Climate Investment Funds (CIF) Renewable Energy Integration (REI) Program

India REI Investment Plan

October 2024 V.1

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ACC	Advanced Chemistry Cell
ACS	Average Cost of Supply
ADB	Asian Development Bank
ARR	Aggregate Revenue Requirement
ASPIRE	Accelerating Smart Power and Renewable Energy
AT&C	Aggregate Technical and Commercial
BEEP	Building Energy Efficiency Project
BESS	Battery-based ESS
BU	Billion Unit
CAGR	Compound annual growth rate
CCEA	Cabinet Committee on Economic Affairs
CCUS	Carbon capture, utilization and storage
CEA	Central Electricity Autharity
CECP	Clean Energy and Climate Partnership
CERC	Central Electricity Regulatory Commission
CFA	Central Financial Assistance
CFD	Contract for Differences
CIF	Climate Investment Funds
COP	Conference of the Parties
DDUGJY	Deendayal Upadhyaya Gram Jyoti Yojana
DEA	Department of Economic Affairs
DISCOM	Distribution Company
DMS	Distribution Management Systems
DRE	Distributed Renewable Energy
DSM	Deviation Settlement Mechanism
EA	Electricity Act
ECBC	Energy Conservation Building Code
MoEFCC	Ministry of Environment, Forest and Climate Change
ESCO	Energy Service Companies
ESO	Energy Storage Obligations
ESS	Energy Storage Systems
EU	Europe
EV	Electric Vehicle
FCDO	Foreign, Commonwealth & Development Office
FDI	Foreign Direct Investment
FDRE	Firm and Dispatchable Renewable Energy
FTE	Full-time equivalent
GB	Gender Budgeting
GBA	Global Biofuels Alliance
GDP	Gross domestic product
GEC	Green Energy Corridors
GEM	Green Electric Mobility
GENCO	Generation Company
GGEF	Green Growth Equity Fund
GHG	Greenhouse Gas
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
GSDP	Gross State Domestic Product
GST	Goods and Services Tax
GW	Gigawatt
HPO	Hydro Power Obligation
HVDC	High-voltage direct current
IEA	International Energy Agency
IFC	International Finance Corporation
IGEN	Indo-German Energy Programme

IMF	International Monetary Fund
INR	Indian rupee
IP	Investment Plan
IPDS	Integrated Power Development Scheme
IPP	Independent Power Producers
IRENA	The International Renewable Energy Agency
IRF	Integrated Results Framework
ISA	International Solar Alliance
ISTS	Inter-State Transmission System
ITEC	Indian Technical and Economic Cooperation
JICA	Japan International Cooperation Agency
KUSUM	Kisan Urja Suraksha evam Utthaan Mahabhiyan
LC	Letter of Credit
LCOE	Levelized Cost of Electricity
LED	Light Emitting Diode
LGBTQ	Lesbian, gay, bisexual, and transgender
LHP	Large Hydro Power
LIS	Liquidity Infusion Scheme
LTLCDS	Long-term Strategy for Low Carbon Development
LTS	Long-term Strategy for Low Carbon Development
MDB	Multilateral Development Bank
MMT	Million Metric Tonnes
MMTPA	Million Metric Tons Per Annum
MNRE	Ministry of New and Renewable Energy
MSME	Micro, Small and Medium Enterprises
MU	Million Unit
MVA	Megavolt-amperes
MW	Megawatt
NCR	National Capital Region
NDC	Nationally Determined Contributions
NEP	National Electricity Plan
NEP	National Education Policy
NIWE	National Institute of Wind Energy
NSGM	National Smart Grid Mission
NSS	National Service Scheme
NTPC	National Thermal Power Corporation
NYP	National Youth Policy
OMS	Outage Management Systems
OSOWOG	One Sun One World One Grid
P2P	Peer-to-Peer
PFC	Power Finance Corporation
PHS	Pumped Hydro Storage
PJ	Petajoule
PLI	Production Linked Incentives
PM	Prime Minister
PMEGP	Prime Minister's Employment Generation Programme
POSOCO	Power System Operation Corporation Limited
PPA	Power Purchase Agreements
PPG	Project Preparation Grant
PSOD	Private Sector Operations Department
PSP	Pump Storage Plants
MoPSW	Ministry of Ports, Shipping, and Waterways
PV	Photovoltaic
RDSS	Revamped Distribution Sector Scheme
RE	Renewable Energy
REC	Renewable Energy Certificate

REI	Renewable Energy Integration
REIA	Renewable Energy Implementation Agencies
REMC	Regional Energy Management Centers
RES	Renewable Energy Sources
RGNIYD	Rajiv Gandhi National Institute of Youth Development
RPO	Renewable Purchase Obligation
RTC	Round The Clock
RYSK	Rashtriya Yuva Sashaktikaran Karyakram
SAGE	South Asia Group for Energy
SAREP	South Asia Regional Energy Partnership
SATAT	Sustainable alternative towards affordable transportation
SC	Scheduled Castes
SCADA	Supervisory control and data acquisition
SDC	Swiss Agency for Development and Cooperation
SDG	Sustainable Development Goal
SECI	(Solar Energy Corporation of India
SERC	State Electricity Regulatory Commissions
SHP	Small Hydro Power
SLDC	State Load Despatch Centers
SOE	State-Owned Enterprise
ST	Scheduled Tribes
STAR-C	Solar Technology Application Resource Centre
STEM	Science, Technology, Engineering, Mathematics
TA	Technical Assistance
TCF	Technical Cooperation Facility
TRANSCO	Transmission Company
UDAY	Ujjwal DISCOM Assurance Yojana
UK	United Kingdom
UMREPP	Ultra Mega Renewable Energy Power Parks
UNFCCC	United Nations Framework Convention on Climate Change
USAID	United States Agency for International Development
USD	United States dollar
VGF	Viability Gap Funding
InVITs	Infrastructure Investment Trusts
VPP	Virtual Power Plant
VRE	Variable Renewable Energy
WB	World Bank
YIAPL	Yamuna International Airport Private Limited

1 Proposal Summary

India's Renewable Energy Integration Investment Plan (REI IP), contained in this document, has been prepared by the Ministry of Finance (MoF), with support from Ministry of New and Renewable Energy. Substantial contributions were also made by the Ministry of Power (MoP), Niti Aayog, Central Electricity Authority (CEA). The Asian Development Bank (ADB), The World Bank and International Finance Corporation (IFC) provided extensive technical support throughout.

Project concepts/interventions are based on broader climate ambitions; list of key policy/schemes/plans etc. These documents contain prioritized lists and detailed descriptions of priority clean energy and climate investments and are the result of extensive analysis and consultation with a wide range of stakeholders.

1.1 Objectives

The objective of this Renewable Energy Integration (REI) Investment Plan (IP) for India is to seek both financial support and technical expertise for initiatives aimed at enhancing RE integration. This is to facilitate a seamless integration of a larger proportion of renewable energy sources. The strategy encompasses three primary facets: the deployment of Energy Storage Systems (ESS) to increase grid flexibility, the fortification of infrastructure to boost RE, and technical assistance across RE grid integration value chain. These initiatives are in alignment with India's ambitious goal to establish 500 GW of renewable energy by 2030, reflecting the nation's updated Nationally Determined Contributions (NDCs). These contributions include: (a) a 45 percent reduction in the emissions intensity of its GDP from 2005 levels, an increase from the initial 33-35 percent; (b) achieving over 50 percent of its cumulative electric power capacity from non-fossil fuel sources, up from the previous 40 percent; and (c) expanding carbon sinks by an additional 2.5-3 billion tons of CO2-equivalent.

The strategies proposed under this REI IP are fully in sync with both India's climate action plans and the Climate Investment Funds (CIF) objectives for financing renewable energy integration efforts. The first intervention focuses on the strategic deployment of Energy Storage and renewable energy-enabling technologies to bolster grid flexibility and ensure a smoother integration of renewable sources. The second intervention involves the enhancement of grid infrastructure to improve both inter and intra-state transmission capabilities, specifically for renewable energy, thus elevating the overall grid reliability and resilience. This aspect could also include upgrading port infrastructure to support offshore wind projects. The third intervention will offer technical assistance to foster innovation in renewable energy technologies and the development of robust power markets, thereby encouraging green electricity adoption and creating an attractive investment climate for firm and dispatchable renewable energy investments. Emphasis will be placed on establishing smart grid infrastructure and improving weather and resource forecasting to optimize grid operations and maximize renewable energy use. The activities proposed will cover all the eligible areas of the REI program, thereby contributing to a comprehensive approach to renewable energy integration in India.

The $70 million concessional funding from CIF plays a pivotal role in the initial phase of this initiative, representing the first coordinated effort by Multilateral Development Banks (MDBs) to address renewable energy integration (REI) challenges. This immediate intervention will catalyze the deployment of critical ESS infrastructure and grid strengthening projects but acknowledges that more work will need to follow. Given the scale of India's energy transition, the REI IP is only the starting point. Further initiatives beyond the REI IP's timeframe will be essential, necessitating additional concessional funding from CIF or other climate financing mechanisms to support the sustained integration of large-scale renewable energy. This longer-term approach will ensure continued progress toward achieving India's climate goals, enhancing the resilience of its power systems, and unlocking future investments in clean energy technologies.

1.2 Expected Outcomes

The financing and technical assistance interventions foreseen under this REI IP are expected to enhance renewable energy integration, facilitate the uptake of zero carbon electricity in India's electricity mix and attract private sector investment across RE integration value chain. The expected outcomes are:

- Increased renewable energy generation capacity by ~1500 MW, and an additional ~2800 Mus/year of renewable energy.
- Addition of energy storage capacity to the tune of ~1500 MWh catering to various applications supporting generation and distribution segments
- Enhancing distribution and transmission infrastructure by facilitating ~3700 ckm. of 33 kV distribution lines and ~580 ckm. of 400 kV DC transmission infrastructure to enhance RE integration.
- A consequent reduction in the volume of global (CO2) emissions of ~3.2 MtCO2/year.
- Improved policies and institutional capabilities, including advanced forecasting tools and successful third-party forecasting models for DISCOMs and REMCs; innovative methods for uptake of RE such as Contracts for Difference (CFD); introduction of new concepts like Virtual Power Plants (VPP), Blockchain-based P2P solar rooftop systems, and RE-based EV charging.
- US$1100 million leveraged under the financing plan, supporting to the creation of ~13500 FTE green jobs, capacity building and training (upskilling) of women officials.
- Better electricity reliability, resulting from a more diverse portfolio of domestically available renewable fuels and enhanced energy storage and grid management technologies and techniques.
- Better resilience—especially of the transmission and distribution network—to climate-induced disasters and damage to infrastructure.

1.3 Program Criteria, Priorities, and Budgets

As noted above, India's REI IP is based on project concepts developed around three key focus areas- strategic deployment of energy storage systems, grid infrastructure strengthening and technical assistance. The focus areas are finalized after intensive consultations between concerned ministries, development organizations, grid operators, DISCOMs and think-tanks, as well as the CIF implementing MDBs. The proposed focus areas capture the immediate and near future needs of India's power system which is set to be dominated by green energy in near future.

- **Energy Storage Systems deployment**: The projects are aligned with one of the qualifying themes of CIF REI Programme- viz. Scaling up renewable energy enabling technologies. The following projects will provide flexibility to the grid by focusing on the strategic deployment of energy storage systems to support grid integration of variable RE: Enabling Round the Clock (RTC) Supply through Advanced Grid Management and Energy Storage at the State Level

- **Infrastructure Strengthening**: The following projects will strengthen infrastructure to provide greater grid reliability and resilience and are aligned with the 'Enhancing infrastructure to be renewable energy ready' qualifying theme of the CIF REI Programme and will support GoI initiatives such as Green Energy Corridor. Supporting grid strengthening in one or more RE rich states and Infrastructure (including port infrastructure) to support Offshore Wind Development Programme

- **Technical assistance** across RE grid integration value chain: These interventions is as a pivotal element of the CIF Renewable Energy Integration (REI) program, addressing a spectrum of regulatory, technical and capacity needs critical for enhancing the uptake of renewable energy (RE) across various stakeholder domains. This intervention is designed to navigate the complexities of integrating a substantial amount of RE capacity and is aligned with both selected themes of the CIF REI Programme, namely "Supporting renewable energy innovation" and "Enhancing system and market design and operation." The proposed intervention will focus on Advanced Forecasting Tools and Innovative Methods for Uptake of RE, each of which are key gaps in the current RE market and integration context.

India is requesting $70 million in financing from CIF of which only $5 million would be requested as technical assistance including project preparation grants and capacity building. The proposed projects expected to mobilize nearly $ USD 1100 million will be funded by the ADB, World Bank and the IFC, including funding mobilized through development partners and the private sector. The following table shows the amounts estimated for each of the interventions described above.

Table 1: Indicative Financing Plan ($ million)

Financing Source	CIF				Others				Total
Program	CIF Financing	CIF Guarantee	Project Preparation (Grant)/ TA	Total CIF	ADB	World Bank	IFC	Private Sector	
(US$ Million)									
Power System Strengthening Project	23	0	2[1]	25	200			200	425
Integrated RE Solutions Providing RTC Supply for C&I Consumers	10	0	0	10	100*			100	210
Supporting Grid Strengthening in One or More RE Rich States Offshore Wind Development Program	23	0	2	25		200		200	425
IFC (sand-alone BESS)	9	0	1	10			45	20	210
Total	**65**	**0**	**5**	**70**	**300**	**200**	**45**	**520**	**1135**

[1] for capacity building, project management, and regulatory support

2 Country Context

2.1 Introduction

India's journey over the past two decades has been marked by significant strides towards economic stability, poverty reduction, and an increasing focus on sustainable development. The nation has successfully halved the rate of extreme poverty from 22.5% in 2011 to 12.7% in 2019[2], a testament to its concerted efforts in enhancing the well-being of its population. Despite the setback caused by the pandemic in 2020, which saw a rise in extreme poverty by two percentage points, India's swift action through broad vaccine distribution and government mitigation strategies enabled a notable recovery, bringing the extreme poverty rate down to an estimated 11.9% in FY 2021/22[2]. This resilience in the face of adversity is further highlighted by the significant reduction in multidimensional poverty, from 27.7% in 2015/16 to 16.4% in 2019/21[3], alongside stable consumption inequality with a Gini index of around 35[3]. These achievements, coupled with improvements in child malnutrition and employment indicators, underline India's commitment to fostering inclusive growth and setting a foundation for sustainable energy initiatives as part of its broader economic reforms.

India's economic landscape, characterized by a robust ~7% GDP growth rate in 2022-23[4], showcases the pivotal role of the service, industrial, and agricultural sectors in driving its economic engine. The service sector, making up nearly half of the GDP, alongside significant contributions from the industrial and agricultural sectors, underscores the diverse nature of India's economy. With the industrial sector accounting for 41% of electricity consumption and agriculture consuming 18%[5], the critical importance of the energy sector in supporting sustainable economic growth is evident. In response, India has embarked on a series of ambitious economic reforms aimed at improving competitiveness, attracting foreign investment, and enhancing the ease of doing business. These reforms, which include raising the limit for FDI across various sectors and focusing on infrastructure development, are intricately linked to India's energy security and attracting investments in renewable energy sector, aligning economic growth with environmental sustainability.

Looking ahead, India is poised to remain the fastest-growing large economy, with forecasts predicting a GDP growth rate between 6.3-7.3% in FY23/24[4]. This growth is supported by a strong investment push expected to crowd in private investment, buoyed by healthy corporate profits, easing inflation, and strong macroeconomic fundamentals. The government's commitment to narrowing the fiscal deficit to 8.7% in FY23/24[6] and stabilizing the debt-to-GDP ratio underscores the strategic management of public finances, further contributing to a favorable external position marked by growing services exports and substantial foreign exchange reserves exceeding USD 600 billion[4]. These macroeconomic indicators, coupled with India's demographic advantage and strategic reforms, present a compelling case for enhancing renewable energy into its development paradigm. The emphasis on renewable energy not only addresses the critical need for energy security but also aligns with India's goals for sustainable growth, environmental conservation, and enhanced global competitiveness, positioning India as a leader in the transition towards a more sustainable and resilient future.

2.2 Current State of Energy Generation & Transmission and Distribution Systems

India, with its burgeoning economy and vast population, stands at a critical juncture in its holistic energy transition journey. As the nation is preparing to meet its pressing need to cater to its growing energy demands, the structure and composition of its energy mix are poised to change with an increasing share of RE. With a reliance on fossil fuels, the current state of India's energy generation, transmission, and distribution systems presents both challenges and opportunities for integrating renewable energy at a scale necessary to meet future demands sustainably.

India’s total energy consumption was 35,159 Petajoule (PJ) in 2022-23[8]. Coal accounts for 54.2 percent of India’s primary energy mix, along with oil 28.2 percent, gas 6.7 percent, nuclear 1.3 percent, hydro 4.5 percent, and renewable

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[2] World Bank. Macro Poverty Outlook (MPO). October 2023
[3] World Bank. Poverty and Equity Brief. Fall 2023 Edition
[4] Reserve Bank of India
[5] Energy Statistics India 2024
[6] India: 2022 Article IV Consultation-Press Release; Staff Report; and Statement by the Executive Director for India

energy only 4.5 percent[7]. India imported substantial 42% of its total primary energy requirement in 2020-21[8]. It is noteworthy that in the same year, India's electricity import was a negligible 0.6%[8], indicating a potential area for growth in domestic electricity generation to enhance energy security and reduce reliance on imports.

India's per capita power consumption at 1,255 kWh is well-below the global average and demand for electricity is expected to grow by ~55% in the coming decade[9]. The industrial sector, being the largest consumer of electricity, underscores the critical need for robust and efficient transmission and distribution systems. However, the current electricity infrastructure will face constraints, especially in light of the increasing shares of renewable energy into the grid. Enhancing the grid's capacity to integrate renewable energy sources effectively is paramount to addressing these challenges along with the escalating demand.

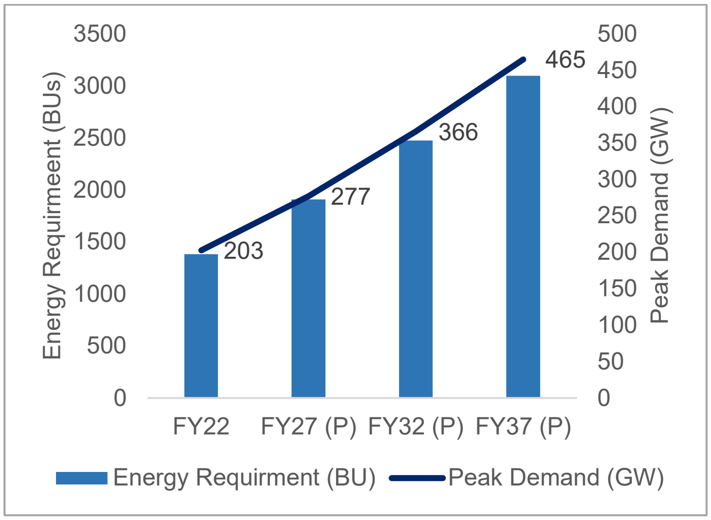


Figure 1: India's Electricity Demand Projections (Source: CEA)

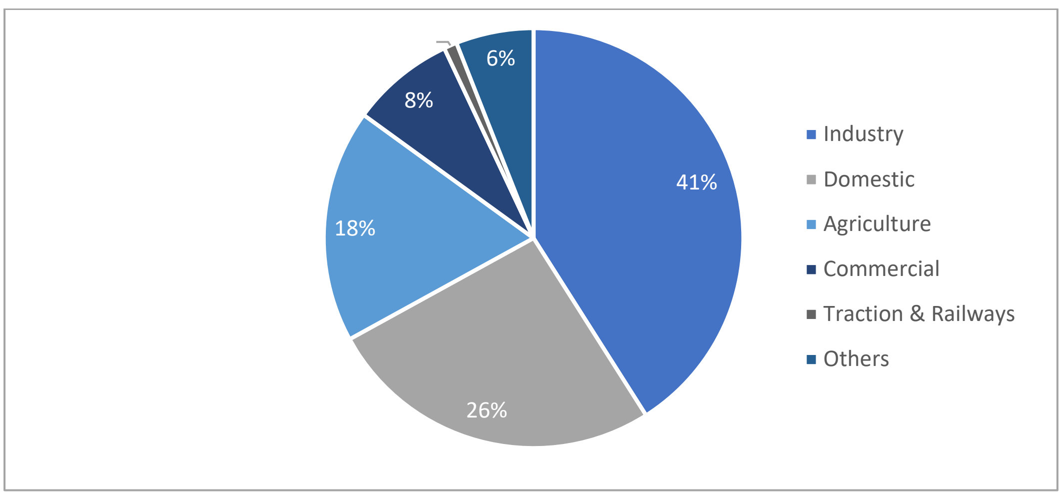


Figure 2: Consumption of Electricity by Sectors in India during FY23

The **generation segment** of the Indian power sector has shown significant diversification with a blend of conventional (thermal, hydro, and nuclear) and non-conventional (renewable energy sources) means. Over the years, there has been a notable shift towards renewable energy sources, increasing their share of installed generation capacity from 8.9% in

7 BP statistical survey
8 Energy Statistics India 2023
9 Report on twentieth electric power survey of India, CEA

2008-09 to ~40% in 2022-23. This shift has contributed to the Compound Annual Growth Rate (CAGR) of total installed electricity generation capacity at about 7.7%, with renewable energy sources (RES) growing at a remarkable rate of 17.4%. The liberalization of the generation process by the Electricity Act of 2003 encouraged more private participation, significantly enhancing the sector's competitiveness and efficiency.

As on September 2024, India had an overall installed power generating capacity of 417 GW, comprising 52.3 percent coal, 6.2 percent natural gas, ~40 percent renewables and 1.7 percent nuclear.[10] The RE installed capacity in the country was 178.98 GW (including 46.85 GW large hydro).[11] As per the CEA estimates, the installed power generation capacity is poised to reach 899 GW and 1466 GW by the end of FY32 and FY40 respectively.

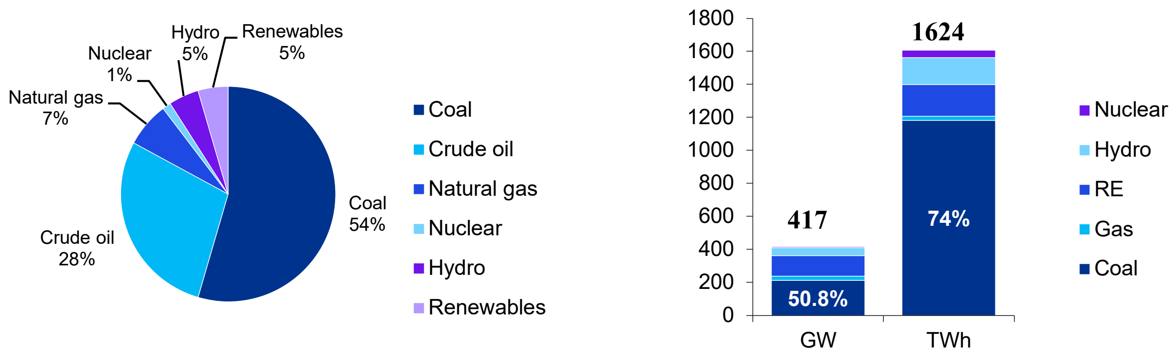


Figure 3: India's Primary Energy and Power Generation Mix Source: BP Statistical Survey and Central Electricity Authority

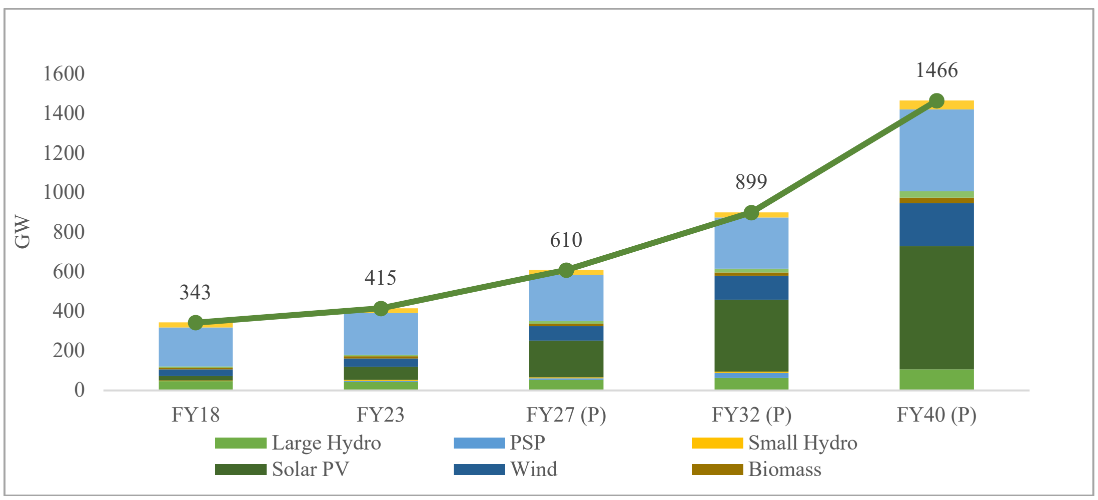


Figure 4: Installed Generation Capacity Projections (Source: NEP 2023, IEA India Energy Outlook)

The expansion of the transmission sector plays a crucial role in supporting India's growing electricity demand and the integration of renewable energy sources. From 2008-09 to 2022-23, the transmission line network experienced a comprehensive extension from 2.21 lakh circuit kilometers (ckm) to 4.71 lakh ckm, and the transformation capacity of substations escalated from 2.89 lakh MVA to 11.80 lakh MVA.[12] This growth facilitated an enhanced CAGR of

[10] https://powermin.gov.in/en/content/power-sector-glance-all-india
[11] https://cea.nic.in/wp-content/uploads/psp___a_i/2024/01/Draft_NEP_Vol_II.pdf, Chapter 10

[12] One lakh is equivalent to 100,000.

5.6% in transmission lines and an impressive 10.6% in substation capacity, ensuring the robustness and reliability of India's power transmission network. Moreover, the introduction of Open Access has democratized the transmission sector, allowing a multitude of players, including generators and large consumers, to access the transmission network on a non-discriminatory basis, thus fostering competition and efficiency within the sector. This strategic expansion and regulatory foresight have been instrumental in meeting the burgeoning electricity demand while accommodating the surge in renewable energy generation.

The **distribution sector**, the final leg of the electricity supply chain, has seen a focused intervention to address its operational and financial challenges. Recognizing the critical role of distribution in ensuring universal access to reliable electricity, the government has launched several initiatives aimed at revitalizing this segment. Among these, the UDAY scheme sought to improve the operational efficiencies and financial health of DISCOMs, resulting in a decrease in AT&C losses and narrowing the ACS-ARR gap. Despite these efforts, the sector continues to face challenges, highlighted by the all-India average AT&C losses standing at approximately 16.42% in 2021-22.[13] To further address these issues, the Revamped Distribution Sector Scheme (RDSS) was introduced, targeting a reduction in AT&C losses to 12-15% by 2024-25 and aiming for zero ACS-ARR gap, marking a significant push towards enhancing the quality, reliability, and affordability of power supply to consumers. These concerted efforts signify a strategic overhaul of the distribution sector, emphasizing efficiency, financial sustainability, and improved consumer experience.

The Electricity Act of 2003 is the key governing act of Indian power sector. The Act, which came into force on 15 June 2003, has the objective to introduce competition, protect consumer's interests and provide power for all. The Act provides for National Electricity Policy, Rural Electrification, Open access in transmission, phased open access in distribution, mandatory State Electricity Regulatory Commissions (SERCs), license free generation and distribution, power trading, mandatory metering and stringent penalties for theft of electricity. The National Electricity Policy aims at laying guidelines for accelerated development of the power sector, providing supply of electricity to all areas and protecting interests of consumers and other stakeholders keeping in view the availability of energy resources, the technology available to exploit these resources, the economics of generation using different resources, as well as overall energy security issues. Right from unbundling and privatization(s) of generation, transmission, and distribution segments to Revamped Distribution Sector Scheme, India's power sector is shaped by multiple waves successive reforms. Renewable Purchase Obligation (RPO), Net Metering Policy, Green Tariff Policy, Green Hydrogen Mission are some of the key policies in RE sector of India.

2.3 National and International Climate Strategies and Plans

India is among the countries most vulnerable to climate change, facing some of the highest disaster risk levels in the world, ranked 29 out of 191 countries by the 2024 Inform Risk Index.[14] More than 80 percent of India's population lives in districts highly vulnerable to extreme hydro-met (floods, droughts, cyclones) disasters.[15] Climate induced disasters combined with resource stress will impact India's goals of providing reliable electricity and transport to its citizens. More than 60 per cent of the country's agriculture is rainfed, leaving its poorest people, especially women, vulnerable to food insecurity and malnutrition. India is not only vulnerable to extreme heatwaves like the recent one experienced in 2022, but to a range of other climate impacts on "agriculture, water resources, Himalayan region, coastal regions, health and disaster management".[16] This extreme climate vulnerability, along with the public's concerns about air pollution, has prompted the country to respond holistically to the challenge of climate change by demonstrating leadership both internationally and domestically by promoting low-carbon growth and reducing its overall emissions intensity, as well as adopting adaptation measures to enhance India's climate resilience.

Following its COP-26 announcement of Net Zero emissions by 2070, the GoI released both an updated NDC as well as shared its Long-term Strategy for Low Carbon Development (LTLCDS or LTS) with the UNFCCC. India's climate change-related goals over both the long-term (2070) and the short-term (2030) are intended to be in line with its overall commitments to economic development, equity, and welfare**.** The updated NDC by 2030 includes:

[13] https://www.pib.gov.in/Pressreleaseshare.aspx?PRID=1985549
[14] https://reliefweb.int/sites/reliefweb.int/files/resources/Inform%202019%20WEB%20spreads.pdf
[15] https://www.ceew.in/publications/mapping-climate-change-vulnerability-index-of-india-a-district-level-assessment
[16] %20First%20Nationally%20Determined%20Contrib.pdf

(a) reducing emissions intensity of its GDP by 45 percent from 2005 levels (up from 33-35 per cent in the initial NDC); (b) achieving 50 percent cumulative electric power installed capacity from non-fossil fuel-based energy resources (up from the previous 40 per cent); and (c) enhancing carbon sinks by an additional 2.5-3 billion tons of CO2-equivalent. India's short-term NDC milestones are intended to provide a clear signal of the country's future climate mitigation objectives related to catalyzing a clean energy transition and ushering in low emission growth pathways with sufficient lead-time for the relevant sectors and the capital markets to respond by shifting investments toward the lower emitting and innovative technologies required to achieve India's long-term Net Zero ambition.

The LTS shared that India's achievement of its long-term objectives rested on "seven key transitions to low-carbon pathways" that "were comprehensive and covered the entire economy."[17] Anchored on eradicating India's development deficits and maintaining energy security, the LTS identified the electricity sector as the first of these seven transitions because of its importance for "enabling industrial expansion, enhanced employment and incomes, and achievement of Aatmanirbhar Bharat where low carbon options were to be "assessed in the context of inclusive growth and expansion needed in the sector". The LTS recognizes that India's long-term transition would be "evolutionary and flexible, accommodating new developments in technology, the global economy and international cooperation". It notes that it is "based upon an economy-wide multiple objectives approach, including integrating dimensions of gender equity and inclusion of marginalised and vulnerable groups, that consciously seeks to move to a low-carbon path of development."[18]

The Government has launched a series of actions and initiatives, including several national "missions" to help achieve its NDC climate change objectives. India is implementing an extensive range of domestic climate mitigation actions, including putting into place the *National Solar Mission*, along with other national missions such as the National Green Hydrogen Mission, and other relevant national missions on Energy Efficiency and on *Battery Storage & Transformative E-mobility and,* among others. In addition, India has also demonstrated its global climate leadership in several ways, including by launching the *International Solar Alliance* (ISA) initiative and through its active involvement and commitment to the multilateral climate change process. In October 2022, India's Prime Minister along with United Nations Secretary General Antonio Guterres launched "Mission Life", a flagship initiative to motivate every individual to adopt a more sustainable lifestyle.

India has made noteworthy progress on implementing its climate agenda, including through increasing the share of energy production from renewables and by improving energy efficiency. India has been rapidly scaling up renewable energy to meet the expected growth in electricity demand over the coming years, with some projections that electricity demand growth is not likely to peak until around 2030-2035.[19] From a low base, modern renewables are the fastest growing source of domestic primary energy production driven, in part, by state renewable purchase obligations which mandate minimum purchase levels of wind power, large hydro power, and energy storage. The structural orientation of India's economy towards the services sector has also long been an important driver of economic growth and improvement in energy efficiency, resulting in a steady decline in the carbon intensity of India's electricity grid to 710 g CO_2/kWh, with future declines expected.[20]

Accelerating this transformation to more affordable, efficient, and sustainable energy generation will help stimulate overall economic growth and competitiveness, including providing a boost to India's emerging green economy and exports. The National Solar Mission includes production-linked-incentive (PLI) schemes for domestic production of batteries and solar panels which aims to bring down the cost of solar energy. India is targeting improved energy efficiency through the sale of LEDs, compulsory audits for energy intensive firms, and improved consumer information about appliance energy efficiency. Households are gradually replacing traditional cooking biofuels with clean fuels.. Incentives for the development of local green manufacturing and service industries create green jobs and help maintain national resilience and safeguard supply chains, including those for critical minerals that are important for RE and battery storage. Initiatives such as "Make in India" to make the country a global hub for design and manufacturing will, in turn, benefit from cleaner, more efficient, and affordable energy. Fiscal incentives have been used in the transport sector to encourage the production and sale of electric vehicles (EVs). India's National Green

[17] https://unfccc.int/sites/default/files/resource/India_LTLEDS.pdf

[18] https://moef.gov.in/wp-content/uploads/2022/11/Indias-LT-LEDS-2.pdf (pp. 20)

[19] https://pib.gov.in/Pressreleaseshare.aspx?PRID=1885381

[20] Approved_report_emission__2021_22.pdf (cea.nic.in)

Hydrogen Mission to promote the development of 5 Million Metric Tonnes (5 MMT) of green hydrogen capacity annually by 2030, would alone require an additional renewable energy capacity of 125 GW within the 2030 timeframe.[21] India has also approved legislation to design and implement a carbon credit trading scheme which could allow effective pricing of carbon emissions.

2.4 Gap/Barrier Analysis for RE deployment

India's journey towards achieving its ambitious domestic renewable energy targets of 500 GW by 2030 is riddled with various challenges across multiple fronts. The supply chain presents hurdles due to limited domestic manufacturing capacity for crucial components like silicon wafers and polysilicon ingots. Land availability is another critical issue, necessitating efficient coordination between the central and state governments to ensure smooth land acquisition processes consistent with India’s democratic traditions and participatory systems. The development of transmission infrastructure and grid upgrades is essential but faces execution challenges that need to be addressed promptly. Financing remains a crucial aspect, with the need for diverse funding options with long tenors and affordable terms for the upfront financing required to scale up renewable energy deployment. Procurement frameworks require further institutional innovations to facilitate accelerated deployment and project execution. Additionally, power market design must evolve to accommodate the rise in renewable energy generation, and grid integration challenges need to be tackled to ensure stability despite intermittent resources and lack of flexibility. These challenges collectively highlight the complexity and urgency of transitioning India's energy landscape towards sustainability and renewable sources.

A. **Revamping Procurement Frameworks:** The evolution of procurement frameworks has been a pivotal institutional innovation in unlocking the renewable energy (RE) market, exemplified by the tendering processes, notably issued by SECI (Solar Energy Corporation of India), SJVN and NTPC, among others. The presence of such institutions in the procurement space has notably elevated credit quality within the sector, leading to substantial growth in recent years. However, the trajectory towards achieving the ambitious 500 GW target by 2030 demands a faster pace and significantly larger scale, necessitating further institutional innovations. This includes the creation of additional institutions akin to SECI, capitalizing on and reinforcing SECI's capabilities, empowering state-based agencies to drive procurement processes, and establishing accessible risk mitigation funds and instruments tailored for newer technologies. These measures are crucial to navigate the challenges and complexities associated with scaling up renewable energy deployment to meet national targets effectively.

B. **Land Acquisition:** Land availability presents a significant challenge in the deployment of renewable energy in India, with coordination between the central and state governments being paramount. The central government has urged all states and union territories to develop renewable energy plans, emphasizing the importance of land acquisition and necessary approvals to meet the ambitious 500 GW target. Addressing this issue requires a multifaceted approach, considering that some states are resource-rich but face constraints in land availability, while other resource-rich states like Rajasthan boast substantial land reserves. It is imperative for the top renewable energy-rich states to lead and enable the generation capacity addition efforts by proactively preparing for land acquisition, streamlining approval processes through mechanisms such as single-window clearances, and implementing facilitative measures to expedite project approvals. This coordinated effort is crucial for overcoming land-related obstacles and achieving significant progress in renewable energy deployment across the country.

C. **Transmission and distribution infrastructure upgrade:** The development of transmission infrastructure and grid upgrades is a critical aspect of renewable energy deployment in India, particularly due to the longer gestation period required for setting up such infrastructure compared to wind and solar generation capacity additions. The government has taken proactive measures by releasing a plan aimed at augmenting transmission infrastructure to support the achievement of the 500 GW target, including the implementation of Battery Energy Storage systems crucial for absorbing large-scale renewable energy. Additionally, the establishment of a parliamentary consultative committee reflects a concerted effort to address these infrastructure challenges. These concerted efforts should be supplemented by investments in developing

[21] https://mnre.gov.in/hydrogen_energy_government_of_india
https://www.pv-tech.org/india-approves-national-green-hydrogen-mission-adding-125gw-of-renewables-by-2030/

intra-state transmission networks and upgrading existing ones. However, the historical challenge lies in execution, highlighting the importance of timely approvals and efficient execution of transmission infrastructure projects. Delays in this regard could act as a significant impediment to the ambitious renewable energy plans, underscoring the critical need for streamlined processes and effective execution strategies to ensure the success of renewable energy deployment in India.

D. **Financing**: Financing for renewable energy, particularly wind and solar, has transitioned into mainstream investment with significant private financial flows. Assets are often held by private equity funds/platforms, pension funds, sovereign wealth funds, and various capital options are available. As stated earlier, the establishment of SECI (Solar Energy Corporation of India) as a central entity has notably enhanced credit quality within the sector. However, achieving three to four times the current RE deployment rate will necessitate significant further expansion of financing options and frameworks. Innovative instruments such as Infrastructure Investment Trusts (InVITs), newer private equity funds/platforms, green bonds, and blended financial instruments will play a crucial role in facilitating this expansion. Additionally, such innovation will be crucially important as the sector explores newer technologies like hydrogen, battery energy storage, floating solar, and offshore wind, which may not yet be considered fully bankable due to various factors such as unproven technology, undeveloped use cases, higher risks, and initial costs.

E. **Domestic Supply Chain**: The ambitious target of 500 GW, with a significant portion allocated to solar and wind energy, highlights the critical need for a well-aligned supply chain. However, as noted above, the country faces a shortfall in manufacturing capacity for key components like silicon wafers and polysilicon ingots, which remain crucial for solar panel production. This deficit forces India to heavily depend on imports, with 100% of silicon wafers and 80% of cells being sourced from abroad. While the government has introduced the Performance Linked Incentive (PLI) scheme to promote domestic solar panel manufacturing, its impact may take time to materialize. Losing even a couple of years could significantly impact the capacity addition rate, necessitating alternative supply chain strategies such as grandfathering past contracts and accelerating deployment efforts.

F. **RE grid integration**: The increasing deployment of renewable energy (RE) sources poses significant challenges to grid integration, primarily stemming from the intermittent and variable nature of these resources. Grid stability is a major concern due to the fluctuating output of solar and wind power, which can lead to imbalances in supply and demand. This is compounded by the lack of flexibility in traditional grid systems and the need for accurate forecasting to effectively manage energy flow. Addressing these grid integration challenges requires advanced grid management techniques, innovative business models such as Distributed Renewable Energy (DRE), and investments in technologies that enhance grid flexibility and resilience.

2.5 Social Equity and Inclusion

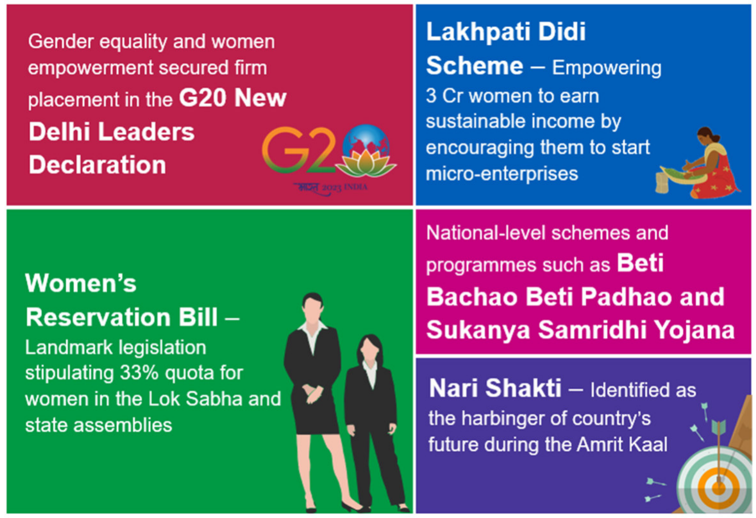
Increasing female workforce participation not only drives economic growth and innovation but also fosters gender equality, empowerment, and societal progress – crucial for India's ambitious development goals.

Full participation of women in the workforce confers many advantages to the economy and to society. In addition to being a matter of equal opportunity and fairness, it's an economic game-changer. Numerous studies have shown that increased female participation boosts GDP growth, drives innovation, and fosters a more diverse, and resilient workforce. For instance, according to the International Monetary Fund (IMF), raising women's participation in the labour force to the same level as men could boost India's GDP by as much as 27%[22].

Over the years, India has implemented a diverse array of interventions aimed at enhancing women representation in the workforce and achieving the targets outlined in SDG-5

[22] Chapter 1. The Macro Story - An India Economic Strategy To 2035 - Department of Foreign Affairs and Trade (dfat.gov.au)

India has undertaken a host of measures in the past few decades to enhance the social position of women as well as their representation in the workforce. For instance, under the Presidency of the recently conducted G20 summit, **India advocated for increased female leadership and representation through shifting the focus from women's development to women-led development.** India's dedication to championing gender equality led to the creation of a **Working Group on the empowerment of women**, which focuses on aspects such as job creation in science, technology, engineering, mathematics (STEM) and green sectors; better access to financial and digital assets; increased leadership opportunities; food and nutrition security for women and children, etc[23].



Empowering Indian women is not just a step towards gender equality but a leap towards unlocking the country's vast economic potential. With women comprising half of the population, their empowerment through equal opportunities is pivotal for driving inclusive growth. This empowerment is especially crucial in sectors pivotal for India's future, such as renewable energy, where women's participation can significantly influence the country's climate ambitions. Recent data underscores the progress and challenges in this arena: the literacy rate among adult females has surged from 51% in 2006 to 69% in 2022[24], yet their enrollment in technical disciplines like Engineering & Technology remains disproportionately low, with only 10,69,130 female candidates enrolled compared to 26,17,155 male candidates in 2020-21[25]. This discrepancy hinders women's participation in the energy sector, emphasizing the need for targeted efforts to dismantle barriers and foster an environment where women can lead and thrive in renewable energy initiatives. The CIF REI Programme will focus on addressing this gender gap in the sector through targeted women-centric capacity building programmes under the Technical Assistance intervention.

The broader context of social inclusion in India, encompassing disability, LGBTQ+ rights, and youth engagement, lays the foundation for a more equitable society. The literacy rate among persons with disabilities stands at 52.2% for those aged 7 years and above, and the labor force participation rate for this group is 23.8%[26]. Meanwhile, the LGBTQ+ community in India has seen a gradual shift towards greater inclusion, with the Supreme Court deliberating on marriage equality as of 2023. The youth population, with a literacy rate of 97% in 2022[27], embodies the country's potential for driving economic growth and societal progress. However, achieving full inclusivity requires addressing the disparities that persist, particularly in sectors crucial for India's sustainable development. Key policies and initiatives being implemented by Government of India to ensure inclusive growth of the country are listed in Appendix B.

India's energy policies, while aimed at national welfare, often overlook the nuanced impacts on different societal groups, risking the perpetuation of existing inequities. Despite schemes like Pradhan Mantri Ujjwala Yojana and SAUBHAGYA Electrification Scheme, energy affordability and reliability issues persist. Approximately 14% of rural households rely solely on biomass, with another 66% using it to supplement clean fuels[28]. These issues not only underscore energy poverty but also highlight the unique challenges women face, particularly in rural areas where unreliable electricity supply and high energy costs limit economic empowerment opportunities.

[23] UN Women welcomes G20 Delhi Declaration's stress on Gender Equality and women's Empowerment | UN Women – Asia-Pacific
[24] The World Bank
[25] Ministry of Statistics and Programme Implementation, India
[26] Survey of Persons with Disabilities
[27] The World Bank
[28] CEEW

Policymakers and the RE industry recognize the critical role of women in the renewable energy sector for India's holistic clean energy transition. Global data from the International Renewable Energy Agency (IRENA) reveals that the solar PV industry, which creates the most jobs in the renewable sector, employs the highest percentage of women at 40%, compared to lower percentages in other energy sectors. However, in India, women's participation in the clean energy workforce remains significantly lower than the global average, with only an estimated 11% of the workforce in the rooftop solar sector being women[29]. This gap highlights the need for policies and practices that support women's access to opportunities in renewable energy, ensuring their contributions are recognized and valued.

The Ministry of New and Renewable Energy (MNRE)'s efforts to promote women's participation in the renewable energy sector through initiatives like the online session on **"Women in Renewable Energy: Call for Action"** and the formation of a **committee to recommend women-centric policies** represent significant strides towards gender inclusivity. These initiatives aim to address the barriers hindering women's participation and to empower women across the renewable energy sector. However, the lack of training or skilling programs targeted specifically at women underscores the need for more focused efforts to equip them with the skills necessary for leading in the clean energy transition.

As India advances towards its ambitious climate goals, including the target of 500 GW of non-fossil fuel energy sources by 2030, the role of women as change agents cannot be overstated. The projected creation of 3.4 million new clean energy jobs[30] by reaching this goal presents a unique opportunity to enhance women's participation in the renewable energy sector. Doing so not only addresses the growing demand for skilled individuals but also ensures that the clean energy transition is equitable and inclusive, leveraging the full potential of the country's diverse population for sustainable and transformative development. The CIF REI Programme envisages to tap this opportunity through targeted women-centric capacity building programmes under the Technical Assistance intervention.

[29] Women working in the rooftop solar sector – Analysis - IEA
[30] Natural Resources Defense Council, Council on Energy, Environment and Water, Skill Council for Green Jobs

3 Renewable Energy Integration Context

3.1 Renewable Energy in the electricity sector

The power sector contributes nearly 34% of India's overall CO2 emissions, with fossil fuels being the dominant contributor accounting for about half of the country's installed power generation capacity[31]. The greening of India's power sector is a necessary pre-requisite to meeting India's clean energy goals as well as to transforming India's economy to a lower-carbon future over the coming decades. Meeting increasing energy demand for development, particularly in the context of extreme climate events, has driven the importance of an optimal generation capacity mix to achieve the right balance between cost and grid reliability, while ensuring energy security and affordability, along with lower emissions. Driven by concerted government policies and regulations and by lower technology costs, India's power sector is already experiencing a paradigm shift towards RE, which now accounts for about 41.4 percent of power generation capacity, while the share of RE in the electricity mix has increased from 6% in 2015-16 to 13% in 2022-23.

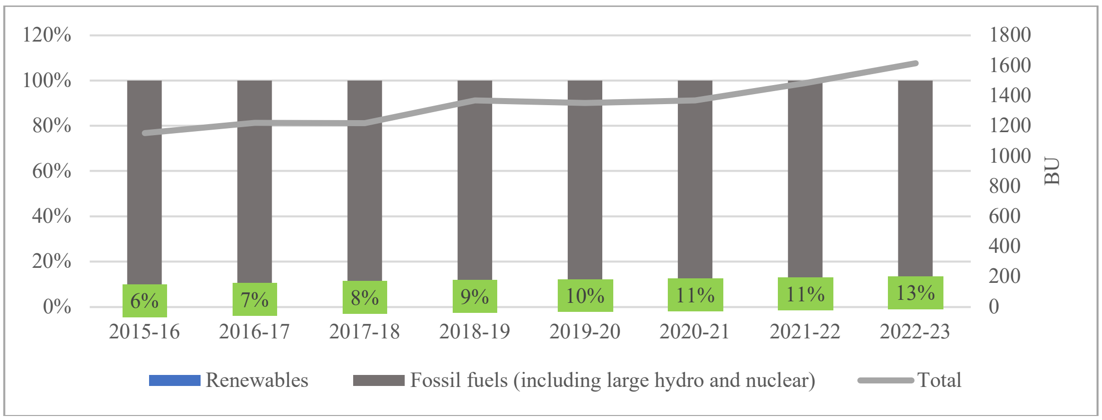


Figure 5: Share of Electricity Generation from RE sources (Source: CEA)

With around 53.4% of share in RE installed generation capacity, solar technology is driving the RE growth in India. Wind power captures a 34.1% share, followed by biomass/ cogeneration power with an 8.2% share. Small Hydro Power and Waste to Energy account for 4% and 0.4% of the RE generation capacity respectively[34]. An overview and key developments in the technologies relevant to India's RE sector are detailed in the Appendix C.

There is a high potential for generation of RE from various sources like wind, solar, biomass, small hydro and cogeneration bagasse in India. The total potential for renewable power generation in the country as on 31.03.2023 is estimated at 2,109,654 MW. This includes solar power potential of 7,48,990 MW (35.50%), wind power potential of 1,163,856 MW (55.17%) at 150m hub height, large hydro power of 133,410MW (6.32%), SHP (small-hydro power) potential of 21,134 MW (1%), Biomass power of 28,447 MW (1.35%) and 13,818 MW (0.66%) from bagasse-based cogeneration in sugar mills[34]. Further, initial assessment by National Institute of Wind Energy (NIWE) within the identified zones suggests 36 GW and 35 GW of offshore wind energy potential exists off the coast of Gujarat and Tamil Nadu respectively[32]. As per the CEA estimates on-river pumped storage potential is 103 GW in India[33].

As renewable energy becomes a larger part of the overall energy mix, mechanisms like Round-the-Clock Power (RTC) and Firm and Dispatchable Renewable Energy (FDRE) are crucial for addressing intermittency issues and ensuring grid stability. These mechanisms rely on Energy Storage Systems, which are essential for storing energy generated during off-peak periods and providing grid balancing support during peak demand. Additionally, the Commercial and Industrial (C&I) segment is increasingly adopting energy storage solutions to mitigate risks associated with renewable energy, while also meeting their sustainability and Renewable Purchase Obligation (RPO) targets

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[31] Central Electricity Authority (CEA)

[32] Ministry of New and Renewable Energy

[33] Pumped Storage Plants Report 2023_11.12.2023.pdf (teriin.org)

Rajasthan, Gujarat, Tamil Nadu, Karnataka, Maharashtra and Andhra Pradesh are the leading RE states and host more than 75% of the total installed RE capacity of India[34]. Rajasthan had the highest installed capacity of grid connected renewable power (22,398 MW) in 2023 followed closely by Gujarat (19,436MW) mainly on account of wind and solar power. These states hold the key to rapidly expanding India's RE footprint in the 2030 time-frame, provided that sufficient grid capacity and flexibility is available to integrate intermittent RE both within the states and across state-lines.

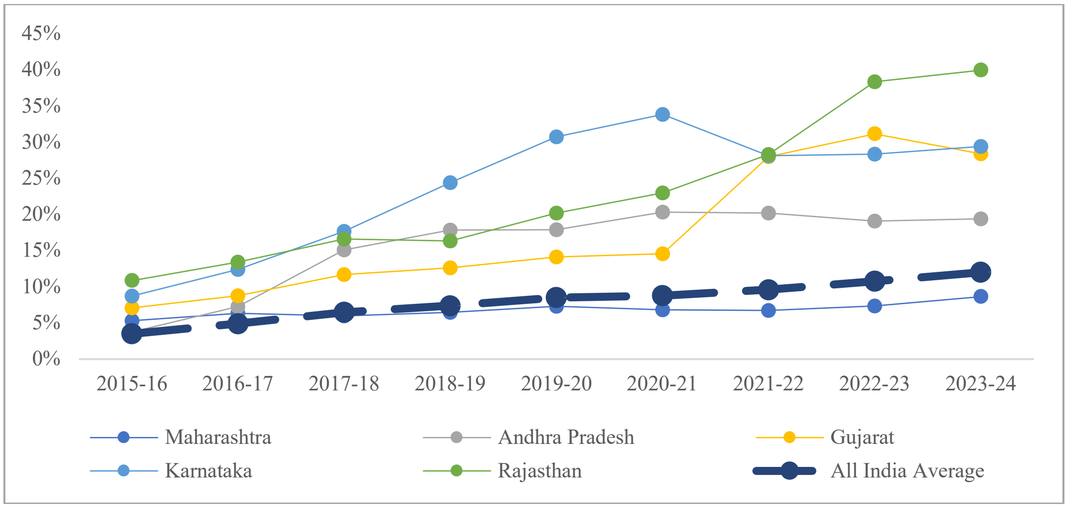

Figure 6: Share of RE in Overall Electricity Mix in RE Rich States (Source: CEA)

In line with their high RE installed capacity, RE rich states also boast of a high RE share in their overall electricity mix. For example, Rajasthan's electricity generation mix contains 40% share of RE. Similarly, in Karnataka and Gujarat, share of RE remains 29% and 28% respectively. Such high shares of RE in generation mix poses grid stability challenges associated with intermittent and variable nature of RE. It becomes critical to focus on addressing these challenges by introducing grid flexibility to facilitate integration of RE.

GoI has adopted several initiatives and reforms to scale-up RE for clean energy transition and to reduce the carbon intensity of the power sector. India has substantially reduced the energy intensity of its economy and is fully committed to the long-term transformation of its economy to one powered by more affordable, clean, and efficient energy generation. The RE scale-up is expected to be achieved through a number of initiatives, including further accelerating the addition of onshore wind and ground-mounted solar capacity. In addition, new technologies such as offshore wind, floating solar and energy storage will increasingly make a significant contribution to achieving RE targets set for 2030.

- The Ministry of New and Renewable Energy (MNRE) has taken a proactive step in advancing India's RE capacity by prescribing an annual bidding trajectory for Renewable Energy Implementation Agencies (REIAs). As part of this trajectory, bids for an impressive 50 GW[35] per annum of RE capacity are slated to be issued each year from 2023-24 to 2027-28, with a specific emphasis on ensuring at least 10 GW per annum of wind power capacity.
- The Government of India has implemented various strategic measures to boost the production of RE sources, such as solar energy, wind energy, and Green Hydrogen. One key initiative involves waiving Inter State Transmission System (ISTS) charges for the inter-State sale of solar and wind power projects commissioned by June 30, 2025, with graded ISTS charges thereafter. This move aims to incentivize the growth of these sectors by reducing financial barriers.
- To ensure sustained progress, the government has declared a trajectory for Renewable Purchase Obligation (RPO) towards a target of 43.33 percent by 2030, with a separate RPO for distributed renewable energy[36]. This

[34] Energy Statistics India 2024

[35] Press Information Bureau (pib.gov.in)

[36] Renewable_Purchase_Obligation_and_Energy_Storage_Obligation_Trajectory_till_2029_30.pdf (powermin.gov.in)

commitment provides a clear roadmap for meeting RE targets and fostering a transition towards cleaner and more sustainable energy sources. Alongside this, new schemes and programs have been launched, including the Development of Solar Parks, Pradhan Mantri Kisan Urja Suraksha evam Utthaan Mahabhiyan Yojana (PM-KUSUM)[37], and the Grid Connected Solar Rooftop Programme, PM-Surya Ghar: Muft Bijli Yojana, National Framework for promoting energy storage systems[38], Viability Gap Funding (VGF) scheme for 4GWh of energy storage systems indicating a comprehensive approach to diversify RE initiatives. VGF is a financial tool used by governments to bridge the gap between the cost of deploying expensive energy storage systems and their current economic viability which is diminished because they do not always generate direct income for the owner. helps make energy storage projects more attractive for businesses by covering some of the upfront expenses and can provide for as much as 40 per cent of the capital cost of BESS.

- India has established Ultra Mega Renewable Energy Parks[39] as a notable step in the effort to streamline and facilitate RE development, these parks provide a plug-and-play infrastructure for RE developers, facilitating a more efficient setup that invites external investment. Additionally, the government is investing in enhancing transmission infrastructure and creating new sub-station capacity to accommodate the increasing demand for renewable power.
- Recognizing the importance of private investment, the government has set up a Project Development Cell to attract and assist investors in RE projects. Standard Bidding Guidelines for tariff-based competitive bidding processes further contribute to a transparent and competitive procurement process for power from Grid Connected Solar PV and Wind Projects, fostering a conducive environment for business and investment.
- Round The Clock (RTC)**-** Wind and Solar projects alone cannot meet baseload demand on account of their intermittent nature. As the share of RE in power generation mix increases substantially, RTC power supply becomes more critical to ensure that the grid is balanced, energy demand and supply are adequately managed, and intermittency issues do not hamper the efficiency of the power system. One key aspect of the regulatory framework under the EA 2003 is the flexibility in determining project tariffs. Developers are shortlisted based on competitive bidding, a method encouraged by the National Tariff Policy 2016 to maintain competitive pricing. The government's emphasis on fair competition is evident in the Competitive Bidding Guidelines, which standardize the bidding process for grid-connected solar, wind, hybrid, and Round-The-Clock (RTC) projects. An innovative approach to address intermittency issues in RE projects is the Reverse Bundling[40] tender issued by the Solar Energy Corporation of India (SECI) for RTC power. This initiative aims to balance the intermittency of RE by combining high-cost power with cheaper RE power, and promoting stability in the grid. Captive generating plants, exempted from certain regulatory charges, also play a vital role in promoting private investment in the sector.
- Firm and Dispatchable Renewable Energy (FDRE)- Guidelines for competitive bidding of firm and dispatchable power from grid-connected RE projects with energy storage system facilitates tenders with the provision of assured peak power and RTC power at any hour of the day as per the demand specified by the DISCOM. The monthly demand fulfilment ratio of 90% under the FDRE tenders strategically anticipates bidders to having the installed RE capacity exceed the capacity committed by the generators, thereby increasing the overall installed capacity of RE within the grid.
- In alignment with financial security, the government has mandated that power dispatches against Letter of Credit (LC)[41] or advance payments to ensure timely payments by distribution licensees to RE generators. This measure enhances financial reliability in the sector, encouraging continued growth. Other regulatory measures, such as the Notification of Promoting Renewable Energy through Green Energy Open Access Rules 2022[42] and the Electricity Amendment Rules 2022[43], further signify the government's commitment to creating an enabling environment for RE development.

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[37] National Solar Water Pumping System (mnre.gov.in)

[38] https://powermin.gov.in/sites/default/files/National_Framework_for_promoting_Energy_Storage_Systems_August_2023.pdf

[39] Development of Solar Parks and Ultra Mega Solar Power Projects | Ministry of New and Renewable Energy | India (mnre.gov.in)

[40] Reverse Bundling or Reverse Auction serve as a contracting mechanism, where project developers bid for power purchase agreements (PPAs) from a utility, end customer, or other contracting authority.

[41] Letter_of_Credit.pdf (powermin.gov.in)

[42] Electricity_Renewable_Energy_Through_Green_Energy_Open_Access_Amendment_Rules_2023.pdf (powermin.gov.in)

[43] Electricity_Amendment_Rules_2022.pdf (powermin.gov.in)

- The National Green Hydrogen Mission has been launched to promote the production and use of hydrogen from RE as a transportation fuel and to replace the use of fossil fuel as an industrial feedstock in fertilizer production. India also has launched and is implementing a wide set of initiatives such as "Make in India" to make the country a global hub for design and manufacturing, which, in turn, will benefit from more affordable, clean, and efficient energy generation.
- The Guidelines to Promote Pumped Storage Projects (PSP) takes into account the energy transition, ancillary services and temporal considerations and aims to facilitate smooth integration of the growing share of renewable energy in the overall energy mix. CEA targets to concur at least two PSPs each month during the current year depending upon the completion of the DPRs by the developers. During 2024-25, CEA has targeted to concur 15 Hydro PSPs of 25,500 MW capacity, out of this 4 PSPs of 5,100 MW capacity have already been concurred.[44]
- The National Bioenergy Programme (Phase-I) for FY 2021-22 to 2025-26, aims to set up biogas plants to provide clean cooking fuel, lighting, and meet the thermal and small power needs of users. This initiative would result in reduced greenhouse gas emissions, improved sanitation, women empowerment, and the creation of rural employment. Additionally, the digested slurry from biogas plants, which is a rich source of organic manure, will benefit farmers by supplementing or reducing the use of chemical fertilizers.[45]

3.2 RE integration challenges

According to the CEA's report on Optimal Generation Mix 2030[46] (version 2 released in April 2023), the total installed capacity of generation is projected to reach 777 GW by 2030. The proportion of fossil fuels is anticipated to decrease from 60% in 2022 to 36% by March 2030, according to the same report. Subsequently, non-fossil fuel capacity is expected to surpass 500 GW, constituting 64% of the overall installed capacity in 2030. Achieving India's ambitious goal of attaining 500 GW of RE by 2030 hinges on addressing pivotal challenges across the electricity value chain. The country's ambitious RE targets necessitate addressing these challenges through a combination of policy reforms, infrastructure development, and technological innovation.

A. Technical Challenges:

- **Grid Stability and Reliability:** A significant challenge is maintaining grid stability as renewable sources, which accounted for approximately 30.1% of India's total installed capacity of 416.06 GW by 2022-23, are inherently variable. To bolster grid stability, investments in advanced management systems and technologies, including wide-area monitoring, are crucial. These systems can provide real-time data and predictive analytics, allowing for more effective grid balancing and reliability in the face of fluctuating renewable outputs.
- **Grid integration and transmission bottlenecks**: The challenge of integrating over 500 GW of RE (RE) by 2030 in India significantly stresses the transmission network, highlighting critical issues at both the inter and intra-state levels. The CEA's report[47] underlines the mismatch in the gestation periods of wind and solar generation projects, which are significantly shorter than the time required to develop the necessary transmission infrastructure. This mismatch necessitates advanced planning to ensure the timely availability of transmission networks to evacuate power from high solar and wind potential areas to load centers. According to the report, the transmission network needs a massive expansion to accommodate the RE integration, with an additional 50,890 circuit kilometers (ckm) of transmission lines and a sub-station capacity of 433,575 MVA required by 2030, at an estimated cost of Rs. 2,44,200 crores (USD 29.17 Billion)). The present inter-regional transmission capacity stands at 112,250 MW, and with the planned additions, it is expected to increase to about 150,000 MW by 2030. This represents a roughly 34% increase in inter-regional transmission capacity, highlighting the substantial scale of infrastructure development needed. The augmentation of the transmission network, both inter and intra-state, is crucial not only for the evacuation of power from RE zones across diverse regions such as Ladakh, Rajasthan, Gujarat and offshore in Tamil Nadu and Gujarat but also for addressing the connectivity gap within states. Similarly, in case of Uttar Pradesh, with rapidly growing energy demand, the inadequate transmission network poses a great challenge for integrating new RE capacity. With AT&C losses of over 20% in the state, there is a need of significant investment in grid upgradation and augmentation.

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44 Press Release: Press Information Bureau (pib.gov.in)
45 https://biogas.mnre.gov.in/about-the-programmes
46 Optimal_mix_report__2029_30_Version_2.0__For_Uploading.pdf (cea.nic.in)
47 Renewable energy cover Final.cdr (cea.nic.in)

- **Strengthening Distribution Network**: Integrating Distributed Renewable Energy (DRE) sources and Electric Vehicle (EV) charging infrastructure into India's electricity distribution network presents challenges, including grid stability and load management. The increasing demand from EVs and the variability of renewable sources require advanced management to ensure reliable power distribution. Enabling smart technologies like SCADA, Distribution Management Systems (DMS), Outage Management Systems (OMS), and other intelligent solutions can help overcome these challenges by enhancing grid flexibility, real-time monitoring, and efficient load balancing to support India's growing energy needs and transition to sustainable sources.
- **Forecasting and scheduling**: The Central Electricity Regulatory Commission (CERC) and State Electricity Regulatory Commissions (SERCs) have developed guidelines in 2014 to manage the variability of renewables like solar and wind, requiring producers to **accurately forecast generation** and adjust schedules accordingly. This is crucial for maintaining grid stability, especially in states like Tamil Nadu and Rajasthan, which have experienced significant wind energy curtailment. However, equally crucial is **manpower resource forecasting**, which involves predicting the human resource needs to operate, maintain, and manage renewable energy systems efficiently. This ensures the availability of skilled professionals for technical operations, maintenance, emergency responses, project development, and expansion. Despite advancements and regulatory efforts, achieving accurate forecasting remains challenging, compounded by the lack of uniformity in permissible error bands for deviation across states, and the complex grid system characterized by load shedding and frequency variation. Addressing these challenges necessitates accurate forecasting and scheduling, technological advancements, regulatory uniformity, and the exploration of new business models incorporating advanced storage technologies, such as grid-scale battery systems and green hydrogen, to support the successful integration of RE into India's energy mix. Apart from RE energy generation forecasting, it is also important to have resource (manpower) forecasting and planning in place in advance to successfully implement the policies.
- **Flexibility and Ramp-up Challenges:** Integrating large-scale renewables into the Indian power grid presents flexibility and ramp-up challenges due to the variable nature of RE and increasing peak demand, particularly from air conditioning and future electric vehicle charging. The existing coal-fired plants, which significantly contribute to India's power generation, often lack the operational flexibility to adjust their output swiftly to match these variations. With renewable penetration at about 18-20% in energy terms, instances where thermal flexibility is maximized are already occurring. Challenges like cloud cover over solar parks can cause abrupt changes in solar output, risking the load-generation balance. To manage such situations and integrate 175 GW of RE, the Central Electricity Authority (CEA) estimated[48] that ramp-up and ramp-down requirements would reach 380MW/min and 375MW/min, respectively, necessitating thermal plants to operate at 26% technical minimum capacity on critical days.
- **Curtailment Issues**: RE curtailment in India is primarily driven by grid stability issues due to the variable nature of renewable sources like wind and solar. Technical challenges such as inaccurate load forecasting by electricity distribution companies and unforeseen power grid outages contribute to technical curtailment, while commercial considerations can lead to the reduced dispatch of older renewable projects in favor of cheaper power sources. The penetration of solar and wind energy in the Indian grid system increased significantly from 3.5% in FY 2015 to 13% by FY 2023[49], exacerbating these challenges. High renewable penetration levels, particularly in states like Rajasthan (40%), Gujarat (28%), Karnataka (29.4%) and Andhra Pradesh (20.6%), have placed additional pressure on local substations to ensure continuous offtake. An analysis by SECI suggests that without demand profile changes, solar generation curtailment could reach 50% by FY 2030.

B. Policy, Market, and Regulatory Challenges

- **Market Mechanisms for Flexibility**: The significant surge in India's RE generation, particularly from variable sources such as solar and wind, has brought about a set of new challenges for the nation's electricity grid. As the share of renewables in the energy mix is estimated to reach 43.96% by FY32 from ~12% in FY23, the existing power market design needs to evolve to effectively address these challenges and ensure the optimal utilization of available resources. The transition towards RE sources in India's electricity grid necessitates a comprehensive overhaul of the existing power market design. Despite early initiatives like the Renewable Energy Certificate (REC) Mechanism, which aimed to decouple the energy component from the green attribute of RE, the market failed to garner significant traction, resulting in a mere -60 GW of installed capacity. To address these challenges, a multifaceted approach to power market reform is imperative. Firstly, there is a need to harness the inherent

[48] Report_21022023.pdf (cea.nic.in)
[49] CEA

diversity of India's large and synchronous grid by implementing mechanisms that facilitate the efficient exchange of energy across regions. This entails reducing barriers to inter-state power trading and promoting market participation among diverse stakeholders, including independent power producers (IPPs) and state-owned generating companies (Gencos). Furthermore, enhancing ancillary services procurement and adopting mechanisms such as contracts for difference (CFD) through well-developed markets is crucial for enhancing RE penetration and improving reliability. Ancillary services become more critical with increased penetration of variable RE into the grid to maintain grid stability and security. These services are capable of maintaining frequency and voltage by balancing demand and supply. Contracts for Difference (CfDs) have emerged as a powerful tool in driving the transition to renewable energy by providing long-term revenue stability and incentivizing investment in low-carbon electricity generation. The strike price represents the pre-agreed price that the generator will receive for each unit of electricity they produce. It provides long-term revenue stability for the generator, reducing the risk associated with renewable generation. The strike price is determined through a competitive auction process, ensuring cost-effectiveness and encouraging price reductions in renewable energy generation. The reference price is the average market price for electricity, acting as a benchmark for comparison. If the market price for electricity falls below the reference price, the counterparty pays the generator the difference, bridging the gap and ensuring revenue stability. On the other hand, if the market price exceeds the reference price, the generator pays back the excess to the counterparty.

- **Compensation for Curtailment**: The lack of a standardized mechanism for compensating RE generators for curtailment can deter investment and affect the financial health of both RE projects and distribution companies (DISCOMs). Establishing clear compensation guidelines is crucial for maintaining investor confidence.
- **Grid Codes for System Security**: India's grid codes need to be updated to ensure that VRE plants contribute to system security, including requirements for frequency support and reactive power management. Implementing such technical standards would enhance the grid's ability to integrate higher shares of RE.
- **Incentives for supporting grid flexibility services**: Introducing mechanisms to incentivize and support power plants equipped to support grid flexibility services for providing increased flexibility, such as faster ramp rates and lower minimum load levels, could facilitate a smoother integration of RE into the grid.
- **Demand-Side Flexibility:** India's electricity demand reached ~1500 BU in 2022-23, and projections suggest that it will more than double by 2036-37[49]. Aligning this demand with the intermittent supply from renewables is paramount. Time-of-use tariffs and smart metering initiatives represent significant steps towards enhancing demand-side flexibility. Expanding these projects nationally and integrating smart appliances and systems can shift consumption patterns, making them more responsive to renewable generation cycles. This shift not only aids in balancing the grid but also empowers consumers to play an active role in energy conservation and efficiency.

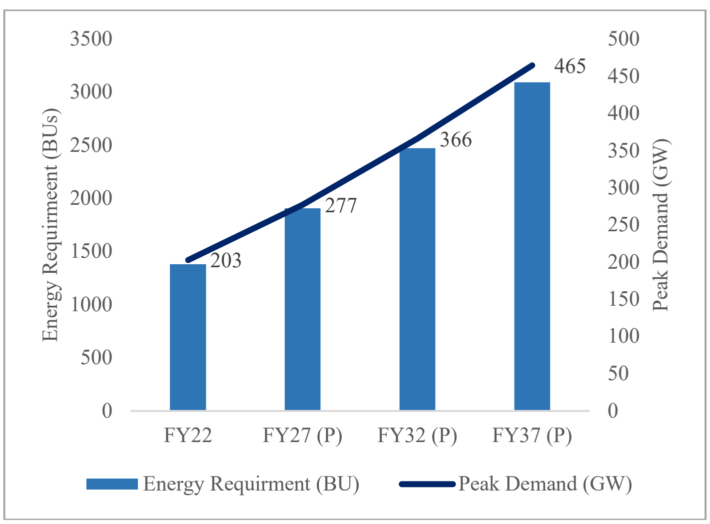

Figure 7: India's Electricity Demand Projections (Source: CEA)

To achieve its ambitious goal of integrating 500 GW of RE by 2030, India is poised to adopt a holistic strategy that addresses critical elements across the electricity value chain and aligned with the proposed CIF REI program, which outlines four pivotal themes: scaling up technologies that enable RE, upgrading infrastructure to accommodate RE, fostering innovation in the RE sector (excluding direct investments in RE generation), and refining the operational and market frameworks for energy systems. These themes align with the significant challenges facing RE integration in, and detailed in chapter 4 of the IP, which describes the proposed Program.

3.3 States' Low or Zero Carbon Strategies

In line with the Central Government's ambitious RE targets, various Indian states have rolled out their specific RE policies to meet their climate agenda and renewable targets. These policies are designed to address the unique environmental, economic, and industrial challenges each state faces, ensuring a tailored approach to achieving net-zero targets and enhancing their respective RE capacities. Below is a summary of the RE policies from several key states, highlighting their focus areas, targets, incentives, and special initiatives aimed at promoting RE development and usage.

Table 2: RE Development in Key States in India

State	Policy Focus	Targets	Incentives	Special Initiatives
Madhya Pradesh	Developing the state into a RE hub, focusing on equipment manufacturing and large-scale RE adoption.	50% RE mix by 2030; INR 15,000 Crore by 2024 and INR 50,000 Crore by 2027 in RE generation. Is there a MW target	GST exemption on RE equipment, Land allotment and Banking for Power	Financial incentives for setting up GH and energy storage projects, Green transformation, skill development, and R&D in RE technologies.
Uttar Pradesh	Accelerating the deployment of solar power to meet India's ambitious solar energy capacity extension program.	22,000 MW of solar projects by 2026-27. By 2030, UP envisions having more than 20% of RE in its energy mix[50].	Exemption of stamp duty, subsidy on rooftop solar installations, Priority Open Access, Mechanisms supporting consumers, businesses and developers.	Development of plug & play solar parks, solarization of agriculture electrical feeders. Special incentives for small hydro projects.
Gujarat	Tapping the state's RE potential, ensuring energy security by reducing dependency on fossil fuels, and promoting decentralized RE generation.	50% of cumulative electric power installed capacity from non-fossil fuel-based energy resources by 2030. Cumulatively, 34.5 GW of additional RE generation capacity in planning stage.	Solar park policy, capital subsidies for rooftop solar, priority Open Access to RE developers, Encouragement of investment, employment, skill enhancement in the RE sector.	Creation of energy awareness.
Karnataka	Developing the State as a hub of renewable energy generation energy	10 GW of additional RE projects by 2022-27.	Stamp duty exemptions, RPO enforcement, Banking of power along with strategy to attract investments and tap RE potential.	Focus on green energy corridors, RE parks, solar and wind energy projects. Special tax breaks for small hydro and wind-solar hybrid projects.
Rajasthan	Aims to promote renewable energy integration into the state's power grid and develop 90GW	90,000 MW renewable power projects by 2029-30.	50% exemption on transmission charges, capital subsidy for solar power projects, land lease policy for solar parks.	Additional incentives for projects in desert areas, special GH corridors. Development of solar parks/UMREPPs,

[50] VISION Doc Eng.pdf (up.nic.in), Accessed 27 September, 2024, Page 193

State	Policy Focus	Targets	Incentives	Special Initiatives
	renewable energy capacity by 2030		Promotion of RE projects with storage systems, electric vehicle charging stations by RE.	promoting RE for electric vehicle charging.

3.4 Institutional Framework & Capacity

At the central level, the institutional framework for electricity in India is multifaceted, comprising key entities such as the Ministry of Power (MoP), which formulates national policies and oversees the sector's development. The Ministry of New and Renewable Energy (MNRE) focuses on promoting clean energy sources. The Central Electricity Authority (CEA) provides technical guidance, setting standards for generation, transmission, and distribution. The Central Electricity Regulatory Commission (CERC) regulates the sector at the national level, determining tariffs and ensuring compliance. The Power Grid Corporation of India Limited (POWERGRID) manages interstate transmission, and the Grid Controller of India Limited, formerly known as Power System Operation Corporation Limited (POSOCO) handles real-time grid operations.

At the state level, State Utilities play a crucial role in planning and developing the power sector within their jurisdictions. Distribution Companies (DISCOMs) are responsible for the last-mile supply, purchasing power, and maintaining distribution networks. State Electricity Regulatory Commissions (SERCs) regulate the power sector within each state, ensuring fair practices and consumer protection. State Load Despatch Centers (SLDCs) monitor real-time operations within the state, balancing electricity demand and supply. State Transmission Companies (TRANSCOs) manage intrastate transmission, while State Generation Companies (GENCOs) contribute to in-state power generation. This intricate framework promotes coordination between central and state entities, ensuring a well-regulated and efficient electricity sector in India.

3.4.1 Key energy sector policies, laws, and regulations

India's progressive shift towards augmenting the RE share in its electricity grid is a strategic move to address both the escalating energy demands and the imperative of environmental sustainability. Over the years, a series of policies and regulations have been implemented to not only foster the growth of electricity generation, transmission, and distribution across the nation but also to ensure a significant part of this expansion is powered by RE sources and financed by the private sector and private capital. These measures have catalyzed the integration of RE into the national grid, contributing to energy security, reducing carbon footprints, and promoting socio-economic development. The table below highlights some of the key policies and regulations that have facilitated this transformative journey.

Table 3: India's Journey in Sustainable Energy Leadership

Policy/Regulation	Year of Enactment	Key Features	Source
National Solar Mission	2010	Aims to establish India as a global leader in solar energy by creating policy conditions for its diffusion.	Source: Ministry of New and Renewable Energy
Renewable Purchase Obligation	2010	Mandates a certain percentage of electricity generation to be from renewable sources.	Source: Central Electricity Regulatory Commission
Electricity Act, 2003	2003	Liberalized the generation, distribution, and transmission of electricity; facilitated competition and promoted rural electrification.	Source: Ministry of Power
National Electricity Policy	2005	Aims at laying guidelines for accelerated development of the power sector.	Source: Ministry of Power

Rural Electrification Policy	2006	Focuses on providing access to electricity to all rural households.	Source: Ministry of Power
Green Energy Corridor	2013	Promotes the flow of RE energy into the national grid through dedicated transmission corridors	Source: Ministry of New and Renewable Energy
Integrated Power Development Scheme (IPDS)	2014	Strengthens the transmission and distribution networks in urban areas.	Source: Ministry of Power
National Smart Grid Mission (NSGM)	2015	Aims at modernizing the Indian power grid technology to improve efficiency and reliability.	Source: Ministry of Power
Deendayal Upadhyaya Gram Jyoti Yojana (DDUGJY)	2015	Focuses on rural electrification and the improvement of sub-transmission and distribution networks.	Source: Ministry of Power
Ujjwal DISCOM Assurance Yojana (UDAY)	2015	Intended to improve the financial health and operational efficiency of India's power distribution companies.	Source: Ministry of Power
SAUBHAGYA- Pradhan Mantri Sahaj Bijli Har Ghar Yojana	2017	Aims at universal household electrification across the country.	Source: Ministry of Power
Tariff Policy, 2016	2016	Stresses on affordability and sustainability of power supply. It promotes renewable energy sources through various incentives.	Source: Ministry of Power
'Green Energy Open Access' Rules	2022	Facilitates the purchase and consumption of green energy, including faster approval processes.	Source: Ministry of Power
Energy Conservation (Amendment) Act, 2022	2022	Introduces energy efficiency and conservation measures, pushing for a reduction in energy consumption.	Source: Bureau of Energy Efficiency
Revamped Distribution Sector Scheme (RDSS)	2021	Targets improvements in the operational efficiencies and financial sustainability of DISCOMs.	Source: Ministry of Power
National Green Hydrogen Mission	2023	Aims to make India a global hub for the production, utilization, and export of green hydrogen.	Source: Ministry of New and Renewable Energy

4 Program Description

The CIF Renewable Energy Integration (REI) Program is a strategic initiative designed to address the significant challenges and opportunities associated with India's ambitious target of achieving 500 GW of renewable energy capacity by 2030, a substantial increase of capacity additions of 50 GW per annum from the current 15 GW per annum. This massive ramp-up in renewable energy installations will help meet India's demand for electricity as it grows from a relatively small base, but also poses a range of technical and commercial hurdles that must be overcome to ensure the successful RE integration and effective utilization of renewable energy resources.

One of the primary challenges faced in scaling up RE capacity is the lack of grid flexibility and balancing options, particularly concerning energy storage. The intermittent nature of renewable energy generation, such as solar and wind power, requires robust energy storage solutions to manage fluctuations in supply to meet demand effectively. Additionally, high curtailment rates due to inadequate inter and intra-state transmission systems hinder the full utilization of renewable energy potential.

Another critical aspect is the need for accurate forecasting, scheduling, and advanced grid management capabilities to optimize renewable energy integration while maintaining grid reliability and stability. The absence of smart grid infrastructure further complicates this scenario, limiting the ability to dynamically adjust demand and respond to changing energy patterns.

Furthermore, there are challenges related to system security, institutional capacity in managing renewable energy, and the necessity for new regulatory and policy frameworks to activate flexibility from storage and power plants. Additionally, robust power markets are essential to facilitate the large-scale deployment of renewable energy and ensure efficient market mechanisms for renewable electricity. Finally, given the massive resource needs to transform India's grid, the REI program must align with planned activities and investments with other ongoing initiatives in India, while prioritizing strategic actions and proactive investments that will add value by addressing anticipated bottlenecks and overcoming barriers to meet India's 2030-31 goals.

In response to these challenges, the proposed CIF REI Program aims to target three key strategic themes in key RE resource-rich states:

Theme 1: Deployment of Energy Storage and RE enabling technologies: This includes initiatives to enhance grid flexibility through the deployment of advanced energy storage technologies, enabling better integration of renewable energy sources into the grid.

Driven by concerted government policies and regulations and by lower technology costs, India's power sector is already experiencing a paradigm shift towards renewable energy, which now accounts for about 40.9 percent of power generation capacity on the grid. As discussed in section 3.5, grid stability and reliability, grid flexibility and ramp-up challenges are some of the key challenges pertaining to higher share of RE in power generation mix. The challenge with RE sources arises due to their varying nature with time, climate, seasonality, and geographic location. Further, integration of renewable energy into the grid may be constrained in the absence of full power market reforms. In addition, there will be increased demand for certain grid support services or ancillary services. There is a critical need to increase the flexibility of the Indian power system to accommodate a higher share of RE.

Energy storage systems (ESS) are gaining prominence in India's energy landscape, offering crucial support for grid stability and providing flexibility for integration of renewable energy.

Table 4: Grid Service Applications of Energy Storage Technologies

Application	Description	Duration of Service Provision
Arbitrage	Purchasing low-cost off-peak energy and selling it during periods of high prices	Hours
Firm Capacity	Provide reliable capacity to meet peak system demand	4+ hours
Operating Reserves		
• Primary Frequency Response	Very fast response to unpredictable variations in demand and generation	Seconds

• Regulation	Fast response to random, unpredictable variations in demand and generation	15 minutes to 1 hour
• Contingency Spinning	Fast response to a contingency such as a generator failure	30 minutes to 2 hours
• Replacement/ Supplemental	Units brought online to replace spinning units	Hours
• Ramping/Load Following	Follow longer-term (hourly) changes in electricity demand	30 minutes to hours
Transmission and Distribution Replacement and Deferral	Reduce loading on T&D system during peak times	Hours
Black-Start	Units brought online to start system after a system-wide failure (blackout)	Hours

Battery-based ESS (BESS) and pumped hydro storage (PHS) are the most widespread and commercially viable means for implementing energy storage solutions in India. India has notified a long-term trajectory for Energy Storage Obligations (ESO) to ensure that sufficient storage capacity is available with obligated entities. As per the trajectory, the ESO shall gradually increase from 1% in FY 2023-24 to 4% by FY 2029-30, with an annual increase of 0.5%. This obligation shall be treated as fulfilled only when at least 85% of the total energy stored is procured from RE sources on an annual basis. The other key policies driving this emerging sector include a national framework for promoting energy storage systems, Guidelines for Tariff Based Competitive Bidding Process for Procurement of Firm and Dispatchable Power from Grid Connected Renewable Energy Power Projects with Energy Storage Systems, National Programme on Advanced Chemistry Cell (ACC) Battery Storage and Viability Gap Funding (VGF) Scheme. The VGF Scheme envisages development of up to 4,000 MWh of BESS projects by 2030-31, with financial support of up to 40% of the capital cost as budgetary support, while the national goal is to develop 50,000 MWh of storage in that timeframe.. While PSP is backed by Energy Storage Obligation, there are other guidelines such as Guidelines to promote development of Pump Storage Projects, and Guidelines for Formulation of Detailed Project Reports for Pumped Storage Schemes. RPO obligation notifies that Hydro Power Obligation (HPO) can be met with power from Large Hydro Power (LHP) projects including Pump Storage Projects with capacity greater than 25 MW, giving further boost to PSP. Recently, India has introduced demand-driven Firm and Dispatchable Renewable Energy (FDRE) tenders, most advanced iteration of tender models, such as round-the-clock (RTC), Solar + BESS and standalone ESS, whose tariffs are competitive and are on decreasing trend.[51]

As of August 2024, the installed capacity of battery energy storage system (BESS) in India was around 40 MWh[52] while PSP based capacity was 4746 MW[53]. After Solar Energy Corporation of India (SECI) launched a 1000MWh battery storage tender, the energy storage sector is appearing to be advancing rapidly. SECI's tender was followed by 500MWh battery storage tender by National Thermal Power Corporation (NTPC). Around 2.5 GWh of such tenders are already awarded. Request for Proposal (RfP) has been released for 4.5 GWh of such tenders. Further announcements have been made for 29 GWh of storage projects. As per the CEA estimates on-river pumped storage potential is 103 GW in India. PSP projects totaling to 2780 MW are under construction with likely benefits starting around 2030. Multiple private sector players such as Adani Green Energy, Greenko, JSW Energy, Tata Power have already entered the sector and are set to develop multi megawatt scale pumped hydro storage projects.

Short-term, medium-term and long-term projections of the large additions of renewable energy needed to meet India's clean energy and climate goals make it clear that there is a requirement for significant additions of battery storage and pumped hydro storage capacity.

[51] https://ieefa.org/articles/india-shows-urgency-energy-storage-systems-already-awarding-more-8gw-tenders
[52] India: BESS capacity 2030 | Statista
[53] Optimal_mix_report__2029_30_Version_2.0__For_Uploading.pdf (cea.nic.in)

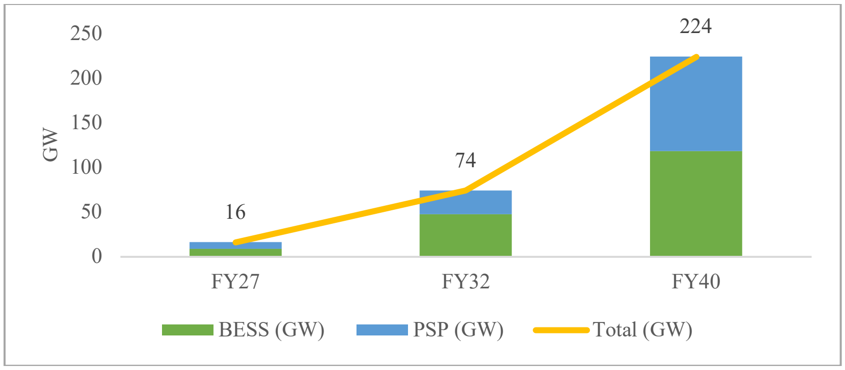

Figure 8: Energy Storage Capacity Requirements (GW) (Source: CEA Optimal Energy Mix Report, IEA India Energy Outlook)

The proposed interventions under CIF REI program for India will seek to address the key challenges, focusing on key RE states. Some of the key bottlenecks with deployment of BESS in India are high upfront capital cost, limited domestic manufacturing, supply chain constraints, concerns about end-user affordability and unavailability of high tariffs for BESS integrated variable renewable energy[54], technological challenges (long duration energy storage solution > 4hrs), grid integration challenges, lack of standardization and skilled workforce shortage. Key challenges in PSP sector are long gestation period, high initial cost, requirement for highly complex, meticulous, and judicious planning and design, geological uncertainties, land acquisition issues and transmission infrastructure[55,56].

Proposed tentative projects include Enabling Round the Clock (RTC) supply through Advanced Grid Management and energy storage at the state level, Wind-Solar Hybrid project with energy storage for C&I customers, concessional financing of BESS projects across India through a financial intermediary, financing greenfield private sector grid tied and/or off grid energy storage projects. The planned interventions are very well aligned with one of the qualifying themes of CIF REI Programme - Scaling up renewable energy enabling technologies.

Need for concessional finance for energy storage projects

The establishment of Battery Energy Storage Systems (BESS) projects in India faces financial hurdles, particularly in the nascent stages where costs are disproportionately high due to low production and adoption volumes. Recognizing this challenge, the Government of India has proposed the implementation of Viability Gap Funding (VGF) to facilitate the initial uptake of BESS technologies among consumers. This strategic move aims to support approximately 4 GWh of BESS projects, which represents only ~8% of the forecasted BESS requirements by the fiscal year 2032, totaling 47.4 GW. The VGF, potentially covering up to 40% of a project's capital costs, mandates that these initiatives be commissioned within a tight timeframe of 18 to 24 months. This approach is critical in reducing the levelized cost of storage (LCoS), thus making BESS a competitive and sustainable option in the energy sector. Furthermore, the high-risk nature of storage projects—characterized by significant upfront costs, uncertain returns, and a scant historical performance record—necessitates innovative financial solutions. The proposed funding under the CIF Renewable Energy Initiative (REI) program is poised to complement these efforts, ensuring that the LCoS remains within affordable thresholds. Such measures are essential for making BESS energy costs competitive with prevailing market rates during peak demand times. Additionally, the development of Pumped Storage Projects, often located in remote areas lacking basic infrastructure, not only addresses energy storage needs but also catalyzes regional development by providing reusable infrastructure for future projects. This includes the establishment of transmission infrastructure up to the pooling point, thereby enhancing the overall utility and feasibility of such endeavors. Together, these financial and infrastructural strategies are crucial for accelerating the adoption of energy storage technologies in India, paving the way for a more resilient and sustainable energy future.

Theme 2: Infrastructure Strengthening: This involves investing in grid strengthening to enhance inter and intra state transmission corridors dedicated for RE facilitate the smooth integration of higher levels of renewables and improve overall grid reliability and resilience. The theme also focusses upon strengthening port infrastructure to facilitate offshore wind technologies.

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[54] (8) Battery Energy Storage Systems (BESS) in India | LinkedIn
[55] TS5-KP.pdf (cbip.org)
[56] TS5-3.pdf (cbip.org)

To ensure the successful integration of large-scale renewable energy (RE) into the national grid, a robust and reliable evacuation infrastructure is paramount. This entails not only pooling power from RE-rich states to high-demand centers but also necessitates a considerable expansion and fortification of both the interstate transmission system (ISTS) and intra-state transmission systems. Given the disparity in gestation periods between wind and solar generation projects and their associated transmission systems, strategic alignment and proactive planning become indispensable. Furthermore, integrating remote islands through undersea cables and enhancing port infrastructure for offshore wind plants are critical components of this infrastructure development. The Central Electricity Authority (CEA) has projected the need for a substantial expansion of the ISTS to accommodate about 537 GW of renewable energy capacity by 2030, highlighting the scale of infrastructure enhancement required.

The envisioned infrastructure development encompasses a comprehensive scope, including the extension of transmission line lengths to 50,890 kilometers and an increase in substation capacity to 433,575 MVA at the ISTS level to support the additional wind and solar capacities by 2030. Moreover, the interregional transfer capacity has witnessed significant growth, recording a Compound Annual Growth Rate (CAGR) of 6.9% from 75,050 MW in 2016-17 to 112,250 MW in 2022-23. Initiatives such as the Green Energy Corridors (GEC) aim to establish an intra-state transmission system dedicated to renewable energy projects across ten states, facilitated by Central Financial Assistance (CFA) for both phases of the GEC. This strategic infrastructure is crucial for eliminating bottlenecks and ensuring the efficient evacuation of power from renewable sources.

The ambitious goals for enhancing and strengthening India's transmission infrastructure to support renewable energy integration call for substantial investment, estimated at ₹84.75 trillion by 2027 by the CEA. This encompasses the development of lines, substations, and reactive compensation systems, with the plan outlining 170 transmission schemes and significant investments for both inter-state and intra-state systems. A notable project includes the proposed under-sea cable to connect the Andaman & Nicobar Islands, aiming to transition from diesel-based power generation to renewable sources. Given the scale of investment required, there is a pronounced need for concessional finance to make these critical projects viable and to pave the way for India's green energy future by reducing financial barriers and facilitating timely project implementation.

Theme 3: Technical Assistance (Cross-cutting): The program will support innovation in renewable energy technologies and promote the development of robust power markets to facilitate the uptake of green electricity, creating a conducive environment for renewable energy investments. The focus will be on implementing smart grid infrastructure, enhancing weather and resource forecasting capabilities, and optimizing grid operations to enhance renewable energy utilization. Additionally, the technical assistance will extend to program management and state-specific project management support, particularly through the project preparation grant, ensuring tailored support for the planning, execution, and integration of renewable energy projects. This will enable the identification and mitigation of state-specific constraints and promote efficient transport of renewable energy across state borders.
India’s CIF REI Program aims to catalyze the transformation of India's energy landscape by addressing barriers and targeting actions and investments in the above three key areas.

India’s CIF REI Program aims to catalyze the transformation of the country’s energy landscape by addressing barriers and targeting strategic investments in these three key areas. By prioritizing finite resources and providing project financing and technical assistance, the Program will support India’s efforts to achieve ambitious renewable energy targets sustainably and efficiently.

The proposed projects under the REI program and the details are enlisted in the section below:

4.1 Power System Strengthening Project

4.1.1 Background

Uttar Pradesh (UP), India's most populous state with nearly 220 million residents, faces significant challenges in its power sector. Despite being the fourth largest state in terms of installed power generation capacity, UP's per capita electricity consumption in FY 2018 was only around 400 kilowatt-hours (kWh), less than half of the national average of 960 kWh. The state also grapples with a high poverty rate of 29%, which is above the national average of 21%, reflecting a lack of economic opportunities and limited access to reliable electricity.

The rural electricity supply in Uttar Pradesh is characterized by frequent power interruptions and an overloaded and aging distribution network. From 2011 to 2019, the Government of India's Deen Dayal Upadhyaya Gram Jyoti Yojana (DDUGJY) scheme allocated approximately $25 billion in grants and loans to improve the rural medium-voltage distribution network (33 kV and 11 kV), focusing on feeder separation between residential and agricultural consumers. However, despite these efforts, the need for further strengthening and modernization of the grid remains.
ADB's ongoing Multitranche Financing Facility (MFF) is already supporting the Uttar Pradesh Distribution Project, which is a multi-tranche financing facility. Under Tranche-1, the program focused on improving the rural electric distribution network, separating the electricity distribution network for agriculture from residential consumers, and enhancing bill collection efficiency. Tranche-2, amounting to $200 million, aims to deploy Battery Energy Storage Systems (BESS), innovative grid management solutions, and smart grids to improve system resilience, among other initiatives. This tranche is well aligned with the objectives of the Climate Investment Funds (CIF) Renewable Energy Integration (REI) program, and offers an opportunity to leverage catalytic concessional funding under the CIF REI to attract additional investments for integrating large-scale RE. **This component will be flexible and can be adapted for other states as well, providing a scalable model for RE integration across the country**.

Currently, the RE capacity in UP stands at 5.5 GW, contributing to only 3.2% of the state's electricity share, in contrast with leading states such as Gujarat with (31%) and Tamil Nadu with (30%) etc. Moreover, U.P. aims to achieve an ambitious target of 47 GW of RE capacity by 2030. Additionally, UP is also targeting the production of 1 million tons per annum (MTPA) of green hydrogen, which will require an estimated additional 25 GW of renewable energy. This will require not only RE capacity additions but also the strengthening of electricity distribution and systems in parallel. In this context, BESS investment and deployment will play a crucial role in facilitating the smooth transition and integration of large-scale RE in the future. With the increasing share of RE in the power mix, integrating variable RE sources such as solar and wind has become crucial for UP's energy security and economic growth. In this context, distribution strengthening and deploying BESS systems can play a transformative role in enhancing grid stability, ensuring reliable power supply, and supporting the integration of renewables.

4.1.2 Need for Distribution Strengthening and Deployment of BESS

BESS play a critical role in enhancing grid stability and reliability by storing excess energy during low demand and supplying it during peak periods, thus reducing the need for load shedding and improving power quality. BESS also supports seamless integration of variable RE by mitigating the issues of intermittency and variability, enabling the grid to accommodate higher shares of RE and promoting a cleaner energy mix.

Grid strengthening complements BESS by reinforcing the infrastructure needed to handle increased RE capacity and ensuring efficient power delivery across the network. Together, BESS and grid upgrades reduce congestion, improve voltage control, and defer costly infrastructure investments, making the power system more resilient, reliable, and capable of supporting future energy demands.

4.1.3 Need for Concessional Financing for Distribution Strengthening and BESS deployment:

Despite the decreasing trend in energy storage tariffs in India, several challenges remain that will require concessional financing in states like Uttar Pradesh:

- **High Initial Capital Costs**: While the cost of lithium-ion battery storage has decreased by over 80% in the last decade, BESS still requires significant upfront investment, making it less accessible for utilities and smaller developers.

- **Alternative Chemistries for Stationary Storage**: There is a need to explore and deploy alternative chemistries such as flow batteries, sodium-ion, and other non-lithium-based storage solutions that are more suited for stationary applications. These technologies are still in the early stages of commercial deployment and require concessional financing to achieve scale and cost reductions.
- **Longer Payback Periods:** Unlike other RE technologies, BESS has longer payback periods, often extending beyond 10 years. This makes it less attractive for private investors who typically seek shorter return periods.
- **Grid Support and Ancillary Services**: BESS can provide essential grid services such as frequency regulation and peak load shaving. However, monetizing these services in India is still evolving, and the absence of established markets for ancillary services means that the financial viability of BESS projects is uncertain without concessional financing.
- **Promotion of Energy Access and Equity:** The deployment of BESS and grid strengthening will significantly improve clean energy access in rural communities, enhancing the reliability and quality of electricity supply. This will have a direct impact on key aspects of rural life, particularly for women. Reliable power will support better healthcare services, boost educational opportunities by enabling uninterrupted learning environments, and promote entrepreneurship by providing the energy needed for small businesses to thrive. Concessional financing is crucial to make these investments viable, ensuring that rural and underserved communities, especially women, benefit from improved energy access and new economic opportunities. This will foster more equitable development and empower communities to achieve better health, education, and economic outcomes.
- **Environmental and Social Benefits**: BESS can significantly contribute to reducing greenhouse gas (GHG) emissions by enabling higher integration of RE and reducing reliance on diesel generators for backup power. Concessional financing can help internalize these external benefits into project economics, making BESS more financially viable.

4.1.4 About the Proposed Project

With a total project cost estimated at $ 425 million, of which $25 million will be sourced from CIF, with $23 million provided as concessional financing and $2 million allocated as a project preparation grant. The CIF financing will be blended with $200 million from the ADB, aimed at supporting the development of distribution infrastructure and deployment of BESS for distribution utility, while an additional $200 million will be mobilized from the private sector (may include equity/debt) to facilitate renewable energy capacity additions to support BESS integration at distribution level.

Financing Source	**CIF**				**Others**		**Total**
Program	**CIF Financing**	**CIF Guarantee**	**Project Preparation (Grant)**	**Total CIF**	**ADB**	**Private Sector**	
(US$ Million)							
Power System Strengthening Project	23	0	2[57]	25	200	200	425

Technical Assistance: In addition to the infrastructure investments, the project includes a $2 million grant allocated for technical assistance. This grant will cover capacity building and training programs aimed at enabling the creation of green jobs, with a focus on increasing employment opportunities for women in the energy sector. These programs will help build the necessary skills and expertise for effective implementation and management of the BESS and grid strengthening initiatives, contributing to the long-term sustainability and impact of the project.

Project Components:

- Deployment of BESS: Installation of BESS with a total capacity of 370 MWh (supporting ~500 MW of RE Generation Capacity) across multiple locations, prioritizing areas with high RE potential and load centers.

[57] for capacity building, project management, and regulatory support

- Grid Integration and Upgrades: Strengthening distribution infrastructure to enable smooth integration of BESS and enhance the ability of the grid to handle higher shares of RE
- Technical Assistance and Capacity Building: Support for policy and regulatory framework development, capacity building for local utilities and regulatory bodies, and technical studies for future BESS deployments.

4.1.5 Outcomes of the Project

The proposed project is expected to deliver the following outcomes:

- Enhanced Renewable Energy Integration: ~1000 MUs of renewable energy generation per annum integrated into the grid.
- Increased BESS Capacity: 370 MWh of BESS capacity installed, improving grid stability and flexibility. Reduction in CO_2 Emissions: ~1 million tons of CO_2 emissions abated annually through improved integration and reduced reliance on fossil fuels.
- Creation of Green Jobs: Generation of ~4000 number of FTE green jobs in construction, operation, and maintenance of Renewable Energy Capacity and BESS
- Improved Power Supply Reliability: Reduction in power interruptions and voltage fluctuations, benefiting residential, commercial, and agricultural consumers.

4.2 Integrated Renewable Energy Solutions Providing Round-the-Clock (RTC) Supply for Commercial and Industrial (C&I) Consumers

4.2.1 Background

India's commercial and industrial (C&I) sectors account for a significant portion of the country's overall energy consumption. These sectors, traditionally reliant on fossil fuels, are crucial to India's economic growth but also contribute significantly to its carbon emissions. To meet its ambitious climate commitments, India needs to accelerate the adoption of renewable energy solutions within the C&I sector. The Integrated Renewable Energy Solutions RTC Program is designed to scale up renewable energy for C&I entities, integrating power generation with energy storage technologies to provide reliable, round-the-clock (RTC) renewable electricity.

4.2.2 Need for RTC for C&I

India's C&I sectors, including manufacturing, textiles, and commercial real estate, require consistent and reliable power to maintain operations. While renewable energy is a viable option, the intermittent nature of sources like solar and wind can pose challenges for sectors requiring 24/7 power availability. Integrating renewable energy with Battery Energy Storage Systems (BESS) enables continuous and dependable energy supply, ensuring that businesses can transition to clean energy without compromising operational reliability. The shift to RTC renewable energy not only helps reduce carbon footprints but also stabilizes energy costs, enhancing competitiveness for businesses while aligning with national and global climate goals.

4.2.3 Need for Concessional Financing

The transition to integrated renewable energy solutions, including the deployment of BESS, involves significant upfront costs, which can be prohibitive for many C&I players. Concessional financing is essential to making these technologies more accessible and attractive. Through concessional funds, private sector companies can mitigate financial risks, invest in advanced storage solutions, and pursue more ambitious decarbonization strategies. The CIF's Renewable Energy Integration (REI) program offers critical financial support by reducing the capital burden and enabling businesses to accelerate their transition to clean energy. Concessional funding will also foster the development of innovative business models and technology solutions that help overcome existing barriers to clean energy adoption.

4.2.4 About the Proposed Project

The proposed project will support the deployment of 200 MW of renewable energy integrated with Battery Energy Storage Systems (BESS) to provide round-the-clock (RTC) energy for India's C&I sectors. The total project cost is estimated at $220 million. Of this, $10 million from the CIF and $100 million from IFC will be blended together to provide debt financing to private developers. The remaining $110 million will be contributed by the developers in the form of equity and debt, sourced from other private commercial lending institutions. The project aims to address the power reliability needs of C&I consumers by providing a stable supply of renewable energy with storage solutions that guarantee 24/7 access.

Financing Source	**CIF**				**Others**		**Total**
Program	**CIF Financing**	**CIF Guarantee**	**Project Preparation (Grant)**	**Total CIF**	**ADB (PSOD)**	**Private Sector**	
(US$ Million)							
Power System Strengthening Project	10	0	0	10	100	100	210

4.2.5 Outcomes of the Project

The successful implementation of this project will contribute to India's clean energy goals by:

- Deploying 200 MW of RE generation capacity integrated with 450 MWh of BESS for C&I sectors.
- Enhanced Renewable Energy Integration: ~380 MUs of renewable energy generation per annum integrated into the grid
- Creation of Green Jobs: Generation of ~3400 number of FTE green jobs in construction, operation, and maintenance of Renewable Energy Capacity and BESS
- Reduction in CO_2 Emissions: ~0.3 million tons of CO_2 emissions abated annually through improved integration and reduced reliance on fossil fuels
- Enabling sustainable power supply through the integration of BESS, enhancing grid reliability and reducing dependence on fossil fuels.
- Supporting India's climate commitments, with significant reductions in carbon emissions across key industrial sectors.
- Enhancing the competitiveness of the C&I sector by stabilizing energy costs and promoting energy independence.
- Creating new green jobs, particularly in energy storage and renewable energy management, while fostering technological innovation in energy solutions for C&I consumers.

This project will serve as a model for scaling integrated renewable energy solutions in other regions and sectors, reinforcing India's leadership in renewable energy adoption and its commitment to a sustainable future.

4.3 Supporting Grid Strengthening in One or More Renewable Energy (RE) Rich States

4.3.1 Background

As India accelerates its renewable energy (RE) transition, the capacity of the transmission infrastructure to support the growing RE generation becomes increasingly crucial. The Central Electricity Authority (CEA) has identified the need for robust inter-state and intra-state transmission evacuation facilities to meet the national target of 500 GW of renewable energy capacity by 2030. Achieving this goal requires expanding the current inter-regional transmission capacity from 112 GW to 150 GW and adding 1,23,577 circuit kilometers (ckm) of transmission lines and 7,10,910 MVA of transformation capacity in substations at 220 kV and above.

This expansion is critical to synchronize transmission planning with the addition of RE capacity, ensuring efficient energy distribution and preventing bottlenecks in the RE supply chain. The Bank is currently in discussions with several states, including Andhra Pradesh, Gujarat, and Madhya Pradesh, to provide financial support for strengthening their transmission and distribution networks, which are key to absorbing more RE into the grid. The proposed financing will also help these states make their networks climate-resilient, integrate innovative technologies such as floating solar and battery energy storage systems (BESS), and promote energy efficiency and inclusivity, especially in empowering women through targeted job creation and skills training in the renewable energy sector. The proposed financing from the Climate Investment Funds (CIF) will be focused on activities in two of these three states.

4.3.2 Need for Intra-State Distribution and Transmission Strengthening and RE Integration

With the rapid expansion of renewable energy in India, strengthening intra-state transmission infrastructure is essential for effective RE integration. As more renewable energy projects are developed, there is an urgent need to ensure that energy can be evacuated efficiently to demand centers. The proposed project will focus on constructing new intra-state transmission lines and substations to support RE evacuation and grid strengthening activities. In addition to improving grid reliability, the integration of BESS will enhance the ability of the transmission system to handle intermittent renewable sources, allowing for round-the-clock RE supply. This infrastructure upgrade is crucial to India's clean energy transition and will help states achieve their renewable energy targets.

4.3.3 Need for Concessional Financing

The financial requirements for grid strengthening, constructing new transmission infrastructure, and deploying innovative technologies for RE integration are substantial. Concessional finance is critical to overcoming these barriers for several reasons:

- **High Initial Costs**: Developing new transmission lines, substations, and BESS infrastructure involves significant upfront costs. Concessional finance, by providing below-market-rate funding, reduces the financial burden, making these large-scale projects more feasible.
- **Risk Mitigation:** Investments in RE transmission infrastructure and new technologies, such as energy storage systems, carry perceived risks. Concessional finance plays a vital role in mitigating these risks by offering favorable financing terms that reflect the long-term social and environmental benefits of these investments.
- **Leveraging Additional Investment**: Concessional finance can act as a catalyst for attracting private sector investment. By providing early-stage funding, concessional finance encourages private sector confidence in the project, leading to additional investments from commercial lenders and financial institutions. Furthermore, the inclusion of gender-responsive measures in the project, such as specific targets for women in leadership and technical roles, will make the project more inclusive and equitable.

4.3.4 About the Proposed Project

The proposed project will support grid strengthening and transmission capacity expansion in two RE-rich states, facilitating the evacuation of renewable energy and ensuring that the grid is climate-resilient and capable of integrating advanced technologies. The project will focus on the development of 400 kV double-circuit (DC) intra-state transmission infrastructure with the following key features:

- Voltage: 400 kV
- Conductor Type: Moose/Quad Moose (high-capacity conductors)
- Capacity: Capable of transmitting approximately 1,000–1,500 MW
- Right-of-Way Requirement: 46 meters for double circuit lines
- Tower Height: 50-60 meters

4.3.5 Outcomes of the Project

The successful implementation of this project is expected to yield significant outcomes, contributing to India's renewable energy and climate goals:

- Enhanced Transmission Capacity: By expanding the transmission infrastructure by adding ~580 ckm of 400 KV DC double circuit line, the project will increase renewable energy evacuation capacity by 1.5 GW, which is critical to meeting the rising demand for clean energy and achieving national RE targets.
- Support in deploying 350 MWh of BESS capacity
- Enhanced Renewable Energy Integration: ~255 MUs of renewable energy will be integrated with BESS
- Creation of Green Jobs: Generation of ~3400 number of FTE green jobs in construction, operation, and maintenance of Renewable Energy Capacity and BESS
- Reduction in CO_2 Emissions: ~0.3 million tons of CO_2 emissions abated annually through improved integration and reduced reliance on fossil fuels

- Improved Renewable Energy Integration: Strengthening the transmission and distribution networks and deploying advanced technologies, such as BESS, will improve the integration of renewable energy into the grid, making the energy system more efficient and sustainable.
- Gender Empowerment: By creating new green jobs and offering capacity-building programs for women, the project will contribute to gender equality in the renewable energy sector. The inclusion of gender-responsive measures will ensure that women are actively involved in the technical and leadership aspects of the project, driving sustainable development for all.

The Supporting Grid Strengthening in RE Rich States project is a pivotal step in ensuring the sustainability and efficiency of India's energy system as the country moves towards its ambitious renewable energy targets. By leveraging concessional finance, this project will attract additional investments, deploy innovative technologies, and build a more resilient and capable energy transmission network. The project's focus on gender inclusivity and empowerment ensures that the benefits of this transformation are shared equitably.

4.4 Offshore Wind Development Programme

4.4.1 Background

India's coastline harbors significant potential for offshore wind energy, with an estimated capacity of 70 GW spread across 16 offshore zones in Tamil Nadu and Gujarat. Recognizing this potential, the Indian government has been proactive in creating a favorable policy environment to harness this resource. In December 2023, the Ministry of External Affairs issued the Offshore Wind Energy Lease Rules, providing a three-year window for conducting resource assessments and surveys. These efforts are part of a broader vision to achieve 37 GW of offshore wind capacity by 2030. The Ministry of New and Renewable Energy (MNRE) further supported this ambition by announcing plans in August 2023 for the installation of 7 GW of offshore wind capacity, followed by a tender for 4 GW in February 2021, and a 500 MW offshore development tender in Gujarat in September 2024. A critical aspect of realizing this potential is the development of adequate port infrastructure, including evacuation facilities, to effectively pool offshore wind energy.

4.4.2 Need for Concessional Financing

The deployment of offshore wind energy in India faces significant financial and logistical challenges. High capital expenditures lead to a higher levelized cost of electricity (LCOE), placing offshore wind at a competitive disadvantage compared to other energy sources. Additionally, the absence of specialized offshore wind vessels and ports capable of supporting the installation, operations, and maintenance of offshore wind projects presents a substantial hurdle. Concessional finance is crucial to overcoming these barriers, facilitating the development of necessary port and grid infrastructure. Moreover, it can reduce project risks, promote investor confidence, and unlock additional private sector investment.

4.4.3 About the Proposed Project

The Offshore Wind Development Program aims to address the infrastructural challenges associated with offshore wind energy development through a comprehensive approach that includes:

- **Concessional Financing and Technical Assistance**: Provision of concessional financing and technical support for the development of grid infrastructure for power evacuation and port infrastructure in Tamil Nadu and Gujarat. These components are essential for handling the offshore wind energy efficiently.
- **Development of Guarantee / Risk Sharing Facility**: Establishment of a guarantee or risk-sharing facility, along with lines of credit, to mitigate risks for offshore wind developers. This initiative aims to reduce the overall project cost by alleviating the financial burden associated with high capital expenditure (CAPEX) projects.

4.4.4 Outcomes of the Project

The successful implementation of the Offshore Wind Development Program is expected to yield significant benefits, including:

- Enhanced Infrastructure for Offshore Wind Evacuation: The development of dedicated grid infrastructure will ensure the efficient evacuation of power from offshore wind farms, significantly improving the integration of offshore wind into the national grid.
- Optimized Port Infrastructure: By upgrading and optimizing port infrastructure and preparing for the anticipated uptake of offshore wind energy, the program will facilitate the installation, operations, and maintenance of offshore wind projects.
- Public-Private Partnership Models: The program will foster public-private partnerships, leveraging successful models for the development of offshore wind energy. These partnerships will help pool resources, share risks, and maximize the sector's growth potential.

By addressing the infrastructural and financial challenges associated with offshore wind energy development, this program aims to position India as a global leader in the offshore wind sector, contributing significantly to the country's renewable energy targets and sustainable development goals.

The total project cost is estimated for **proposed two projects by The World Bank** is $425 million, with $25 million coming from CIF. Of this, $33 million will be provided as concessional financing, while $2 million will be used as a project preparation grant to support detailed studies, gender-responsive project design, and capacity-building activities. The CIF financing will be blended with $200 million from World Bank, which will provide concessional debt financing for grid strengthening activities and the development of port and evacuation infrastructure for offshore wind facilities. The remaining $200 million will be pooled from private sector equity and debt from other commercial lending institutions. The project aims to enhance the transmission network by approximately 1200 ckm, with each corridor supporting 1.5 GW of RE capacity, totaling 4.5 GW and further, this comprehensive project will support the evacuation of more than 10 GW of offshore wind capacity, enhancing India's renewable energy potential.

Financing Source	**CIF**				**Others**		**Total**
Program	**CIF Financing**	**CIF Guarantee**	**Project Preparation (Grant) and TA**	**Total CIF**	**World Bank**	**Private Sector**	
(US$ Million)							
Supporting Grid Strengthening in One or More Renewable Energy (RE) Rich States and Offshore Wind Development Programme	23	0	2	25	200	200	425

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4.5 Stand-alone Battery Energy Storage Systems (BESS)

4.5.1 Background

India's energy transition plan aims to achieve over 2,000 GW of solar and 1,000 GW of wind capacity by 2070. This ambitious target necessitates substantial energy storage solutions to manage the high penetration of intermittent renewable energy in the grid. By 2026-27, it is estimated that India will require a grid-tied energy storage capacity of 16.13 GW/82.37 GWh, including 8.68 GW/34.72 GWh from Battery Energy Storage Systems (BESS). The optimal generation mix by 2030 would need ~34 GW of grid-connected battery storage producing 136 GWh. Energy storage could reach 23% of the power capacity by 2050, driven by BESS. Given the government’s budgetary constraints and the need to address a multitude of other priorities, the ability to reach the ambitious BESS capacity targets largely depends on finding an efficient solution to mobilizing private sector capital at scale.

4.5.2 Need for Concessional Financing

The transition to integrated renewable energy solutions, including the deployment of BESS, involves significant upfront costs, which largely remains prohibitive for private sector companies. Concessional financing is essential to making these technologies more accessible and attractive, and allow the pipeline of private sector projects to proceed, setting up a track record and incentivizing follow up financing. Through concessional funds, private sector companies can mitigate financial risks, invest in advanced storage solutions, and pursue more ambitious decarbonization strategies, while keeping electricity prices affordable. The concessional financing will address constraints associated with high capital cost of the pioneering utility-scale BESS technology and re-balance risk return for the Sponsor. It will help demonstrate benefits of large-scale BESS to address short-term local transmission congestion, and intermittency of variable renewable energy, facilitating its penetration.

4.5.3 About the Proposed Project

The project aims to finance greenfield private sector BESS in India utilizing US$ 10 million CIF financing (in a form of a concessional loan & a Viability Gap Financing grant), particularly focusing on developing a project that will deliver 180MW/360MWh of BESS capacity. By facilitating the deployment of BESS, the project will enhance the integration security of renewable energy into the grid, thereby supporting India's transition to a sustainable energy future. The concessional finance will help address participation constraints associated with the high costs of implementing pioneering utility-scale BESS capacity and demonstrate the commercial viability of a utility-scale BESS at affordable prices. This initiative will also promote climate finance by reducing GHG emissions.

The total project cost is estimated at US$ 75 million (numbers are tentative). Of this, US$ 10 million from the CIF and US$ 45 million from IFC will be blended to provide a debt package of US$ 55 million. The remaining US $20 million will be contributed as equity by the private developer.

Financing Source	**CIF**				**Others**		**Total**
Program	**CIF Financing**	**CIF Guarantee**	**Project Preparation (Grant)**	**Total CIF**	**IFC**	**Equity**	
(US$ Million)							
Stand-alone BESS	9	0	1	10	45	20	75

4.5.4 Outcomes of the Project

The successful implementation of this project will contribute to India's clean energy goals by:

- Installed Capacity: 180MW/360 MWh (2 Cycles)
- GHG Avoidance: 186,000 tons CO2/year (Preliminary estimates related to associated RE capacity)
- Leverage Ratio: Each dollar of CIF investment leverages 6.5x through private finance, including IFC's own money.

This project will serve as a model to increase competitiveness and resilience of the power sector. BESS technology is a central component of India's decarbonization strategy. The project will introduce one of the few initial privately financed utility scale BESS and demonstrate the commercial viability of operating a large-scale BESS. The project will demonstrate benefits of large-scale BESS to address short-term local transmission congestion, and address intermittency of renewable energy, facilitating its penetration.

4.6 Technical Assistance

Technical assistance is as a pivotal element under the CIF Renewable Energy Integration (REI) program, addressing a spectrum of needs critical for enhancing the uptake of renewable energy (RE) across various stakeholder domains. This intervention is designed to navigate the complexities of integrating a substantial RE capacity, aiming for a 500 GW target, into the national grid, especially in a context where some states are on the brink of having RE constitute more than 40% of their energy mix. Such a transformation demands not only innovative project implementation strategies but also robust forecasting, regulatory support, and the development of new market mechanisms.

A. Advanced Forecasting Tools

The cornerstone of this technical assistance is the development and deployment of advanced forecasting tools. Accurate RE forecasting is indispensable for mitigating curtailment issues and avoiding deviation settlement mechanism (DSM) penalties. It also plays a crucial role in ensuring system reliability and facilitating efficient planning across the value chain. With states poised to achieve a significant share of their energy mix from RE, the challenge of predicting the variable output of renewable energy sources becomes pronounced. Advanced forecasting tools, supported by institutional strengthening, will provide Distribution Companies (DISCOMs) and Regional Energy Management Centers (REMCs) with the capabilities needed to effectively integrate RE into their operations. This includes implementing successful third-party forecasting models as well.

B. Capacity Building to Enhance RE Integration

Skilled personnel are the cornerstone of successfully integrating renewable energy into the grid across various dimensions. The REI Program places a strong emphasis on building institutional capacity, ensuring that all stakeholders are adequately equipped and supported to adapt to new technologies and methodologies seamlessly. Efforts to enhance capacity under this program will involve a broad spectrum of critical participants, including Distribution Companies (DISCOMs), Renewable Energy Management Centers (REMCs), transmission companies, and key players in the energy storage sector, among others. Moreover, the program aims to foster and encourage the involvement of the female workforce by implementing capacity-building initiatives specifically designed for women, underscoring the commitment to gender equality within the renewable energy sector.

C. Innovative Methods for Uptake of Renewable Energy

Moreover, the CIF REI program emphasizes supporting innovative methods to boost the adoption of renewable energy. This involves exploring and implementing Contract for Differences (CFD) contracts and virtual Power Purchase Agreements (PPAs), which offer more flexible and financially viable options for both producers and consumers of RE. Such mechanisms can significantly lower the entry barrier for new participants in the renewable energy market, making it more accessible and appealing.

Another area is the utilization of blockchain technology for peer-to-peer (P2P) trading, which revolutionizes the way solar rooftop systems are monetized and managed. By enabling direct energy transactions between producers and consumers, blockchain minimizes the reliance on traditional grid infrastructures and empowers homeowners and businesses to become active participants in the energy market.

In addition, the program is keen on fostering innovative models for renewable energy-based electric vehicle (EV) charging infrastructure. This not only supports the adoption of EVs but also integrates them into the renewable energy ecosystem, creating a synergistic relationship where EVs can act as mobile energy storage units that contribute to grid stability and energy storage solutions.

Through these multifaceted technical assistance interventions, the CIF REI program will set the stage for a transformative shift in the renewable energy sector. By addressing forecasting challenges, encouraging market innovations, and supporting the institutional and capacity building of stakeholders, the program aims to create a robust framework for the successful and sustainable integration of renewable energy into the national grid, paving the way for a cleaner, more resilient energy future.

5 Financing Plan and Instruments

1. The affordability of energy is an important consideration in the political economy of facilitating and catalyzing India's clean energy transition in a sustainable manner and consistent with the country's development goals and energy security objectives. Although the costs of renewable energy generation have been declining, there is still a premium to be paid for RE-based firm and dispatchable energy to be competitive against traditional fossil fuel-based generation. A price differential remains in terms of the cost of generation and the resulting tariff, depending on availability of the solar and wind resources in target regions, available transmission capacity, and on the cost-effectiveness and availability of storage technologies in order to attract investment in new dispatchable generation capacity.

2. CIF financing will help to overcome first-mover costs, build confidence among local stakeholders and communities, and accelerate the participation of private developers as well as commercial lenders along the process of finding solutions to integrating RE. The concessional terms of CIF financing are particularly important, given the current global inflationary and high interest financial context, including global caution regarding supply chain discontinuities, e.g., for battery storage.

3. The estimated total resource requirement to finance India's REI Investment Plan is USD 1135 Million. CIF concessional financing is expected to catalyze more than 10 times in overall investment from MDBs, development partners, and contributions from national and local governments and SOEs. It is anticipated that the CIF will finance a total of USD 70 million, which includes a grant of USD 4 Million for technical assistance, while the remaining USD 1100 Million will be funded by the ADB, World Bank and the IFC, including funding mobilized through development partners and the private sector. India's REI IP includes a schedule of proposed interventions under each of the three main avenues identified, with the estimated cost of each proposed intervention provided. Table 1 highlights a summary of the estimated budget. The costs, financing instruments and funding sources of India's REI IP and of each IP component are based on the best estimation as possible by the GoI and the MDBs as identified at the time of the development of this programmatic IP. These numbers, including those estimated from private sector mobilization, are subject to change over the course of project preparation.

4. India's Ministry of Finance (MoF) will be the Borrower and the REI program will be implemented through the MNRE, the relevant lead agency. CIF concessionality will be channelled through the ADB, the World Bank, and the IFC as a blend of MDB public sector and private sector financing. The CIF financing instruments deployed will include both concessional loans, and grants (both TA and investment grants). In addition, ADB POSD and the IFC may also consider using CIF resources as equity and mezzanine financing. The public sector blended funds will be received by the MNRE, through the Government of India (DEA in the Ministry of Finance) and will be disbursed to the relevant implementing agencies. CIF grants will be focused largely on support for technical assistance, small pilots, and enabling activities across various proposed projects and, in particular, for community, youth and gender-sensitive activities in the selected states. CIF Grants and any risk financing will also provide the necessary flexibility to address both non-revenue generating technical assistance and to mitigate technology, performance, or other variable risks. Funding from other development partners and the philanthropic community will be explored during the investment project development stage. The precise structure of the financing shall be agreed upon during the GoI discussions with ADB, WB, IFC and other Development Partners as relevant. The costs, financing instruments and funding sources of India's REI IP and of each IP component are based on the best estimation as possible by the GoI and the MDBs as identified at the time of the development of this programmatic IP. These amounts, including those estimated from private sector mobilization, are subject to change over the course of project preparation. Table 1 specifies the CIF financial instruments envisaged for each activity.

6 Additional development activities

USAID: USAID's power sector programs in India, notably SAGE (South Asia Group for Energy) and SAREP (South Asia Regional Energy Partnership), have been instrumental in promoting sustainable energy solutions and enhancing regional energy cooperation. While specific funding amounts and dates for these programs vary, they collectively aim to foster energy security, integrate RE, and facilitate cross-border energy trade. SAGE and SAREP have supported policy reforms, capacity building, and infrastructure development for smart grids, leading to significant outcomes such as increased RE adoption and improved operational efficiencies of utilities. These efforts are part of USAID's broader commitment to sustainable development in South Asia's energy sector, contributing to enhanced economic growth and regional connectivity.

UK's FCDO: The flagship Accelerating Smart Power and Renewable Energy Programme (ASPIRE) by FCDO contributes towards India's low carbon energy transition through supporting the Ministry of Power and the Ministry of New and RE to standardise policy and regulatory frameworks; to develop new, sustainable business models to encourage more investment; to introduce new and innovative technologies; and to build the capability of key stakeholders in the energy sector. Few other key programmes by FCDO include- 'Supporting Structural Reform in the Indian Power Sector' programme aiming at providing world class expertise to support the market reforms and scale up of RE supply, 'The Green Growth Equity Fund Technical Cooperation Facility (GGEF TCF)' focusing on catalysing private investments into Indian green growth projects.

Germany's GiZ and KfW: The GiZ and KfW has been actively involved in supporting RE initiatives in India through various programmes. The Integration of Renewable Energies into the Indian Electricity System (I-RE) project, focuses on integrating a high share of RE, particularly rooftop solar power, into India's electricity mix. It aids the Ministry of New and Renewable Energy (MNRE) in developing integration models, supports cities in creating renewable energy roadmaps, and assists Discoms in transitioning to a low-emission energy supply. The Indo-German Energy Programme (IGEN), encompasses energy efficiency in industries, development of the Energy Conservation Building Code (ECBC) for residential buildings, grid integration of renewables, and photovoltaic roof systems. Additionally, the IGEN-Green Energy Corridors (IGEN-GEC) project, focuses on enhancing the balancing capability for RE integration, developing solar generation forecasting models, designing Renewable Energy Management Centres (REMCs), and fostering international dialogue on RE integration.

ADB: ADB's portfolio of approved sovereign loans under implementation for India's energy sector totals USD 2.7 billion, and its pipeline for 2023-2025 includes nearly 4 billion in investments. ADB has supported investments in power transmission undertaken by central agencies such as Power Grid Corporation of India Limited for interstate transmission and has supported intrastate transmission and distribution network investments in Assam, Bihar, Himachal Pradesh, Madhya Pradesh, and Rajasthan. ADB is presently supporting transmission and distribution network strengthening and augmentation in Maharashtra, Chennai-Kanyakumari Industrial Corridor, Meghalaya, Uttar Pradesh, and the underground cabling network in Bengaluru. Apart from this, ADB is supporting various emerging technologies such as CCUS, green hydrogen, electric vehicles, energy storage, biofuels etc.

World Bank: The World Bank has an extensive energy program in India combining policy, technical assistance and financing consisting of a USD 3 billion portfolio and a USD 5 billion project pipeline. The WB engagement is divided into five broad pillars of support:

a. Scaling up renewables (including grid connected solar and decentralized solar, off-shore wind, and RE hybrids of hydro/solar/wind) and integration of renewables in the grid including battery storage and pump storage,
b. Commercialization of the distribution sector to improve power sector financial viability, reduce off-taker risks for RE, and increase supply side efficiency. The engagement covers more than half the states of the country, including Jharkhand, West Bengal, Andhra Pradesh
c. Improving demand side efficiency through engagement in improving energy efficiency at household level and providing a risk sharing facility to ESCOs
d. Reducing the carbon footprint of the industrial and transport sectors; through engagements in electric vehicle, compressed bio-gas and green hydrogen among others

IFC: IFC was one of the earliest international financiers of wind and solar projects in India. IFC is one of the key investors in Azure Power, a leading player in the grid-connected solar-power sector and Sembcorp Green Infra Limited, which established over 200 MW of solar and wind plants in four Indian states. On the advisory side, IFC's Lighting Asia/India program promotes safe, affordable, and modern off-grid lighting for three million people in rural India. IFC helped the Government of Gujarat structure a first-of-its-kind pilot grid-connected solar rooftop power project as a public-private partnership. Recently, IFC partnered with the Madhya Pradesh government to set up the 750-MW Rewa ultra-mega solar-power project.

Swiss Agency for Development and Cooperation (SDC): SDC's Clean Air Project (CAP India) Switzerland responds to a demand for support raised in India's new National Clean Air Programme. SDC supports energy efficiency measures as well as the Integration of Renewable Energy in buildings through the long-standing Building Energy Efficiency Project (BEEP). The Green Electric Mobility (GEM) project supports eight cities by contributing to a GIZ initiative to support India's efforts to move towards sustainable e-mobility. Other projects such as CapaCITIES support building capacity for climate action plans and responsive urban planning in two states and eight cities in waste management transport, water, and climate finance; disaster risk management in up to twelve Himalayan states, insurance for farmers, solar irrigation, clean air, and on testing and promoting technology solutions for the decarbonization of the cement industry. In addition, Yamuna International Airport Private Limited (YIAPL), a 100% subsidiary of Zurich Airport International AG, in close partnership with Government of Uttar Pradesh and Government of India, is building the new, carbon neutral Noida International Airport in the New Delhi National Capital Region (NCR), demonstrating the contribution that Swiss cleantech companies are making to support Indian infrastructure become more sustainable.

India-EU Clean Energy and Climate Partnership (EU-CECP) aims to reinforce cooperation on clean energy and implementation of the Paris Agreement by strengthening joint activities for deployment of climate friendly energy sources, including solar and wind energy.

Japan International Cooperation Agency (JICA) has funded multiple projects in India to foster growth of RE sector. For example- construction of Turga pumped storage, transmission system strengthening in Madhya Pradesh and Odisha.

International Solar Alliance (ISA) under its various solarization programmes such as Solar Irrigation, Solar Mini-grids, Solar Rooftop, Solar Park, Solar E-Mobility and Storage, Solar Heating and Cooling, Solar Waste Management and Solar for Green hydrogen, facilitates accelerated deployment of solar energy in member countries. The organization also advocates grid integration of solar energy by creating favourable policy and regulatory framework. The flagship OSOWOG (One Sun One World One Grid) initiative by ISA aims at connecting energy supply across borders. ISA's initiatives such as STAR-C, ITEC Scheme, Solar Fellowship, Infopedia focus on capacity building in the solar sector. Further, ISA is committed to mobilize affordable finance for solar deployment by de-risking investments through innovative financing mechanisms.

Global Biofuels Alliance (GBA): Launched in 2023, GBA will support worldwide development and deployment of sustainable biofuels by offering capacity-building exercises across the value chain, technical support for national programs and promoting policy lessons-sharing. It will facilitate mobilizing a virtual marketplace to assist industries, countries, ecosystem players and key stakeholders in mapping demand and supply, as well as connecting technology providers to end users. It will also facilitate development, adoption and implementation of internationally recognized standards, codes, sustainability principles and regulations to incentivize biofuels adoption and trade.

Shakti Sustainable Energy is playing a key role in propelling India towards a sustainable energy future by advocating for and implementing policies related to renewable energy, energy efficiency, and sustainable urban transport. With the support of global and Indian philanthropies, the foundation addresses several key areas, including High Renewable Energy Pathways, Electric Mobility, Energy Access for Development, and Climate Resilience. Shakti actively collaborates with policymakers, civil society, industry, think tanks, and academia to reduce greenhouse gas emissions and align with a net zero future. Key programs, such as supporting India's ambition for 100% electric vehicle sales by accelerating the adoption of electric vehicles and the development of charging infrastructure, underscore their commitment to reducing the carbon intensity of the transportation sector.

7 Implementation Potential with Risk Assessment

There are tremendous opportunities to scale up renewable energy integration in India. The ones selected for this program are well integrated into India's RE scale-up strategy and represent priorities that support scale-up in the short-to-medium terms.

At the same time, it is also important to identify potential risks associated with increased investments in REI in India and outline effective risk mitigation strategies in order to ensure the success of REI projects implemented in the country. Section 7.1 describes risks specific to India; Section 7.2 describes India's absorptive capacity to take on financing and implement the proposed investments.

7.1 Country/Regional Risks

Table 5 describes the main risks, and risk mitigation strategies associated with the investment in REI in India across several dimensions, namely: institutional; social; gender; environmental; technical and technological; economic; and disaster and climate change and political.

Table 5: Country/Regional Risks

Dimension	Risk Rating before mitigation	Risks	Risk mitigation strategies	Risk Rating after mitigation
Institutional	Moderate	• Cross-sectoral issues due to different ministries' policies and lack of coordination • Inconsistent policies between central and state governments • Limited skilled manpower	• Convey project objectives to all ministries and ensure coordination • Promote capacity building for RE integration	Low
Social	Moderate	• High tariffs due to BESS costs • Livelihood impacts on traditional activities • Benefit sharing issues • Vendor and subcontractor alignment	• Define tariff regulations and supportive policies • Follow MDB environment and social safeguards • Ensure compatibility with MDB bidding practices	Low
Gender	High	• Lack of awareness and incentives for women in STEM • Skill gap and training issues • Social norms affecting women's participation	• Promote gender inclusion • Focus on capacity building for women	Moderate
Environmental	Moderate	• Habitat loss and biodiversity impact • Adverse impacts of PSP • Waste management issues • Other environmental risks	• Apply MDB guidelines on environmental and social safeguards • Ensure grievance redress through established channels	Low
Economic	High	• Curtailment risk due to excess RE generation • Impact on existing power plants	• Deploy energy storage to reduce curtailment • Invest in smart grid technologies and forecasting tools	Moderate

Dimension	Risk Rating before mitigation	Risks	Risk mitigation strategies	Risk Rating after mitigation
Disaster and climate change	Moderate	• Increased extreme weather events • Impact of disasters on transmission lines • Climate change affecting resource availability	• Incorporate climate resilience into project design • Include risk-sharing instruments	Low
Political	High	• Change in regulatory environments • Politically influenced public procurement processes	• Identify risks during project inception and prepare mitigation plans • Follow MDB guidelines for procurement	Moderate

8 Integrative Approach to Monitoring, Evaluation and Learning

The Monitoring, Evaluation, and Learning strategy for India's IP is based on CIF REI's Integrated Results Framework (IRF). It is collaboratively established by the GoI, Ministry of New and Renewable Energy (MNRE), and Multilateral Development Banks (MDBs). Its primary purpose is to facilitate the continuous tracking and reporting of progress toward achieving the outcomes and objectives outlined in this IP.

In this comprehensive approach, various dimensions of monitoring, evaluation, and learning are utilized to capture the impacts of programs and projects. Additionally, important elements, such as gender inclusion, are integrated to provide a nuanced and holistic understanding of the program's advancement and thematic specifics and ensure the long-term achievement of the goals outlined in this plan.

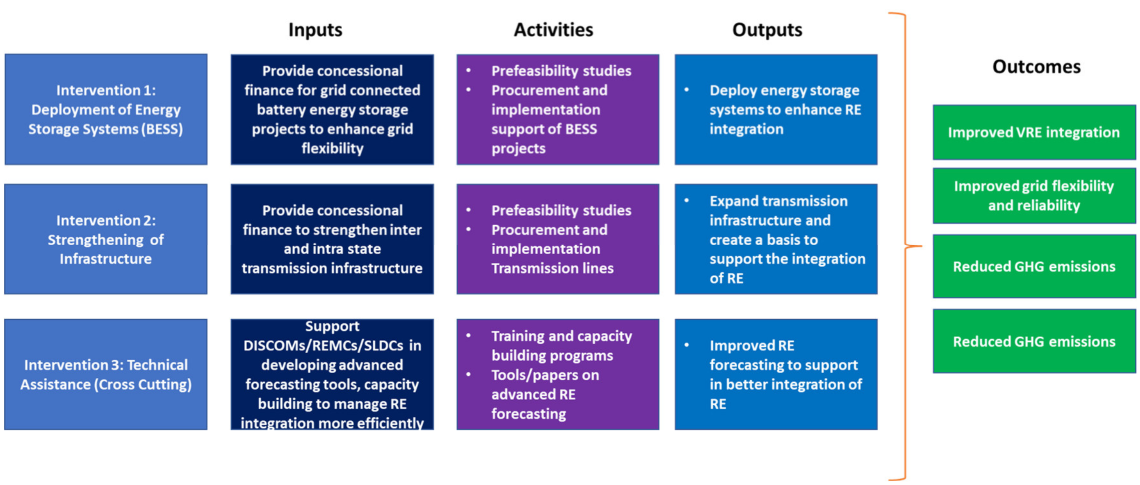
8.1 Theory of Change

India stands on the precipice of a transformative shift in its energy landscape. As the nation embarks on an ambitious journey to achieve net zero emissions by 2070, the proposed investment plan (IP) comprises of three pivotal strategies that support in India's energy infrastructure, thus propelling the country towards a sustainable future.

The first cornerstone is the **strategic deployment of energy storage systems**. By harnessing advanced technologies such as Pumped Hydro Storage (PSP) and Battery Energy Storage Systems (BESS), India aims to significantly enhance its renewable energy (RE) absorption capabilities across RE-rich states like Rajasthan, Karnataka, Uttar Pradesh, Maharashtra, Gujarat, and Kerala. This initiative not only focuses on large-scale storage solutions but also emphasizes the importance of distributed storage deployment, underpinned by technical assistance and capacity-building efforts, to overcome the geographical and logistical challenges of energy storage.

Parallel to energy storage advancements, the **strengthening of infrastructure emerges as a critical enabler for RE integration**. India's multifaceted approach encompasses the support of transmission networks in Green Corridor Phase 3 scheme, state-level transmission strengthening, the bolstering of port and evacuation infrastructure for offshore wind projects, and the establishment of robust transmission linkages, including undersea cables, to green the country's major Indian Ocean islands. Such infrastructural reinforcements are essential for creating a resilient and flexible grid capable of accommodating the fluctuating nature of renewable energy sources.

The third pillar of this IP provides support on **power market reforms**. India seeks to revolutionize its power markets by supporting innovative solutions like advanced forecasting tools, Contracts for Difference (CFD) models, Virtual Power Plants (VPP), Blockchain-based peer-to-peer solar rooftop systems, and renewable energy-powered EV charging stations. India Such reforms are designed to foster a conducive environment for the uptake of renewable energy, thereby facilitating a smoother transition to increased RE in the electricity mix.



Strategic deployment of energy storage systems, the strengthening of energy infrastructure, and the implementation of power market reforms collectively serve as the foundation of this transformative journey. With Each support activity is meticulously designed to address specific barriers as detailed in Chaper-3. This holistic approach is programmed to, attract private sector investments in India's renewable energy integration infrastructure, to reduce carbon emissions and ultimately to catalyse a transformational change in the country's's energy landscape.

Relevance: India has ambitious targets to scale-up renewable energy in the short-to-medium terms to enable it to green its energy mix to meet its goal of 50 per cent non-fossil grid electricity by 2030-31, ultimately transforming the economy toward Net Zero in the long-term. In this regard, each of the components of India's REI Program has been selected to increase in the uptake of VRE in the short-to-medium term to enhance the flexibility and reliability of the grid to sustainably match demand with increased supply of firm and dispatchable renewable resources. This will enable enhanced dispatch of renewables rather than fossil fuel alternatives, enhance grid resilience during climate extremes (e.g. when hydrology is impacted by uneven precipitation leading to lower hydro generation and power supply constraints or when increasingly frequent extreme heat events lead to expanded demand for electricity), and will also offer increased opportunities for mobilization of private investment in renewables.

Systemic Change: The planned expansion of infrastructure under this IP is poised to enable the widespread adoption of significant RE capacities. Such systemic change lays the groundwork for transitioning India's energy sector towards more sustainable and environmentally friendly alternatives, accelerating the shift from non-renewable to renewable energy sources.

Scale: The RE integration activities supported under this IP hold the potential to make a substantial impact in decreasing greenhouse gas (GHG) emissions. With 88% of electricity currently generated from non-renewable sources, including large hydro and nuclear, the proposed energy storage projects aim to support the deployment of large-scale RE projects. These initiatives will act as a benchmark for scaling similar energy projects across the country, thereby contributing to a more sustainable energy landscape.

Speed: The activities proposed can be implemented swiftly and efficiently upon approval. Deploying energy storage systems and constructing transmission lines follow a quick and straightforward process, based on standardized engineering practices and established protocols. Battery Energy Storage System (BESS) solutions, available as containerized plug-and-play models, further streamline the development process. Additionally, the Central Electricity Authority (CEA) has outlined a detailed plan for rolling out transmission infrastructure to meet the 500 GW of RE target, ensuring a fast-paced implementation.

Resilience: Strengthening the grid and deploying energy storage systems are critical to increasing the overall redundancy and resilience of the interconnected transmission and distribution (T&D) system. Incorporating redundant pathways for electricity transmission makes the grid more robust and resilient, thereby reducing the impact of cyclones and other extreme weather events on the continuity of energy supply. Such measures ensure the reliability and sustainability of energy sources, enabling the maintenance of essential services, communication networks, and access to critical resources during climate-related events, thus minimizing the adverse impacts of such occurrences.

Throughout the program's execution, further signals indicating transformational changes will be addressed and analyzed through impact assessments, co-benefit evaluations, and social and gender inclusion studies. Additionally, specific learning-oriented activities will contribute to this evaluative process. These evaluations and studies, driven by the CIF, the country, and the MDBs, will be conducted as necessary, based on the activities receiving financial support from the program. By integrating systematic monitoring with research and evaluation, employing mixed methods, and utilizing diverse forms of evidence, a comprehensive understanding of the program's achievements and lessons learned will be developed, providing an informed perspective on its overall impact and effectiveness.

8.2 Integrated results framework

The India's IP responds to CIF's integrated approach to results measurement, as presented within the REI IP's Integrated Results Framework in Table 6 below. CIF's integrated approach combines essential monitoring and accountability functions with a holistic multi-level and multi-dimensional approach, including a complex systems orientation, and emergent learning opportunities. Within this integrated approach, measurement of program and project impacts are captured via the multiple dimensions of monitoring, evaluation, learning, gender, and other key cross-cutting approaches, coalesced within the objective of delivering a nuanced and complete understanding of the program's progression, and thematic specificities, in delivering a complex and multifaceted program goal.

The left-side columns of the REI IRF, tracking the key performance indicators of program and project performance, are captured within the Fiji IRF below, wherein the program's performance is tracked via targeted, core indicators defined within the REI IRF, in response to the REI Theory of Change and its constituent objectives. The right-side columns of the REI IRFs, focused on evaluation of learning approaches (encompassing transformational change signals across dimensions, co-benefits/development impact evaluations, gender and social inclusion analytics, and other targeted evaluations and learning activities) are captured via CIF, country, and MDB-driven evaluations and studies responsive to the program's evidence needs and priorities, as outlined below. In sum, the approaches allow for a duality between systemized tracking and responsive research and evaluation, designed to complement each other, and leverage mixed methods approaches utilizing different tools, methods, and forms of evidence, but strategically combining them when applicable.

The indicators outlined in India's IP IRF will enable the monitoring and assessment of progress based on the program's envisioned outcomes. However, it is important to note that the targets set for these indicators are somewhat **tentative and indicative**, as they depend on assumptions about the type of investments sub-borrowers will ultimately undertake and the projects that will meet eligibility criteria. The final results will heavily rely on the preferences of sub-borrowers and the financing assessment decisions of Implementing Entities.

Table 6: Integrated results framework

CIF IMPACT Accelerated transformational change toward net zero emissions and inclusive, climate-resilient development pathways						
RESULT STATEMENT	MONITORING APPROACH					EVALUATION AND LEARNING APPROACH
	INDICATORS	DESCRIPTION	BASE LINE	MEANS OF VERIFI CATION	TARGET	KEY AREAS
CIF-LEVEL IMPACTS						
Accelerated transformational change toward net zero emissions and inclusive, climate-resilient development pathways	**CIF 1. Mitigation: GHG emissions reduced or avoided (mt CO2 eq)**	CO2 emissions reduced as a result of RE deployment	0 as based on BAU assumed scenario (without CIF REI IP contributions)	Annual reporting by projects	Refer to CORE 1 target indicator below.	**Transformational Change:** CIF aims to drive transformational change across all funded programs and activities. Broadly defined, transformational change is a deep and fundamental change in a system's form, function, or processes. In the context of the climate crisis, this refers to the many profound, rapid changes in social, economic, and technical systems needed to achieve net zero greenhouse gas emissions, increase social inclusion, manage distributional impacts, enhance resilience and adaptation to climate change, and reduce stress on

	CIF 2. Adaptation: Strengthened climate resilience of land (ha), people (#), and physical assets ($) through a CIF supported adaptation mechanism	Based on resiliency features incorporated within the design and construction of financed infrastructure and installation of technology assets. Also based on users accessing climate change resilient RE solutions.	Already implemented or programmed and financed resiliency measures, and users benefited from solutions similar to those to be financed with CIF-REI funding.	Reporting from projects on built and deployed infrastructure and technology assets, same as on number of benefited users.	To be derived from CORE Indicators #2, #4, and #7, below to accommodate higher shares of VRE.	finite natural systems. **Signals** of transformational change will be assessed through both evaluative and learning-based approaches across **dimensions.** Unlike indicators, signals mark multiple levels of complex systems dynamics based on mixed methods data collection and analysis of CIF contributions toward transformational change in-situ. As these signals are highly context-specific, they will be proposed, defined, tracked, and reported on according to each IP's unique context analysis and Theory of Change, and using a range of methodological approaches. Disaggregated data collection to capture impacts on women, youth, migrants, Indigenous Peoples, and local communities, as well as persons with disabilities is encouraged. Ongoing learning and adaptive approaches, including the identification and tracking of new and emerging signals as programs and contexts evolve, is also encouraged. **This impact area will be measured through CIF-driven evaluation and learning activities, which will not be**
	CIF 3. Beneficiaries: Number of women and men benefiting from CIF investments	The number of customers benefiting from the deployment of energy storage projects and strengthen of transmission infrastructure, disaggregated by gender, income, and other descriptive characteristics available.	0 as based on BAU assumed scenario (without CIF REI IP contributions)	MDBs	Refer to CORE 7 target indicator below.	

	CIF 4. Co-Finance: Volume of co-finance leveraged (USD)	The volume of co-financing leveraged through CIF investments.	0 as based on BAU assumed scenario (without CIF REI IP contributions)	Annual reporting by projects	Refer to CORE 6 indicator below.	**the direct responsibility of MDBs for annual reporting.** **Gender-Transformative Impacts:** The CIF Gender Program outlines (I) improved asset position, (ii) voice, and (iii) resilient livelihoods of women through gender-responsive institutions and markets as its key impact objective. These aspects are to be assessed through evaluative and learning-based approaches, as relevant to the REI program, and in combination with other monitoring data. **Areas for further analysis include: mechanisms through which women and their organizations are represented in decision-making on renewable energy generation; share of women working in the energy sector; and the impact of off-grid access on women's labor/time use.** **New and additional climate finance mobilized**: Beyond the immediate co-financing CIF leverages, CIF aims to plays a role as a market catalyst by contributing to the creation of markets and driving non-concessional financing through replication of CIF investments, technologies and innovations,

RESULT STATEMENT	MONITORING APPROACH					EVALUATION AND LEARNING APPROACH
						regulatory improvements, and other areas. Evaluation and/or learning approaches may be employed to better understand CIF's contributing role in market systems transformation and volumes of follow-on green financing in CIF-supported markets. Data might also be sourced through national/local market reports and other third-party data aggregators (e.g., IRENA, BNEF, etc.)
Program Theory of Change: If CIF improves market design and system operations, provides enabling technologies and infrastructure, and develops new business models, countries will increase renewable energy penetration in their energy mix, achieve a more flexible and decentralized energy system, improve policies and capabilities, mobilize capital, increase renewable energy access, reduce systems costs, and foster renewable energy innovation, which will contribute to and CIF's transformative impact.						
RESULT STATEMENT	INDICATORS	DESCRIPTION	BASE LINE	MEANS OF VERIFI CATION	TARGET (DATE)	KEY AREAS
REI PROGRAM-LEVEL IMPACTS						
Flexibility of energy systems for smooth integration of higher shares of variable renewable energy generation into the grid and enhance grid evacuation infrastructure	REI Proxy Indicator #1: Installed capacity utility scale Renewable Energy	Renewables based electricity generation installed capacity integrated with storage and due to grid strengthening	0	CEA Generation Capacity Annual Report	1500 MW (2027)	**Signals of transformational change**: Signals of transformational change at the program level will focus on more narrowly bounded aspects of energy systems transformation than in the section above (i.e., CIF-level impact). They might cover dimensions of systems transformation that are more
	REI Proxy Indicator #2: Installed Energy Storage Capacity	Energy storage installed capacity to facilitate RE integration	0	CEA Generation Capacity Annual Report	1500 MWh (2028)	

	REI Proxy Indicator #3: Installed Transmission Lines dedicated to evacuate RE	Dedicated transmission lines installed to support RE evacuation	0	CEA Generation Capacity Annual Report	580 ckm (2027) - 400 KV DC Double Circuit	closely tied to individual REI recipient countries, Investment Plans and/or project-level impacts. Specific definitions and methodologies are to be determined. **Gender and just transition elements**: The program impact level allows space for further evaluations, assessments, and other approaches to take place as the program evolves in these areas. These activities may be tailored to specific recipient countries or applied more broadly across the program.
RESULT STATEMENT	**3**					**EVALUATION AND LEARNING APPROACH**
	INDICATORS	**DESCRIPTION**	**BASE LINE**	**MEANS OF VERIFI CATION**	**TARGET (DATE)**	**KEY AREAS**
REI PROGRAM-LEVEL IMPACTS						
A. Increased penetration of variable renewable energy into power systems and maximized renewable energy potential of countries	**REI CORE 1. Mitigation:** GHG emissions reduced or avoided (t CO2 eq) – direct/indirect	Emissions avoided as the result of additional RE capacity installed	0 (with reference scenario established)	Annual estimates by projects	3.2 million tons/year CO2 (2028)	The proposed REI program in India will support BESS capacity of ~1.2 GWh . The BESS will be integrated with solar energy capacity of ~1300 MW (22% CUF), which will support 2 cycles per day. The other component on infrastructure strengthening will support 400 ckm of 400 KV DC line, which would enable integration of 1.5 GW of RE capacity.
	REI CORE 2. Installed Capacity: Installed capacity of variable renewable energy	Based on installed capacity of new solar integrated with storage (BESS) and connected to 400 KV	0	MDB project results data	1500 MW (2027)	

	available to the grid (MW) – direct/indirect	DC transmission corridor				
	REI CORE 3. Renewable Energy Production: Annual renewable energy output (MWh)	Based on installed capacity of new solar integrated with storage (BESS) and connected to 400 KV DC transmission corridor	0	MDB project results/ utilities data	2800 MUs/year (2028)	
B. Improved policies, plans, and institutional capabilities	**REI CORE 5. Policies:** Number of policies, regulations, codes, or standards related to renewable energy integration that have been amended or adopted (#)	# of policies, laws, regulations or codes	0	MDB project results/ country data	0	Government foresees substantial revisions to the Electricity Act and regulations under the Act as well as the creation of centralized procurement of renewable energy generation.
C. Mobilized public and private capital	**REI CORE 6 (= CIF 4). CoFinance:** Volume of cofinance leveraged (USD)	Actual co-finance resources entering into CIF-REI benefited projects Disaggregation: Source of cofinancing (MDB, Government, Private Sector, Bilateral, and Other)	0	MDB project financial data	US$1100 million (2027)	This is the amount foreseen to be leveraged under the financing plan.
D. Increased renewable energy access	**REI CORE 7. Renewable Energy Access:** Number of women and men, businesses, and community services benefiting from improved access to electricity and/or other modern energy services – direct/indirect (# of people)	# of customers having access to renewable energy generation	0			**Gender-responsive aspects of energy access** can be studied in more detail through targeted research, evaluations, and/or case studies. Examples of relevant issues include: impact on women-owned businesses/firm users; impact on community services specifically catering to women; and women's awareness and ability to use electricity access for productive purposes.

E. Reduced total system cost	**REI CORE 8. System Costs:** Reduced total energy system cost (USD)		0	MDB project results/utility data		
RESULT STATEMENT	**MONITORING APPROACH**					**EVALUATION AND LEARNING APPROACH**
	INDICATORS	**DESCRIPTION**	**BASE LINE**	**MEANS OF VERIFI CATION**	**TARGET (DATE)**	**KEY AREAS**
REI PROGRAM-LEVEL IMPACTS						
Social and Economic Development Co-Benefits	**CO-BENEFIT 1. Employment and Livelihoods: Jobs created – direct and indirect**	# of permanent jobs created as result of expanded electricity network and operation of RE plants # of temporary jobs resulting from construction of new assets	0	MDB project results data / CIF modeling	13000 (2028)	**Quality and distribution of jobs:** Permanent jobs will be created at renewable energy generation plants and also with expansion of the transmission network.
	CO-BENEFIT 2. Just Transition: Social Inclusion and Distributional Impacts	# of people trained to carry a more skillful and better paid job	N/A	N/A		Introduction of gender and social inclusion criteria into bidding documents for subcontractor companies (e.g., specification of percent of women to be employed for the project). Introduction of targeted trainings on STEM and measures to attract (internships; bursaries; and scholarships) and retain (mentorship schemes) female talent. Provision of training for women and vulnerable groups interested in operation and maintenance of solar plants.

	CO-BENEFIT 3. Policy and Planning: Coherence across sectors		N/A	N/A		
RESULT STATEMENT	**MONITORING APPROACH**					**EVALUATION AND LEARNING APPROACH**
	INDICATORS	**DESCRIPTION**	**BASE LINE**	**MEANS OF VERIFI CATION**	**TARGET (DATE)**	**KEY AREAS**
REI PROGRAM-LEVEL IMPACTS						
A. Improved market design and systems	OPTIONAL: Number of policies, regulations, codes, or standards supported to enhance the enabling environment for renewable energy uptake (#)	Publication of new or revised policies, acts, and regulations	0	MDB project results / country data	xx (2026)	feasibility studies of energy storage systems colocated with renewable energy plants Feasibility study of energy storage applications at distribution level and identification of potential locations for setting up DRE integrated with energy storage systems Advanced forecasting tools for better management of RE integration
	OPTIONAL: Number of technical/financial analyses completed to enhance the enabling environment for RE uptake (#)	Publication of technical studies foreseen under components 1, 2 and 3	0	MDB project results/ operations data	4 (2026)	

System-wide Analysis

The IP's Integrated Results Framework serves as a fundamental instrument that grounds the country program's high-level goal statement on measurable national indicators and targets, and thereafter links the program's theoretical objectives with the measurable outcome-level results anticipated via its constituent project pipeline. As the IP is developed collaboratively among the Government, implementing MDB partners, and other stakeholders, the process of defining project objectives, and aggregating the related results via the IRF, constitutes a consistent and system-wide approach on the coherence of and between interventions, and on accountability between proposed goal statements and pragmatic results estimations.

Activities defined to be supported based on CIF-REI program objectives have been defined based on thorough examination of the country's context in terms of RE deployment and barriers to achieve expected and further integration of renewable energy into the system.

Anticipated Program Impacts

The India's IP currently expects to deliver on eight of the nine REI core objectives of the REI Investment Program, and the country's IRF therefore tracks core indicators as relate to each of these outcomes, with the expected target values collating the fractional outcomes expected from each of the two individual projects within the program pipeline. Each target value delineates the share of results anticipated from each discrete project, allowing for a differentiated analyses of the varying levels of impacts, vis-à-vis investment volumes and targeted approaches. As such, the IRF will be responsive to any changing dynamics within individual projects, and under- or over-achievement of program-level results will allow for learning and adaptation based on challenging or opportune investment environments:

As relevant outcomes, the IP will help the Government's NDC commitments by achieving the following:

- Increased renewable energy generation capacity by ~1500 MW, and an additional ~2800 Mus/year of renewable energy.
- Addition of energy storage capacity to the tune of ~1500 MWh catering to various applications supporting generation and distribution segments
- Enhancing distribution and transmission infrastructure by facilitating ~3700 ckm. of 33 kV distribution lines and ~580 ckm. of 400 kV DC transmission infrastructure to enhance RE integration.
- A consequent reduction in the volume of global (CO2) emissions of ~3.2 MtCO2/year.
- Improved policies and institutional capabilities, including advanced forecasting tools and successful third-party forecasting models for DISCOMs and REMCs; innovative methods for uptake of RE such as Contracts for Difference (CFD); introduction of new concepts like Virtual Power Plants (VPP), Blockchain-based P2P solar rooftop systems, and RE-based EV charging.
- US$1100 million leveraged under the financing plan, supporting to the creation of ~13500 FTE green jobs, capacity building and training (upskilling) of women officials.
- Better electricity reliability, resulting from a more diverse portfolio of domestically available renewable fuels and enhanced energy storage and grid management technologies and techniques.
- Better resilience—especially of the transmission and distribution network—to climate-induced disasters and damage to infrastructure.

Appendix A: Investment Concept Briefs

Theme 1: Deployment of Energy Storage Systems and RE enabling technologies

Driven by concerted government policies and regulations and by lower technology costs, India's power sector is already experiencing a paradigm shift towards renewable energy, which now accounts for about 40.9 percent of power generation capacity on the grid. As discussed in section 3.5, grid stability and reliability, grid flexibility and ramp-up challenges are some of the key challenges pertaining to higher share of RE in power generation mix. The challenge with RE sources arises due to their varying nature with time, climate, seasonality, and geographic location. Further, integration of renewable energy into the grid may be constrained in the absence of full power market reforms. In addition, there will be increased demand for certain grid support services or ancillary services. There is a critical need to increase the flexibility of the Indian power system to accommodate a higher share of RE. Energy storage systems (ESS) are gaining prominence in India's energy landscape, offering crucial support for grid stability and providing flexibility for integration of renewable energy. through.

Battery-based ESS (BESS) and pumped hydro storage (PHS) are the most widespread and commercially viable means for implementing energy storage solutions in India. India has notified a long-term trajectory for Energy Storage Obligations (ESO) to ensure that sufficient storage capacity is available with obligated entities. As per the trajectory, the ESO shall gradually increase from 1% in FY 2023-24 to 4% by FY 2029-30, with an annual increase of 0.5%. This obligation shall be treated as fulfilled only when at least 85% of the total energy stored is procured from RE sources on an annual basis. The other key policies driving this emerging sector include a national framework for promoting energy storage systems, Guidelines for Tariff Based Competitive Bidding Process for Procurement of Firm and Dispatchable Power from Grid Connected Renewable Energy Power Projects with Energy Storage Systems, National Programme on Advanced Chemistry Cell (ACC) Battery Storage and Viability Gap Funding (VGF) Scheme. The VGF Scheme envisages development of 4,000 MWh of BESS projects by 2030-31, with financial support of up to 40% of the capital cost as budgetary support in the form of Viability Gap Funding (VGF). While PSP is backed by Energy Storage Obligation, there are other guidelines such as Guidelines to promote development of Pump Storage Projects, and Guidelines for Formulation of Detailed Project Reports for Pumped Storage Schemes. RPO obligation notifies that Hydro Power Obligation (HPO) can be met with power from Large Hydro Power (LHP) projects including Pump Storage Projects with capacity greater than 25 MW, giving further boost to PSP. Recently, India has introduced demand-driven Firm and Dispatchable Renewable Energy (FDRE) tenders, most advanced iteration of tender models, such as round-the-clock (RTC), Solar + BESS and standalone ESS, whose tariffs are already comparable to, if not lower than, traditional fossil fuel-based power generation.[58]

As of March 2023, the installed capacity of battery energy storage system (BESS) in India was around 40 MWh[59] while PSP based capacity was 4746 MW[60]. After Solar Energy Corporation of India (SECI) launched a 1000MWh battery storage tender, the energy storage sector is appearing to be advancing rapidly. SECI's tender was followed by 500MWh battery storage tender by National Thermal Power Corporation (NTPC). Around 2.5 GWh of such tenders are already awarded. Request for Proposal (RfP) has been released for 4.5 GWh of such tenders. Further announcements have been made for 29 GWh of storage projects. As per the CEA estimates on-river pumped storage potential is 103 GW in India. PSP projects totaling to 2780 MW are under construction for likely benefits till 2030. Multiple private sector players such as Adani Green Energy, Greenko, JSW Energy, Tata Power have already entered the sector and are set to develop multi megawatt scale pumped hydro storage projects.

Different states in India are leveraging their unique geographical and climatic advantages to develop renewable energy projects. Rajasthan, with its vast desert areas, is focusing on large-scale solar power projects. Karnataka and Tamil Nadu are harnessing wind energy due to their favorable wind conditions. Uttar Pradesh is emphasizing solar energy projects, particularly in rural areas, to enhance energy access and support agricultural activities. The state is also developing significant pumped storage projects in Sonbhadra and Vindhyachal regions, initiating a pilot green hydrogen production facility in Gorakhpur, and setting up battery energy storage systems through Uttar Pradesh Power Corporation Limited (UPPCL) to support grid stability. Madhya Pradesh is developing both solar and wind energy

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[58] https://ieefa.org/articles/india-shows-urgency-energy-storage-systems-already-awarding-more-8gw-tenders
[59] India: BESS capacity 2030 | Statista
[60] Optimal_mix_report__2029_30_Version_2.0__For_Uploading.pdf (cea.nic.in)

projects, taking advantage of its central location and diverse climate. The state is advancing with the Gandhi Sagar Pumped Storage Project, expected to provide 1.9GW of storage capacity, investing in green hydrogen initiatives, and enhancing its transmission infrastructure to support the integration of renewable energy. Maharashtra and Gujarat are exploring hybrid renewable energy projects that combine solar and wind power to ensure a more stable and reliable energy supply. These state-specific initiatives are crucial for achieving India's overall renewable energy targets and addressing regional energy demands effectively.

Short term, medium term and long-term projections of the large additions of renewable energy needed to meet India's clean energy and climate goals make it clear that there is a requirement for significant additions of battery storage and pumped hydro storage capacity.

The proposed interventions under CIF REI program for India will seek to address the key challenges, focusing on key states. Some of the key bottlenecks with deployment of BESS in India are high upfront capital cost, limited domestic manufacturing, supply chain constraints, concerns about end-user affordability and unavailability of high tariffs for BESS integrated variable renewable energy[61], technological challenges (long duration energy storage solution > 4hrs), grid integration challenges, lack of standardization and skilled workforce shortage. Key challenges in PSP sector are long gestation period, high initial cost, requirement for highly complex, meticulous, and judicious planning and design, geological uncertainties, land acquisition issues and transmission infrastructure[62,63].

Proposed tentative projects include Enabling Round the Clock (RTC) supply through Advanced Grid Management and energy storage at the state level, Wind-Solar Hybrid project with energy storage for C&I customers, Concessional financing of BESS projects across India through a Financial intermediary, financing greenfield private sector grid tied and/or off grid energy storage projects. The planned interventions are very well aligned with one of the qualifying themes of CIF REI Programme - Scaling up renewable energy enabling technologies.

Theme 2: Transmission and Distribution Infrastructure Strengthening

The Government of India has had a keen focus on strengthening its transmission and distribution infrastructure to facilitate integration of 500 GW renewable energy by 2030. As discussed in section 3.5, grid integration and transmission bottlenecks remain key challenges constraining the higher penetration of RE. Although India has made considerable progress in renewable energy capacity additions, further integration of renewable energy into the grid may be constrained in the absence of adequate grid infrastructure to evacuate renewable energy. To enable and maximize growth of RE capacity in the 2030 time-frame, the areas with high solar and wind energy potential need to be connected to the Inter-State Transmission System (ISTS), so that the power generated could be evacuated to the load centres.

The enhancements and strengthening of the transmission systems on the intra-state and inter-state levels have to be planned well in advance since the gestation period of wind and solar based generation projects is much shorter than the gestation period of the associated transmission system. Recent reforms have allowed for private developers to bid to build and operate in the transmission sector. The payoff from planning and investment could be significant; for example, while the present inter-regional transmission capacity is 1,12,250 MW, it is anticipated that once the additional inter-regional transmission corridors under implementation/planned are completed, the cumulative inter-regional transmission capacity would rise to about 1,50,000 MW in 2030[64].

Transmission system development is also planned for major RE potential zones like Fatehgarh, Bhadla, Bikaner in Rajasthan; Khavda RE park in Gujarat; Anantapur, Kurnool RE Zones in Andhra Pradesh; and offshore wind farms in Tamil Nadu and Gujarat etc. The transmission schemes have been planned considering energy storage, so as to meet the requirement of Round-the-Clock (RTC) power.

Several HVDC transmission corridors have also been planned for the evacuation of power from large RE potential Zones.

[61] (8) Battery Energy Storage Systems (BESS) in India | LinkedIn
[62] TS5-KP.pdf (cbip.org)
[63] TS5-3.pdf (cbip.org)

[64] Transmission System for Integration of over 500 GW RE Capacity by 2023, CEA

The length of the transmission lines and sub-station capacity planned under the Inter-State Transmission System (ISTS) for integration of additional wind and solar capacity by 2030 has been estimated as 50,890 ckm and 4,33,575 MVA respectively at an estimated cost of Rs 2,44,200 crores. Further, the present inter-regional transmission capacity is 1,12,250 MW and with the additional inter-regional transmission corridors under implementation/planned, the cumulative inter-regional transmission capacity is targeted to be about 1,50,000 MW in 2030[65].

The Government of India has keen focus on strengthening its transmission and distribution infrastructure to facilitate integration of 500 GW renewable energy by 2030. The transmission system of India has become increasingly robust and has attracted significant private sector participation for inter-state transmission projects. India added 14,625 ckm of transmission line and 75,902 MVA[66] of transformation capacity in FY 2022-23. To facilitate construction of Intra-State and Inter-State transmission systems for grid integration of large scale solar and wind power plants Green Energy Corridor was planned. In January 2022 Phase II of Intra-State Transmission System Green Energy Corridor was approved by Cabinet Committee on Economic Affairs (CCEA) with total target of 10,750 ckm intra-state transmission lines and 27,500 MVA sub-stations[66]. The Ministry of Power, in FY 2021-22, revised Standard Bidding Documents for selection of developers for Inter State Transmission Systems (ISTS) projects to promote ease of doing business for private developers in transmission sector. However, the distribution segment which comes under the state governments continues to underperform with high technical and commercial losses, inadequate cost recovery and less than satisfactory quality of service. The Government of India has made several interventions to improve financial and operational efficiencies of DISCOMs linked to reform measures including Liquidity Infusion Scheme (LIS); Additional Borrowing of 0.5% of GSDP to States linked to power sector reforms; introducing additional prudential norms for lending by Power Finance Corporation (PFC) Limited and REC Limited; and Revamped Distribution Sector Scheme (RDSS)[67].

Central Electricity Authority (CEA) of India has put in place a detailed Transmission System Plan for integration of over 500 GW RE capacity by 2030. The plan outlines transmission system development for major RE potential zones like Leh RE park in Ladakh; Fatehgarh, Bhadla, Bikaner in Rajasthan; Khavda RE park in Gujarat; Anantapur, Kurnool RE Zones in Andhra Pradesh; and offshore wind farms in Tamil Nadu and Gujarat etc. The transmission schemes have been planned considering energy storage, so as to meet the requirement of Round-the-Clock (RTC) power. Several HVDC transmission corridors have also been planned for the evacuation of power from large RE potential Zones. The length of the transmission lines and sub-station capacity planned under ISTS for integration of additional wind and solar capacity by 2030 has been estimated as 50,890 ckm and 4,33,575 MVA respectively at an estimated cost of Rs 2,44,200 crores. Further, the present inter-regional transmission capacity is 1,12,250 MW and with the additional inter-regional transmission corridors under implementation/planned, the cumulative inter-regional transmission capacity is likely to be about 1,50,000 MW in 2030[68].

65 Transmission System for Integration of over 500 GW RE Capacity by 2023, CEA
66 Ministry of Power
67 Ministry of Power

68 Transmission System for Integration of over 500 GW RE Capacity by 2023, CEA

Appendix B: Key Policies and Initiatives by Government of India to Ensure Inclusive Growth

Policy	Overview
Gender equality	
The National Education Policy (NEP), 2020	The National Education Policy (NEP) 2020 prioritizes gender equity and aims to provide quality education to all students, especially those from socially and economically disadvantaged backgrounds. The Samagra Shiksha program, launched in 2018-19, now aligns with NEP 2020 recommendations to ensure equitable and inclusive classrooms. This involves catering to diverse backgrounds, multilingual needs, and varying academic abilities to make all students active participants in the learning process.
Samagra Shiksha, 2018	Samagra Shiksha targets girls and marginalized groups including SC, ST, Minority communities, and transgender children. To boost girls' participation, it offers interventions like nearby school access, free textbooks, two sets of uniforms, gender-segregated toilets, stipends for girls with disabilities from pre-primary to class XII, and self-defense training.
The National Skill Development Policy, 2009	The National Skill Development Policy focuses on inclusive skill development, with the objective of increased women participation for better economic productivity. Pradhan Mantri Kaushal Vikas Kendras lay emphasis on creating additional infrastructure both for training and apprenticeship for women; flexible training delivery mechanisms, flexible afternoon batches on local need-based training to accommodate women; and ensuring safe and gender sensitive training environment, employment of women trainers, equity in remuneration, and complaint redressal mechanism.
Schemes to help women to set up their own enterprise	Pradhan Mantri Mudra Yojana (2015), Stand Up India (2016), Prime **Minister's** Employment Generation Programme (PMEGP, 2008), The Startup India initiative (2016)
Gender Budgeting (GB)	Since 2005-2006, India has adopted Gender Budgeting (GB) which is concerned with gender responsive formulation of legislation, policies, plans, programmes, and schemes; resource allocation; implementation; monitoring review, audit and impact assessment of programs and schemes. The Gender Budget Statement is a gender-specific accountability document produced by the Government of India with the Union Budget. It is a reporting mechanism for Ministries/Departments to review their programmes from a gender perspective and present information on allocations for women and girls.
Inclusion of persons with disabilities	
The National Policy For Persons With Disabilities, 2006	The Government recognizes the value of Persons with Disabilities as a valuable human resource and aims to provide them with equal opportunities and effective access to rehabilitation measures. The National Policy for Persons with Disabilities outlines measures for their rights protection and societal inclusion.
The Rights of Persons with Disabilities Act, 2016	**The** Act seeks *inter alia* to ensure that reasonable accommodations are made in all aspects of social life whether by educational institutions, commercial establishments, public buildings and/or transport systems in order to ensure that people with disabilities have access to all such facilities, alongside prohibiting discrimination.
Inclusion of LGBTQ community	
The Transgender Persons (Protection of Rights) Bill, 2019	The bill prohibits discrimination against transgender individuals in areas like education, employment, and housing while granting them the right to self-perceived identity. However, a major drawback is the requirement for transgender individuals to register with the government for official recognition, necessitating proof of gender confirmation surgery for legal recognition of their gender identity.
Decriminalization of Section 377 Indian Penal Code, 2018	The landmark judgment against Section 377 stated that sexual orientation forms an inherent part of self-identity and denying the same would be violative of the right to life, and that fundamental rights cannot be denied on the ground that they only affect a small amount of the population. Thus, at present, Section 377 stands decriminalized, and no person can be penalized under this section based on their sexual orientation.
Inclusion of youth	

Draft National Youth Policy, 2022	The draft NYP envisages a ten-year vision for youth development that India seeks to achieve by 2030. It is aligned with Sustainable Development Goals (SDGs) and serves to 'unlock the potential of youth to advance India'. The NYP seeks to catalyze widespread action on youth development on five priority areas viz. education; employment & entrepreneurship; youth leadership & development; health, fitness & sports; and social justice.
National Youth Policy, 2014	The NYP-2014 proposes a holistic 'vision' for the youth of India, which is "To empower youth of the country to achieve their full potential, and through them enable India to find its rightful place in the community of nations". In order to realize this Vision, the NYP-2014 identifies 5 clearly defined 'Objectives' which need to be pursued and the 'Priority Areas' under each of the Objectives.
Rashtriya Yuva Sashaktikaran Karyakram (RYSK), 2016	The umbrella scheme 'Rashtriya Yuva Sashaktikaran Karyakram (RYSK)' will now act as the flagship programme of the Department for empowerment of the youth to enable them to realize their potential and in the process, to contribute to the nation building process.
National Service Scheme (NSS), 1969	National Service Scheme (NSS) was introduced in 1969 with the primary objective of developing the personality and character of the student youth through voluntary community service. 'Education through Service' is the purpose of the NSS.
Rajiv Gandhi National Institute of Youth Development (RGNIYD), 1993	RGNIYD functions as a vital resource centre with its multi-faceted functions of offering academic programmes at Post Graduate level encompassing various dimensions of youth development, engaging in seminal research in the vital areas of youth development and conducting Training/ Capacity Building Programmes in the area of youth development, besides the extension and outreach initiatives across the country. The Institute functions as a think-tank of the Ministry and premier organization of youth-related activities in the country.

Appendix C: Overview of Renewable Energy Technologies in India

On shore wind technology captures wind energy using turbines installed on land and it is a mature, cost-effective renewable energy source with significant potential to contribute to India's energy security and climate change goals. With over three decades of experience in harnessing wind energy technology for power generation, India has already achieved ~42 GW of installed capacity, making it the fourth-largest market globally. Key governing policies include wind renewable purchase obligation, National Wind Energy Mission, Repowering Policy 2023[69] of the wind power projects especially for the wind rich states like Tamil Nadu, Gujarat, Karnataka and Rajasthan, Wind-Solar Hybrid Policy[70], Change in tariff system[71,72]. Onshore wind installed capacity has increased with an average growth rate of ~6% over the past 5 years.[73] India has set a target of harnessing 140 GW (out of which 100 GW is onshore wind) wind energy capacity by 2030.[74] By leveraging these initiatives, the renewable energy sector can achieve greater resource adequacy while also promoting the integration of wind and solar hybrid projects, ultimately facilitating the transition towards a more sustainable and resilient energy landscape. Key challenges faced by onshore wind include land acquisition conflicts, intermittency, and grid integration issues.

Offshore Wind: India boasts a vast coastline of 7600 km offering immense potential for harnessing offshore wind energy. Despite this, the sector remains its nascent stages, with no operating projects as of today. Considering this, govt. of India notified National Offshore Wind Energy Policy for the development of offshore wind power in the country. Currently India has zero installed capacity for offshore wind energy. The focus is now on expediting project development to achieve the ambitious target of 30 GW by 2030. India's first offshore wind projects to come up across the Tamil Nadu and Gujarat coast and in Budget 2024, GoI announced viability gap funding (VGF) to support 1 GW of offshore wind capacity. Key challenges for the sector include initial high upfront cost, lack of infrastructure and expertise, subsea cabling, reliable grid integration into the national grid[75]. As India ventures into the nascent offshore wind sector, it anticipates encountering various operational challenges pertaining to clearances and approvals as the industry matures. The lack of thorough examination regarding the socio-economic implications of offshore wind projects underscores a pressing need for future assessments, especially with the anticipated proliferation of such projects in India. Additionally, the establishment of robust supply chains for offshore wind projects will be imperative, necessitating significant governmental assistance. Initiatives like the Production Linked Incentives (PLI) targeting critical components such as subsea cables are poised to bolster the development of these supply chains, ensuring the resilience and sustainability of the offshore wind industry in India.

Grid-Scale Solar PV: India with its abundant sunshine has emerged as a global leader in grid scale solar energy deployment. From negligible capacity a decade ago, the country boasts over 56 GW of installed capacity, ranking 4th globally[76,77]. Key policies governing solar sector include: national solar mission[78], renewable purchase obligation (RPO), production linked incentive (PLI)[79], national wind solar hybrid policy. Grid scale solar energy installed capacity has increased with an average growth rate of ~18% over the past 5 years. India has set an ambitious goal of achieving 280 GW of cumulative installed solar capacity by 2030. Despite the progress, challenges remain securing land for large grid scale projects can be difficult, grid integration (intermittency issue), financing large projects, reducing manufacturing dependencies on imported solar components is necessary for long term sustainability.

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71 Committee Reports (prsindia.org)

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73 India: wind energy capacity 2022 | Statista

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75 Offshore wind energy status, challenges, opportunities, environmental impacts, occupational health, and safety management in India

76 ARC FY 2023 (jmkresearch.com)

77 Press Information Bureau (pib.gov.in)

78 Jawaharlal Nehru National Solar Mission (Phase I, II and III) – Policies - IEA

79 Production Linked Incentive (PLI) Scheme: National Programme on High Efficiency Solar PV Modules | Ministry of New and Renewable Energy | India (mnre.gov.in)

Solar Rooftop in India offers immerse potential for decentralized renewable energy generation. India has set a target of 40 GW of rooftop solar by 2022, out of which ~11 GW installed capacity has been achieved as of 2023[80,81]. To accelerate the pace of rooftop solar installations, govt of India launched National solar rooftop policy. India's households have the potential to deploy more than 600 GW of rooftop solar capacity[82]. Challenges include policy uncertainty, regulatory pushbacks, restrictions and/or ambiguity on provisions such as banking of electricity and net metering[83], delays in net metering approvals [84], lack of established demand aggregation business models, awareness, and outreach. This is compounded by the high upfront capital cost to deploy the systems, particularly for residential consumers and challenges to access finance by MSMEs.

Small Hydro power projects (SHPs) defined as those with capacity up to 25MW in India, offer vast potential for clean energy generation in remote areas. Key policies governing this technology include Hydro power purchase obligation, grid connectivity waiver charges including SHP[85] commissioned by June 2025. India currently has around 4.9 GW of installed small hydro capacity, representing only a fraction of the estimated 21.13GW [86] potential. Key challenges include high capital cost per MW compared to large hydro, grid connectivity issues[87], and lack of technical expertise for plant maintenance and operations are scarce.

Large hydropower, which generates energy through water falling from a height, plays a dominating role in the India energy transition. Hydro power provides immense benefits, such as clean energy and acts as a base and peak load support and support in quick ramp-up and ramp-down rates, black start, and operating reserve capability[88]. Key policies governing large hydro include hydro power purchase obligation and national hydro power policy[89]. India has installed about 46 GW[90] and has the fifth largest global hydropower installed capacity. The hydropower capacity in India is expected to reach 70 GW by 2030 and its potential is estimated at 145GW at 60% plant load factor[91]. However, India's hydropower sector has increased marginally by a mere 2% annually, in the last decade[92]. This decline is due to the various challenges encountered during hydropower development including high upfront costs, environmental and social concerns, geological constraints, and remote and undeveloped locations.

Biomass energy in India has emerged as a crucial component of the renewable energy portfolio. Governed by the national policy on biofuels (Biomass programme)[93,94,95], the sector aims to harness organic materials for sustainable energy production. India currently has installed capacity of over 10.5 GW of biomass power (including Bagasse Cogeneration)[96,97]. However, India's Biomass power sector has increased marginally by a mere 2% annually, in the last 5 years[98]. The likely installed projected capacity by the end of 2029-30 projected to be 14.5 GW of biomass power

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80 What is India's Residential Rooftop Solar Potential? CEEW Study

81 India: installed capacity of rooftop solar by sector 2023 | Statista

82 PowerPoint Presentation (ceew.in)

83 Why the rooftop sector is lagging in India's race for solar energy

84 India's residential rooftop solar capacity to increase by ~60% in FY2023 | IEEFA

85 CERC Notifies ISTS Charges Waiver for Renewable Energy Projects (mercomindia.com)

86 An overview of small hydro power development in India (aimspress.com)

87 Study of different Issues and challenges of Small Hydro Power Plants Operation

88 Role of Hydropower in India's Energy Transition | ISEP (sais-isep.org)

89 Policy on Hydro Power Development | Government of India | Ministry of Power (powermin.gov.in)

90 Power Sector at a Glance ALL INDIA | Government of India | Ministry of Power (powermin.gov.in)

91 India targets 70GW hydropower capacity by 2030 | Asian Power (asian-power.com)

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95 Press Information Bureau (pib.gov.in)

96 Power Sector at a Glance ALL INDIA | Government of India | Ministry of Power (powermin.gov.in)

97 pib.gov.in/PressReleaseIframePage.aspx?PRID=1911482

98 India: bioenergy capacity 2022 | Statista

(including Bagasse Cogeneration)[99]. High upfront costs and biomass aggregation and round the clock availability pose a high challenge for project developers. Bagasse, a byproduct of sugarcane processing, can play a pivotal role in India's renewable energy landscape. Polices like the sustainable sugarcane initiative govern the utilization of bagasse for energy production[100]. India currently has installed capacity of over 10.5 GW of biomass power (including Bagasse Cogeneration)[101,102,103]. The likely installed projected capacity by the end of 2029-30 projected is 14.5 GW of biomass power (including Bagasse Cogeneration)[104]. However, sector faces significant challenges in ensuring farmer's profitability, mill profitability and availability of sugar to consumers at affordable price with cyclic nature of sugarcane production and sugar price[105]. Sugar cane production generates ~100 million tonnes annually of bagasse, a major agriculture residue, contributing a major proportion of the waste generated by the sugar industry. This waste does not just present a challenge, but also creates an opportunity where investment in proper waste resource management can yield to the generation and sale of surplus heat and power leading to additional revenue[106].

Biogas, produced by the anaerobic digestion of organic waste such as cattle dung and municipal solid waste, offers clean energy source for rural India. Governed by policies such as National Biogas and Organic Manure Programme, Biogas Programme under the National Bioenergy Programme and Sustainable alternative towards affordable transportation (SATAT)[107,108,109]. The biogas energy capacity in India is approximately 14 MW as on December 2022. Though the estimated biogas potential in India is approximately 17,000 MW[110]. Feedstock availability and quality, supply chain and awareness level are some of the key barriers faced in biogas system in India[111].

Waste-to-energy (WtE), also known as energy-from-waste, is the process where energy (typically heat and electricity) is generated using waste as a fuel source. Converting waste into energy holds huge potential for tackling India's burgeoning waste crisis and generating renewable energy. Key policies governing this sector include policy on Waste Management[112,113],Waste to Energy Programme under the National Bioenergy Programme[114]. Despite its promise, only a tiny 554MW of Waste-to-energy has been installed until now[115]. However, India can generate 65 GW energy annually from waste by 2030[116]. Barriers faced by Waste-to energy include lack of awareness, public perception on environmental issues[117]. As in the case of biogas, proper technologies/ strategies for waste segregation, collection and transportation are not in place in cities and towns, which remains as one of the main reasons for the slow growth of the waste-to-energy sector in India.[118]

Battery Energy storge systems (BESS) are gaining prominence in India's energy landscape, offering crucial support for grid stability and renewable energy integration. Key policies driving this emerging sector include National

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101 Power Sector at a Glance ALL INDIA | Government of India | Ministry of Power (powermin.gov.in)
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103 Fuelling India's future with bioenergy (pwc.in)
104 Optimal_mix_report__2029_30_Version_2.0__For_Uploading.pdf (cea.nic.in)
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106 Sugarcane bagasse based biorefineries in India: potential and challenges
107 New National Biogas and Organic Manure Programme (NNBOMP) | India Science, Technology & Innovation - ISTI Portal (indiascienceandtechnology.gov.in)
108 SATAT Scheme (Sustainable Alternative Towards Affordable Transportation)| National Portal of India
109 Press Information Bureau (pib.gov.in)
110 Why the biogas sector presents a compelling case for growth of clean energy and startups, ET EnergyWorld (indiatimes.com)
111 Barriers to biogas dissemination in India: A review
112 Microsoft Word - SWMlikelyimplications.doc (pib.gov.in)
113 Presentation for Oversight Committee on Bhopal Gas Tragedy's Remediation and Environment Related Issues (mospi.gov.in)
114 Press Information Bureau (pib.gov.in)
115 Power Sector at a Glance ALL INDIA | Government of India | Ministry of Power (powermin.gov.in)
116 India: India can generate 65 GW energy annually from waste, say experts - The Economic Times (indiatimes.com)
117 Key Challenges in the Implementation of Waste-to-Energy (bioenergyconsult.com)
118 Barriers to biogas dissemination in India: A review

framework for promoting energy storage systems[119], energy storage obligation[120], national tariff policy, National Programme on Advanced Chemistry Cell (ACC) Battery Storage and Viability Gap Funding Scheme[121]. As of March 2023, the installed capacity of battery energy storage system (BESS) in India was around 40 MWh. By 2030, the energy storage capacity required is likely to be around 41.65GW with storage of more than 208 GWh[122,123]. After Solar Energy Corporation of India (SECI) launched 1000MWh battery storage tender, the energy storage sector is appearing to be advancing rapidly. SECI's tender was followed by 500MWh battery storage tender by National Thermal Power Corporation (NTPC). Around 2.5 GWh of such tenders are already awarded. Request for Proposal (RfP) has been released for 4.5 GWh of such tenders. Further announcements have been made for 29 GWh of storage projects. Some of the key Bottlenecks with deployment of BESS in India are high capital cost, limited domestic manufacturing, supply chain constraint, unavailability of high tariffs for BESS integrated variable renewable energy[124], technological challenges (long duration energy storage solution > 4hrs), grid integration challenges, lack of standardization and skilled workforce shortage.

Pumped storage project (PSP) offers a mature and reliable technology for storing large amount of electricity, crucial for integrating and managing renewable energy in India. The technology has received recognition on account of its ability to store energy for long hours. Closed loop pumped hydro storage is being considered as an energy storage option with lesser environmental impact as as they are not connected to existing river systems. In addition, they do not need to be located near an existing river and can therefore be located where needed to support the grid. Policy framework for this area include guidelines to promote development of Pump Storage Projects (PSP)[125,126] and Guidelines for Formulation of Detailed Project Reports for Pumped Storage Schemes. Notification issued by Ministry of Environment, Forest and Climate Change (MoEFCC) in May 2023 has amended their earlier notification of 2006 regarding requirement of prior Environmental Clearances for Pump Storage Projects. PSP developers may interact with the MoEFCC for clarifying issues related to Environmental Clearances required for developing PSPs. Multiple private sector players such as Adani Green Energy, Greenko, JSW Energy, Tata Power have already entered the sector and are set to develop multi megawatt scale pumped hydro storage projects. The installed capacity of PSP as on December 2023 is about 4.76 GW in the country. As per the CEA estimates on-river pumped storage potential is 103 GW in India[127]. By 2030, the energy storage capacity required from PSP is likely to be around 18.98GW with storage of more than 128 GWh[128]. Key challenges in this sector are long gestation period, high initial cost, requires highly meticulous and judicious planning and design, geological uncertainties, land acquisition issues and transmission infrastructure[129,130].

Fuel cells convert chemical energy into electricity through an electrochemical process. Fuels cells are gaining attention in India as a promising technology for clean energy production and have various potential applications including transportation and stationary power generation. Key policy governing this sector include the National Green Hydrogen Mission[131]. Despite its potential, the fuel cell sector in India remains in nascent stage currently. However, it is likely to reach a green hydrogen production capacity of 160 GW by 2030, according to a Niti Aayog report[132]. Key hurdles that hinder its wider potential are: lack of technical expertise, high upfront manufacturing cost, technological challenges, lack of fuel cell infrastructure, and perceived safety concerns[133].

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131 National Green Hydrogen Mission | Ministry of New and Renewable Energy | India (mnre.gov.in)

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133 Sustainability | Free Full-Text | Hydrogen Fuel Cell Vehicles: Opportunities and Challenges (mdpi.com)

Green Hydrogen: The growing demand for Green Hydrogen stems from its potential to decarbonize various sectors, including transportation, shipping, and steel production. By substituting traditional fossil fuels, Green Hydrogen can significantly reduce greenhouse gas emissions in transportation and industrial processes like ammonia and methanol production. Moreover, its versatility extends to serving as a backup energy source for renewable energy plants, ensuring a constant and reliable energy supply. Recognizing its pivotal role, India has initiated the National Green Hydrogen Mission [134]with an initial allocation of Rs. 19,744 crores (USD XY billion) and a target of achieving a production capacity of 5 million metric tons of Green Hydrogen annually by 2030. Several states in India, including Maharashtra, Andhra Pradesh, Gujarat, Uttar Pradesh, and Rajasthan, have taken significant steps towards promoting green hydrogen through the formulation of policies and incentive frameworks.

Moreover, India is positioning itself as a major global exporter of green hydrogen, with announcements totaling approximately 30 million metric tons per annum (MMTPA) of capacity. This ambitious target underscores India's commitment to becoming a key player in the international green hydrogen market. Additionally, plans to ramp up electrolyzer manufacturing capacity to 15 gigawatts (GW) per year demonstrate the country's intent to develop a robust domestic supply chain for green hydrogen technologies. Furthermore, India is strategizing to establish hydrogen hubs to serve as focal points for green hydrogen production, distribution, and utilization. These hubs are envisioned as integrated ecosystems that bring together stakeholders from across the value chain to drive innovation and scale up green hydrogen deployment. Moreover, the Ministry of Ports, Shipping, and Waterways (MoPSW) has identified three ports[135] in India for setting up export-led green hydrogen production hubs.

[134] Hydrogen Overview | Ministry of New and Renewable Energy | India (mnre.gov.in)

[135] Press Information Bureau (pib.gov.in)

Appendix D: Independent Technical Review

Appendix E: Stakeholder Consultations

A joint mission led by the Asian Development Bank (ADB) along with the World Bank, IFC for the proposed CIF REI program was fielded from March 5th to March 20th, 2024. During the consultation mission, the mission held meetings with the Joint secretaries of the Ministry of New & Renewable Energy (MNRE) responsible for energy storage, solar and wind, Energy Advisor of Niti Aayog, Chairperson of the Central Electricity Authority (CEA) and other development partners and thinktanks. The discussions were held to understand the priority areas/projects linked to the theme of 'Renewable Energy Integration'. Below is the summary of key suggestions that emerged during the consultation:

1. Deployment of energy storage systems was among the top priorities of most stakeholders. This includes exploring multiple storage options like Pumped Hydro Storage (PSP) and Battery Energy Storage Systems (BESS) to enable higher RE absorption in the grid. Such deployment could be considered across RE rich states including Rajasthan, Karnataka, Uttar Pradesh, Maharashtra, Gujarat and Kerala due to high RE penetration. Considering the fund size and timelines, focus can be on distributed storage deployment including technical assistance and capacity building.

2. Infrastructure strengthening for enhancing RE integration emerged as a next priority. This includes various aspects including – (i) transmission strengthening (Green corridor Phase 3); (ii) state level transmission strengthening programs; (iii) strengthening of port and evacuation infrastructure linked to upcoming Off-shore wind projects; and (iv) strengthening transmission linkages (through undersea cables) for Greening the islands.

3. Third broad priority was around Power market reforms that included range of suggestion including support for advanced forecasting tools and successful third-party forecasting models for DISCOMs and REMCs; innovative methods for uptake of RE such as Contracts for Difference (CFD); introduction of new concepts like Virtual Power Plants (VPP), Blockchain-based P2P solar rooftop systems, and RE-based EV charging.

In addition to the above, the consultation also covered discussions with various development partners and think tanks to understand their ongoing programs, experiences, insights, and strategic perspectives of these entities for renewable energy integration. The objective was to leverage the existing knowledge and success stories and align with and complement ongoing and planned initiatives aimed at supporting renewable energy integration in India. These meetings have been instrumental in shaping the strategic direction of the REI program, ensuring that the interventions proposed are in sync with the on-ground realities and needs of India's renewable energy sector.

List of Mission Team Members		
Sr. No.	**Name**	**Organisation**
1.	Jiwan Sharma Acharya	ADB
2.	Karan Chouksey	
3.	Jigar Arvindbhai Bhatt	
4.	Keshari Nandan Agrawal	
5.	Malavika Pillai	IFC
6.	Malavika Kumar	
7.	Andrey Shlyakhtenko	
8.	Poorna Bhattacharjee	
9.	Rajesh Kumar Miglani	
10.	Mani Khurana	World Bank
11.	Surabhi Goyal	
Public Sector		
12.	Dinesh Jagdale	MNRE
13.	Lalit Bohra	
14.	Rajnath Ram	Niti Aayog
15.	Ghanshyam Prasad	CEA
Other Development Partners and Think Tanks		

List of Mission Team Members		
Sr. No.	Name	Organisation
16.	Ramana Reddy	KfW
17.	Rukmini Parthasarthy	
18.	Harsha Meenawat	WRI
19.	Tirthankar Mandal	
20.	Jyoti Parekh	IRADe
21.	Shirish S Garud	TERI
22.	Saswat Sourav Panda	The Climate Group
23.	Saptak Ghosh	CSTEP
24.	Hari Krishna	
25.	Amit Kumar Singh Parihar	Shakti Sustainable Energy Foundation
26.	Navaro Hernandez	Embassy of Spain

Appendix F: Absorptive Capacity

The REI program will provide concessional financing to support catalyzing the scale-up of clean energy transition in India in line with the country's NDC, its 2070 Net Zero goal and in context of the country's broader support for energy transition in a sustainable and socially just manner. There is considerable literature on energy transition, including how to ease the transition from primarily "brown" to "green" assets.[136] The focus of this IP is primarily to accelerate deployment of variable renewable energy resources and their integration into the national grid. This section addresses the REI requirement for an analysis of the absorptive capacity of the host country for REI and related investments.

Factors relevant to REI implementation

India's absorptive capacity can be assessed against factors relevant to the country's circumstances. First, an assessment of the country's demand for REI resources which is measured by the country's capacity to absorb the requested USD 70 million REI funding for holistic energy transition. Second, an assessment of the stability of the country's economic indicators measured firstly by the ratio of public investments to GDP and secondly, by the International Monetary Fund (IMF) framework for evaluating the sustainability of public debt. Third, an assessment of complementary factors related to the power system such as overall rates of energy access, the capacity of the country's electricity system to absorb the investments in context of the country's overall electricity demand-supply balance and the share of renewable energy in the country's generation mix, among others.

Demand for REI resources

Demand for capital is a major driver of the absorption of overall investment in the country. Overall expected investment in renewable energy sector of India by 2030 is USD $225-250 billion.[137] The requested USD 70 million in REI financing represents only a meagre fraction of the total expected demand for renewables, leaving significant room for additional funding and investment, including for other investments in energy transition. Not only can the REI investment be adequately absorbed, but it is important for leveraging additional investments that will comprise some of the required investment in energy transition costs over the 2030 time-frame. Transmission and distribution investments to support new generation will require an additional USD 260 billion in investment and are not included in this ratio. It is also noted that the success of India's planned emphasis on electric mobility as a major measure to reduce dependence on fossil fuels and reduce GHG emissions rests on further electrification of the sector based on renewables. India's economy has rebounded strongly since the threat from the COVID-19 pandemic faded, with economic growth in 2024 expected to be 6.1 per cent,[138]which will create even more room to absorb investments. Finally, the war in Ukraine has ushered in the possibility of higher commodity prices and inflation, which may lead to a further rise in demand for capital in the short term.

Stability of country economic indicators

There are several indicators of economic stability. This IP uses two indicators, first, the ratio of public investments to GDP and second, the IMF framework for evaluating the sustainability of public debt.

(a) Adequacy of the scale of CIF investments compared to GDP

The IMF India 2023 Article 4 Consultation Report[139] recommends that India should focus on developing structural policies to invigorate inclusive and green growth. It also stated that "Continuing investment in infrastructure, strengthening governance, and enhancing a sound business environment are critical." Finally, the report also urged

136 See, for example, a recent IMF Working Paper 2023/011 https://www.imf.org/en/Publications/WP/Issues/2023/01/20/A-Market-for-Brown-Assets-To-Make-Finance-Green-528413

137 renewable energy: India needs $225-250 bn investment to meet its 2030 renewable energy target: Moody's - The Economic Times (indiatimes.com)

138 India: India to remain fastest-growing major economy in 2024 - The Economic Times (indiatimes.com)

139 https://www.elibrary.imf.org/view/journals/002/2023/426/002.2023.issue-426-en.xml

that increased infrastructure investments and transition to a carbon-neutral green economy could also mitigate the impact of natural disasters and increase resilience.

India has been investing in its historically inadequate and under-invested infrastructure sector in order to promote economic growth and opportunity. It has been empirically demonstrated that when public investment exceeds 10 percent of GDP, the productivity of public investment projects decreases.￼. From historically low previous levels, overall infrastructure investment (including spending on digital, urban infrastructure, transportation and water supply) is projected to grow at a CAGR of 11.4 per cent between FY 21 and FY 26 and overall infrastructure investment in the 11th Five Year Plan was 9 per cent, compared to 5 per cent in the 10th plan. [140] For financial year 2021, the proportion of infrastructure investments to the gross domestic product (GDP) was estimated to be nearly four percent.[141] After years of stable ratios between four and five percent, it lowered since 2019.[141] Building on the massive tripling of the capital expenditure outlay in the past 4 years resulting in huge multiplier impact on economic growth and employment creation, the outlay for the next year (FY 2024-2025) is being increased by 11.1 per cent to INR 11,11,111 crore.[142] This would be 3.4 per cent of the GDP. Although infrastructure investments are expected to increase and assuming the trend does not abruptly reverse, the requested USD 70 million REI investment is a fraction of India's GDP of USD 3.73 trillion is small and can be absorbed easily without compromising investment efficiency.

Sustainability of Public Debt

With public debt of USD 1,459 billion in FY 2022,[143] India's public debt to GDP ratio at the general government level has barely increased from 81% in 2005-06 to 84% in 2021-22 and back to 81% in 2022-23.[139] IMF states that given the negative r-g (interest rate-growth) differential and the secularly declining primary deficit, the debt-GDP ratio cannot exceed 100%. Public debt in India is primarily contracted at fixed interest rates, with floating internal debt constituting only 1.7 per cent of GDP in end-March 2021. The debt portfolio is, therefore, insulated from interest rate volatility, which also provides stability to interest payments.[143]

India's external debt to GDP ratio is lower than its major peers, except China, and, in terms of reserve cover of total external debt, India fares better than Brazil, Malaysia, Mexico, Indonesia, South Africa, Argentina, and Turkey. The IMF estimated that India's external debt was USD 624.3 billion in 2022-23, which was 18.4 per cent of GDP. Short-term debt in 2022-23 was USD 8.1 billion and the country's ratio of gross reserves to short-term debt was 2.1. External debt is projected to increase to USD 681.1 in 2023-24 and to USD 748.3 billion in 2024-25, accounting for 18.7 and 18.5 per cent of projected GDP in those years respectively, while the ratio of gross reserves to short-term debt is expected to be 2.1 for both the years.[139] India's external debt liabilities are low compared with those of its peers, and short-term rollover risks are limited.[139]

The IMF 2023 India Consultation Report assessed that risks to debt sustainability are moderated by India's debt composition, comprising of long-dated, fixed rate, local currency denominated securities held by residents. Foreign currency denominated public debt is low and largely on a concessional basis. The reliance on financing from domestic banks can crowd out private investment. Long-term debt sustainability risks are high, stemming from investments required to address the challenges of climate change mitigation and adaptation. Gross financing needs are estimated at 15 percent of GDP in the medium term. The bulk of financing needs is expected to continue to be met by the issuance of medium and long-term debt denominated in domestic currency and held by residents. Specifically, the distribution of issuances across different maturities follow those observed in FY2022-23. The inclusion of India in global bond indices should provide India with access to a wider pool of investors, and likely to increase nonresident ownership in India's bond market. While acknowledging that India's debt composition helps mitigate debt sustainability risks, the executive board assessment recommends that ambitious medium-term consolidation efforts are required given elevated public debt levels and contingent liability risks.

[140] https://www.financialexpress.com/economy/how-increased-capital-spending-in-the-infrastructure-sector-will-spur-growth-of-the-indian-economy/2806613/
[141] https://www.statista.com/statistics/1232531/india-infrastructure-spending-to-gdp-ratio/

[142] Interim Budget 2024-2025, GoI
[143] Economic survey 2022-23

The IMF 2023 India Consultation Report recommends that policy priorities should focus on replenishing fiscal buffers, securing price stability, maintaining financial stability, and accelerating inclusive growth through comprehensive structural reforms while preserving debt sustainability. Looking forward, India's elevated public debt calls for additional revenue and expenditure measures, such as further GST and subsidy reforms, while continuing to prioritize public investment and targeted support for the vulnerable.

REI support including CIF concessional loans is an important catalyst for the clean energy transition of the sector that continues to fuel the country's economic growth and supports the delivery of improved health and livelihoods. In the long-term, deeper penetration of renewable energy across sectors will help improve debt sustainability by achieving universal energy access and thus enabling economic activities across the country. CIF concessional financing instruments are an attractive available option for the needed clean energy transition for its affordable lending rate and long maturities, thereby minimizing the additional burden on the already severe debt distress of the country. Without CIF financing, the country and the SOEs would become more indebted, and or fall into a slump, thereby not only jeopardizing economic growth, but also raising doubts about the sustainability of the long-term transformation to a lower-carbon future.

Complementary factors relevant to power system

Renewable Energy (RE) has played a pivotal role in India's transition to a power surplus country. The changing electricity price dynamics under the marginal but rising influence of REs can contribute to a greener and low-cost economy going ahead. Estimates suggest that even without the policy support that the sector enjoys, it can be commercially viable. There are evidences that the lower generation cost of RE sources are exerting downward pressure in the spot and wholesale markets for electricity though the same is yet to be witnessed in the retail market for electricity. Competitive tariff structure and targeted steps to minimise transmission and distribution losses and also limiting cross-subsidisation could promote efficient price discovery and attract higher RE investment.

A clean, affordable and sustainable energy supply should drive future growth. Besides environmental benefits, countries that manage to transition effectively to RE sources will be home to competitive energy solutions and making firms more resilient to energy shocks and weather disruptions.[144]

[144] Reserve Bank of India