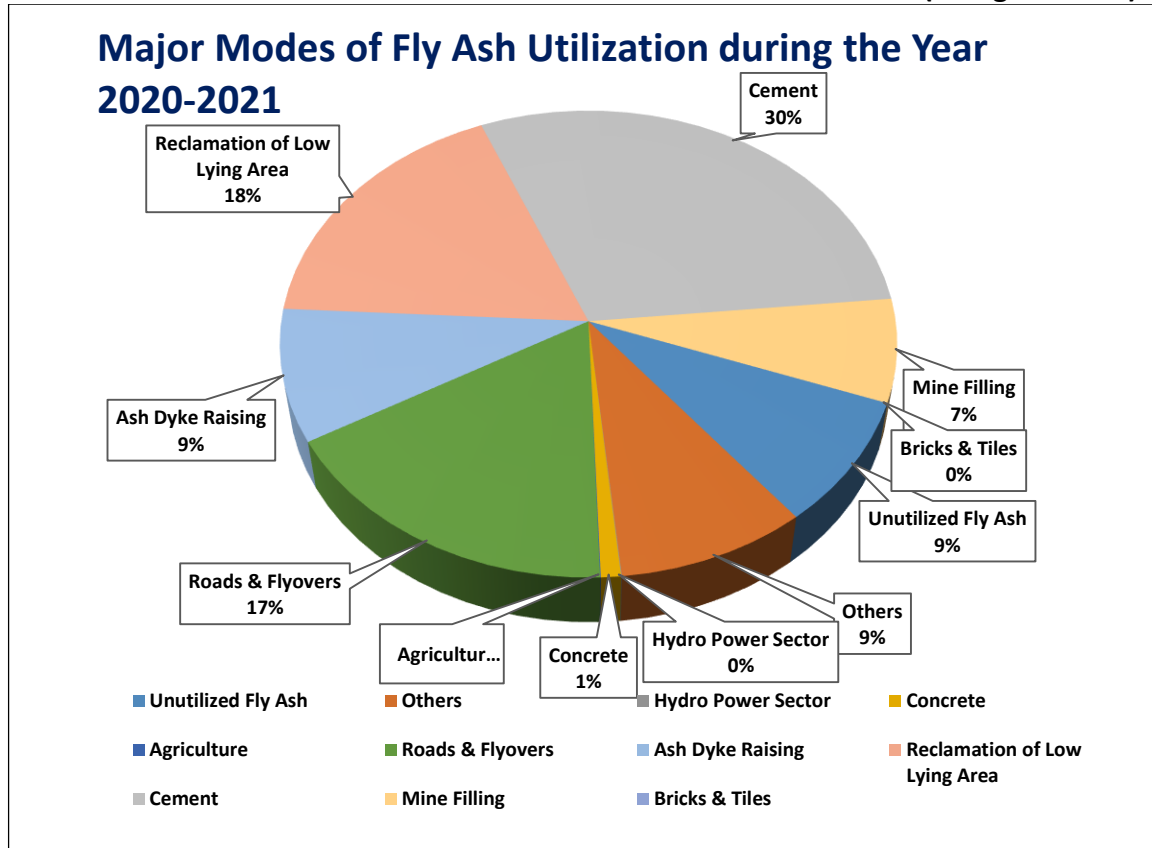
Following steps are presently being taken by power utilities to reduce the pollution from thermal power stations:

- **PM Emissions:** - High Efficiency Electrostatics Precipitators (ESP) are installed in the power station to arrest fly ash and reduce suspended particulate matter within the prescribed emissions norms. A PM norm stipulated by MOEF & CC are generally adhered to by coal based power stations. However, depending upon the local condition, Pollution Control Board or other implementing agencies within the provision of Environment Protection Act has stipulated more stringent norms.
- **NO_x Control:** - Low NO_x burners are being used in the power station for NO_x control through primary combustion control. Further, NO_x emission norms as specified by MoEFCC notification dated 7.12.2015 is required to be met by TPPs and as amended.
- **SO_x Control** – Indian coal used in the thermal power station generally has low sulphur content about 0.3% to 0.5% and SO₂ control is being achieved as per new norms specified by MOEF & CC notification dated 07.12.2015.
- **Liquid Effluent Discharge:** - Effluent Treatment Plant is being installed to control parameters like pH, Free available Chlorine Suspended solids, Oil & Grease, Copper, Iron, Zinc, TDS & Total Suspended Solids. Many power stations have achieved zero liquid discharge. Most of the power plants are adhering to the norms stipulated.
- **Fly Ash Utilization:** - The steps have been taken by Thermal Power Stations to ensure 100% utilization of ash generated by them. The Fly ash collected in the dry form is being used for brick making, coal mines backfilling, road construction and cement manufacturing. Data of 202 coal based thermal stations, with an Installed capacity of 209990.50 MW, consuming coal of 686.34 Million tonnes and generating Fly Ash of 232.56 Million tonnes were

analysed in 2020-21 by CEA. The analysis shows that country has achieved Fly Ash Utilization of 214.91 Million tonnes with percentage utilization of 60.97 % (However, the actual utilization of fly ash may vary from station to station). Fly ash utilisation in various sectors is shown in **Exhibit 10.1**

Exhibit 10.1.

(All figures in %)



• **Mercury emissions:**

India has signed Minamata convention on legally binding instrument to protect human health & environment from adverse effects of Mercury in September 2014. Article 8 of the Minamata convention pertains to reducing mercury emissions to the atmosphere through measures to control mercury emissions from coal based power stations. The studies carried out by CIMFR, Dhanbad on mercury content in Indian coal has estimated mercury emission factor of coal as 0.14 g/tonne or 14ppm. Control systems provided for NOx and SOx (SCR and FGD) along with ESP also offer the co-benefit of mercury emissions control. MOEF & CC vide notification dated 07.12.2015 has put limit of mercury emission from thermal power plants.

10.3 NEW EMISSION STANDARDS FOR THERMAL POWER PLANTS

MOEF&CC has notified new Environment norms for Thermal power station including Emission and specific water consumption on 7th December,2015. The **Table 10.3 and 10.4** show the new environmental norms for thermal power stations which are to be complied at different time schedule.

Table 10.3
New Environmental Norms for Thermal Power Stations

Emission parameter	TPPs (units) installed before 31st December, 2003	TPPs (units) installed after 31st December 2003 and up to 31st December 2016	TPPs (units) to be installed from 1st January 2017
Particulate Matter	100 mg/Nm ³	50 mg/Nm ³	30 mg/Nm ³
Sulphur Dioxide (SO₂)	600 mg/Nm ³ for units less than 500MW capacity 200 mg/Nm ³ for units 500MW and above capacity	600 mg/Nm ³ for units less than 500MW capacity 200 mg/Nm ³ for units 500MW and above capacity	100 mg/Nm ³
Oxides of Nitrogen (NO_x)	600 mg/Nm ³	450* mg/Nm ³	100 mg/Nm ³

*Vide MOEF & CC notification dated 19.10.2020. As per notification dated 31.3.2021 of MoEFCC emission norms are to be implemented by 2022 to 2024 based on location of the power plant.

Table 10.4
MoEFCC WATER NORMS FOR THERMAL POWER PLANTS

S No.	MoEFCC WATER NORMS FOR THERMAL POWER PLANTS
1.	All plants with Once Through Cooling (OTC) shall install Cooling Tower (CT) and achieve specific water consumption of 3.5 m ³ /MWh within 2 years of notification.
2.	All existing CT based plants shall reduce specific water consumption up-to maximum of 3.5 m ³ /MWh within a period of 2 years of notification.
3.	New plants to be installed after 1st January 2017 shall have to meet specific water consumption of 3.0* m ³ /MWh and achieve zero water discharge.

*Vide notification dated 28.06.2018

10.4 IMPLICATIONS OF NEW EMISSION STANDARDS ON POWER SECTOR

After notification of new environmental norms in December, 2015, a detailed phasing plan, for installation of FGD to be completed till 2024 was prepared by CEA in consultation with all stake- holders and was sent to MoEFCC in June,2017. However, subsequently, time line was squeezed by MoEFCC to comply by December, 2022.

CEA started monitoring the implementation of measures to comply with new norms. More than 90% TPPs are installing wet lime stone based FGD system as it is economical. Major

issues/challenges being faced during the implementation of FGD system in thermal power plant are as under:

1. Till the end of 2015 no SO₂ norms were applicable, thus FGD manufacturing capacity was almost non-existent in the country.
2. FGD technology being new to our country, there are at present limited vendors with limited capacity to supply FGD components. Therefore, there is an availability constraint.
3. A sudden surge of demand has arisen as all thermal generating units, about 470 running units of 180 GW capacity, have to implement FGD system in one go. Proper planning was not there for development of infrastructure to meet the demand surge.
4. Although India has the manufacturing capability of 70% FGD components, it depends on the imports from other country as manufacturing capacity is insufficient to cater to huge demand in a short period of time.
5. Balance 30% of FGD component is not manufactured in India. Thus, import from other countries is the only option and to create a manufacturing capability of these items in India would take few years.
6. A huge foreign exchange for importing technology, equipment and skilled manpower from other countries shall be required.
7. Impact of Covid-19 pandemic on planning, placing of order, supply chain of equipment and installation of FGD is severe.

To overcome all the above issues/challenges being faced by power industry, CEA prepared a paper on location specific norms for thermal power plants and suggested a graded action plan for FGD implementation in TPP. The action plan was approved by MOP and forwarded to MOEF&CC for consideration in January, 2021. The summary of the action plan is as given below

1. The target should be uniform ambient air quality across the country and not the uniform emission norms for thermal power plants. Implementation of uniform emission norms in TPPs located in different atmosphere may result in different ambient air quality.
2. Thermal power plants located in an area, where quality of air is very good in terms of SO₂ level, can be exempted from immediate installation of additional equipment to control SO₂ emission from stack. A large number of thermal power stations are located in remote locations away from towns with little habitations around. Thermal power plants located in remote locations, ambient air quality (AQI) can be made as the guiding factor for formulating emission control. This may avoid installation of additional emission control equipment without compromising the ambient air quality.

3. To explore such a feasibility, the 24hr avg.(max) SO₂ ground based measured levels (CPCB, 2018 data) were categorized into 5 distinct levels:
 - i. Level I : >40 µg/m³
 - ii. Level II : 31-40 µg/m³
 - iii. Level III : 21-30 µg/m³
 - iv. Level IV : 11-20 µg/m³
 - v. Level V: 0-10 µg/m³.
4. To achieve tangible results, the SO₂ emission control equipment in the thermal power plants located in level-I should have to be installed on priority basis. The regions as identified under level-II can be covered subsequently under the next phases seeing the performance of FGD system in Level-I. Presently no action is required for the plant located in region under level III/IV/V as the SO₂ level in ambient air of these area is very less and as per CPCB the quality of air is good in regards to SO₂ level.
5. Graded action plan will help in utilizing the resources in effective manner and it will help in fine tuning the technology for local conditions. If the process of emission control is completed in 10-15 years' time frame, and consider thermal power plants located in critically polluted areas in first phase, it will help in developing indigenous manufacturing base, skilled manpower in the country which shall take care of the local operating conditions.

Thereafter, MOEFCC notified G.S.R.243(E) dated 31.03.2021, that the emission compliance would mean all the plant emission norms (2015) for PM/SO₂/NO_x are to be met by the specified timeline (Table II), any deviation in the above norms beyond the timeline would be liable for the levy of emission compensation (EC) as detailed in **Table10.5**.

Table 10.5

S.No.	Category	Location/Area	Timeline for Compliance	
			Non retiring Units	Retiring Units
(1)	(2)	(3)	(4)	(5)
1	Category A	Within 10 km radius of National Capital Region or cities having million plus population.	Upto 31st December 2022	Upto 31st December 2022
2	Category B	Within 10 km radius of Critically Polluted Areas or Non-attainment cities.	Upto 31st December 2023	Upto 31st December 2025
3	Category C	Other than those included in category A and B	Upto 31st December 2024	Upto 31st December 2025

Based on the 31st March 2021 notification, MOEF&CC has constituted a task force comprising of representative from MOEF&CC, MOP, CEA and CPCB to categorize the thermal power plants in above mentioned three categories. The finalization of aforementioned categorization is still under progress and expected to complete very soon. **CEA has prepared “A review report on new SO₂ norms” and submitted to MOP.**

For implementing NO_x control, coal based power stations have to carry out combustion modification/to install Selective Catalytic Reduction (SCR) as NO_x emissions are in range of 600-1000 mg/NM³. The main challenge with SCR is that they have not been proven for high ash Indian Coal. Also space constraint/layout constraints is also expected to be a major challenge for installation of SCR. Also for operating SCR, large amount of Ammonia will be required involving challenges in transportation and storage of Ammonia due its toxic nature. Apart from all the issues and challenges, availability of vendors to supply SCR in such a large quantity will be the main constraint.

10.5 CARBON EMISSIONS FROM POWER SECTOR

The world over consumption of fossil fuel is the primary contributing factor in the build-up of atmospheric concentration of GHGs like carbon dioxide resulting in Global warming. As per UN Human Development Report 2020, the per capita carbon dioxide emission in India is among the lowest and is estimated to be around 2.0 metric tonnes as compared to the world average of 4.6 tonnes per capita and 16.6 tonnes per capita for USA (**Table 10.6**).

Table 10.6
Per capita emission of CO₂ of different countries

Country	CO ₂ emission Per capita(production) in the 2018 (tonnes of CO ₂)
India	2.0
USA	16.6
Australia	16.9
U.K	5.6
Japan	9.1
China	7.0
World	4.6

Source: UNDP Human Development report 2020

About half of total carbon dioxide from India is estimated to be generated from power sector. The other major contributors of CO₂ emission in our country are transport and industrial sector. CEA is annually estimating the amount of CO₂ emissions from grid connected power stations. The total amount of CO₂ emission from grid connected power stations in the year 2020-21 has been estimated at 910.01 million tonnes. Year wise carbon di-oxide emissions from Indian power sector during the last 6 years are given in **Table 10.7**.

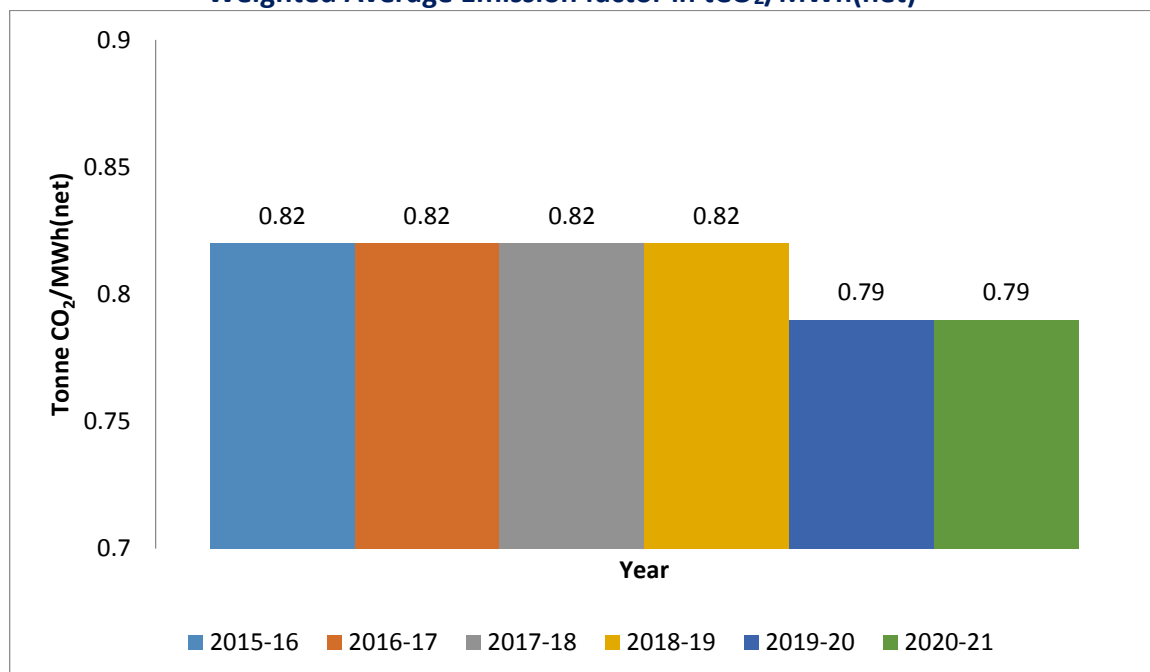
Table 10.7
Total Absolute Carbon Di-oxide Emissions of the power sector (2015-16 to 2020-21) in Mtonnes CO₂

	2015-16	2016-17	2017-18	2018-19	2019-20	2020-21
India	846.26	888.34	922.18	960.89	928.14	910.01

Source: CEA CO₂ baseline database for the Indian power sector version 17. October 2021

In the year 2020-21, the weighted average CO₂ emission rate from grid connected power stations (excluding captive power stations and stations on islands and from Renewables) is 0.79 kgCO₂/kWh_{net}. Year wise weightage average emission factors are shown in **Exhibit 10.2**.

Exhibit 10.2
Weighted Average Emission factor in tCO₂/MWh(net)



Source: CO₂ baseline database for power sector

The CO₂ emission from gas based power stations is almost half of that is generated by coal based power stations. The weighted average CO₂ emissions for various fossil fuels used in Indian power stations for the year 2020-21 are shown in **Table 10.7**.

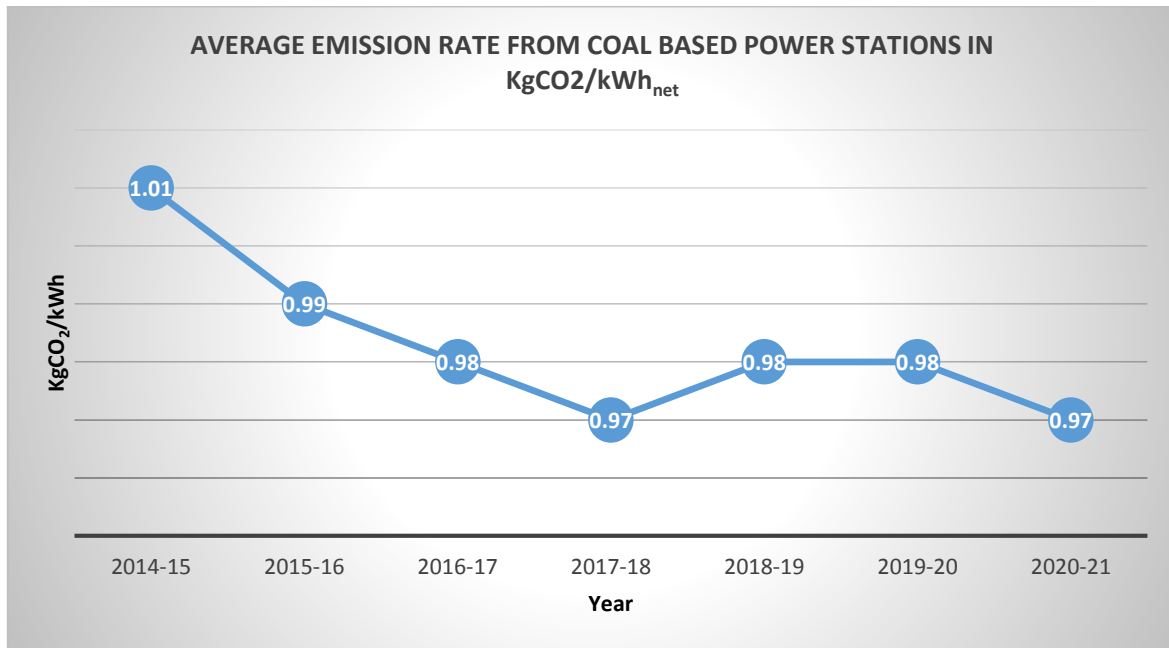
Table 10.8
Weighted average specific emissions for fossil fuel-fired stations in FY 2020-21, in tCO₂/MWh_{net}

Coal	Diesel	Gas*	Lignite
0.97	0.58	0.42	1.30

* Only gas-fired stations that do not use any other fuel. Stations that use naphtha, diesel or oil as a second fuel are excluded from the weighted average.

The weighted average emission rate of coal and lignite based generation is 0.97 kg CO₂/kWh_{net} and 1.30 kg CO₂/kWh_{net} respectively during the year 2020-21. However, the average emission rate from coal based stations has been on declining trend due to the fact that more number of efficient supercritical technology based units are getting commissioned and also due to introduction of Perform Achieve and Trade (PAT) scheme which aims at improving the efficiency of power plants.

The **Exhibit 10.3** shows the declining trend of average CO₂ emission rate from coal based power stations.

Exhibit 10.3

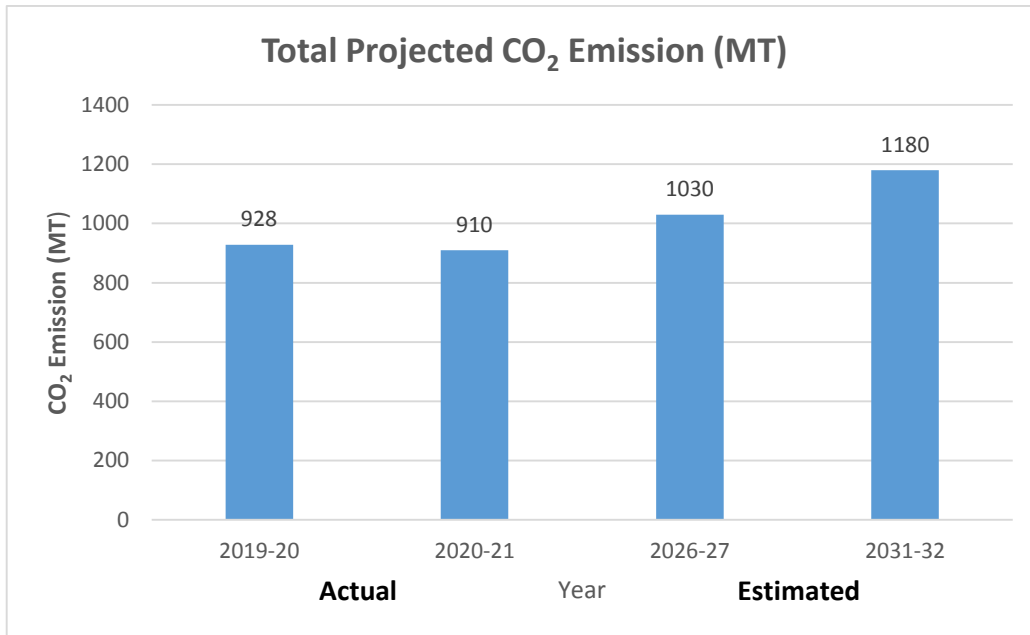
10.6 PROJECTIONS OF CARBON EMISSIONS IN 2026-27 AND 2031-32

On the basis of generation from each fuel source including renewables, carbon footprint i.e. projected carbon emissions and the emission factors considering base year of 2020-21 have been worked out.

Emissions factors (gCO₂/MJ) as given for Indian Coal/Lignite in the Initial National Communication and for Imported Coal Gas/Oil/Diesel/Naphtha as given by Inter Government Panel on Climate Change (IPCC 2006) have been considered for estimating Carbon emissions from various fuels. The methodology as given in CO₂ Baseline Database for the Indian Power Sector User Guide published annually by CEA has been followed in arriving the carbon emissions.

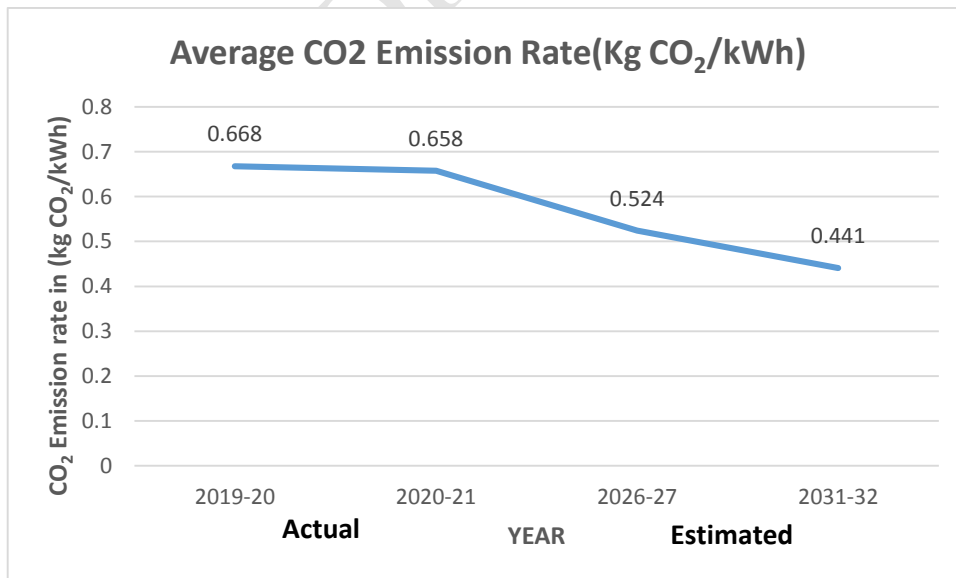
The total CO₂ emissions projected will increase from 910 Million tonnes in 2020-21 to 1030 Million tonnes in the year 2026-27 and 1180 Million tonnes in 2031-32 and are shown in **Exhibit 10.4**.

Exhibit 10.4



The average emission factor kgCO₂/kwh from the total generation including renewable energy sources in base case scenario has been estimated and are shown in **Exhibit 10.5**.

Exhibit 10.5



It may be seen that the average emission factor is expected to reduce to 0.524 kg CO₂/kWh in the year 2026-27 and to 0.441 kg CO₂/kWh by the end of 2031-32.

10.7 INITIATIVE OF GOVERNMENT OF INDIA TO REDUCE CARBON EMISSIONS

Mitigation of CO₂ emission is an important agenda on international level. Improving efficiency of thermal power stations is one of the effective methods to reduce CO₂ emissions which is being achieved by various schemes introduced by Government of India like Perform Achieve and Trade Scheme under National Mission on Energy Efficiency and adopting super critical/ultra-super critical technology for coal based generation. Also efficiency improvement measures through Renovation and Modernization (R&M) of old and inefficient units is undertaken and units in which R&M is not possible are being considered for retirement. Thrust is being given for increasing the share of non-fossil fuel (renewable, hydro etc.) based generation in the energy-mix to reduce the CO₂ emissions from power sector.

10.8 COUNTRY'S STAND ON CLIMATE CHANGE- INDCs

Under the Copenhagen Accord, India had pledged to reduce its CO₂ intensity (emissions per GDP) by 20 to 25 percent by 2020 compared to 2005 levels. Also in October, 2015, India had submitted its Intended Nationally Determined Contribution (INDC) to UNFCCC. The key elements are:

- To reduce the emissions intensity of its GDP by 33% to 35 % by 2030 from 2005 level.
- To achieve about 40 percent cumulative electric power installed capacity from non-fossil fuel based energy resources by 2030, with the help of transfer of technology and low cost international finance including from Green Climate Fund (GCF).
- To create an additional carbon sink of 2.5 to 3 billion tonnes of CO₂ equivalent through additional forest and tree cover by 2030.

However, during the COP26 summit held in November 2021 in Glasgow, Honourable Prime Minister of India has announced five key aspects of India's commitment 'Panchamrit', to combat the Global Climate change challenge, detailed below: -

- To achieve 500GW of non-fossil fuel-based capacity by the year 2030
- To meet 50 percent of Energy requirement from Renewable sources by 2030
- To reduce the total projected carbon emissions by one billion tonnes till 2030
- To reduce carbon intensity of the Indian economy by 2030
- To achieve the target of Net Zero by the year 2070

10.8.1 Share of Non-fossil fuel in total Installed Capacity

As on 31st Mar, 2022, share of non-fossil fuel based capacity (Hydro + Nuclear + RES) in the total installed capacity of the country is likely to be around 40%. It is expected that the share of non-fossil based capacity will increase to 57.5% by the end of 2026-27 and may likely to further increase to 68.4% by the end of 2031-32. Details of expected installed capacity and % share is shown in **Table 10.8**.

Table 10.9

Installed capacity and share of non-fossil fuel

Year	Installed Capacity (GW)	Installed Capacity of Fossil fuel (GW)	Installed Capacity of Non-Fossil** fuel (GW)	%of Non-fossil fuel in Installed Capacity
Mar,2022	399.5	236.1	163.4	40.9%
March,2027	622.9	264.6	358.3	57.5%
March,2032	865.9	274	591.9	68.4%

** Non Fossil Fuel – Hydro, Nuclear and Renewable Energy Sources

Note: The actual % may change to the extent of the quantum of capacity materialising and actual retirement taking place during 2022-27 and 2027-32.

10.9 CONCLUSIONS

- Government of India has taken various measures to reduce environmental emissions from thermal power stations. This includes improving efficiency of power generation, notification of stricter environment norms and retiring old and inefficient plants, Perform Achieve and Trade scheme etc.
- The average CO₂ emission rate from coal based stations in the country has been on declining trend indicating improvement in efficiency of power generation from coal based power plants.
- During 2020-21, the country has achieved Fly Ash Utilization of 107.77 Million tonnes with percentage utilization of 60.97%.
- The total CO₂ emissions projected will increase from 910 Million tonnes in 2020-21 to 1030 Million tonnes in the year 2026-27 and 1180 Million tonnes in 2031-32.
- The average emission factor is expected to reduce to 0.524 kg CO₂/kWh in the year 2026-27 and to 0.441 kg CO₂/kWh by the end of 2031-32.
- The share of non-fossil based capacity will increase to 57.5% by the end of 2026-27 and may likely to further increase to 68.4% by the end of 2031-32 from around 40% as on Mar'2022.
- Indian coal used in thermal power station generally has low sulphur content about 0.3% to 0.5% and SO_x control is being achieved as per new norms specified by MoEFCC notification.

CHAPTER 11

Technological Advancements and Research & Development

11.0 INTRODUCTION

India has witnessed a phenomenal growth in the Power Sector in terms of electricity generation, capacity addition as well as development in Transmission and Distribution (T&D) systems over the last decades. This has been possible with the introduction of enabling policies and regulatory changes favourable for a competitive environment encouraging the growth. Measures like participation of the private investment in the Power Sector, adoption of state-of-the-art technologies, thrust on improvement in the efficiency of the existing plants and setting up of new plants with improved efficiency have acted as catalysts to the growth of the Sector. Concerted efforts have also rendered improvement in electricity connectivity within the country and also with the neighbouring countries for cross border transmission of electricity.

The Government of India has paid higher attention on supply of electricity at an affordable price, and to deliver it in an efficient and sustainable manner to the consumers without causing adverse impact on the environment. In order to provide clean energy to the consumers, an ambitious target of 500 GW from non-fossil fuel based capacity by 2030 has been set by the Government of India. Minimal reliance on import of products and maximal indigenous development are the top priorities of the Government to lead the nation towards being “Aatma Nirbhar” or “self-reliant”. To materialize the above visions effectively and efficiently, synergetic research and development (R&D) efforts are required in all the areas of power sector like generation, transmission, distribution, trading and utilization and to ensure the safety, security, reliability and stability of the grid.

The research efforts should be directed towards Introduction of novel smart technologies and improving the efficiency of the Indian power system.

This chapter review the technological advancements and recommends the areas of Research and Development (R&D) to be taken up during 2022-27 and roadmap for future R&D initiatives in the Power Sector in the next 10 years.

The Report has been divided in five parts viz.

- i. Existing R&D facilities and research programs in Power Sector,
- ii. Technological Advancements,
- iii. Research and Development,
- iv. Initiatives proposed for improving R&D In the Power Sector, and
- v. Recommendations.

11.1 REVIEW OF EXISTING R&D FACILITIES AND PROGRAMMES IN POWER SECTOR

11.1.1 Facilities for Research in Power Sector

R&D activities in the power sector are presently being pursued by different institutes under the control of the Organizations /Ministries in the Central Sector, State Sector and Private Sector. The organizations may be the Central Government Ministries/Departments, Autonomous Bodies, Central Public Sector Undertakings (CPSUs), Academic Institutes, R&D organizations, Private Sector organizations etc. The following Institutions are actively engaged in R&D in the power sector:

- Ministry of Power (MoP), Ministry of New and Renewable Energy (MNRE), Department of Science and Technology (DST), Ministry of Human Resource Development (MHRD) now known as Ministry of Education, etc.
- Central Power Research Institute (CPRI).
- Electrical Research & Development Association (ERDA).
- Academic Institutions like Indian Institute of Science (IISc), Indian Institute of Technologies (IITs), National Institute of Technologies (NITs), Engineering colleges and other Institutions.
- CPSUs like BHEL, NTPC-NETRA, NHPC, SJVNL, POWERGRID, THDC etc.
- National Institute of Wind Energy (NIWE), Chennai.
- National Institute of Solar Energy (NISE), Delhi.
- Gujarat Energy and Technology Research Institute (GETRI), Vadodara.
- R&D laboratories/institutions like CSIR, CMET, and TERI working on energy related areas.

Apart from the above, Private sector organizations like Adani Power, TATA POWER, Reliance Energy, L&T, TERI, GE, Siemens etc. also undertake research in the areas of their interest in the Power Sector.

Central Electricity Authority (CEA) promotes research in the matters affecting the generation, transmission, distribution and trading of electricity.

The research arms of major CPSUs aim at introduction and absorption of new technologies primarily through project routes. Major manufacturers like BHEL, ABB, GE etc., have their own R&D set up, focusing on product development. As in recent years, the Power Sector is adopting the Information Technology (IT) advancements, it is suggested that the IT product development should incorporate development, security, and operations (DevSecOps) theme. Cyber Security by design should be imbibed in all technological developments undertaken by the above stated organizations. It is expected that all organizations involved in Research & Development must have a cyber security cell inbuilt to take care of cyber security needs in the present scenario.

11.1.2 Schemes for funding research in Power Sector

The Ministry of Power is promoting Research and Development for the Indian Power Sector through CPRI, under the “R&D schemes of Ministry of Power being implemented through

CPRI". Ministry of Power funds these schemes, CPRI and CEA monitors and co-ordinates the three R&D schemes viz:

- (i) R&D under National Perspective Plan (NPP)-under which projects with industry collaboration are funded
- (ii) Research Scheme on Power (RSoP) under which R&D projects from IISc, IITs, NITs, CSIR, Utilities and other reputed institutes are funded, and
- (iii) In-House R&D (IHRD) scheme for in-house R&D projects at CPRI for Augmentation of Research and testing facilities, improvements/new techniques in testing/diagnostic methods/research studies, product/Process Improvements, and for improvement in product standardization.

Besides In-house R&D, CPRI also undertakes sponsored research projects from manufacturers and other agencies in different areas of specialization.

Research in specific topics pertaining to energy domain are also assisted by various Ministries like Ministry of New and Renewable Energy (MNRE) assisting projects related to renewable energy generation, Department of Science & Technology (DST) assisting basic and applied research in energy domain.

Department of Science and Technology (DST) has initiated the smart grids R&D programs which includes national, bilateral and multilateral collaboration under Clean Energy Research Initiative (CERI) scheme. DST has supported four international research programs in this endeavour:

I. Bilateral

(i) Joint Virtual Clean Energy Centre (India-UK)

Towards the joint commitment to clean energy led low carbon economy, DST and UK together have set up virtual Joint Clean Energy Centre on Clean Energy. This centre focuses on integration of intermittent clean energy with storage for stable power supply at grid as well grid isolated communities.

(ii) Joint Clean Energy Research and Development Centre on Smart Grids and Energy Storage (India-US)

The Indo-US Joint Clean Energy Research and Development Centre (JCERDC) is a joint initiative of the Ministry of Science and Technology, Government of India and the US Department of Energy. The overall aim of the JCERDC is to facilitate joint research and development on clean energy by teams of scientists, technologists and engineers from India and the United States, and related joint activities, needed to deploy clean energy technologies rapidly with the greatest impact. To achieve this objective, the Indo-US JCERDC has supported a project which is multi-institutional network project viz. US-India collaborative for smart distribution system with storage (UI-ASSIST). The overarching objective of this project is to evolve the future distribution grid that will allow the increased penetration of Renewable Energy Sources (RES) and Energy Storage Systems (ESS) and to demonstrate the Distribution System Operator (DSO) functions for optimal utilization and management, interfaced with the micro grids in rural, urban and semi-urban settings.

(iii) Integrated Local Energy Systems (India-EU)

This joint initiative between India and EU aims to develop and demonstrate novel solutions, integrating all energy vectors like electricity, heating, cooling, water, wastes, etc., including possibilities offered by batteries and electric vehicles, interconnect them and optimize joint operation with increased share of renewables and higher energy efficiency. The system developed will be robust, replicable, scalable, sustainable and cost effective with low maintenance and less skilled manpower dependent. Supported two projects which focuses on integration of a number of energy sources/vectors with or without local grid connectivity, the demo units are proposed in different locations covering rural, semi-urban and urban environments and varied climatic conditions with additional services.

II. Multilateral

(i) Mission Innovation Programme on Smart Grids

DST supported nine Smart Grids Projects in collaboration with twenty Mission Innovation member countries which focusses on integration to conventional grid, transition from conventional vehicle to electric vehicle, financial and market strategies considering renewable penetration and cyber physical systems in smart grids.

Inter-ministerial collaborative research schemes like Uchchatar Avishkar Yojana (UAY) and Impacting Research Innovation and Technology (IMPRINT) have been initiated by **the Ministry of Human Resource Development (MHRD)** for focused research on identified themes in the energy domain. Under UAY, projects to promote innovation of a higher order that directly impacts the needs of the industries are taken up while the projects on socially relevant science and engineering challenges are taken up under the IMPRINT Scheme. Now under revised scheme (i.e. IMPRINT-2), the UAY has been subsumed into IMPRINT Scheme and is being implemented through Science and Engineering Research Board (SERB) under DST. The scheme would be co-chaired jointly by the MHRD and the DST.

The Utilities and manufacturers also take up research projects through their Institutional funds. Some of these projects are carried out in collaboration with academia.

11.2 TECHNOLOGICAL ADVANCEMENT

Continued and sustained efforts through involvement of various science and technology laboratories like CPRI, CSIR and Government bodies like DST, DSIR and MNRE, along with academic institutions have enabled promotion of technology in India. A strong research ecosystem is in the making in India by forging a closer relationship between the industry and academia through various research platforms.

In order to come up with a comprehensive list of R&D areas to be taken up in the coming years, the R&D activities and infrastructure developed by CPSUs, CPRI and MNRE during the 12th plan and 3-year action plan period were reviewed and the thrust areas investigated for research were noted.

The thrust areas which are relevant and require further research have been recommended for investigation during the years 2022-27. In addition to this keeping in mind the future of the Power Sector, new R&D areas have also been proposed for investigation.

The following are the advancements that have happened in the technological landscape of the Power Sector:

11.2.1 Advancement in Generation Technologies

11.2.1.1 Thermal Power Generation Technologies

- Material and metallurgical developments
- Developments in material for Construction of the parts/components/equipment of the plant
- Technology for latest site survey, site selection tools, and for construction of the power plant
- Ultra-Supercritical Power Plants (USC)
- Advance Ultra Supercritical Power Plants (A-USC)
- Energy Conservation and Efficiency enhancement
- Digital Technologies for Thermal Power Plants
- Flexible operation of the Thermal Power plants
- Integrated Gasification Combined Cycle (IGCC) power plants
- Air Pollution Control technologies
 - Selective Catalytic Reduction (SCR) for NO_x removal,
 - Electrostatic precipitator (ESP) that uses electrostatic force to remove dust,
 - Flue Gas Desulphurization (FGD) unit that removes sulphur dioxide from the flue gas, and
 - CO₂ Removal Technology.
- Ash treatment facilities and recovery of rare earth elements (REE) and useful minerals from fly ash for quality bricks.
- Technologies to mitigate “blackouts”.
- Technologies to reduce transmission and distribution (T&D) losses.

11.2.1.2 Hydro Power Generation Technologies

- Material and metallurgical developments for manufacturing of the parts/components/ equipment of the plant.
- Technology for latest site survey, site selection tools, and for construction of the power plant
- Pumped Storage Power Plants (PSPs)
- Power plant renovation and modernization
- Operation and Maintenance services with digital solutions
- Remote monitoring services
- Short term generation forecasting

11.2.1.3 Solar Technologies

- Concentrated Solar Plants (CSP)
- Photovoltaic solar plants - rooftop/ground mounted/floating
- Energy yield prediction
- Site Selection
- Plant design
- Permits, licensing and environmental considerations

- EPC Contracts
- Construction
- Operation and Maintenance (O&M) services with digital solutions
- Plant instrumentation and control system
- Plant upgrade technologies
- Power plant assessment and engineering
- Predictive management of fluids in solar energy plants:
 - Which helps sustain the life-time of a heat transfer fluid (HTF)
 - Which avoids costly and unnecessary interruptions to operations through pre-planned maintenance
- Remote monitoring services
- Technologies for disposal after end of life.

11.2.1.4 Other forms of energy generation

- Biomass combustion or co-firing
- Municipal solid waste incineration
- Removal of waste heat and energy generation from the conversion of water-to-steam-to-electricity
- Natural-gas-fired fuel cells
- Emergency backup generators, usually fuelled by gasoline or diesel fuel
- Tri-generation or Combined Cooling Heat and Power (CCHP).

11.2.1.5 Wind Power Technology (offshore /onshore)

- Integration of wind, wave, tide and solar energy in coastal and near shore regions.
- Ocean temp gradients for power and desalination

11.2.1.6 Geothermal technology

Geothermal energy is one of the promising energy resources in India, especially in the Himalayan region. In addition to power generation, geothermal energy can cater to space and process heating requirements and improve the energy resilience of this region. A review of international best practices indicate the medicinal value and energy/mineral recovery potential of this resource.

11.2.1.7 Tidal Power generation

- Marine and hydrokinetic (MHK) technology (These devices capture energy from the natural motion of ocean water, such as waves or tides)

11.2.1.8 Energy Storage System

- Concentrated Solar Power (CSP) thermal energy storage - in molten salt form
- Battery energy storage systems (BESS)
- Pumped hydro storage, where water is pumped uphill into a reservoir and released to power turbines when needed
- Compressed air energy storage (CAES)
- Advanced batteries
- Supercapacitors, Capacitors Energy Storage System (CESS)

- Superconducting energy storage
- Mechanical Energy Storage System (MESS)
- Magnetic Energy Storage System (MESS)
- Gravitational Energy Storage System (GESS)
- Thermal Energy Storage Systems (TESS) for cooling and heating using phase change material
- Flywheels
- Fuel Cells

11.2.2 Advancement in Transmission Technologies

11.2.2.1 Gas Insulated Switchgears

- Non-flammable gas insulated transformer
- Advanced Site Assembly (ASA) transformer
- Small, light-weight, easy-to-handle polymer-type arrester
 - silicone direct moulding type
 - composite insulating tube type

11.2.2.2 Voltage and Reactive Power Control

- Flexible AC Transmission System (FACTS)
 - Shunt devices like static VAR compensator (SVC). A Static VAR Compensator (SVC) is a fast acting power electronic device used to dynamically control the voltage in a local area or at an interface point.
 - Thyristor controlled reactors (TCR),
 - Thyristor switched reactor (TSR),
 - Thyristor switched capacitors (TSC).
 - Static Synchronous Compensator (STATCOM), which are mainly used for voltage control and reactive power flow control;
 - Static Synchronous Compensator (STATCOM)
 - Voltage Source Converters (VSC)
 - Insulated Gate Bipolar Transistor (IGBTs)
 - Integrated Gate Commutated Thyristors (IGCTs).
 - Series devices like Thyristor-Controlled Series Compensation (TCSC), and Static Synchronous Series Compensator (SSSC), Thyristor Controlled Phase Angle Regulator (TCPAR)
 - Series-shunt device such as Unified Power Flow Controller (UPFC)

11.2.2.3 Frequency Converter (FC) systems

11.2.2.4 HVDC system for improving the power transmission efficiency and enhancing the interconnection of asynchronous grids

- Voltage Sourced Converter (VSC) with state-of-the-art Modular Multilevel Converter (MMC) technology
- Line-Commutated Converter (LCC) for long-distance large-capacity transmission

11.2.2.5 HVDC Power Transmission

- Mass Impregnated HVDC Cables
- Extruded Cross Linked Poly Ethylene (XLPE) High Voltage Direct Current (HVDC) Cables
- HVDC underground and submarine cables
- Line Commutated Converter (LCC) technology
- Voltage Source Converter (VSC) technology
- Insulated Gate Bipolar Transistors (IGBT), which provide the switching between HVAC and HVDC systems.
- DC Gas insulated lines

11.2.2.6 HVAC Power Technologies

11.2.2.7 HVAC / HVDC Hybrid System

- HVAC / HVDC system interaction
- Hybrid HVAC / HVDC overhead lines

11.2.2.8 Electronic Devices And Components

11.2.2.9 Gas insulated lines

11.2.2.10 Overhead Lines

- Overhead lines (OHL)
- Aluminum Conductor Steel Supported (ACSS),
- Aluminum Conductor Composite Core (ACCC),
- Aluminum Conductor Composite Reinforced (ACCR)
- Aluminum Conductor Steel Reinforced (ACSR)
- High Temperature Conductors (HTC),
- Real Time Thermal Rating (RTTR)

11.2.2.11 HVAC cables

- Onshore cable technology
- Offshore cable technology
- HVAC extruded insulation cables for the submarine connections.

11.2.2.12 HVAC Substations, breakers, bus bars, disconnectors and power transformers.

11.2.2.13 Control and Monitoring Devices

- Power control devices: Flexible AC Transmission Systems (FACTS), phase-shifting transformers (PST)
- Monitoring devices and systems: Wide Area Measurement System (WAMS), Phasor Measurement Units (PMU), Synchrophasors
 - **WAMS**- The main application of synchrophasors is in the field of system monitoring with Wide Area Monitoring Systems (WAMS).
 - **PMU** - A Phasor Measurement Unit (PMU) measures the electrical waves on an electricity grid to determine the health of the system.

- **WAPS-** Wide Area Protection Systems (WAPS). The main benefits of synchrophasors are for on-line monitoring, protection systems and off-line analysis.

11.2.2.14 Control and Monitoring System

- Next generation Energy Management System (EMS)
- Real-time monitoring and control system
- Advanced Analytics and forecasting
- Disaster Management System

11.2.2.15 Development of 1200 kV transmission technologies:

- 1200 kV sub-station, circuit breakers, shunt reactors and controlled shunt reactors for dynamic reactive power compensation.
- Development of High Energy (55 MJ) ZnO blocks for lightning arrestor of class 5 duty is required for dissipation of high energy.
- Development of operating mechanism for 1200 kV dis-connector is essential in the light of Ultra High Voltage (UHV) transmission system technology.
- GIS for HVDC system in order to overcome space limitations.
- DC Cables
- New type and configuration of towers to reduce the height and right-of-way (RoW).
- Rupture proof tank for transformer and reactor
- Development of faster and cost effective Pressure Relief Device (PRD)
- Development of insulated cross arm towers for optimizing RoW requirement.

11.2.3 Energy Distribution

11.2.3.1 Inclusion of distribution automation

Detailed investigations and developments are in progress on power distribution systems and the monitoring of apparatus. These are on:

- a. “Digital Technology” based on the application of semiconductor high-speed elements
- b. Intelligent substations applying IT (information technology)
- c. System configurations aimed at high-speed communication.

Incorporated in these are demands for the future intelligent control of substations, protection, monitoring, and communication systems that have advantages in terms of high performance, functional distribution, information sharing and integrated power distribution management also closely knit for cyber security requirements. Such technologies include:

- Intelligent/Digital Substation
 - i. Concept of Intelligent/digital Substations
 - ii. Apparatus Monitoring System (AMS)
 - iii. Protection and Control
- Latest Protection and Control System
 - i. Trends in Protection and Control Systems
 - ii. Unified Protection and Control Unit
 - iii. Remote Control Functions by Web Correspondence

- iv. Connection between Protection/Control Equipment and Apparatus
 - Advanced Equipment and Components
 - i. Power Electronics
 - ii. AC and DC Lines and Cables
 - iii. Fault Locators
 - iv. IoT Devices
 - Distribution Transformers - Potential for Future Deployment
 - Sensing, Measurements, Communications, and Controls:
 - i. Data Acquisition systems (DAS)
 - ii. Supervisory Control and Data Acquisition (SCADA) systems
 - iii. Remote terminal Units collecting field data via communication systems
 - iv. Advance Distribution Management System (ADMS)
 - v. Intelligent Electronic Devices (IEDs),
 - vi. Global Positioning System (GPS) signals.
 - vii. Geographical Information System (GIS)
 - viii. Outage Management System (OMS)
 - ix. High-bandwidth communication
 - x. Smart meters
 - xi. Advanced Metering Infrastructure (AMI)
 - xii. Two-way communications and 4-quadrant metering
 - xiii. Integrated Communications
 - xiv. Advanced Control Methods - Potential for Future Deployment
 - Improved Decision-Support Tools (IDST)
 - i. System Operations
 - ii. Grid visualization.
 - iii. Decision support.
 - iv. Demand based supply, production and distribution through integrated EMS.
 - v. Systems operator training.
 - vi. Potential for Future Deployment.

11.2.3.2 Applications of artificial intelligence (AI)/Machine Learning (ML)

11.2.3.3 Cybersecurity

- **Accelerating research, development and demonstration of resilient energy delivery systems**
- **Evaluation** of IOT and SCADA upgrades with a security first mind-set
- R&D on the adaptability of Information security controls for the energy utility industry given in ISO 27019:2017 in ICS of Power Utilities.
- For every Power Utilities, Integrated Security Operation System (I-SoC) need to be in place for visibility of Security in IT-OT integrated environment and

application of appropriate security controls to protect them from cyber-attacks.

- Secured data and device interoperability.

11.2.3.4 Microgrids and Virtual Power Plants

- **Distributed Power Generation (DPG).**
- **Microgrids (MG)**
- **Virtual Power Plants (VPP)**
- **Smart Grids (SG)**
 - Controls**
 - Automation**
 - Grid Integration**
 - Development of new equipment to penetrate Renewable Energy into conventional grids.**

11.2.3.5 Software for grid management

11.2.3.6 Social media presence and automated messaging

11.2.3.7 Standards development for data interoperability, cybersecurity, IoT, and field devices communication.

11.3 Research and Development

It is observed that India has been at the forefront of technology deployment but not very much on development. With the technological advancements happening across the globe at a very fast pace, it is of utmost importance to identify the right technologies at an early stage, tailor them to Indian needs and research on them in India so that the same can be imbibed in the Indian Power System at an early stage. In view of the “Digital India” and “Swachh Bharat” missions led by the Government of India, special emphasis has to be given for areas of immediate importance right from “cyber security” up to “waste to energy”. The adoption of technology should be seen with the cyber security threats involved and their possible mitigation.

All efforts are to be directed towards realization of an “Aatma Nirbhar Bharat (self-reliant India)”, thus the R&D outcome should lead to indigenization of the major equipment/components in Power Sector.

The focus areas of research for the Power Sector for the next five years have been categorized into five different conventional categories, viz. Generation, Transmission, Distribution, Renewables including Microgrid, Smart Grids and reducing adverse effects on Environment and Cyber Security.

The category wise details of the thrust areas of research are as follows:

11.3.1 Electricity Generation (Conventional Sources)

The major challenge to the power sector is to optimally make use of the generation resources so that there is no short fall from the generating end as well as to provide reliable and cost-effective power supply to the customers. Efforts are to be made to achieve the above goal in a sustainable manner without causing harm to the environment.

Generation sector is in the midst of a paradigm shift. With the capacity addition of renewable energy (RE) in India the thermal power plants are forced to operate in cyclic manner and with frequent ramp up and ramp down. Also, most of the thermal power plants are forced to operate at part load for substantial period. All these indicate that novel technologies and strategies have to be devised to make the thermal power plants more flexible and extract maximum benefit from both renewable as well as conventional plants in a sustainable manner in future.

At present although solar, wind and other sources of renewable energy have gained momentum; still the thermal power generation caters to majority of the load demand. RE plants are dependent on the various factors like wind speed and solar irradiance, and are not available for long periods at a stretch. During the period of absence of renewable energy, dependence would be exclusively on conventional power sources or energy storage. Hence, it is important to focus on improving the conventional generation system, including aspects like better plant design, increasing efficiency, improvement in fuel quality and waste heat recovery. Although RE are a good support for the energy security as deployment of RE leads to saving of equivalent fossil fuels, the role of the conventional plants in meeting the peak and seasonal demands cannot be undermined. Following are the different technologies with proposed prototypes and pilot plant demonstration for implementation:

11.3.1.1 R&D for Thermal Power Generation

Some of the important areas of R&D in Thermal Power generation are identified as follows:

11.3.1.1.1 IGCC Technology

Integrated Gasification Combined Cycle (IGCC) integrates a coal gasifier, a gas clean up system and gas turbine in a combined cycle mode where coal is gasified with either oxygen or air. The resulting synthesized gas (or syngas) consisting of primarily hydrogen and carbon monoxide is cooled, cleaned and fired in a gas turbine. The technology has shown capability of power generation at higher efficiency and lower emission levels with respect to pulverized coal combustion technologies as demonstrated in the USA, Netherland and Spain.

Research in IGCC technology may be focused to open up new product areas along with electricity generation like liquid fuel generation, hydrogen production, pre-combustion CO₂ capture and integration of fuel cell which may provide future options of zero emission coal technologies with higher efficiency.

11.3.1.1.2 Carbon Capture and Utilization Techniques

The impending danger of climate change and pollution is very much evident today. Carbon dioxide is one of the main greenhouse gases that are the cause for global warming and climate change. One of the primary sources of the increase in atmospheric CO₂ is the combustion of fossil fuels.

The development and installation of technologies for reducing the carbon intensity of existing power plants is an important area and requires focused research efforts. Carbon Capture (post-combustion) and Utilization (CCU) coupled with fossil energy-based power plants is considered as a key technology with significant potential to mitigate carbon emission while limiting climate change.

Despite the fact that various carbon capture techniques have gained maturity in the past, there are many challenges associated with it such as high cost, large scale deployment, etc.

Further, the technologies for conversion of CO₂ to useful products is also very costly and proprietary of few companies around the world. Significant efforts are required for the development and indigenization of above mentioned technologies and should be a priority area for research in the Power Sector.

Cost effective capture of CO₂ and its conversion to 'value added' products should be taken in a focused manner so that the entire initiative first becomes self-sustainable and thereafter create new revenue stream for power stations. In this regard, it is suggested to develop, design and setup reasonable scale demonstration plant in following domain:

- Liquid Fuel equivalent by catalytic hydrogenation of power plant CO₂ : Likely products – Methanol (Petrol equivalent), Di-Methyl Ether (Diesel equivalent)
- High value chemicals by reformation of power plant CO₂: Likely products – Olefins, Formaldehyde, Formic acid, Acetic acid etc.
- Carbon Black by catalytic reduction of power plant CO₂ : Likely products – Carbon black, Carbon nano tubes, Carbon nano particles etc.
- Carbonated Fly Ash Aggregate, Concrete from power plant CO₂ : Likely products – Fast curing concrete (21 hours instead of 21 days), Coarse aggregate.
- Photo-Bio-Reactor for synthesis of power plant CO₂ to high value human grade nutrients: Likely products - Beta Protein, Omega 3 Fatty Acid (Veg Fish Oil), Laminaria - Anti Ageing cosmetic.

11.3.1.1.3 Ash Utilization Technologies

Fly ash is a by-product of power generation with coal. Combustion of coal in thermal power plants produces either fly ash or bottom ash. Ash Disposal is a major problem because of the sheer magnitude of its quantity produced from thermal power generating stations. It is also a serious threat to environment as it adversely affects the flora and fauna. Disposal in the form of slurry requires large area of land as well as water, which are scarce commodities now a days.

Sustainable method for 100% ash utilization is the key concern of thermal power sector. Over the years many new technologies for ash utilization have been developed but still full utilization of ash is a distant goal. Following research studies should be conducted for development of new segments having long term potential of ash utilization:

a) Development of Construction materials:

- i. Like bricks etc.

b) Development of other products: Recovery of valuable minerals and treat fly ash suitable for quality ceramics and other products.

c) New technology advancement for High Volume Ash utilization such as

- i. Fly ash and Pond Ash to Controlled Low Strength Material (CLSM)
- ii. Geo Polymeric (GP) Concrete road with GP aggregate
- iii. Use of Coarse Fly Ash for cement production
- iv. Development of Angular shaped fly ash aggregate

11.3.1.1.4 Technologies for conservation of water in Thermal Power Plants

Various Innovative technologies are the need of the hour for reducing water requirement in power plants as well as improving the quality of water used to prevent long term damage of the components due to water. Following new areas should be implemented:

- i. Application of advance technologies for water treatment and handling in Thermal Power plants
- ii. Desalination of sea water to be used in thermal power plants
- iii. High Water and energy recovery from waste water system
- iv. Electrochemical process for descaling
- v. Custom Non-Chemical Solution for water treatment: Ozone (O₃) and Ultra-violet (UV) treatment
- vi. Advanced technologies for treatment of waste water and water for emerging pollutants and geogenic contaminants as a part of the thermal power plants
- vii. Advance chemistry for water conservation: higher cycles of concentration (COC) formulation of cooling water system

11.3.1.1.5 Waste Heat Recovery Systems for enhancing the power plant efficiency

The thermal power plants operating on Rankine power cycle normally achieve power generation efficiency in the range of 35–40% depending on various site conditions, turbine inlet steam conditions and design of equipment etc. Balance of the heat input is essentially lost as condenser losses (about 48–50%) and boiler exhaust gas losses (about 6–7%) besides other nominal losses viz. radiation losses, un-burnt carbon losses etc. In a 500 MW unit, about 25 MW of thermal heat would be available if the flue gas temperature is dropped, say, from 140°C to 110°C. The major challenge in low temperature heat recovery system is the requirement of large heat transfer area and thus additional pressure drops, which increases the cost of the system. Use of waste heat recovery system, though desired for obvious cost benefits, is equally important for environmental protection since lower quantity of fossil fuels shall be burnt for same quantum of useful energy.

Efforts are being made in developing technologies where waste heat can be gainfully recovered and applied to:

- (i) Produce refrigeration/air-conditioning using Vapour Absorption/Adsorption Machines (VAM) based on Li–Br, Ammonia absorption system.
- (ii) Plant cycle efficiency improvement using condensate pre-heating and fuel oil heating
- (iii) Produce electric power independent of the main plant turbo-generator (TG) set using aqua-ammonia Cycle or Organic Rankine Cycle.
- (iv) Flue Gas Desalination of sea water
- (v) Flue Gas Blow down recovery.

11.3.1.1.6 Advanced surface engineering technologies for higher life expectancy of Thermal plant components

The surface engineering technologies are becoming essential in critical applications of power plants involving wear, erosion as well as corrosion. Thus the immediate technological requirements to be addressed in respect of damage tolerance capacity of materials are development of high temperature wear and erosion resistance materials for thermal components (Burner, liner and shield).

11.3.1.1.7 The other important areas where research advancement/ assessment is required for Thermal Power Generation include the following:

- Identifying the impact of cyclic loading on power plant components due to increased renewable penetration in the grid.
- Online coal sampling.
- Technological advances in syngas cleaning especially at higher temperature in IGCC (Integrated Gasification Combined Cycle) technology.
- Improvement of Electrostatic Precipitator (ESP) performance.
- High temperature wear and erosion resistance of thermal components (Burner, liner and shield etc.)
- Design and Development of Last Stage Steam Turbine Blades and balancing of flue gas flow inside boiler for Improved Performance.
- Boiler combustion Computational Fluid Dynamics (CFD) modelling of sub and Supercritical boilers.
- Development of nano particles for application in high thermal coefficient lubricants, additives in water to reduce evaporation losses.
- Advanced non-destructive testing/non-destructive examination (NDT/NDE) based diagnostics and inspection tools for condition assessment of plant components such as in-situ inspection of Low Pressure (LP) Turbine Blades by Ultrasonic Phased Array.
- Establishment of advanced facilities for coal combustion/blended coal combustion evaluation studies.
- Development of technologies for on-line measurements of coal flow, fineness, heating value, and balancing for combustion optimization in utility boilers, sensor systems for online fuel calorific value and un-burnt carbon in ash measurement.
- Robotic Inspection of inaccessible/congested/hazardous areas inside boilers and other enclosures.
- New improved methods of prevention of scaling on turbine blades and piping system in thermal power plants.
- Application of nano technologies in thermal power plant
- Application of latest technologies such as Drone/ Light Detection and Ranging (LiDAR), Robotics, in power plants mission control technologies including control/mitigation of Nitrous Oxides (NO_x), Sulphur Oxides (SO_x) emissions.
- Feasibility study on Co-firing of Biomass in conventional thermal plants
- Development of non-air gasifiers like steam gasifiers
- Quantitative and Qualitative analysis of deposit, solvent selection and post operational chemical cleaning recommendations for boilers.
- Robotic Inspection of Low Temperature Super Heater (LTSH) tubes without lifting tube panels.

- Alloy analysis for identification of material mix-up in boiler, turbine auxiliary etc.
- Condition assessment of super heater/re-heater tubes of ageing boilers through accelerated creep testing.
- Metallurgical Failure analysis of pressure parts components
- Wear debris analysis – lubricating oils of rotating components.
- Analysis of deposits of boiler, condenser, effluents, ash, cooling waters, coal, etc. using equipment like atomic absorption spectroscopy (AAS), X-ray diffraction (XRD), Ion Chromatography (IC), Total Organic Carbon (TOC), Energy Dispersive X-Ray Analyzer (EDX) , etc.
- Monitoring of ion exchange resins and activated carbon for capacity and kinetics from stations
- Diagnosis of vibration problems of rotating machines
- Condition Monitoring and life assessment of high voltage transformers through dissolved gas analysis, Polarization and Depolarization Current (PDC) measurement, recovery voltage method (RVM) measurements and Furfural content and degree of polymerization.
- Specialized analytical support for characterizing the turbine deposits, corrosion products, heavy metals in effluents, etc.
- Switchyard condition assessment by early detection of incipient faults.

11.3.1.2 R&D initiatives for Hydro Power Generation Sector

India is blessed with immense amount of hydro-electric potential and ranks 5th in terms of exploitable hydro-potential on global scenario. As per assessment made by CEA, the total hydroelectric potential from large hydro (above 25 MW) is 2,35,590.6 MW. Out of this pump storage potential is 90,270.6 MW and balance hydroelectric potential is 1,45,320 MW. Research in the area of Hydro-electric power generation should get prime focus and issues such as widening of operating ranges for turbines, development of suitable coatings to avoid silt erosion, transient operation of turbines etc. should be minutely studied.

The following are the broad R&D areas to be explored:

1. Cavitation/Vortex rope mitigation
2. Silt erosion and corrosion

Following areas are identified which can be addressed by further research and development:

- New superior silt erosion resistant and anti-acidic materials for water carrying/under-water components/parts/equipment such as hydro turbine blades, runner, guide vanes, water conductor system etc.
- Application of GIS/GPS in River Flow Discharge Measurement, flood forecasting for generation planning.
- Application of short term weather forecast in generation planning
- Analysis and Monitoring of cavitation phenomenon in Turbines.
- Rock Stabilization techniques for large size caverns.

Following are the areas where technological advancement should be considered:

- Integrated operation of cascade hydro power projects.
- Tunnel construction techniques/methodology in Soft Rocks/Fragile Himalayan Geology for safe and expeditious construction.
- Measures to tackle Bad Geology during Excavation of Tunnels and Construction of Dam Foundation as seepage control measure for construction of Dam.
- Indigenous development of variable speed drives for PSPs.
- Analysis of measures to increase service life for Silt Flushing Gates, Numerical Flow Simulation, Performance Optimization of Hydro Plant components and for Improving De-silting Chamber Efficiency using Computational Fluid Dynamics (CFD).
- Indigenous development of software on O&M methods including High Risk Predictive Maintenance based on past experiences and specific to HEPs.
- Indigenous development of software for control and protection system of Hydro Power plant against cyber-attacks on the infrastructure. (It may be made common for entire Power System)
- Development of coating materials or metal alloys for underwater parts which are resistant to acidic water prevalent in North-Eastern Part of India.
- Use of nanotechnology to optimize and upgrade the control & protection system. (It may be made common for entire Power System)
- A strategic start-up and shutdown technique of the Francis turbine may be developed considering transient dynamic behaviour and runner blade loading during no-load run/run-away, load rejection, and start-up as well as shutdown of the turbine.
- Indigenous development of PTFE (Polytetrafluoroethylene) material for Bearings and high grade quality XLPE compound for electric cables.
- Indigenous development of CRGO Steel and Resin Insulated Paper (RIP)/Resin Insulated Synthetic (RIS) conductor bushing. (It may be made common for entire Power System)
- Research in the area of developing compact generators and transformers.
- Generator modernization to increase efficiency.
- Site assembly and acceptance testing of 400 kV and above generator-transformers (GTs).
- Monitoring system for on-line measurement of turbine efficiency
- Construction methodology for arch dams.
- The causes of pressure recovery loss near the best efficiency point in draft tube.
- Indigenous development of Splitter Runner for higher capacity turbines.
- Optimization of movement of guide vanes during turbine start-up after emergency shutdown of the Francis turbine.
- Indigenous development of Computational Fluid Dynamics (CFD) tools for optimization of hydro turbine design for enhanced efficiency and minimize cavitation.

11.3.2 Thrust areas of research for Power Transmission

The R&D in power transmission shall focus on a reliable, safe and efficient systems for transfer of electricity. While utilities/organizations shall give more impetus on demonstration and evaluation of new technologies through pilot projects, manufacturing organizations shall give more stress on development of new technologies/products. The areas of focus for research and development have been highlighted as follows:

11.3.2.1 New designs for Transmission Towers and Conductors

Transmission towers and conductors play major role in power transfer. To meet the growing demand for power in urban and industrial areas there is a need for transfer of huge quantum of power from generating stations. Due to the constraints in getting environmental clearances, and acquiring right of way (RoW), introduction of compact transmission lines is an alternative choice to conventional ones. The compact transmission lines have the advantage of reduced RoW and reduced tower dimensions.

Re-conductoring of existing lines with High Temperature and Low Sag (HTLS) conductor is a viable option to increase the power transfer capacity. Design aspects of compact towers and feasibility study of different types of HTLS conductors are to be explored for implementation.

The growing concerns about environmental impact of transmission line construction and protest against siting of towers added with the requirement of reducing tower material, necessitates new tower designs with reduced right of way and slimmer structure.

- **Development of high temperature electrical conductors** for transmission lines is essential, keeping in view of bulk power transfer. The major challenges are to overcome the transmission losses, increase the power transmission on the existing lines and the development of more efficient power conductors for new lines. The development of efficient power transmission system seems to have the major stake in the future of transmission system and will become the national priority keeping in view of the current scenario.

11.3.2.2 HVDC transmission

Considering the implementation of High Voltage Direct Current (HVDC) transmission, indigenous manufacture of equipment may be required. The research focus will cover the following aspects:

1. DC electric field, corona studies on equipment and electrodes;
2. Performance of bushings under DC electric stress.,
3. Effects of DC stress on transformer insulation,
4. Ageing studies,
5. Development of diagnostic tools,
6. Overhead transmission Lines,
7. Bushings and transformers,

Some of the other potential areas of research are as follows:

- Voltage Sourced Converter (VSC) based HVDC transmission has become an attractive option for bulk power transfer between meshed grids. The advantages of VSC based HVDC transmission are high controllability of active and reactive power at the converters terminal and the ability to improve the stability.
- High Speed Grounding Switches (HSGS) for HVDC systems are required to connect the station neutral to the station ground, if the ground electrode path becomes isolated.
- The concept of transformer less HVDC transmission.
- To adopt the VSC based HVDC transmission technology, High Speed Grounding Switches for HVDC systems and to absorb the concept of transformer less HVDC transmission system in power sector, pilot project study is required to be undertaken to gain the experience for wider acceptability and implementation.

11.3.2.3 Development of controllers for Flexible Alternating Current Transmission System (FACTS) devices.

Application of FACTS devices in Indian power system is proposed, extensively supported through system studies. Research in the direction of developing indigenous development of FACTS devices and its controls is essential and the objective is to design, develop controls for FACTS devices such as: Static Compensator, HVDC, multi-terminal HVDC, switchable shunt reactors, series and shunts HVDC taps, Unified Power Flow Controller (UPFC), Interline Power Flow Controller (IPFC), and static synchronous compensator (STATCOM), Static Synchronous Series Compensator (SSSC) and deploy in the network. The controller performance is to be studied in real time.

There is a need to develop controller for controlled switching of circuit breakers, which is used to close or open the contacts of circuit breaker by time dependent control of trip coils, to eliminate undesirable transients. Substantial research in this direction is required.

11.3.2.4 Design and development of equipment for 1200 kV UHV AC System

Power sector growth necessitates development of indigenous technology for absorption in to network at higher voltage levels, mainly to strengthen the system and power evacuation. The key equipment to aid in 1200 kV UHV transmission systems should be indigenously developed.

11.3.2.5 Design and development of seismic resistant substation

It is necessary to maintain reliability and safety of electrical equipment after an earthquake. This depends on the seismic response of individual substation components such as transformer, bushings, switchgear etc.

11.3.2.6 Exploring features of technologies like Machine Learning and Artificial Intelligence, Big data, Internet of Things, Cloud computing, Block chain etc. for application in power system operation and monitoring

In the current era of Industry 4.0, where the influence of IT and communication technology has been making a big change in the lives of citizens, capabilities of Machine Learning and Artificial Intelligence, Big Data, capacity of Internet of Things, power of cloud computing,

security of block chain architecture etc. needs to be explored and applied in the power transmission system to make it more secure, efficient and reliable.

11.3.2.7 Explore alternative fluids for transformer oil like nano-doped oil and environmental friendly fluids

Nano-fluids are a class of fluids having stable suspensions of nanoparticles, with sizes typically less than 100 nm. Nano-particles when mixed in transformer oil could improve various electrical and thermal properties as found from various research studies. Such promising nano-material doped oils could be developed further for improving the operational performance of transformers. In addition, biodegradable alternatives to transformer oil like natural esters could also be developed to make transmission system environment friendly.

11.3.2.8 Explore environmental friendly dielectric gas as an alternative to SF₆ gas

SF₆ being a greenhouse gas leaves significant impact on environment in case of release into atmosphere due to leakages. Development of environment friendly alternatives to SF₆ gas could be taken up to reduce the effect on environment caused by transmission system equipment.

11.3.2.9 Development of Inspection Robot for monitoring and maintenance of Transmission Lines and Substations

A remote controlled transmission line inspection and maintenance robot, which crawls along the high voltage line conductors autonomously and relay data to the control module as well as do minor maintenance tasks on line, could help in efficient management of the transmission system. Likewise, an autonomous substation robot, which could perform regular inspection for any damages in switchyard equipment and components, could also be developed. Use of such robots will also allow utility staff to access areas in transmission lines and substations that are manually difficult to inspect. Cyber Security due to this feature may be kept in perspective before implementation.

11.3.2.10 Development of transformer inspection robot

For a human being to enter inside the confined space of transformer for inspecting the internal components of transformer is a dangerous task. This human inspection requires significant downtime due to the lengthy process of draining oil and refilling again after inspection. A transformer inspection robot will help immediate inspection of the transformer after taking outage thus saving cost and time.

11.3.2.11 Development of real-time wide area protection system with Phasor Measurement Units (PMUs)

Currently, synchro phasor measurements are used mainly for power system monitoring, model validation, post-event analysis, real-time display etc. However, synchro phasors have a greater potential than monitoring and visualization. Real time synchro phasor measurements can be utilized in control and protection schemes, called as Wide Area Monitoring, Protection, and Control Systems. These schemes will take action for protection and control of power system using synchro phasor measurement on real time basis thus providing fast and automated solution for grid operations. In addition, it will be helpful in real time power swing detection, fault detection, voltage stability, power oscillation damping and network islanding schemes. Reliable transmission of data from PMUs to the control station must be ensured.

11.3.2.12 Other major areas of Research and Development in Transmission domain are mentioned below:

- System Security and Operator Training software and simulation tools.
- Gas Insulated Transmission Lines (GITL).
- Extra High Voltage (EHV) Cables and submarine cables for bulk power transmission.
- Superconducting Magnetic Energy Storage System (SMES).
- Alternate Fault Current Limiters
 - a. **Superconducting Fault Current Limiter development and field trial**

Superconducting fault current limiting devices rely on the property of superconductor element to undergo transition from superconducting state to resistive state on subjecting to current above its critical level. When installed in grid and once subjected to fault conditions, the rise in current above critical level is due to the system fault current, which forces the Superconductor to transit to its high resistance state, and in turn limits the fault current causing it. They have the ability to reduce fault current levels within the first half cycle of fault current level, which results in an increased transient stability of power system. These devices are self-regulating in the event of fault and are fail safe, development of which could be a much-needed breakthrough in fault current limitation techniques.
 - b. **Solid State Fault Current Limiter development:** Solid State Fault Current Limiter uses power electronics based system to detect and limit the fault currents in the system. As soon as fault current happens, before the first peak, the device dynamically inserts additional impedance into the line thus limiting the fault current to the desired level so that circuit breakers can then interrupt current. The device rely on the fast acting capabilities of components like thyristors for its near instantaneous operation.
- High quality pressboard insulation for transformers
- Resin Impregnated Paper (RIP)/Resin Impregnated Synthetic (RIS) bushing.
- SF₆ filled large capacity power transformer technology.
- GIS mapping of transmission assets.
- Reduction of Transmission and distribution (T&D) losses
- Transformer-less HVDC transmission.
- Development of Emergency Restoration System (ERS)
- Reduction of Electromagnetic interference with Television (TV) and Communication signals.
- Biodegradable Insulating Oil for Transformer, lubricating oil for Turbo-Generator.
- High-voltage recovery transformers,
- Use of Robotics and unmanned aerial vehicles (UAV e.g. DRONE) in construction, supervision, operation and maintenance of power system equipment in difficult and inaccessible areas.

- Development of outer sheath of overhead conductors
- Development of techniques for large scale Renewable Energy integration
- Development of adaptive protection system against bi-directional power flow
- Development of cyber secure monitoring and control system

11.3.2.13 Indigenous development of following technologies may also be taken up which will make India self-reliant:

- High Voltage Direct Current (HVDC) and Flexible Alternating Current Transmission System (FACTS) components
- Digital substation components including Non-conventional Instrument transformers (Optical Current Transformers / Voltage Transformers)
- Phasor Measurement Unit and Phasor Data Concentrator for Wide Area Monitoring System
- Implementation of latest technologies like Virtual Distributed Network (VDN) may be explored for safeguarding and securing the communication in power sector.

11.3.3 Thrust areas of Research for Power Distribution

Distribution system is the most important part of the whole chain of Power System as it is directly connected to the consumers. A large share of system losses occur in distribution circuits and a significant amount of power system investment goes in the purchase and installation of distribution hardware. In recent times, the development of smart grid and the use of roof top solar power, storage and adoption of electric vehicles (EV) will herald a new way distribution networks to function.

The distribution sector requires priorities in research and development since the efficiency, financial viability and losses in the distribution system affect the reliability and quality of power supply along with economic viability of the total power sector as a whole. The R&D in distribution system should be based on the following objectives:

- Providing 24x7 reliable, quality and economic power to all consumers
- Minimum technical and commercial losses
- 100% metering, billing and collection by use of meters in pre-paid mode to do away with manual metering, billing and collection deficiencies.
- Using Information Technology for data acquisition, data analysis and control for better management and planning of the system.
- More consumer satisfaction/faster disposal of the Consumer Grievances

The existing Distribution system needs careful attention in many areas such as reduction in losses, 100% metering, billing and collection efficiency, distribution automation, smart metering, harmonics reduction, Demand Side Management (DSM), integration of solar roof top systems, Microgrids, energy storage systems etc.

Smart grid represents a vision for a digital upgrade of power distribution system to both optimize present operation as well as to open up new avenues for alternative energy production. Improvement in reliability of distribution network can be achieved with

deployment of Supervisory Control and Data Acquisition (SCADA) System/Distribution Management System (DMS)/ Advance Distribution System Management (ADSM) for remote monitoring and control of various network elements, obviating need for manned substations. DMS/ADSM extends the monitoring and control functionality of SCADA to distribution transformers. Remote Terminal Units (RTU) and Fault Passage indicators (FPIs) are installed at substations.

Some of the important areas for research in the Distribution sector is as follows:

11.3.3.1 Distribution Automation (DA)

The research and development work in Distribution sector should be aimed at developing indigenous know-how of full scale distribution automation system, which can cover from primary substations to consumer level intelligent automation. The future research initiatives for power distribution automation may be:

- Customer level intelligent automation system
- Computer aided monitoring and control of distribution transformers
- Substation and feeder level automation
- Data communication system for Distribution Automation
- Development and Standardization of Distribution Automation software

Also, IEC 61850 compliant relays and sensors for distribution automation are required to be developed for future smart grids.

11.3.3.2 Feeder Load Characteristics

Individual feeder loads differ widely in their behaviour. A methodology needs to be evolved for studying feeders in order to characterize them. The technique should be relatively simple and trade off accuracy against effort involved, since any distribution entity has a large number of feeders, and needs to accurately predict their contributions to the total load curve for the next day, so as to contract for energy supplies from generation companies.

11.3.3.3 Security and Protection

In conventional distribution schemes, loads are protected mainly through over-current relays and fuses. A smart grid has the facility to provide more sophisticated protection. In addition, the ability to operate the feeder through remote control opens up the possibility of load control in response to under-frequency conditions and voltage collapse.

11.3.3.4 Mobile Substation development

Disasters like earthquake, cyclone, flood, fire in substations and transformers, sabotage attempts etc. can have impact on power transmission and distribution system availability. When disruption is prolonged, a Mobile Substation, which can be moved from one location to another, could play a critical role in re-establishing the grid connection by acting as an emergency restoration system, by circumventing damaged substation equipment, allowing time for conventional restoration works.

11.3.3.5 Underground substations for Space Constraint Areas

Building new transformer substations in inner-city zones or expanding existing facilities is a challenging task due to the lack of space. There is an increasing demand for compact and

discreet transformer substations in city environments for urban development projects and other densely populated areas around the globe.

11.3.3.6 Development of Digital Energy meters (IEC 61850-9-2 compliant)

World is moving with fast pace towards digitization. In the transmission system, digital substation with process bus is gradually moving from pilot stage to commercial installations. Non-Conventional (Optical) Instrument Transformers (NCIT) are being adopted in substations due to its superior characteristics over conventional measuring transformers. However, absence of digital energy meters is restricting the penetration of NCITs and thereby digital substations. As there are only limited suppliers for IEC 61850 compliant digital energy meters world over, with the growing adoption of Full Digital substation technology, an IEC 61850 sampled values based Energy Meter is required to be indigenously developed. This will further pave way for adoption of NCIT and digital substations.

11.3.3.7 Development of smart grid applications

A smart grid is an electrical grid with automation, communication and IT systems that can monitor power flows from points of generation to points of consumption and control the power flow or curtail the load to match generation on real-time basis.

The smart grid enables increased predictability and control of generation and demand through consumer involvement, thus bringing flexibility in both generation and consumption, enabling the utility to better integrate intermittent renewable generation and reducing costs of peak power. A smart grid is cost-effective, responsive, and engineered for reliability of operations.

Development of Smart Grid attributes in distribution like Advanced Metering Infrastructure (AMI), Outage Management System (OMS), Supervisory Control and Data Acquisition, Peak Load Management, Integration of Distributed Generation, etc. could be taken up which will make distribution system more resilient and reliable. Smart Grid facilitates bidirectional communication between utility and consumers resulting consumer participation in the energy management process.

The following are thrust areas identified under four different themes for smart grid implementation:

11.3.3.7.1 Operation, Control and Protection

- Operation and control of large, medium and small scale renewable energy sources
- Protection technologies for AC and DC smart grids
- Wide area monitoring, protection and control (WAMPC)
- Energy management techniques including ADSM.
- Supervisory control of network with multiple micro and nano grids
- Network analysis and optimal power flow
- Modelling and simulation of large power grids (including cyber systems)
- Seamless Grid operation involving Transmission System Operator (TSO) and Distribution System Operator (DSO).
- Forecasting of renewable and loads

11.3.3.7.2 Information & Communication Technology (ICT) and Cyber security

- Reliable wired and wireless communication technologies, communication security testing
- Interoperability (data and device) and ICT architecture
- Audit and validation tools for cyber security features
- Home Area Network (HAN), Wide Area Network (WAN), and Internet of things (IoT) in distribution system
- Threat models and Cyber security
- Information privacy and handling challenges
- Cloud Computing, data storage and big data analytics
- Cybersecurity standard as well as standard operating procedure (SOP) development and adoption
- Cybersecurity compliance procedure development (Device and system)
- IoT device security development
- Data protection system
- Multi-layer Data Abstraction Mechanism development

11.3.3.7.3 Devices and Technology (Converters)

- Fault ride through enhancement of converter interfaced to renewable energy sources
- Optimal design of flexible power converters
- Coordination and control of multiple converters and modular multi-level converters
- Converter technologies for HVDC and MVDC systems
- Multi-functional hardware and smart grid enablers
- Smart and unified control of converters
- Hot swappable converters for smart grids
- Standardization of voltage and power levels
- Network voltage regulation and power quality
- Use of wide band gap devices - Gallium nitride (GaN) and silicon carbide (SiC)

11.3.3.7.4 Distributed Energy Resources, Storage and Deployment Issues

- Policy, regulatory and market design issues
- Demand side management with optimization and forecasting techniques for storage and renewable energy source (RES)
- Inertial issues of renewable energy resources with stochastic behaviour
- Optimal mix, siting and sizing of energy storages at various levels of network

Some other focused areas of research in smart grid are as follows:

11.3.3.7.5 Advanced metering infrastructure (AMI)

Advanced metering infrastructure (AMI) is an integrated system of smart meters, communications networks, and data management systems that enables two-way communication between utilities and customers. Smart meters help DISCOMS reduce aggregate technical and commercial (AT&C) losses, improve their financial health, incentivize energy conservation, enhance ease of bill payments, consumer satisfaction and ensure billing accuracy by getting rid of manual errors in meter reading. There is continuous need for innovation in smart metering and advance metering infrastructure. The existing system needs

to be overhauled to support a completely digitized ecosystem that will also take the country into the future in terms of smart grid feasibility.

The following deployment and Research areas can be explored for making AMI systems manageable:

- Smart Meter with multiple communication systems as option at time of procurement and field placement
- NBIoT / LPWA/LoRaWAN based AMI deployment. Narrowband Internet of Things (NBIoT) is a Low Power Wide Area Network (LPWAN).
- Head End System (HES) with multiple Meter interoperability both communication and manufacturing heterogeneity
- Technologies for reliable information exchange between DISCOMs and customers
- Head End system interoperability with Meter Data Acquisition System (MDAS).
- Reliability of information exchange between DISCOMs and Customers is a cause of concern.

11.3.3.7.6 Intelligent Universal Transformers

The intelligent universal transformer concept involves a state-of-the-art power electronic system and is not a transformer device in the traditional sense. It would be designed to replace conventional transformers with a power electronic system that steps voltage as traditional transformers do, but can also manage and control consumer demand and power flows, and compensate for reactive power.

11.3.3.7.7 R&D in power semiconductor devices

The power electronic devices for grid applications must be extremely reliable; Research is required for development of power electronic devices which will have higher reliability and security. It should focus on various applications such as smart inverters/converters for RES integration, automotive and industrial applications, solid state transformers and breakers, consumer electronics etc.

11.3.3.7.8 Reduction of harmonics and electromagnetic interference

Development of switching strategies that minimize harmonics or different converter topologies, such as multilevel converters that minimize the generation of harmonics, is required. In addition, research may focus on the ability to switch at higher switching frequencies which will enable harmonics to be more easily filtered out with smaller capacitor and/or inductors.

11.3.3.7.9 Development of advanced control systems for multiple converters

There might be multiple power converters connected to the T&D system. These converters might induce circulating current in one another, and/or their functions might compete with one another. Presently, limited research has been done on controlling multiple power converters. More advanced control systems must be developed to better utilize multiple converter systems tied to the grid.

11.3.3.7.10 Development of test-bed for power electronics components and systems

The demonstration phase of advanced technologies is typically a cautious attempt by the utility industry to operate in a field environment, but it can be quite expensive and of little value if the technology is not fully evaluated because it is operated in a low-impact location or not placed into full service. Since many demonstrations do not provide a full spectrum of events that a device or system might see over the course of its life, the credibility of the technology may require many expensive demonstrations and years of field testing to gain the confidence of the utility/industry. Thus, the expensive and lengthy technology demonstrations must be resolved by providing a full-power (high-voltage and high-current) testing environment that can fully test and evaluate a range of early prototypes to near-commercial distribution technologies. This process would reduce the lead time to implementation.

11.3.3.7.11 Automatic Fault Detection and self-healing

Compared to the conventional impedance based or travelling wave based fault location methods, artificial intelligence based fault location methods may have better adaptability, which may be examined. With the ever increasing computation and communication abilities, artificial intelligence based fault location will play a more significant role for automatic fault detection in future. Advanced machine learning methods may have a better performance than the methods used currently. Thus, research on development of artificial intelligent /machine learning algorithms may be considered for future research for fault detection, fault localization, faulted area isolation, and power restoration in the electrical distribution system.

11.3.3.7.12 Demand Response and Peak Load Management

The electric power industry considers demand response programmes as an increasingly valuable resource option. One of the goals of the Smart Grid research is to develop grid modernization technologies, tools, and techniques to utilize demand response and help the power industry design, test, and demonstrate integrated national electric/communication/information infrastructures with the ability to dynamically optimize grid operations and resources and incorporate demand response and consumer participation. It provides an opportunity for consumers to play a significant role in the operation of the electric power grid by reducing or shifting their electricity usage during peak periods in response to time-based rates or other forms of financial incentives.

11.3.3.7.13 Cloud Interoperability

Interoperability within the context of Cloud Computing means enabling the Cloud Computing Ecosystem whereby individuals and organizations are able to widely adopt Cloud Computing technology and related services in such a fashion that multiple Cloud platforms can exchange information in a unified manner and ultimately work together seamlessly. Utilities have to deal with lot of data for day to day requirements. Either they have to establish or maintain their data centres or use cloud services. In this context, cloud services and interoperability will be a necessity in future and appropriate technologies may be developed for the same. In a hybrid cloud / ICT infrastructure, ensuring security requirement in CASB (Cloud Access Security Broker) platform for facilitating iSoC (integrated Security Operations Centre) needs attention. Implementation of Cloud Controls and concept of data localization must be ensured.

11.3.3.7.14 Public perception and reaction to Electrical Hazards

Very little research has been done on consumers' reactions to blackouts, whether caused by natural disasters, equipment failure, or terrorism. The goal of the research work would be to study the perception and various reactions of general public in the event of a blackout and develop protocols for the DISCOMs for responding effectively to major disruptions of the power supply. The research may lead to development of technology/software so that the consumers could be kept informed and made aware of constructive steps undertaken. This will help to minimize public unrest.

11.3.4 Thrust areas of research for Renewable Energy

Hydrocarbon resource limits are bound to force the world away from fossil fuels in coming decades. In addition, the environmental and health burdens arising out of the use of hydrocarbons may force mankind towards clean energy systems. Therefore, there is need for electric power industry to look at other technologies of power generation through solar, wind, biomass, municipal solid waste, agro-residue based plants, small hydro, fuel cells, geothermal etc.

Technologies related to wind, biomass, solar, small hydro, geo-thermal, fuel cells, Waste to Energy (WtE) need to be identified. Research to focus on grid connectivity of large wind mills, self-healing wind connected micro grids, distributed generation and large use of ethanol/methanol for energy products. Development of micro and mini grids and larger penetration of renewable energy is an important area of research. Further, some of the research areas are as follows:

11.3.4.1 Renewable Energy Integration

With the rapid growth of variable renewable energy mainly from solar photovoltaic and wind, innovative technologies and operation modes to support renewable energy grid integration into the electric distribution and transmission system is need of the hour. A systems approach is being used to conduct integrated development and demonstrations to address technical, economic, regulatory, and institutional barriers for using renewable and distributed systems. The goal of Renewable energy integration is to develop advance system design, planning, and operation of the electric grid to reduce carbon emissions, peak load management, support achievement of renewable portfolio standards for renewable energy and energy efficiency, support reductions in oil use by enabling plug-in hybrid electric vehicle (PHEV) operations with the grid and support protection of critical infrastructure in highly constrained areas of the electric grid.

11.3.4.2 R&D in renewable energy may be carried out on the following thrust areas:

- Development of micro grids and suitable control mechanism - integration of renewable energy into the grid.
- Interconnection of Micro grids at distribution voltage level and control of power flow between micro grids.
- Energy storage: electrical and thermal storage with enhanced charge-discharge efficiencies and new technology routes like sand, concrete, particle storage media,

magnetic, electro-static, compressed air energy storage, concentrated solar PV storage etc.

- Development of Solar PV and Wind forecasting technologies
- Solar PV performance and degradation studies
- Indigenous development of cost effective floaters for floating solar PV (FPV) plants.
- Identification of best-suited technology for maximum solar PV generation.
- Indigenous development of wet and dry robotic cleaning system for PV modules.
- Development of super hydrophobic coatings for PV modules.
- Utilization of Unmanned Aerial Vehicles (UAVS) Drone, Light Detection and Ranging (LiDAR) for PV Plant inspection.
- Utilization of concentrated solar thermal (CST) energy for cooking systems, desalination and cooling systems.
- Development of solar thermal and fossil fuel based hybrid power plants.
- Development of solar thermal collectors, tracking mechanism, receiver coatings, thermal heat storage configurations and control system for heating, cooling etc.
- Synchronization of roof top solar and micro generation to the grid.
- Reactive power management at the level of micro grid and distribution system and its contribution towards the stability of the grid.
- Impact of climate, weather, geography, seasonal and other factors on renewable energy generation.
- Impact of socio-economic factors and life style of society at different strata on the usage pattern of energy at distribution level.
- Suitability of Pico hydropower in isolated hilly areas/villages of India.
- Fuel cell development.
- Electric Mobility issues – development of super-efficient batteries with fast charging capabilities suitable for transport application.
- Indigenization of Concentrated Solar power technology
- Increased use of Floating Solar Photo Voltaic
- Building integrated Photo voltaic
- Application of nano technologies for power plant applications
- Bio Mass and Bio Fuel for energy generation
- Waste to energy conversion
- Mechanism for safe disposal, reuse, recycling and reclamation of useful material of solar PV panels, storage batteries and other material to counter the related environmental pollution.

- Impact of large scale integration of renewables into the Grid
- Road top/Canal top solar plants
- Development of methodology/equipment to detect micro cracks in solar cells
- Smart utilization of solar and wind farm inverters as FACTS devices in grid integrated renewable energy
- Large-scale thermal energy storage
- Technologies to reduce demand on the power system like efficient lighting, efficient space conditioning (building heating/cooling), efficient domestic water heating
- Virtual Power Plants
- Electric Vehicles :
 - Impact of large-scale EV charging on Power Quality
 - Smart charging of EVs with renewables and V2G/V2H in micro grid
 - Participation planning of EVs in smart grids for demand response
 - Battery Safety by Early Examination, Prediction and Prevention of failure for Future Electric Powered Vehicle

11.3.4.3 Indigenous development of following technologies may also be taken up which will make India self-reliant:

- Indigenous manufacturing of bidirectional EV chargers
- Indigenous manufacturing of EV Supply Equipment (EVSE)
- Indigenous development of connected car technology and protocols for EV Supply Equipment (EVSE) and V2G/V2H
- Indigenous manufacturing of distribution power electronic devices
- Indigenous manufacturing of Energy Storage Systems including the battery Energy storage system (BESS).
- Recycling of batteries, solar panels and blades of wind turbines as well as other power sector residue. These need to be recycled and useful material reclaimed.

11.3.4.4 Development of Energy Storage Systems

Energy storage systems provide a wide array of technological approaches to managing our power supply in order to create a more resilient energy infrastructure and bring cost savings to utilities and consumers. However, existing ESS technology faces challenges in storing energy due to various issues, such as charging/discharging, safety, reliability, size, cost, life cycle, and overall management like disposal and recycling after useful life. Development of Battery Energy Storage System at grid level based on different technologies like Advanced Lead Acid, Lithium Iron Phosphate etc. could be taken up. Battery system may be useful for applications like frequency regulation, energy time shift, dynamic frequency regulation, voltage/reactive power support, renewable energy capacity firming etc. However, these aspects need to be further researched.

11.3.4.5 Development of Super Capacitor

Super capacitors are an alternative to batteries, which gets charged much faster and have more charging / discharging cycles possible in comparison to batteries. Even though they have much lesser storage capacities than batteries, they can be used in critical applications, which involve frequent charge and discharge cycles, extreme operating temperatures, or rapid discharge of high amounts of energy.

11.3.4.6 Superconducting Magnetic Energy storage system development

Superconducting magnetic energy storage (SMES) system stores electrical energy in the form of magnetic field created by the flow of direct current in a superconducting coil, which has been cryogenically cooled to a temperature below its superconducting critical temperature. As the superconducting coil has negligible resistance, there will be no losses of stored energy. SMES is a highly efficient grid-enabling storage device that stores and discharges large quantities of power almost instantaneously with unlimited number of charging and discharging cycles possible. Its applications include system stability improvement and effective damping, power quality improvement, load levelling, spinning reserve, protection of critical loads etc. which could be much needed energy storage device for integration of renewable energy.

11.3.4.7 Other storage technologies

11.3.4.7.1 Research and Development in Hydrogen Technologies

Hydrogen is the most abundant element on earth, but it doesn't typically exist by itself in nature and must be produced from compounds that contain it. Hydrogen can be used for diverse energy solutions such as electricity production from the fuel cell, energy storage, etc. The hydrogen can also be converted into hydrogen based fuels, including methane, methanol, etc. and can be used for transportation purposes. Owing to its clean combustion characteristic and zero carbon footprint, hydrogen has the potential to be the fuel of the future. Going forward, a developed hydrogen economy provides for a cleaner environment ensuring national energy security.

Currently, Hydrogen is primarily produced from fossils fuels, especially natural gas. Hydrogen can also be produced from coal, biomass and water. Most of the hydrogen production at present is fossil-based which leads to significant emission of CO₂ to the atmosphere. As the cost of renewable electricity is decreasing, the same can be used to produce hydrogen through electrolysis of water. Hydrogen can also be produced directly from sunlight and biomass. Electrolytic hydrogen produced from green power, instead of conventional grid electricity, and hydrogen produced from other cleaner mechanisms have been termed as "Green Hydrogen". The production of green hydrogen should be the primary focus of research in the coming years.

In spite of recent advances in the production of hydrogen, the cost of each component of hydrogen technology is much higher than the conventional fossil fuel-based economy. Research and development is extremely important for reducing the cost, improving the performance, and increasing the reliability of fuel cells, electrolyzer, storage, and transport components, etc. It is essential to promote Pilot/large-scale integrated demonstration project for a complete hydrogen ecosystem. This would provide data for safe handling, O&M, and identifying gaps/concerns in terms of cost, reliability, safety, standards of performance (SOPs), and training. Hydrogen is the foundation on which success of several initiatives are

critically dependent viz CO₂ utilization, waste to hydrocarbon, energy storage, green transport etc. The domain of hydrogen has multiple facets to work on, but the one's relevant for power sector are brought out below:

- Development of electrolyzers :
 - High Temperature Solid Oxide Steam (HT-SO-S) Electrolyzer: Hydrogen production from electrolyser route is seriously energy intensive i.e 50-55 kWh/Kg H₂. Compared to these, HT-SO-S Electrolyzer are ~30% efficient. The technology is at nascent stage – and therefore it is time that India makes a foray into it.
 - Sea / Hard Water Electrolyzer: 10 kg DM water is required for production of 1 kg Hydrogen. Tomorrow, when huge quantum of hydrogen production is envisaged, 10X quantity of DM water shall be required. Considering this, development of Sea/Hard Water Electrolyzer may be contemplated.
- Development of various novel techniques for hydrogen storage and compression
 - Metal Hydride based Hydrogen Compression and Storage: Hydrogen is the smallest molecule – therefore its storage and compression is highly energy intensive. Also, due to the very small molecular size – precision manufacturing and maintenance of hydrogen compressors makes it quite expensive. Metal Hydride is a non-moving unit and it practically takes care of all of the above issues.
- Development of technologies for the production of hydrogen directly from sunlight and biomass
- Low cost green hydrogen production on a large scale
- Prevention of catalyst poisoning in case of catalytic conversion for large scale hydrogen production
- Substitute for expensive catalysts in case of green hydrogen production processes
- Reducing cost of catalyst, membrane and components of fuel cell
- Catalytic reformation of SynGas to Hydrogen: Development of this process shall open door for utilization of Municipal Solid Waste (MSW), Agri Waste/Agri Residue, Coal Mill Reject and other carbonaceous material for distributed/centralized hydrogen production. Also development of efficient gasification (oxy, steam or plasma gasification in absence of nitrogen) shall be an important building block in this direction.

11.3.4.8 R&D for mitigation of adverse effects on Environment

The need for electricity generation to be clean and safe has never been more obvious. Environmental and health consequences of electricity generation are important issues, alongside the affordability of the power which is produced. Production of electricity from any form of primary energy has some environmental effect. The power sector in India is one of the main sources of CO₂ emission in the country.

There are various technologies and processes that have substantial potential to reduce GHG emissions, for instance, coal and biomass gasification technology; gas turbine technology; power generation with solar thermal and photovoltaic technology, fuel cells, etc. Clean coal

technologies and renewable energy usage have been adopted in India as methods of best approach to tackle climate change.

Apart from the above-mentioned measures, further steps can be implemented for reduction of CO₂ emissions. These are research and development; information and education (for awareness); economic measures; regulatory measures; and voluntary agreements. Each step offers advantages and drawbacks and has different effects on CO₂ reduction. Low carbon generation options, such as carbon capture and storage (CCS), nuclear and renewable technologies, are needed to substantially reduce emissions. Due to the high ash content of Indian coal, oxy fuelling and post combustion CO₂ capture would appear to be suitable options for India. Pre-combustion capture in a coal fired IGCC plant would require the adaptation of the technology to the Indian coal quality, or the use of imported coal. Retrofitting coal power plants with CO₂ capture technologies and new plants with CCS may be a good option for the country like India.

Developments of following technology ready methods are being tried:

1. Use of CO₂ for reduction in pH of ash water
2. CO₂ capture by Modified Amine Solution
3. Development of Pressure Swing Adsorption (PSA) process for CO₂ capture and conversion of CO₂ into useful products

PSA is a technology used for separation of some gas species from a mixture of gases under pressure according to the species' molecular characteristics and affinity for an adsorbent material. Special adsorptive materials (e.g., zeolite) are used as a molecular sieve, preferentially adsorbing the target gas species at high pressure. The process then swings to low pressure to desorb the adsorbent material.

Clean environment mechanism at thermal power stations, creating data base for ash quality, advanced ash management schemes, sustaining coal based power generation considering new and emerging environmental issues, effects of electromagnetic waves on human beings with specific reference to up-gradation of transmission voltages, eco-design and energy efficient power transformers, development of waste water treatment and recycling technologies, emission control technologies for NO_x, SO_x and mercury are some of the areas where R&D activities are required for improvement of environment and for sustainable development.

11.3.5 Cyber Security of Power Systems

With the integration of communication and information technology in power system, it becomes essential to address the issues related to cyber security. Establishment of Safe, Secure and Resilient information infrastructure against cyber threats in all the three segments of the Power System viz. Generation, Transmission and Distribution of Power is the need of the hour. Cyber Security breach of the systems deployed in Power Sector may impact the stability of Grid as well as Public Safety. Therefore, the aspect of Cyber Security should be included in designing, installation, operations and maintenance of the systems in all organizations of the Sector. Cyber Security in all above verticals must include Security-by-design and not by retrofitting. Thus, research shall focus towards Critical Information Infrastructure (CII) protection in Power Sector and on proprietary protocols in the field of

power systems to secure the systems in better ways. The following are some of the areas for research and technological advancement:

- Establishment of cyber security test bed for the following:-
 - Validation and testing of cyber security aspects in Intelligent Electronic Devices and Network Devices, with respect to IEC 61850-based communication within a substation.
 - Validation and testing of cyber security aspects in smart meters and AMI
 - Validation and testing of cyber security aspects in OT applications such as SCADA, EMS, DMS/ADMS, OMS
 - Validation and testing of cyber security aspects in IoT devices
 - Validation and testing of cyber security aspects in WAMS devices and systems
 - Facility/ Lab for Security labeling and certification of power equipment by an appropriate authority at national level.
 - Identification and assessment of presence of embedded Malware/Trojan in potential vulnerable devices/systems used in power transmission or distribution system.
 - Detection and development of mitigation strategy for various cyber-attacks including exercises of Red and Blue teams for updating new threat vectors regularly. Also, suggested to have “Cyber Range Facility” having capabilities to simulate OT / ICS.
- Stronger “Role Based Access Control (RBAC)” mechanism at Industrial Control Systems (ICS)
- Multi-factor authentication mechanism needs to be explored at device and application level.
- Centralized, dedicated Security Operation Centre (SOC) and the facility and deployment of SOAR for automated response in case of cyber-attacks. Automation in generation of advisories for the detected cyber threats and vulnerabilities in real time.
- Removal of the old and unsupported Operating Systems (OS) and deployment of new Operating Systems may be taken into consideration in a phased manner, in order to mitigate the cyber risk. The efforts should be made to migrate from Windows based systems to more secure Linux/Unix based systems.
- Phasing out of Legacy system with or without indigenous in-house research and development of relevant technologies and equipment.
- Protection of PMUs from cyber-attacks especially GPS spoofing attacks.
- Detection and prevention of false data injection attacks in smart grid.
- Decision support tool for prediction and prevention of catastrophic failure from cyber attacks.
- Data security protocols for power systems.
- Cyber security for Substation Automation (especially for SCADA) in Power Transmission/Distribution
- Wide Area Monitoring System (WAMS)
- Security of Wireless Network Communication Infrastructure in Power Sector
- Design and Development of best strategies for detection, mitigation and control of Supply Chain exploitation on SCADA/Industrial Control Systems (ICS, DCS) and Smart Grid utilities of the Power Sector.

- As power utility control systems will be operational for 24x7, most of the time updating patches is a very difficult task and requires OEMS' support since some patch updates requires rebooting of the system which is not desirable and also these patches needs to be tested in offline with the applications before deploying in operational systems. Online testing and deployment of patches need attention.
- R&D projects on “Evaluation of Quantum Computing” may be considered. The Power grid infrastructure in today's time is vulnerable towards security breaches. If utilities don't apply quantum encryption to the grid, hackers will be easily able to penetrate it. Adding quantum keys to encryption could make it possible to create hack-resistant algorithms. R&D on the same may be very useful as futuristic approach towards cyber security.
- Exploring secure IT-OT convergence
- Model ICT architecture needs to be developed which can be used as a framework in power system
- A guideline needs to be developed for internal/third-party cyber forensic audit at a regular interval
- A guideline needs to be developed for ensuring various cybersecurity compliances such as IEC27001, IEC62351, NERC CIP.
- Standard operating procedure (SOP) needs to be developed for device or application integrations
- Multi-level data abstraction needs to be explored
- Development of cyber-resilient redundant and distributed architecture
- Development of a directory of best practices for making cyber secure power system operation.
- Explore ethical hacking as a strong measure to secure the system.

In addition to the above, the following may also be taken into account to aid in research on cyber security of Power Sector:

- Identification of Critical Information Infrastructure (CII) and Non-CII elements in the streams / utilities and appropriate planning for allocation of resources.
- Establishment of Cyber Security (CS) structure in organizational working hierarchy (Chief information security officers (CISO) and teams for Cyber Security. A clear governance is required to ensure that ICS cybersecurity efforts will be successful in the long run.
- Empowerment to Sectoral CERTS to meet cyber security needs.
- Identification of gap areas in cyber security posture of CII elements. This could ideally be achieved by doing holistic Vulnerability/Threat/Risk (V/T/R) analysis of Critical elements and interdependent systems.
- Shifting of Web Based Scheduling systems from Internet to Private Intranet.
- Threat analysis and penetration testing needs to be undertaken before commissioning the elements of power system, which are vulnerable to cyber-attacks.
- Cyber Security capacity development of the manpower and testing facilities.
- A minimum baseline cyber security to be formulated and applied in all the streams.
- Situational awareness & Information Sharing of cyber incident with relevant agencies.
- Defense in-depth approach security and electronic security perimeter has to be devised
- Networking Segmentation /zoning/ Demilitarized zone implementation to be followed at levels of OT & IT interfaces connecting points

- Exploring the option of virtual machines, tokenized system, Virtual Private Network (VPN) in day to day operation
- Adopt best IT practices in OT systems.

11.3.6 AREAS FOR R&D TO BE TAKEN UP DURING 2027-32

In order to have a long term vision for the Power sector of India, it is necessary to identify some of the promising technologies and keep a track on the adoption of the technologies by various sectors. Accordingly, small scale feasibility studies can be taken up on the following topics during the year 2022-27 and based on the results research projects may be formulated for being taken up during 2027-32:

- Quantum Computing in Power Sector
- Edge analytics in Power Sector
- Gravity based energy storage
- Lithium-Air Batteries
- Aluminium-Air Batteries
- Distance Wireless Charging
- Printable Batteries
- Energy Harvesting Using Thermal Gradients
- Augmented Reality in Power Sector

11.4 INITIATIVES Proposed for improving R&D in the Power sector

11.4.1 Management of Technology and Innovation

As number of research activities are being carried out simultaneously in the power sector, it is of utmost importance to maintain a robust knowledge management portal to keep a track on the findings of the research projects and bring out the best results into prominence for further refinement and subsequent adoption in the Power Sector.

A national level 'Digital Database of R&D projects' of all nationally funded major projects may be created which in turn will not only help in the realization of the R&D objectives but also keep a track of the technology landscape in the country. A suitable online R&D management system also needs to be in place, primarily at CPRI, and also across the other national R&D centres of importance for managing the research projects.

11.4.2 Strengthening of the R&D Infrastructure

R&D Infrastructure at National Level needs strengthening in terms of facilities especially for type testing of prototypes with a view to minimize development / commercialization cycle. A national audit may be conducted through industry and utility forums to identify the gaps and efforts should be made to bridge the gaps.

11.4.3 R&D programmes

The R&D programme of the Ministry of Power being implemented through CPRI has been of great benefit to the Academia, Utilities and Industry in the Power Sector. The schemes have helped in building R&D infrastructure in many organizations over a period of time and enabled training of manpower for applied research. Collaborative research projects from Academia,

Industry and Utility may be encouraged under the programmes. CPRI and CEA may also propose various research projects of national importance and execute them in a collaborative manner.

11.4.4 Periodic Call for focused Research projects on a thrust area

Under the RSoP and NPP schemes of MoP proposals are invited on the thrust areas of research. Beside the regular proposals, CPRI may identify specific themes like “E-cooking”, “Light Emitting Diode”, “Cyber Security” in the recent past, and separately advertise for research proposals on those themes to targeted research groups. This will help in covering the research topics of importance where previously very less proposals may have been received.

11.4.5 Mission Mode projects in Power Sector

In order for the power sector to leapfrog in the technology advancement, research on two main aspects may be carried out as mission mode projects:

1. Research on Disruptive technologies for Power Sector
2. Research promoting Indigenous manufacturing of technologies for Power Sector

A breakthrough in the disruptive technologies like ‘Wireless power transmission’, ‘High Temperature Superconductors’, New and cost effective storage technology etc. will bring the nation to the forefront of technology development. Such technologies can transform the Power Sector landscape of the country and transform India from a technology adopting nation to a technology exporting nation. CPRI in association with CEA may take the lead role in initiating mission mode research projects on such technologies in a collaborative manner.

It is also necessary to build competence within the country to manufacture the power equipment imported from abroad. Such initiatives may be taken up by CEA with the prominent Indian Manufacturers to lead the way towards creation of manufacturing hubs for specific equipment within the country. Initiatives such as these will reap benefits in the long run towards making India a self-reliant nation.

11.4.6 Competence mapping in Power Sector

India has one of the largest skilled manpower in the world consisting of national and international level experts. There is a need to scientifically measure the competence level and areas of the experts and the organization to classify the country’s expertise level on various aspects of the Power Sector. This would help in deploying the right scientific input to a given R&D project. The ‘measurement matrix for competence mapping’ has to be created and the experts and expert organizations are to be evaluated against the norms stipulated. This will help in creating a ‘knowledge bank of country’s expert resources’, rather than arbitrarily rating the country’s expertise and the experts in various areas. The up-gradation of knowledge level through training could thus be more structured and measured. India’s key technical competence areas, the competence level of various R&D organizations, the competence level of the experts, etc. can be documented for improvement purpose.

11.4.7 Revised norms for acceptance of products indigenously developed under research projects

In the context of Power Sector, many indigenously researched and developed products, especially those involving substantial developmental investment, face entry barrier in the

form of qualification requirements pertaining to equipment performance over a minimum period specified by end users.

There is need for enunciation of a clear policy / guidelines to provide incentives for the commercialization of products developed through indigenous R&D efforts. Procurement process may be adjusted for adoption of new technology in an easier way. The incentive could be among others, in the form of excise duty exemption at least for a period of five years from the date of commercialization. Approval for testing/trials for newly developed product shall be encouraged through speedy approvals by customer and CEA.

11.4.8 Policies for R&D

- Developing integrated R&D plans based on a multi-disciplinary approach. A well-integrated R&D plan would ensure that proposed programs are appropriate, reflect current and planned resource endowments, and involve communities in discussions of energy policy;
- Removing fossil fuel subsidies to balance the energy pricing mechanism in order to attract or drive private capital to the energy industry;
- Developing skills and capacities to create a knowledge workforce leads to success of energy efficiency programs, proper operation and maintenance of clean technologies;
- Providing as much certainty as possible concerning long-term (e.g. 5 to 10 years) funding for R&D
- Monitoring and evaluating R&D programs enables timely adjustments to funding levels and strategies when necessary

11.4.9 Institutional and funding framework for R&D

Government should fund the R&D programme through schemes such as “R&D Schemes of MoP being implemented through CPRI”. The projects can also be carried out in collaborative mode with participation from CPSUs, Industry and academic institutes and utilities.

CPRI, NTPC, NHPC, SJVNL, THDCIL, POWERGRID, DISCOMs, BHEL, CSIR laboratories, Government funded R&D Institutions, IITs, NITs may execute the projects identified, which shall be coordinated and managed by CEA and CPRI on behalf of MoP.

Government should continue to support CPRI through capital grants. The regional laboratories of CPRI can help India’s small and medium entrepreneurs to produce globally competitive electrical products. This will be a major initiative to boost our “Make in India” programme.

Policy to earmark a larger percentage of profit after tax (PAT) by PSUs as part of CSR should be considered to provide the much needed impetus to R&D in Power sector. It may be worth creating a large corpus funds for R&D in power through CSR funding from various organizations in power sector.

11.5 RECOMMENDATIONS

Followings are the important recommendations of this sub-group:

1. Collaborative research projects having high impact on the Power Sector may be taken up with Industry, Academia, and Research Labs. Such projects should have specific deliverables which can be immediately implemented on field.
2. Short-term R&D Projects on specific priority areas as identified by Utilities/Industry for adoption in the major domains may be taken up every year.
3. The focus of research should be on product development and the Industries should be encouraged to become product oriented rather than service oriented.
 - a. Our country has a vast talent pool and very capable research groups. Efforts should be made to identify potential research groups working on the same areas and initiate joint projects and startups to achieve specific targets.
 - b. Promote a culture for research, IPR creation and commercialization within the CPSUs/ research organizations under the MoP, through conduct of 'In-house' Awareness Programmes, Workshops, etc.
 - c. Specific mission mode projects are required to be identified which can be taken up during the next five years. To this end the following could be done:
 - i. One or two brainstorming meetings/conclave/workshops should be organized twice every year to identify research problems that are of interest to the industry and review the ongoing one.
 - ii. Industries may come up with focused project write ups identifying contemporary problems as well as the impending research requirements, which could then be communicated to experts in IITs/NITs/other engineering institutes to elicit project proposals from these institutes
 - iii. Industry should be associated in evolving and designing these R&D projects and steering the execution of the same, as applicable (e.g., by way of mentoring and field visits by experts from industry etc.).
 - iv. Obtaining the patents and converting the patents/prototype to commercialization need to be promoted.
 - v. Periodic review of i-STEM (Indian Science Technology and Engineering facilities Map) data base w.r.t power sector to be conducted
 - vi. Technology Readiness level assessment and associated blue print for funding priorities and methodologies
 - vii. Collaboration amongst IITs, other higher educational Institutes, Industry, R&D centers and BIS for standardization of new technologies be developed
 - viii. An apex committee at CEA level may be formulated for granting approvals related to foreign procurement for R&D projects thus smoothening current guidelines necessitating approvals from Ministry.
4. The right balance should be maintained between exploratory research and research leading to product development. The allocation of R&D funds among these two categories should be decided at the beginning of each financial year. The quantum of allocation between the two categories could be reviewed periodically and readjusted.

5. A central agency to facilitate the collaboration among different research bodies and research groups working on the same/similar themes be created.
6. A cadre of R&D professionals need to be created/maintained. Researchers be given opportunities to higher education and exposure to training and testing methods. They need to keep themselves updated in the areas of their research and also interact with other groups where their research efforts could be made use or they can acquire the research expertise from other group of different area.
7. There is a need to review the method of induction of the professional into the research bodies. The training of new professional and refresher training of seniors, especially for R&D management should be taken care of.
8. Analytics and Data Science (AI/ML, Big Data) domain is a horizontal cognitive layer that works primarily on huge amounts of data. Internet of Things generates huge amount of data that can be consumed by Analytics and Data Science practitioners and solutions. A common Research, Design and Engineering lab that works on data across all sub-sectors is recommended for this domain. This lab can work with various stakeholders on specific data science related problem statements.
9. Information security (e.g. block chain) and cybersecurity domains are horizontal technology layers that are relevant to all phases of a project, viz, product/ project design, procurement, installation & commissioning, operations & management, supply chain etc. Research on Cyber security of Power Systems should be taken up by a common Research, Design and Engineering lab that works across all sub-sectors. This lab can work with various stakeholders on problem statements, specifically focused on design and engineering of systems, networks, applications etc. This lab will also work with the AI/ML and Data Science lab for application of AI/ML in Information & Cyber security.
10. In order to support high value projects, inter-departmental funding from Ministry of Power, Department of Science & Technology, NITI Aayog etc. may be encouraged. If possible a corpus can be created with CSR contributions from various power sector organizations for promoting R&D and commercialization activities.

CHAPTER 12 HUMAN RESOURCE DEVELOPMENT

12.0 INTRODUCTION

Trained Manpower is an essential prerequisite for the rapid development of all areas of the power sector. The trained manpower comprises of skilled engineers, supervisors, managers, technicians and operators. Power sector is poised for massive growth in generation and commensurate growth in transmission and distribution infrastructure.

Manpower development including training facilities shall be proportional to this capacity addition requirement. The technical knowledge acquired needs to be supplemented with applied engineering in various fields of power generation, transmission and distribution. All these skills need to be regularly updated to cope with rapidly advancing technology.

12.1 MANPOWER ASSESSMENT

12.1.1 Norms for Manpower Requirement

The Norms have been taken from National Electricity Plan 2017-22 Volume I-Generation (Notified in 2018). The norms have been arrived at by considering both contractual and non contractual manpower. These norms are given in **Table 12.1** below:

Table 12.1
Norms for Manpower Requirement

S No	Particulars	Technical	Non-Technical
1	Thermal Generation	0.486	0.144
2	Solar	0.550	0.165
3	Wind	0.321	0.096
4	Biomass	0.486	0.144
5	Hydro Generation	1.341	0.405
6	Nuclear	1.098	0.468

Note: Norm for manpower considered is including regular as well as contractual employment. These norms are average of all sizes of generation capacity. However, value changes with project site and size, higher the plant size lower is the Man/MW ratio. Further Man/MW ratio may further get reduced with increase in level of automation.

12.1.2 Manpower requirement during the years 2022-27

For a capacity addition of 2,28,541 MW considered (including renewables of 1,87,909 MW and 33,632 MW thermal (coal & gas)) in 2022-27, the manpower requirement shall be of the order of 167.65 thousand out of which 128.25 thousand will be technical and 39.40 thousand will be

non-technical. The details of the same are given in **Table 12.2** and **Table 12.3** below:

Table 12.2
Capacity addition during 2022-27

Particulars	Total (MW)
Thermal	33632
Nuclear	7000
Hydro	10951
Solar	132080
Wind(On shore)	40500
Biomass	2318
Pump Storage Plants	2060
Total	228541

Table 12.3
Manpower required for Capacity Addition of 2,28,541 MW envisaged during 2022-27
(Figures in Thousands)

	Technical	Non-Technical	Total
Thermal	16.35	4.84	21.19
Nuclear	7.69	3.28	10.96
Large Hydro	14.69	4.44	19.12
Small Hydro	0.00	0.00	0.00
Solar	72.64	21.79	94.44
Wind (on-shore)	13.00	3.89	16.89
Biomass	1.13	0.33	1.46
PSP	2.76	0.83	3.60
TOTAL	128.25	39.40	167.65

Note : Manpower requirement for Transmission and Distribution will be covered in Vol. II of NEP

12.1.3 Manpower requirement during the period 2027-32

For a capacity addition requirement of 2,43,042 MW (including renewables of 2,24,908 MW) during 2027-32, the manpower requirement shall be of the order of 188.04 thousands out of which 143.70 thousands will be technical and 44.34 thousands will be non-technical. The details of the same are given in **Table 12.4** and **Table 12.5** below:

Table 12.4
Capacity addition during 2027-32

Particulars	Total (MW)
Thermal	9434
Nuclear	8700
Hydro	10888
Solar	147400
Wind(On-shore)	43100
Wind(Off-shore)	10000
Biomass	1500
Pump Storage Plants	12020
Total	243042

Table 12.5

Manpower required for the Capacity Addition of 2,43,042 MW envisaged in 2027-32

(Figures in Thousands)

	Technical	Non-Technical	Total
Thermal	4.58	1.36	5.94
Nuclear	9.55	4.07	13.62
Large Hydro	14.60	4.41	19.01
Small Hydro	0.00	0.00	0.00
Solar	81.07	24.32	105.39
Wind(onshore)	13.84	4.14	17.97
Wind(offshore)	3.21	0.96	4.17
Biomass	0.73	0.22	0.95
PSP	16.12	4.87	20.99
TOTAL	143.70	44.34	188.04

Note : Manpower requirement for Transmission and Distribution will be covered in Vol. II of NEP

12.2 TRAINING NEED ASSESSMENT

12.2.1 Training Strategy

To fulfil the above needs, training to the power sector personnel is required in the following categories:

- i) O&M Training to all existing employees engaged in O&M of generating projects (Thermal, Hydel, Gas) and Transmission & Distribution System as per statutory requirements under the Gazette Notification of September 2010 issued by CEA ranging from 4 Weeks to 30 Weeks.

This inter-alia includes the following:

- Classroom Training
 - Simulator Training for Thermal and Hydel
 - On-Job Training
- i) Induction level training for new recruits Technical & Non-Technical is considered a must in the power sector
 - ii) Refresher/Advanced training of 5 Days in a year to all existing personnel of varying degrees in various specializations in line with National Training Policy for Power Sector.
 - iii) Management training of 5 Days in a year to the Senior Executives/Managers in India/Abroad in line with National Training Policy for Power Sector.
 - iv) Training for personnel from retiring units found suitable for re-engagement.

The most important component of the strategy should be “Training for All” irrespective of the level in the hierarchy. At least one-week of training in a year must be provided to every individual. Five days training per annum per technical person based on National Training Policy is being implemented selectively at some utilities. This needs to be strictly implemented.

12.2.2 Recommendations for Capacity Building

◆ O&M Training

As per the Gazette Notification No. CEI/1/59/CEA/EI (Measures relating to Safety and Electric Supply) Regulations, 2010 and amendment thereof, if any, issued by CEA, Engineers, Supervisors and Technicians engaged for O & M of Power Projects (Thermal, Hydel, Gas) and T&D have to mandatorily undergo training ranging from 4 weeks to 30 weeks.

◆ On-Job Training Facility

On-Job training is also now mandatory for all trainees who are being given training in O & M of Generation Projects (Thermal, Hydel, Gas) and Transmission & Distribution. This training varies from 2 weeks to 16 weeks.

◆ Induction Training

Induction training to all technical personnel is a must.

◆ Refresher/Advanced Training

Refresher/Advanced Training must be arranged for each individual on promotion, which calls for performing new/different roles and working conditions.

A mix of Technical, Commercial and Management capabilities of 1 week is proposed.

◆ Training of Personnel engaged in the thermal plants to retire for their re-engagement in new power plants

Manpower engaged in the plants to be retired needs to be reoriented / retrained in the

modern thermal technology for engaging them in new power plants planned to be commissioned in 2022-32.

♦ **Management Training**

Continuous development of Executives/Managers, especially at the transition period of their career and in the context of constantly changing business environment and the Regulatory aspects is of utmost importance. Aspects of Commercial and Regulatory affairs of the power sector should be taught to the executives. Also, Executives in Finance and Management with non-technical background should be provided technical orientation through suitable training programs. For this a training of 1 week is proposed.

♦ **Simulator Training**

As per the Gazette Notification No. CEI/1/59/CEA/EI (Measures relating to Safety and Electric Supply) Regulations, 2010, Simulator training of 2 weeks & 1 Week is a must for operation and maintenance personnel of Thermal and Hydro plants respectively. This is included in O&M training above. For safe and efficient functioning of manual and automatic equipment, personnel have to be trained on Simulators. Load Dispatch System Operators may also be imparted training on Simulators.

♦ **Training in Renewable Sources of Energy**

Since it is envisaged that about 234,639 MW of Renewable Energy is added in 2022-27 and 195,179 MW in 2027-32, it is proposed that specialized training of at least 1-2 months should be given in various renewable energy technologies like solar, wind, bio-mass, small hydel etc. Grid connectivity of Renewable energy sources may also be given importance in training.

♦ **Training in Demand Side Management, Energy Efficiency and Energy Conservation**

Training for Energy Managers and Energy Auditors, Industry personnel, Operators, Farmers should also be provided in respect of DSM, Energy Conservation & Energy Efficiency. Energy Conservation should also be a part of course curriculum for students.

♦ **Power System Operators Training**

System Planners, Operators & Engineers should be given regular refresher training and the new entrants should be given exhaustive training of 3 months. This training shall be required to be given to about 250 – 300 trainees every year during the years 2022-27.

♦ **Capacity Building under DDUGJY & IPDS**

Capacity Building of various GOI schemes such as DDUGJY and IPDS scheme is recommended for the employees of Power Distribution Utilities.

♦ **HRD and Technical Competence building due to Technology Advancement and R&D**

There is a need to match the growth rate, Technology Advancement and R&D needs of both skilled manpower as well as highly qualified research personnel to sustain a steady growth in technology development. Thus, emphasis needs to be laid upon skill development of such

Manpower.

❖ Introduction of Training on Attitudinal Changes / Behavioral Sciences

It is highly recommended to introduce training on Attitudinal Changes / Behavioral Sciences in the curriculum of induction level training as well as re-training programs. After undergoing such training, the personnel develop a sense of belongingness to the organization.

In addition to Technical Skills, Power Professionals need to have Life Skills like Communication Skills, Time Management, Team Work, Technical Writing, Morals & Ethics etc.

❖ Training in Information Technology & Cyber Security

Information technology has pervaded all facets of life. Adequate training according to the job requirement should be provided in the field of information technology & cyber security. Use of IT should be promoted and maximum number of personnel should be made computer literate.

❖ Training of Non-Technical Officers and Staff

Training of non-technical officers and staff should be done in regular intervals in the functional skills/management areas in association with the concerned Institutes as per needs.

❖ HRD and Capacity Building for Power Generating Stations

It is proposed to have a capacity building program for the Executives, Engineers, and Operators of Power Stations in both State and Central Sectors in the areas of DSM, Energy Management and Energy Audit during the years 2022-27 and 2027-32.

❖ Training for Nuclear Power Personnel

Due to stringent safety requirements and other national and international regulations, every person working in Nuclear Power Sector is exposed to specialized training. To meet the multi-disciplinary needs, the Department of Atomic Energy (DAE) has built in-house training facilities both for professionals and non-professionals.

❖ Training Abroad

Live liaison should be made with the concerned authorities to depute the eligible personnel for training in the developed countries to keep them abreast of the latest global developments.

❖ Hot Line Maintenance Training

There is a great demand from various Utilities for Hot Line Maintenance Training. There is an urgent need for augmentation of Training Capacity as this type of Training is presently being imparted by only two institutes in the country.

- ◆ Training through Distance learning education, E-Learning & Web based Training
Since it may not be possible for all the persons engaged in Construction and O&M of Power Projects, knowledge upgradation & training is suggested through correspondence and also by way of Web based Training and also through e-learning.
- ◆ Need for written Training Policy by every Utility
Every Utility of Central Sector, State Sector & Private Sector should have a written Training Policy indicating how the organization proposes to meet its Training needs.
- ◆ Adoption of ITIs
More than sixty (60) nos. of ITIs have been adopted by CPSUs wherein about 18,000 technicians pass out every year from these institutions. Such initiatives by CPSUs under their CSR activities may be encouraged.
- ◆ Provision for Training budget
In line with the National Training Policy for the Power Sector, every organization should have a training budget starting at least equal to 5% of the annual salary budget.

12.3 RECOMMENDATIONS

- All the organizations under central/ state/private sector are required to impart training to their personnel at the institutes recognized by the Government (CEA/MoP) as mandated in Regulation 6 & 7 of CEA (measures relating to safety and electric supply) Regulations 2010.
- It is proposed that all Central Sector Utilities, State Sector Utilities and IPPs provide O&M and refresher training as per the norms stipulated in Regulation 6 & 7 of CEA (measures relating to safety and electric supply) Regulations 2010.
- NPTI has been entrusted with the role and responsibility as a National Apex Body for training by the Government of India (Gazette Notification July 3, 1993) and it runs the training programmes for the power sector personnel as mandated in the Regulations 6 & 7 of CEA Regulations 2010. NPTI's expertise in the training activities may be utilized by all Utilities / Industries of Power Sector to meet their mandatory requirement of Induction training to their new entrants as well as refresher training to their existing personnel which would, apart from meeting their training requirement, ensure effective utilization of the huge infrastructure available with the NPTI.
- Power sector training in the areas of Smart Distribution, Smart Transmission and Smart Generation may also be strengthened in coordination with NPTI in order to accommodate emerging areas. This will help prepare competent man power for upcoming Renewable Installations of 175 GW in Solar, Wind, Small Hydro, etc.
- In compliance with the National Training Policy (NTP) of Ministry of Power, all organizations need to allocate training budget at least equal to 5% percent of the salary budget exclusively for funding training activities.

Chapter 13

Energy Storage Systems

13.0 Introduction

Indian power sector is poised to witness significant capacity addition from renewable energy sources resulting in increase of variable renewable energy (VRE) penetration. The cost economics also indicate that the share of RE based capacity addition in future is expected to increase in the total capacity addition. However, this large-scale addition of RE capacity would require additional flexible generation in the system to balance the grid.

Apart from significant addition of RE generation, a considerable increase in electrical peak demand is also expected in coming years. However, as peak VRE generation does not coincide with the peak demand in the Indian power system, this expected increase in peak demand may also pose a challenge of resource adequacy (along with flexibility) during peak demand hours. Energy storage systems can prove useful in combating the challenges posed by integrating intermittent generation sources and grid stability issues by ensuring quality of supply on real time basis by storing excess generation over different time horizons (minutes, days, weeks)

Many grid scale energy storage systems are commercially available worldwide which includes Pumped storage plants, Battery energy storage systems, etc. However, many energy storage technologies like Molten rocks, flywheel, Super capacitors, Green Hydrogen are in nascent stages of development and projections in respect of costs, technical characteristics are not yet firmed up. The effectiveness of an energy storage facility is determined by its response to changes in demand, the rate of energy lost in the storage process, its overall energy storage capacity, and recharging time

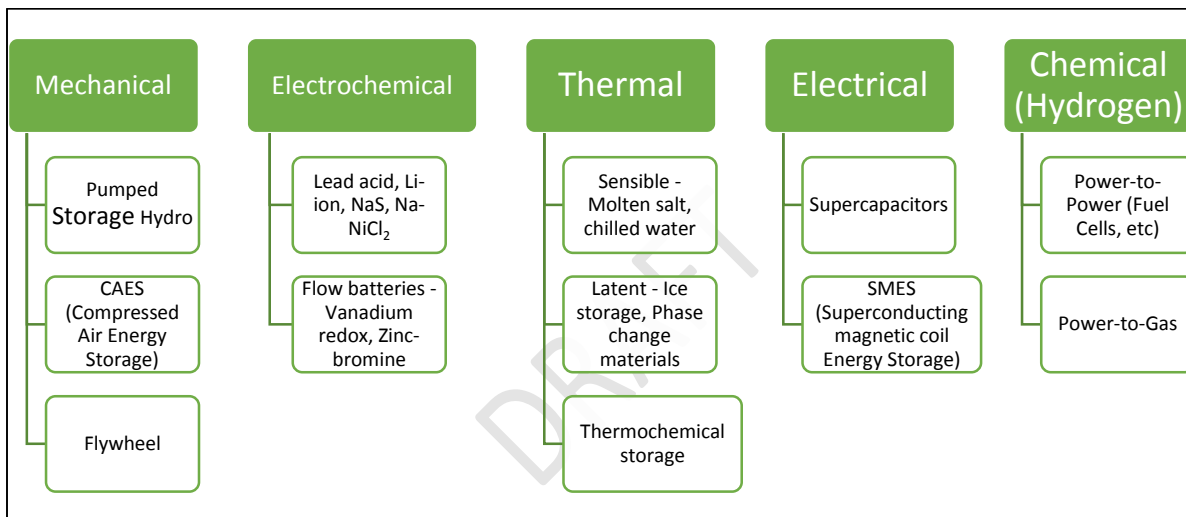
This chapter talks about techno economical parameters of the energy storage system used in the generation expansion-planning studies and gives a brief of the storage solutions that are at nascent stages.

13.1 Energy Storage Overview

Electrical energy storage systems are utilized to exchange power with the grid and can be categorized based on the energy form ultimately stored. There are several different types of energy storage technologies, broadly classified as - mechanical, thermal, electrochemical, electrical and chemical storage systems. Mechanical storage technologies include Pumped Storage Hydro (PSH), Compressed Air Energy Storage (CAES) and Flywheels. Thermal storage includes ice-based storage systems, hot and chilled water storage, molten salt storage and rock

storage technologies. Within the electrochemical category, which includes technologies that use different chemical compounds to store electricity, the most common are lead acid batteries, high temperature sodium batteries, flow batteries, zinc-based batteries and Li-ion batteries. Electrical storage systems also include supercapacitors and Superconducting Magnetic Energy Storage (SMES), while chemical storage typically utilizes electrolysis to produce hydrogen as a storage medium which can subsequently be converted to energy in various modes including electricity (via fuel cells or engines), heat and transportation fuel (power-to-gas). The classification of **Energy Storage Technologies** are shown in **Exhibit 13.1**

Exhibit 13.1



Each technology type has different individual performance metrics for characteristics such as energy efficiency, power-to-energy (P/E) ratio, cycle life, depth-of-discharge (DOD), self-discharge, energy density, space footprint, and suitability for various size ranges (in MW and MWh). The individual performance characteristics of any particular type of energy storage makes it more or less suitable for a particular application.

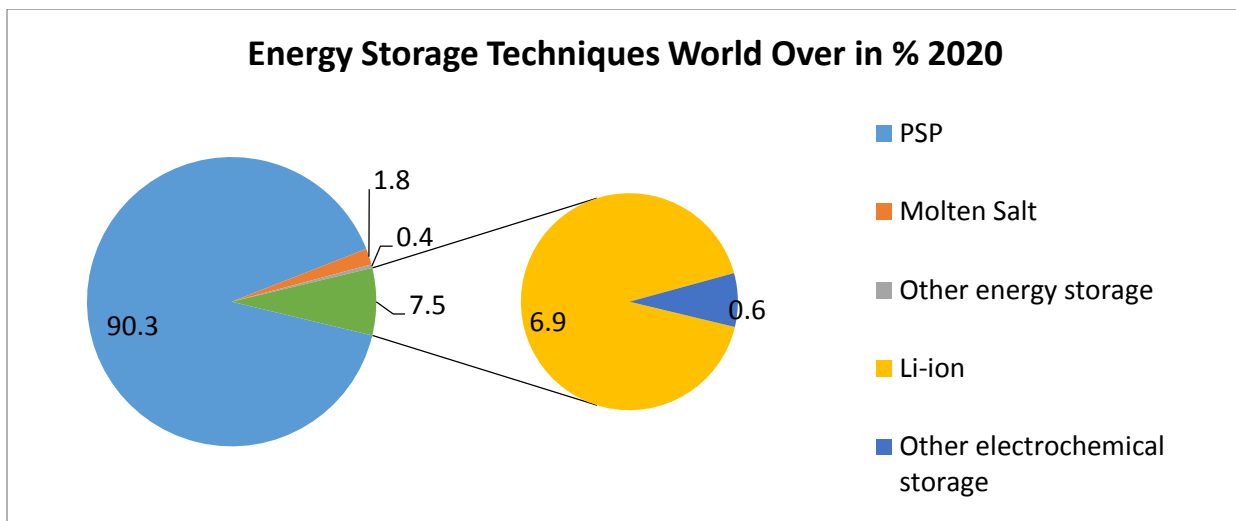
Technologies for electricity storage are further divided into power-intensive storage services and energy intensive storage services.

- Power-intensive services are provided by delivering large amounts of power for time periods on the scale of seconds or minutes, and thus, they are characterized by a high ratio of power to energy (short discharge times) and fast response. Used in power system for balance of frequency and voltage or providing power quality.
- Energy-intensive services are used for storing large amounts of energy in order to match demand and supply, energy arbitrage or reducing congestion in the network. These

technologies are characterized by a lower ratio of power to energy (long discharge times) and used on an hourly to seasonal basis.

The global deployment of various storage technologies is illustrated in **Exhibit 13.2**. The most adopted storage technology is either pumped hydropower storage (approx. 90%) or electrochemical-based storage (approx. 7.5%) to absorb variable renewable energy either locally (behind the meter) or at the grid level (in front of the meter). While other types of storage like flywheels, molten salt, and compressed-air energy storage are also commercially exploited but their proportion is very low in energy storage options worldwide. Besides, there are some upcoming options like Hydrogen energy which can prove to be a game changer in the whole gamut of energy storage system (ESS).

Exhibit 13.2



Source: RENEWABLES 2021 Global Status Report

13.2 Energy Storage Technologies

13.2.1 Pumped Hydro Storage System

While many forms of energy storage systems have been installed globally, Pumped Storage Plants (PSP) are playing an increasingly important role in providing peaking power and maintaining system stability in the power system of many countries. Pumped storage technology is the long term technically proven, cost effective, highly efficient and flexible way of energy storage on a large scale to store intermittent and variable energy generated by solar and wind. PSPs improve overall economy of power system operation and reduce operational problems of thermal stations during low load period. The other advantages of pumped storage technology are availability of spinning reserve at almost no cost to the system and regulating frequency to meet sudden load changes in the network. Also, PSPs provide environmentally friendly large storage

capacity compared to other storage options. It also has the ability to provide ancillary benefits such as flexible capacity, voltage support and Black start facility etc. The life of pumped storage projects is same as hydro projects i.e. 40 years. The Efficiency of PSP is in the range of 70 % to 80 %, due to the losses in the process of pumping water up into the reservoirs. Pumped storage technology has advanced significantly since its original introduction and now includes adjustable speed pumped turbines which can quickly shift from motor, to generator, to synchronous condenser modes, for easier and more flexible operation of the Grid.

A relatively new approach for developing pumped storage projects is to locate the reservoirs in areas that are physically separated from the existing river systems. These projects are termed as “closed-loop” pumped storage because they have minimal to no impact on the existing river systems. After the initial filling of the reservoirs, the only additional water requirement is the make-up water required to offset evaporation or seepage losses. By avoiding the existing complex aquatic systems entirely, these types of projects can greatly reduce the most significant aquatic impacts associated with project development.

13.2.1.1 Status of Development of Pumped Storage Plants in India

In India, the state of West Bengal has been a frontrunner in the promotion of pumped storage technology. Purulia project in West Bengal with a capacity of 900 MW, set up in 2007, is running successfully. As on 31.03.2022 there are 8 number of PSP projects in the country totaling to 4746 MW, out of which projects with a capacity of 3306 MW are working in the pumped mode currently. Balance capacity is currently not operating in pumped mode due to delay in construction of the tail reservoir or due to vibration related issues in the system.

Central Electricity Authority (CEA) has identified a PSP potential of 96,529.6 MW in different parts of the country. Region-wise, the western region has the highest PSP potential at 37,845 MW due to the topographical features.

The following PSP projects are under construction (as on 31.03.2022):

- Tehri Stage II - 1,000 MW located in Uttarakhand implemented by THDC limited.
- Koyna Left Bank - 80 MW in Maharashtra being implemented by the Water Resources Department of Maharashtra; and
- Kundah Pump Storage Project Stages I, II, III and IV (500 MW) in Tamil Nadu being implemented by TANGEDCO.

13.2.2 Battery Energy Storage System

A battery energy storage system (BESS) is an electrochemical device that charges (or collects energy) from the grid then discharges that energy at a later time to provide electricity or other grid services when needed. Several battery chemistries are available or under investigation for grid-scale applications, including lithium-ion, lead-acid, redox flow, nickel cadmium, Sodium-sulfur. Battery chemistries differ in key technical and each battery has unique advantages and disadvantages.

Battery technologies available and their relative advantages are given in **Table 13.1**:

Table 13.1

Technology	Round- trip-efficiency	Life span	Advantages
Lithium-ion	95%	10 - 15 years	High specific energy and high load capabilities with power cell
Sodium-Sulfur battery storage	75-85 %	10 - 15 years	Low-cost potential: Inexpensive raw materials and sealed, no-maintenance config
Nickel Cadmium Battery	60 - 80 %	10 - 15 years	Rugged, high cycle count with proper maintenance
Vanadium Redox flow Batteries	70-75%	5 - 10 years	Long service. Versatility
Lead-acid Batteries	60 - %	3 - 6 years	Low-cost and simple manufacture Low cost per watt-hour

Source: Handbook on energy storage system by ADB, Dec 2018

13.2.2.1 COMPONENTS OF BESS

The battery system consists of the battery pack, which connects multiple cells to appropriate voltage and capacity; the battery management system (BMS); and the battery thermal management system. The BMS protects the cells from harmful operation, in terms of voltage, temperature, and current, to achieve reliable and safe operation and balances varying cell states-of-charge (SOCs) within a serial connection. The Battery thermal management system controls the temperature of the cells according to their specifications in terms of absolute values and temperature gradients within the pack.

The inverter system also called Power Conversion System converts the DC power to AC power while discharging and converts AC power to DC power while charging the batteries.

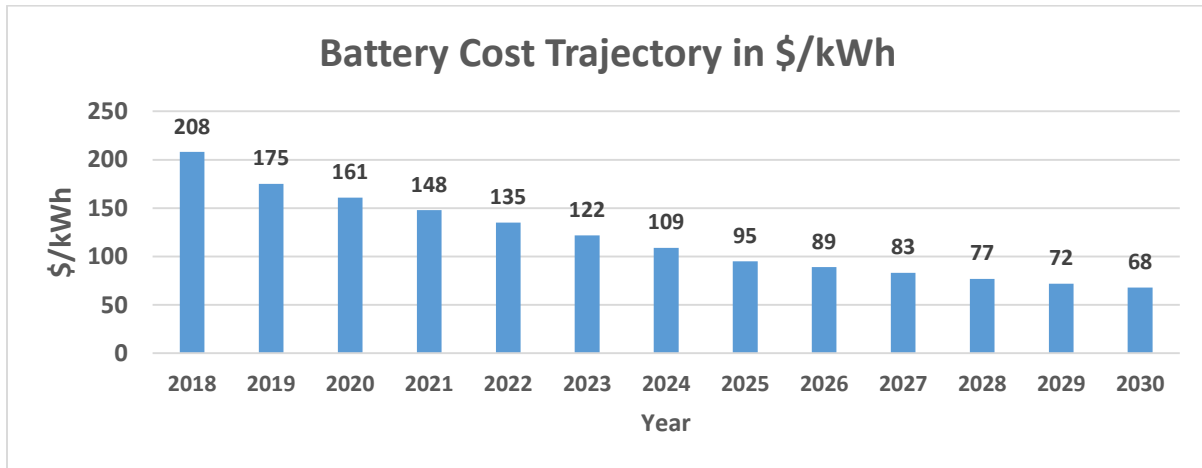
13.2.2.2 KEY CHARACTERISTICS OF BESS

- **Rated power** capacity is the total possible instantaneous discharge capability (in kilowatts [kW] or megawatts [MW]) of the BESS.
- **Energy capacity** is the maximum amount of stored energy (in kilowatt-hours [kWh] or megawatt-hours [MWh])
- **Storage duration** is the amount of time storage can discharge at its power capacity before depleting its energy capacity. For example, a battery with 1 MW of power capacity and 4 MWh of usable energy capacity will have a storage duration of four hours.
- **Cycle life/lifetime** is the amount of time or cycles a battery storage system can provide regular charging and discharging before failure or significant degradation.
- **Self-discharge** occurs when the stored charge (or energy) of the battery is reduced through internal chemical reactions, or without being discharged to perform work for the grid or a customer.
- **State of charge**, expressed as a percentage, represents the battery's present level of charge and ranges from completely discharged to fully charged. The state of charge influences a battery's ability to provide energy or ancillary services to the grid at any given time.
- **Round-trip efficiency**, measured as a percentage, is a ratio of the energy charged to the battery to the energy discharged from the battery.

13.2.2.3 Lithium-ions batteries

Lithium-ion batteries are perhaps the most promising for both small and large-scale electricity storage in power generation. They currently offer superior performance and have dominated the market globally. For Li-ion batteries applications industry is currently in the process of improving capacity, power, size, reliability and safety for applications involving both electrical vehicles and power generation. Due to technological innovations and improved manufacturing capacity, lithium-ion chemistries have experienced a steep price decline since inception. The cost trajectory of Battery Energy Storage system in future years is projected to decline as per Bloomberg NEF projections shown in **Exhibit 13.3**

Exhibit 13.3



Source: Bloomberg NEF

13.2.3 Compressed Air Energy Storage System (CAES)

This is an emerging technology. The principle is on the basis of conventional gas turbine generation. CAES decouples the compression and expansion cycle of a conventional gas turbine into two separated processes and stores the energy in the form of the elastic potential energy of compressed air. In low demand period, energy is stored by compressing air in an air tight space (typically 4.0~8.0 MPa) such as underground storage cavern. To extract the stored energy, compressed air is drawn from the storage vessel, mixed with fuel and combusted, and then expanded through a turbine. And the turbine is connected to a generator to produce electricity. The waste heat of the exhaust can be captured through a recuperator before being released to the atmosphere

A CAES system is made of above-ground and below-ground components that combine man-made technology and natural geological formations to accept, store, and dispatch energy. There are six major components in a basic CAES installation including five above-ground and one under-ground components:

- The motor/generator that employs clutches to provide for alternate engagement to the compressor or turbine trains.
- The air compressor that may require two or more stages, intercoolers and after-coolers, to achieve economy of compression and reduce the moisture content of the compressed air.
- The turbine train, containing both high- and low pressure turbines.

- Equipment controls for operating the combustion turbine, compressor, and auxiliaries and to regulate and control changeover from generation mode to storage mode.
- Auxiliary equipment consisting of fuel storage and handling, and mechanical and electrical systems for various heat exchangers required to support the operation of the facility.
- The under-ground component is mainly the cavity used for the storage of the compressed air.

CAES has a long storage period, low capital costs but relatively low efficiency. The typical ratings for a CAES system are in the range 50 to 300 MW and currently manufacturers can create CAES machinery for facilities ranging from 5 to 350 MW. The round cycle efficiency of CAES is approximately 55 % (electricity to electricity). The CAES plant can provide significant energy storage (in the thousands of MWhs) at relatively low costs (approximately (in 2003 USD) \$400/kWac to \$500/kWac). The plant has practically unlimited flexibility for providing significant load management at the utility or regional levels. (As per Technology Data – Energy storage, First published in 2018 by the Danish Energy Agency and Energinet)

13.2.4 Hydrogen

Hydrogen could provide additional utility-scale energy storage options and unique opportunities to integrate the transportation and power sectors. Although hydrogen is currently a high-cost option, it offers some advantages over competing technologies, owing to the fact that it has a high storage energy density and a potential for co-firing in a combustion turbine with natural gas to provide additional flexibility for the storage system.

Hydrogen technologies have the potential to provide spatial redistribution of energy or storage on the week-month timescale that is required for balancing the output from wind generation unlike CAES, batteries and PSP that allow the temporal shifting of electrical energy over time periods of hours to a few days.

Power-to-gas (P2G) refers to the process of converting excess electrical energy into storable chemical energy in the form of either hydrogen or grid-compatible methane – a key form of ‘sector coupling’. Surplus electricity is used to power hydrogen production *via* water electrolysis. The resulting gas may then be stored and used when required, for instance by a fuel cell, or undergo further processing to produce methane, also known as synthetic natural gas (SNG). Equally, it can then be converted back to electricity or used to displace demand for natural gas in the heating (and power) sector, or indeed for transport. There are two commercially available processes for water electrolysis: alkaline electrolysis cells (AEC) and polymer electrolyte

membranes (PEMEC); while solid oxide (SOEC) offers the possibility of high efficiency but are still at a development stage.

To promote hydrogen the Union Budget for 2021-22 has announced a **National Hydrogen Energy Mission (NHM)** that will draw up a road map for using hydrogen as an energy source. The budget allocates Rs.1500 crore for renewable energy development including hydrogen.

The development of hydrogen infrastructure is an important barrier to the widespread uptake of H₂FC technologies. Developing a cost-efficient infrastructure from these options that may evolve over time with developing demand is a significant challenge. Producing cost-competitive low-carbon hydrogen at a range of scales is arguably the greatest barrier to developing the hydrogen energy system. The efficiency and energy consumption of hydrogen production pathways is given in **Table 13.2**.

Table 13.2

	Efficiency (LHV)	Energy requirement (kW h per kgH ₂)
Methane reforming	72% (65–75%)	46 (44–51)
Electrolysis	61% (51–67%)	55 (50–65)
Coal gasification	56% (45–65%)	59 (51–74)
Biomass gasification	46% (44–48%)	72 (69–76)

Source: Energy Environ. Sci., 2019, 12, 463

13.2.5 FLY WHEELS ENERGY STORAGE SYSTEM(FESS)

Flywheel energy storage systems are comprised of a rotating cylinder (i.e., the flywheel rotor), balanced in a vacuum over an electricity-producing stator via magnetically levitated bearings. The rotor in many flywheels was often made of steel, but some newer, higher speed flywheels use fibre composite materials able to store more energy per unit of mass. Flywheels store kinetic energy in the cylinder that spins in a nearly frictionless environment. To charge the flywheel, a small electric motor using electricity from an external source brings the cylinder up to an extremely high speed—up to 60,000 rotations per minute. As the rim in the flywheel spins faster, it stores energy kinetically in the rotating mass, with a small amount of power used to maintain the operating speed. When energy is needed, the flywheel is slowed and the kinetic energy is converted back to electrical energy.

Flywheels are used in applications where a large amount of power is needed over a short timeframe. While they are generally charged using power from the grid, they can go from a

discharged to a fully charged state within a few seconds. According to the various Energy Storage Association, flywheels generally require low maintenance. Some flywheel technologies can undergo more than 100,000 full discharge cycles or more without performance impacts.

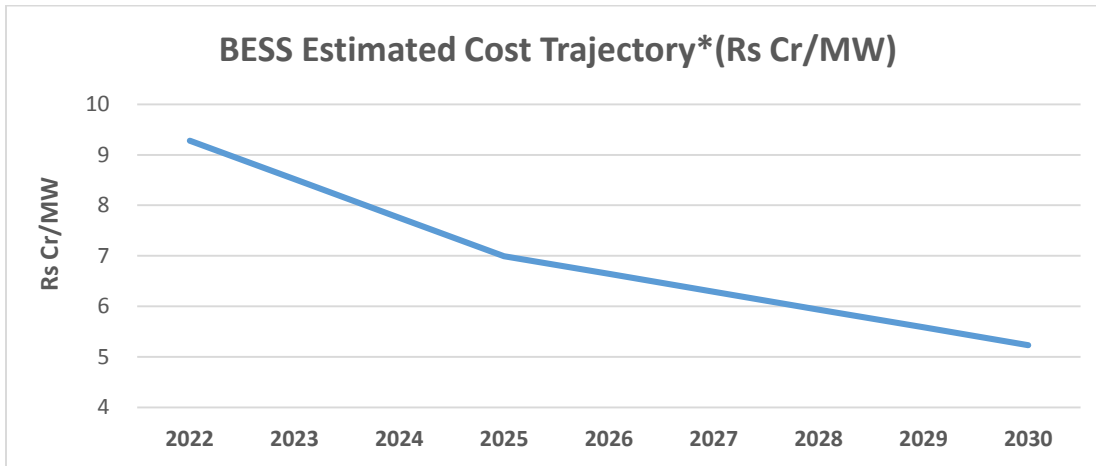
The main characteristics of flywheels are a high cycle life (hundreds of thousands), long calendar life (more than 20 years), fast response, high round trip efficiency, high charge and discharge rates, high power density, high energy density and low environmental impacts. The state of charge can be easily measured from the rotational speed and is not affected by life or temperature. The technology is capable of transferring large amounts of power in seconds, with a high roundtrip energy efficiency in the range of 90%–95%. FESS consist of a spinning rotor, MG, bearings, a power electronics interface, and containment or housing.

Flywheels can have power densities up to five to ten times that of batteries. Due to their relatively lower volume requirements and longer working life, they can replace batteries in certain applications, including in transportation and space vehicles. Flywheel self-discharge at a much higher rate than other storage mediums and flywheel rotors can be hazardous, if not designed safely. The charge holding ability of flywheels and thus the losses in currently available flywheels are high. These losses are mechanical (drag, bearing, friction), electrical (hysteresis, eddy current, copper), and power converter-related (switching and conduction).

13.3 Battery Energy Storage System Modelling

The cost of Battery Energy Storage system has been estimated after consultation with the various battery manufactures/suppliers. The cost of battery energy storage system considered in the modeling studies includes cost of battery, inverter, Battery and Energy Management Systems and other costs (cabling and installation costs). The size of the battery estimated by the model is based on 100% depth of discharge. The actual size of the battery catering to 90% depth of discharge may be more by about 11%. Therefore, for modelling purpose the capital cost of the battery has been increased by 11% to account for the 90% depth of discharge. The O&M cost for the battery energy storage system has been considered as 2%. The cost trajectory for 5-hour BESS has been considered to be reducing from Rs. 9.3 Cr/MW to Rs. 5.24 Cr/MW in 2029-30 as shown in **Exhibit 13.4**. The cost of BESS has been projected assuming levying of Custom duty of 22 % on imported Battery component and a GST of 18 % on system installation.

Exhibit 13.4



*5-hour BESS

13.4 Energy Storage Requirement

Generation Expansion planning studies detailed in chapter 5 indicate that the total non-fossil fuel-based capacity to meet the projected demand in 2026-27 is about 358 GW which includes 267 GW from variable renewable energy sources (VRE) (Solar & Wind). The non-fossil fuel-based capacity is likely to increase to 592 GW in 2031-32, which includes 467.4 GW of VRE based installed capacity. As per the generation planning studies PSP based storage capacity of about 6.81GW with 46.65 GWh of storage is required by the year 2026-27 to fulfill the storage requirement of the Grid. The storage capacity requirement increases to 70.38 GW (18.82 GW PSP and 51.56 GW BESS) with storage of 392.78 GWh (135 GWh from PSP and 257.78 GWh from BESS) by the year 2031-32. It is seen that 5-hour BESS system is found to be operating prominently in single cycle mode throughout the year.

PSP projects along with the storage hours considered for the generation expansion planning studies for the period 2022-27 and 2031-32 are listed in **Annexure 13.1**. The capital cost and all technical parameters of the Pumped Storage plants viz. storage size, open or closed loop, year of commissioning have been considered as per the latest data furnished by the project developer.

Hourly Dispatch studies were carried out along with generation expansion studies for finding out the optimal requirement of BESS which ensures grid stability, efficient utilization of storage and minimal curtailment of RE sources. Since the studies have been carried out on regional basis, it was observed that the BESS requirement is predominant in the NR region as compared to other regions. This is due to the fact that the Northern Region peak coincides with the All-India Peak.

The Storage requirement in terms of percentage of peak demand and energy demand for the years 2026-27 and 2031-32 is given in **Table 13.3**

Table 13.3

Year	Storage in terms of percentage of Peak Demand	Storage in terms of percentage of Energy Requirement
2026-27	2.5%	0.93 %
2031-32	19.41%	5.61 %

The daily operation of BESS and hourly dispatches from all other generation sources on a typical peak day in 2031-32 is shown below in **Exhibit 13.5** and **Exhibit 13.6**:

Exhibit 13.5

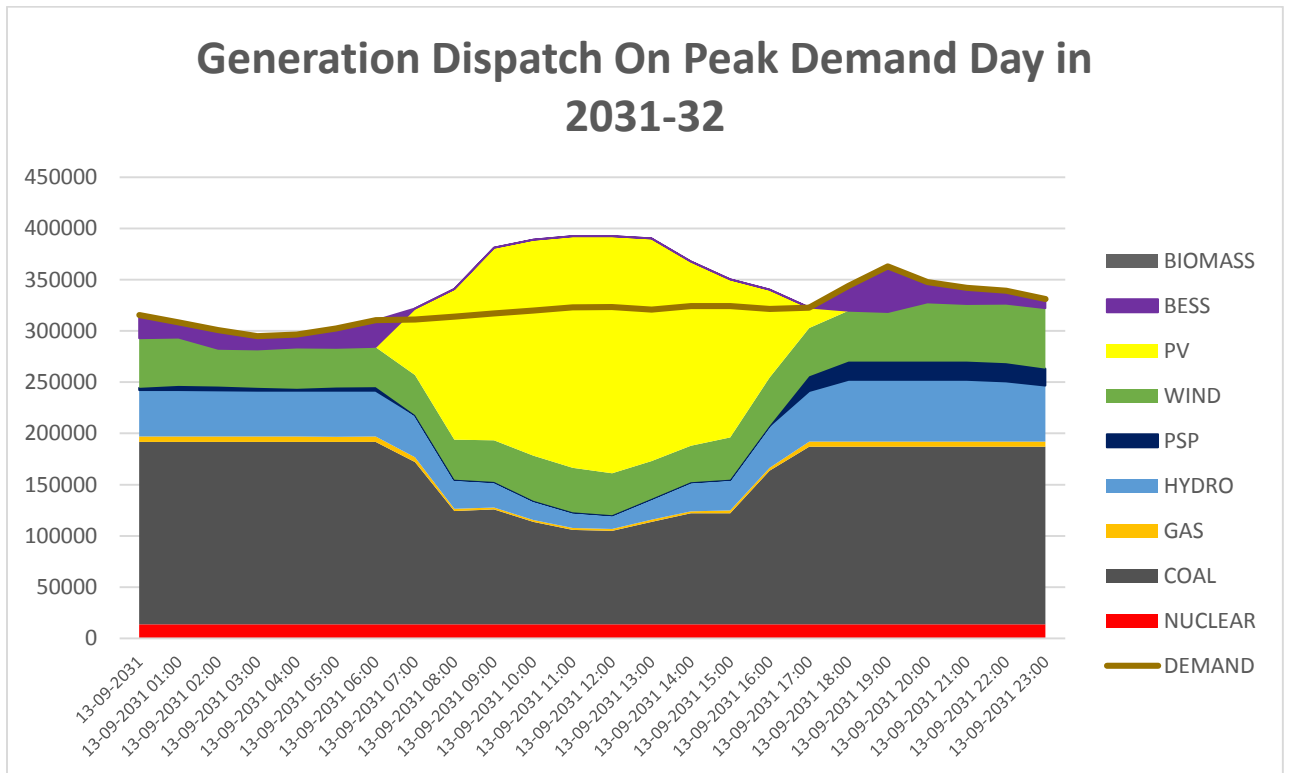
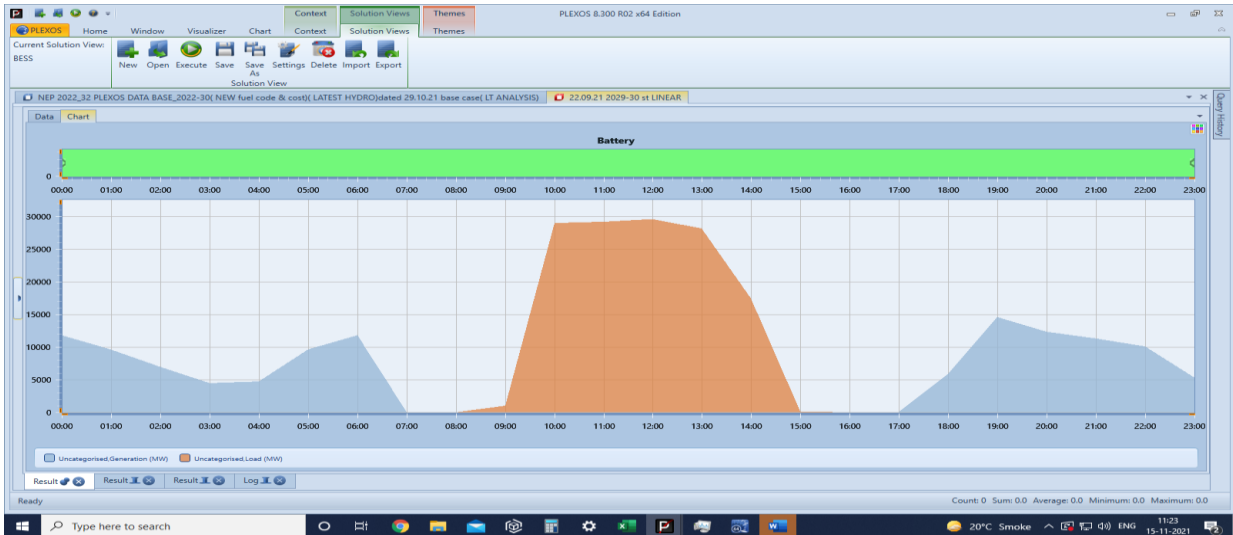


Exhibit 13.6



The Storage (BESS and PSP) is being charged primarily during the solar hours and is used to meet peak demand as well as demand in late night and early morning hours.

13.5 Conclusions

- In view of large amount of Variable RE based generation likely to be integrated in the grid in the future, Energy storage technology is found to be useful in maintaining grid stability and reliability by storing excess generation over different time horizons (minutes, days, weeks) and meeting the peak demand which is not coincidental with the peak RE generation.
- Many storage technologies like Flywheel Energy Storage Systems, Compressed Air Storage Systems, Hydrogen, etc are in nascent stages of development and their technological details for commercial usage are not yet firmed up.
- As per the hourly studies run along with generation expansion planning studies, the Storage capacities (BESS and PSP) is seen to get charged primarily during the solar hours and is used to meet peak demand as well as demand in late night and early morning hours.
- As per the generation planning studies PSP based storage capacity of about 6.81GW with 46.65 GWh of storage is required by the year 2026-27 to fulfil the storage requirements of the Grid. The storage capacity requirement increases to 70.38 GW (18.82 GW PSP and 51.56 GW BESS) with storage of 392.78 GWh (135 GWh from PSP and 257.78 GWh from BESS) by the year 2031-32.
- The Union Budget for 2021-22 has announced a National Hydrogen Energy Mission (NHM) that will draw up a road map for using hydrogen as an energy source.

ANNEXURE-13.1

LIST OF PUMPED STORAGE PLANT CONSIDERED FOR THE GENERATION EXPANSION PLANNING STUDIES FOR THE PERIOD 2022-27 AND 2031-32

(All Figures in MW)

S.NO.	NAME OF PROJECT	STATE	SECTOR	ORGANISATION	STORAGE HOURS	TOTAL CAPACITY (MW)
1	PINNAPURAM	ANDHRA PRADESH	PRIVATE	GREENKO ENERGY	10	1200
2	MP 30 PSP	MADHYA PRADESH	PRIVATE	GREENKO ENERGY	7.22	1440
3	SHARAVATHY PSP	KARNATAKA	STATE	KPCL	6	2000
4	SAUNDATTI PSP	KARNATAKA	PRIVATE	GREENKO ENERGY	11	1260
5	UPPER INDRAVATI	ODISHA	STATE	OHPL	5	600
6	TURGA PSP	WEST BENGAL	STATE	WBSEDCL	5	1000
7	CHITRAVATHI PSP	ANDHRA PRADESH	STATE	NREDCAP	5.6	500
8	UPPER SILERU	ANDHRA PRADESH	STATE	APGENCO	8	1350
9	GANDIKOTA PSP	ANDHRA PRADESH	STATE	NREDCAP	5.38	1000
10	OWK PSP	ANDHRA PRADESH	STATE	NREDCAP	5.6	800
11	SILLAHALLA PSP	TAMIL NADU	STATE	TANGEDCO	6	1000
12	UPPER KOLAB	ODISHA	STATE	OHPL	6	320
13	KODAYAR PSP	TAMIL NADU	STATE	TANGEDCO	6	500
14	BALIMELA PSP	ODISHA	STATE	OHPL	6	500
15	KURUKUTTI PSP	ANDHRA PRADESH	STATE	NREDCAP	7	1200
16	KARRIVALASA PSP	ANDHRA PRADESH	STATE	NREDCAP	7	1000
17	SOMASILA PSP	ANDHRA PRADESH	STATE	NREDCAP	6	900
18	YARRAVARAM PSP	ANDHRA PRADESH	STATE	NREDCAP	7.25	1200
TOTAL						17770