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# Energy Storage: Connecting India to Clean Power on Demand

Storage Systems key to a smarter national power grid, dispatching renewable energy where and when needed

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# Key Findings

**Energy storage systems (ESS) will be the major disruptor in India's power market in the 2020s.**

**ESS will attract the highest investment of all emerging sectors as renewable energy's penetration of the electricity grid ramps up.**

**Pumped hydro is dominating the ESS market, accounting for more than half of grid-scale tender capacity awarded in India in 2023.**

**New demand-driven renewable energy (FDRE) tenders will help reduce India's reliance on coal and other conventional power sources.**

# Executive Summary

**The rapid expansion of renewable energy has both highlighted its deficiencies, such as intermittent supply, and the pressing need for grid-scale energy storage systems (ESS) to facilitate India's transition away from fossil fuel-based power generation. To this end, a new demand-driven capacity tender model for firm and dispatchable renewable energy (FDRE) storage is poised to spark a boom in ESS investment and capacity additions this decade. FDRE is already being embraced by power project developers with more than 8 gigawatts (GW) of FDRE tenders issued in 2023 alone. As the sector expands and matures along with renewable energy, such as pumped hydro and green hydrogen, ESS will be crucial for India to meet its needs of at least 500GW of non-fossil fuel capacity by 2030, delivering clean power reliably when and where needed. Grid-scale ESS also promises to provide energy cheaper than traditional fossil fuel-based generation as costs fall over the lengthy project tenures on offer.**

Globally, power systems are undergoing a pivotal phase of development. The exponential surge in renewable energy installations within the past decade has exposed the grid infrastructure to increased risks arising from the variable nature of renewable energy, especially from solar and wind.

Since solar and wind power supply fluctuates, energy storage systems (ESS) play a crucial role in smoothening out this intermittency and enabling a continuous supply of energy when needed. Thus, for sustainable renewable energy addition, concurrent growth of ESS capacity is imperative.

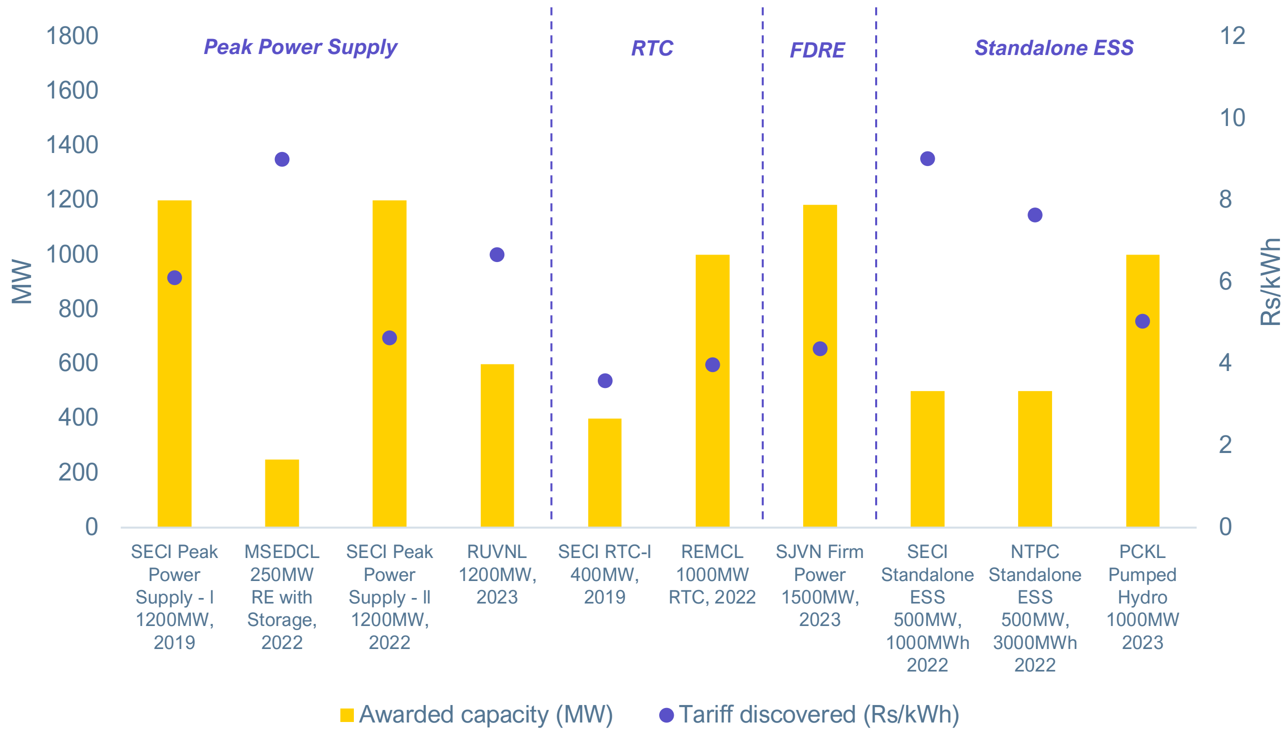
Battery-based ESS (BESS) and pumped hydro storage (PHS) are the most widespread and commercially viable means for implementing energy storage solutions.

The Central Electricity Authority's (CEA) latest optimal generation mix report indicates that India will need at least 41.7 gigawatt (GW)/208.3 gigawatt-hour (GWh) of BESS and 18.9GW of PHS in the fiscal year (FY) 2029-30.

Akin to the growth of renewable energy, large grid-scale tendering will play a crucial role in developing the ESS market in India. As of November 2023, more than 8GW of ESS tenders have been awarded in India, with more than 60% of this capacity allocated in 2023 alone.

The tendering agencies, led by the Solar Energy Corporation of India (SECI), have developed several tender designs over the years to find the ideal model for India. It includes solar + BESS, peak power supply, round-the-clock (RTC), standalone ESS, and firm and dispatchable renewable energy (FDRE). These tenders, first issued in 2023, are demand profile-driven to ensure firmness and dispatchability of renewable energy and create a win-win scenario for power developers and offtakers.

**Figure 1: Auction Results of Major Grid-scale ESS Tenders in India**




*Source: JMK Research*

*Note: 1. For peak power supply tenders, the peak tariff is shown. The off-peak peak tariff for SECI Peak Power Supply-I is Rs2.88/kWh. For MSEDCL 250MW, the off-peak tariff is Rs2.42/kWh. There is no provision for off-peak tariff in SECI Peak Power Supply-II and Rajasthan Rajya Vidyut Utpadan Nigam Ltd. (RUVNL) tenders.*
*2. For the RTC-1 Tender, the tariff shown is the levelised tariff over the project tenure. The bidding tariff was Rs2.9/kWh vis-à-vis the first year of the Power Purchase Agreement (PPA).*
*3. SJVN 1,500MW FDRE tender, whose tender conditions are similar to RTC, has an annual minimum capacity utilisation factor (CUF) requirement of 40%.*
*4. For Standalone ESS, the equivalent Rs/kWh tariff is shown. It only includes ESS per unit cost. It does not include the cost of energy for charging the ESS.*

### Key Insights from Auction Results of Major ESS Tenders

- The discovered tariff in RTC tenders is lower than any peak power supply tenders, even though RTC tenders ensure higher availability and supply of renewable energy. This trend is due to the higher utilisation rate of ESS in the case of RTC tenders, leading to lower levellised tariff rates.
- The first FDRE tender to conclude was SJVN for 1,500 megawatts (MW) in November 2023. The tariff discovered was Rs4.38(US¢5.3)/kilowatt-hour (kWh), marginally higher than the RTC tenders.
  For other FDRE tenders, with stricter power-supply requirements in terms of demand

fulfilment ratio, at a minimum of 90% of the demand profile monthly, the tariffs are expected to be higher, about Rs5(US¢6)/kWh.

- While the standalone storage tariff is lower than the other ESS tenders, these projects offer remarkable flexibility and provide value to the system in terms of the different applications offered, thus remaining competitive with other sources of flexibility.
- An important factor influencing the tariff of standalone ESS is the project tenure. For the tenders from SECI, NTPC and Power Company of Karnataka Limited (PCKL), the tenures are 12, 25 and 40 years, respectively. Falling ESS costs (especially for BESS) and sustained cash flow over a longer duration enable ESS developers to quote lower tariffs.

Despite the surge in ESS uptake in recent years, challenges remain. These include high initial capital expenditure (CAPEX), a longer gestation period of ESS projects (especially for PHS projects), suboptimal transmission and distribution (T&D) infrastructure, and a dearth of domestic manufacturing in ESS, highlighting potential supply chain risks.

With the increasing penetration of renewable energy, ESS will be the central disrupting technology in the 2020s power market. This decade, the ESS market will attract the highest investment of all emerging renewable energy sectors, concurrent with the increasing penetration of renewable energy in the electricity grid. With FDRE, India has found an ideal tender design that can be modelled according to the offtaker demand profile. Market stakeholders foresee that FDRE can match the power quality of thermal, potentially replacing it in the longer term. FDRE tenders will ultimately be crucial to reducing dependence on coal and other conventional power sources. Another key driver for the upsurge in ESS capacity will be the cost decline.

ESS trading on power markets is also likely to increase in coming years, driven by entities aiming to meet their energy storage obligation (ESO) targets and storage developers looking for avenues to sell the excess power from soon-to-be-commissioned grid-scale ESS projects. In addition to ESO, the government has issued other policy initiatives to support the growth of ESS. These include the viability gap funding (VGF) scheme for BESS projects, the national energy storage policy and the national pumped hydro policy. The national transmission plan to 2030,[1] issued by the Ministry of Power in December 2022, identifies ESS as a key component of upcoming power system development.

In terms of ESS technology, in the near term, large grid-scale ESS will favour PHS, mainly due to its levellised cost of energy (LCOE). However, with the likely decline in battery prices, BESS may overtake PHS as the most financially viable option to implement grid-scale ESS. In the long term, with green hydrogen-based ESS possibly attaining parity with PHS and BESS, green hydrogen may also become the dominant grid-scale ESS technology.

[1] Ministry of Power. Transmission system for integration of over 500 GW RE capacity by 2030. December 2022.

# Energy Storage Market Landscape in India

An Energy Storage System (ESS) is any technology solution designed to capture energy at a particular time, store it and make it available to the offtaker for later use. Battery ESS (BESS) and pumped hydro storage (PHS) are the most widespread and commercially viable means of energy storage. Although technically proven, the other ESS technologies, such as gravity storage, thermal storage and hydrogen storage, have yet to demonstrate their commercial viability.

Traditionally, ESS has been used worldwide as ancillary support to the grid, aiding in frequency regulation and grid stability. However, given the rise in variable renewable energy (VRE) penetration into the grid over the past decade, ESS is swiftly gaining prominence for its energy-shifting and smoothening applications. Since solar and wind power supply fluctuates, ESS plays a crucial role in "smoothing out" this intermittency and enabling a continuous supply of energy when needed.

India aims to augment its VRE installed capacity (i.e., solar and wind) from 117 gigawatts (GW) in November 2023 to more than 392GW by 2030.[2] This surge in VRE penetration needs to be supported by a simultaneous growth in ESS capacity. According to the Central Electricity Authority (CEA) optimal generation mix report, India will need at least 41.7GW/208.3 gigawatt-hour (GWh) of BESS and 18.9GW of PHS in the fiscal year (FY) 2029-30.[3]

**Figure 2: Indian ESS Market Snapshot**

| Installed Capacity | Target by 2030 | 8GW | 96GWh |
|---|---|---|---|
| ***BESS**: 33+MW/ 37MWh* | ***BESS**: 41.7GW/ 208GWh* | *ESS tenders awarded (as of Nov 2023)* | *BESS manufacturing capacity in pipeline* |
| ***PHS**: 4.7GW* | ***PHS**: 18.9GW* | | |

*Sources: CEA, CII, Tendering Authorities, JMK Research*
*Note: All installed capacity values are as of March 2023.*

## Evolution in Grid-scale ESS Tender Design

Akin to the rise of renewables, large-scale tendering will play a crucial role in the growth of the ESS market in India. Tendering authorities, led by the Solar Energy Corporation of India (SECI), are

[2] CEA. Report on Optimal Generation Capacity Mix for 2029-30. Page 23 April 2023.
[3] Ibid.

continuously figuring out ideal tender options for different scenarios suitable for India's ESS environment. Over the years, grid-scale ESS tendering has had various iterations and tender types.

Initially, around 2018, all grid-scale ESS tenders were small to mid-sized solar + BESS, wherein the developer's scope was primarily engineering, procurement and construction (EPC). In these tenders, BESS was a secondary add-on component rather than the focus of the solution. Since then, the focus has shifted to GW-scale, application-specific ESS tenders. Most of these new-age ESS tenders, such as peak power supply, round the clock (RTC), standalone ESS and now firm and dispatchable renewable energy (FDRE), are technology and location agnostic, flexible in size, inter-state transmission system (ISTS) connected, and cater to myriad specific applications. Table 1 shows a detailed classification of grid-scale ESS tenders in India. More information on this evolution and classification up to standalone ESS can also be found in the IEEFA-JMK report titled *Evolution of Grid-Scale Energy Storage System Tenders in India*, published in July 2022.[4]

**Table 1: Evolution of Grid-scale ESS Tenders in India**

| | Solar + BESS | Peak Power Supply | RTC | Standalone ESS | FDRE |
|---|---|---|---|---|---|
| **Description** | Small-scale tenders with mandatory fixed solar and BESS components | Tenders designed to meet the power requirements of the offtaker during peak hours through a combination of renewable energy and ESS | Tenders designed to ensure round-the-clock availability of power to the offtaker | ESS facility is accorded to the offtaker "on demand", treats "ESS as-a-service." | Demand profile following ESS tenders ensuring firmness and dispatchability of renewable energy power |
| **First tender issuance date** | March 2018 | August 2019 | October 2019 | January 2022 | June 2023 |
| **Largest Tender** | SECI 100MW/ 120MWh | SECI Peak Power Supply 1200MW | REMCL 1000MW | NTPC 2000MW Pumped Hydro | NTPC 3,000MW |
| **Status and outlook** | Off-grid and behind-the-meter applications of diesel abatement in remote locations such as Andaman and Leh will be the main drivers of this segment. | This tender type will play a significant role in utilities aiming to meet demand in peak hours. | FDRE, with enhanced power output quality due to demand following, will likely replace RTC tenders. Hence, only a few RTC tenders will likely be issued in the future. | This tender type is gaining prominence in grid support applications. | The latest evolution in the ESS tender design. Going ahead, FDRE tenders might be the most dominant ESS tender type. |

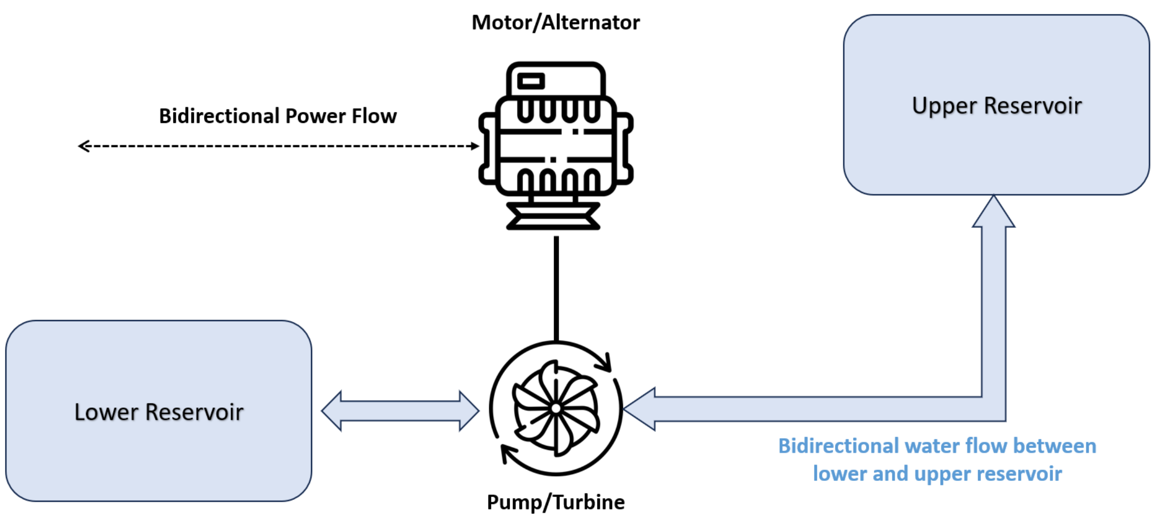
*Sources: Tendering Authorities, JMK Research*

[4] IEEFA-JMK Research. Evolution of Grid-Scale Energy Storage System Tenders in India. 4 July 2022.

Over the past few years, grid-scale ESS tendering in India has had unprecedented growth. Until 2021, only 1,794 megawatts (MW) of grid-scale ESS capacity was awarded, excluding cancelled or dormant tenders. In just two years, tender issuance for grid-scale ESS in India shot up to about 35GW in 2023 alone.

Pumped hydro storage (PHS), often described as a "water battery", is a gravity-based ESS technology. It consists of two water reservoirs situated at different elevations with a turbine and a pump between them. The pump transfers water from the lower reservoir to the upper one in scenarios of excess electricity. The potential energy thus stored in the water of the upper reservoir is converted to electricity by the flow back to the lower reservoir through a turbine, when required. PHS accounted for most of the grid-scale ESS tender issuance capacity (about 56%) in 2023. Madhya Pradesh issued the largest-ever ESS tender in June 2023 for 16.4GW PHS capacity spread across 14 sites within the state.[5]

**Figure 3: Pumped Hydro Storage Flowchart**

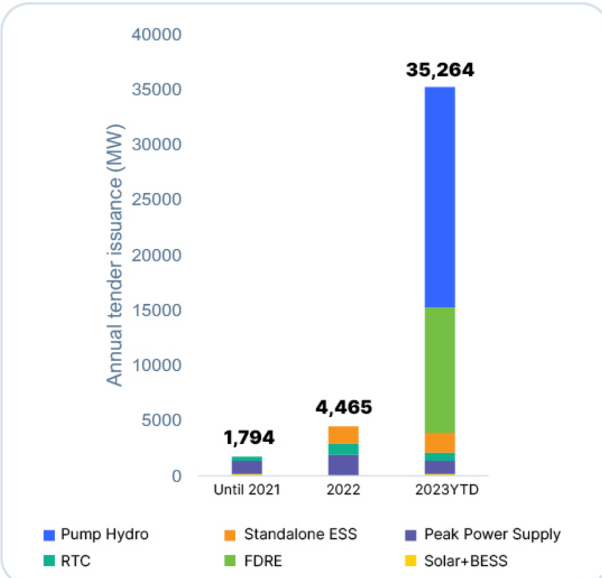


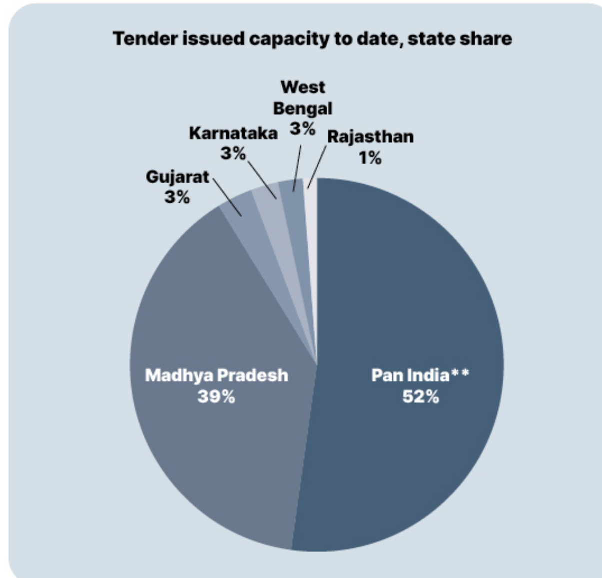

*Source: JMK Research*

Most new-age, grid-scale ESS tenders (such as peak power supply, RTC and FDRE) are flexible regarding size and location. The tenders allow the projects to be set up pan-India along with Inter-State Transmission System (ISTS) connectivity to facilitate power delivery. About 52% of the grid-scale ESS tenders issued to date are under the pan-India category. With the rising flexibility in tender conditions, this share will likely grow in the coming years.

[5] RUMSL. Allotment of Pumped Hydro Storage Sites in Madhya Pradesh. June 2023.

**Figure 4: ESS Tender Issuance in India, Yearly Trends and Regional Share**




*Source: JMK Research*

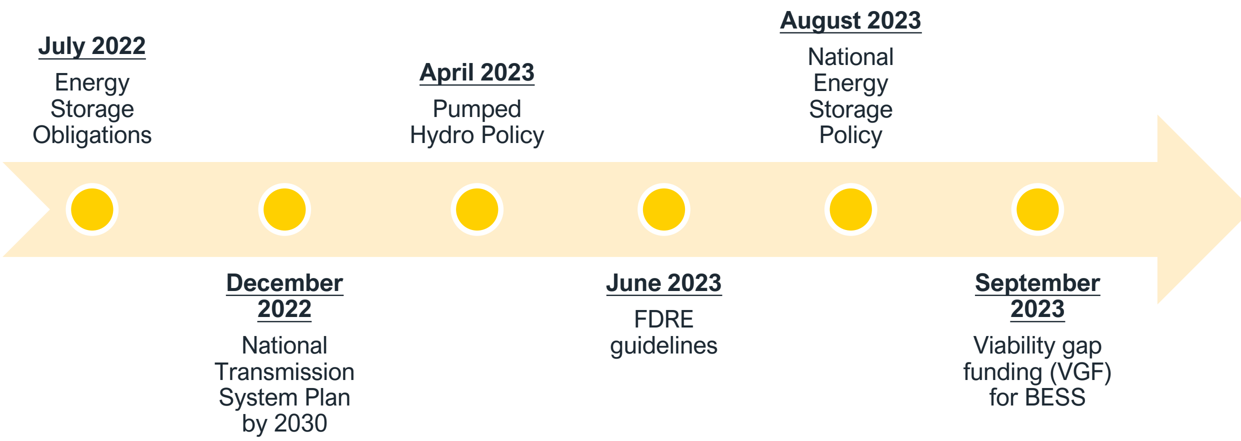
*Note: The above compilation does not include cancelled or dormant tenders*
**YTD = November 2023*
***Projects can be set up anywhere across India and connected with the ISTS network.*

# ESS Market Policy Updates

New central government initiatives and policies also drove the surge in tendering activity in the ESS space. A previous IEEFA-JMK report titled *Evolution of Grid-Scale Energy Storage System Tenders in India* covers the policies and initiatives of grid-scale ESS until June 2022.[6] Since then, the government has issued several ESS policies to broaden the overall market impact. These include ESS technology-specific policies such as for PHS or recognising ESS as a critical parameter influencing India's transmission sector growth planning.

[6] IEEFA-JMK Research. Evolution of Grid-Scale Energy Storage System Tenders in India. 4 July 2022.

**Figure 5: Key ESS Policies issued since June 2022**

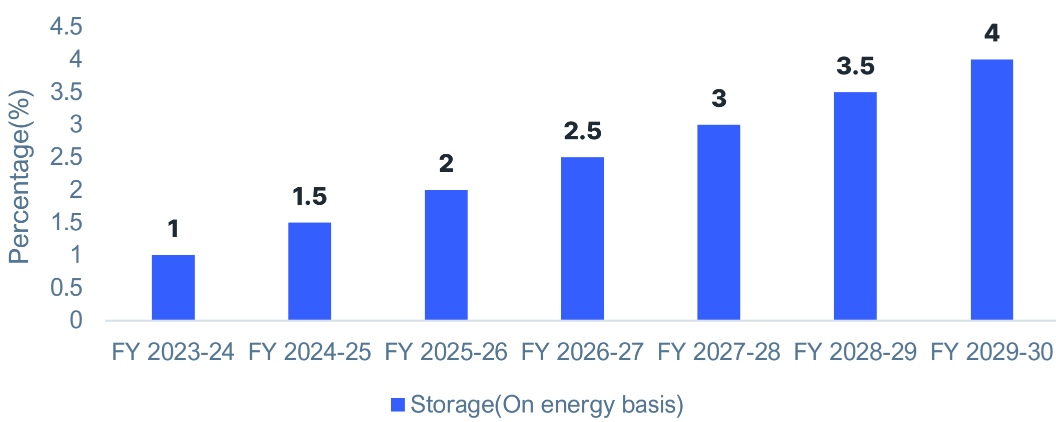



*Sources: Ministry of Power, JMK Research*

## Energy Storage Obligations

In July 2022, the Ministry of Power introduced energy storage obligations (ESO) as a mandatory separate component of renewable purchase obligations (RPO).[7] In addition, the policy document specifies a year-on-year upward trajectory of ESO for all the obligated entities, starting from 1% in FY2023-24 to 4% in FY2029-30. The obligated entity can only count this energy towards meeting ESO if at least 85% of the energy stored in ESS is procured from renewable sources. This decade, ESO is poised to be one of the major drivers for growth in India's ESS market.

**Figure 6: Growth in Storage Obligations by FY2029-30**




*Source: Ministry of Power*

[7] Ministry of Power. RPO and ESO trajectory till 2029-30. July 2022.

The ESO, to the extent of energy stored from renewable sources, shall be considered as part of the fulfilment of the total RPO. The ESO shall be reviewed periodically considering the commissioning/operation of the pumped storage project (PSP) capacity to accommodate any new commercially viable energy storage technologies and reduce the cost of BESS. Power System Operation Corporation (POSOCO) will maintain data related to compliance with RPO obligations.

## National Transmission Plan

In December 2022, the Central Regulatory Authority (CEA) issued the "*Transmission system for integration of over 500 GW RE* [Renewable Energy] *capacity by 2030*" plan.[8] Under the plan, the resource adequacy calculations for transmission infrastructure requirements included ESS as a critical component. The document specifies district-wise BESS capacity that needs to be set up by December 2030 to support solar and wind deployment in the same region.

The total outlay for this plan is Rs2.44 trillion (US$29.2 billion), and will result in the construction of 50,890km of new transmission lines and 433,000 megavolt ampere (MVA) of new substation capacity. This will result in 11% and 38% augmentation of transmission length and substation capacity of the Indian power system, respectively.

## PHS Policy

In April 2023, the Ministry of Power issued a comprehensive policy for the PHS segment. The policy recognises that PHS is a vital ESS technology that provides low-cost, long-duration storage (more than six hours).[9] Hence, to fulfil the PHS potential of more than 100GW, the policy provides a framework for bidding and allotment of PHS sites to developers. The policy also offers incentives in the form of relaxation of land stamp duty and registration fees for land procured for the project. In addition, the Ministry of Power waived ISTS and other transmission charges for PHS projects awarded until June 2025. As specified in the policy, including PHS in ESO will also provide much-needed impetus for the growth of this ESS segment.

The pumped hydro policy emphasises the importance of state governments in developing the PHS market in India. Under the policy, state governments can identify and allot PHS projects directly to developers on a nomination basis. The same project allotment can also be done through a two-step competitive bidding process.

To ensure consumers are charged costs related to power consumption only, the government has approved "*Budgetary support towards cost of enabling infrastructure i.e. roads/bridges*". All large-hydro and PHS projects awarded since 8 March 2019 are eligible for this support. Under this scheme, the government will bear the additional land cost required to lay down roads and bridges to

[8] Ministry of Power. Transmission system for integration of over 500 GW RE capacity by 2030. December 2022.
[9] Ministry of Power. Guidelines to promote development of Pump Storage Projects. April 2023.

connect major project components, such as dams, powerhouses and pressure shafts, to the nearest state or national highway.

## FDRE Guidelines

In June 2023, the Ministry of Power issued "Guidelines for Tariff Based Competitive Bidding Process for Procurement of FDRE from Grid Connected RE [Renewable Energy] Power Projects with ESS".[10] These guidelines provided a detailed framework to design "demand-following" grid-scale ESS tenders and based on similar policies for RTC and peak power supply.

Since the guidelines were released, eight FDRE tenders have been issued in India. The impact of the guidelines will be immense, considering FDRE is set to be the most dominant tender design for the foreseeable future.

## National ESS Policy

In August 2023, the Ministry of Power issued a national ESS policy as the National Framework for Promoting Energy Storage Systems.[11] It consolidates all policies issued by the government for the ESS market, including transmission waivers for ESS projects, ESO and production-linked incentives for advanced chemistry cells (ACC).

The national policy also specifies regulatory measures under consideration by the government. These include budgetary support for PHS, providing concessional green finance to ESS projects and a production-linked incentive (PLI) scheme specific to BESS.

## Viability Gap Funding for BESS

In September, the national cabinet approved the viability gap funding (VGF) scheme to develop BESS with an initial outlay of Rs94 billion(US$1.12 billion).[12] The quantum of financial support (VGF) to be provided under this scheme shall be in the form of capital and operational grants during the project construction stage and for the first five years after the commercial operation date (COD). The scheme intends to support the development of at least 4GWh of BESS capacity in India by FY2030-31. By offering VGF support, the scheme aims to achieve a levellised cost of storage (LCoS) ranging from Rs5.50(US¢6.6)/kilowatt-hour (kWh) to Rs6.60 (US¢7.9)/kWh, making stored renewable energy a viable option for managing peak power demand across the country.

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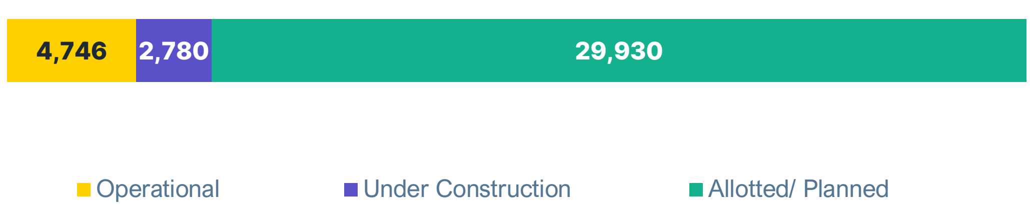
[10] Ministry of Power. Guidelines for Tariff Based Competitive Bidding Process for Procurement of Firm and Dispatchable Power from Grid Connected Renewable Energy Power Projects with Energy Storage Systems. June 2023.
[11] Ministry of Power. National Framework for Promoting Energy Storage Systems. August 2023.
[12] Union Cabinet. Cabinet approves the Scheme titled Viability Gap Funding for development of Battery Energy Storage Systems (BESS). September 2023.

The VGF will be disbursed in five tranches linked to various stages of the implementation of BESS projects. Under the scheme, the selected BESS projects will be provided financial support of up to 40% of the capital cost as VGF. To ensure that the benefits of the scheme reach consumers, a minimum of 85% of the BESS project capacity will be made available to distribution companies (DISCOMs). This will not only enhance the integration of renewable energy into the electricity grid but also minimise wastage and optimise the utilisation of transmission networks. Consequently, it will reduce the need for costly infrastructure upgrades. BESS developers will be chosen for VGF grants through a fair, competitive bidding process, ensuring equal opportunities for both the public and private sectors. However, to avail of the benefits under the scheme, the project under consideration must be from an SECI tender, meaning several BESS projects will be ineligible for VGF.

# Scope of PHS in India

Tendering in the PHS segment has surged since 2022. Some private independent power producers (IPP), such as Greenko and JSW Energy, are only focused on PHS for their ESS solutions. In India, 4,746 megawatts (MW) of PHS capacity is operational. Additionally, four more PHS projects, totalling around 2,780MW, are under construction. Under-construction projects include three on-river and one off-river project. The off-river project of 1,200MW is being constructed by Greenko at Pinnapuram, Andhra Pradesh, as an integrated renewable energy project (IREP) combining solar, wind and PHS.

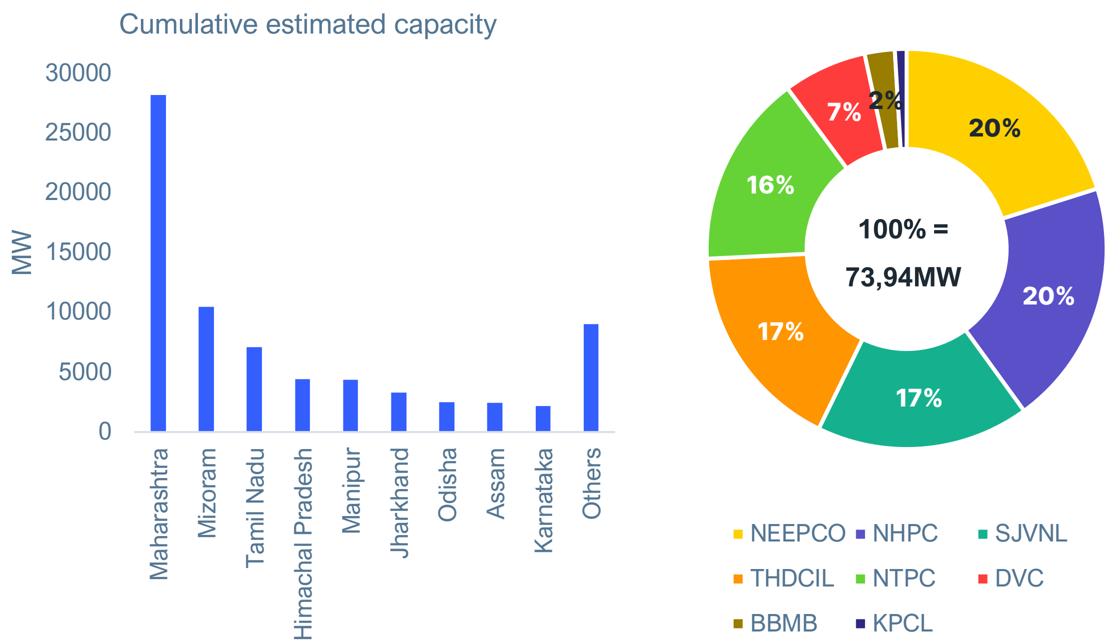
**Figure 7: PHS Capacity in India, Operational and Under Development (MW)**




*Source: Ministry of Power*

As of April 2023, the CEA estimates an on-river PHS potential of 103GW in India. Apart from this, there is significant off-river potential. Some stakeholders also point to several existing dams in India that do not have a hydropower component that could be converted into PHS projects. On 8 August 2022, the Ministry of Power issued a document outlining various potential PHS sites across India and the agencies that could develop those projects.

**Figure 8: Potential PHS sites in India, Capacity by State and Agency (MW)**




*Source: Ministry of Power*

To realise its PHS potential, some states, such as Madhya Pradesh and Karnataka, are issuing large-scale tenders for site allotment. In June 2023, Madhya Pradesh issued a tender to allot PHS sites across the state for a cumulative capacity of 16.4GW. Other states, such as Maharashtra and Uttar Pradesh, are following a different approach wherein they are signing memoranda of understanding (MoU) with independent power producers (IPPs) to set up PHS capacities. In 2023, Maharashtra signed several MoUs with IPPs such as JSW Energy, Torrent Power, NHPC and Tata Power for a cumulative PHS capacity of more than 15GW.

## Factors Driving PHS in India

PHS is a reliable and mature technology. In recent years, the overall focus on energy storage has propelled PHS back into focus to implement grid-scale ESS, especially for longer duration storage of more than six to eight hours. Some key factors driving the renewed push towards PHS in India are:

- **Cost-effective:** For a 10-hour storage solution, PHS offers one of the lowest effective capital expenditures (CAPEX)/kilowatt (kW) (US$2,910/kW) of all ESS technologies.[13] Lower effective cost is achieved primarily due to a significantly longer project life (40 to 80 years) vis-à-vis other ESS technologies, resulting in meagre capacity replacement costs. For

[13] International forum on Pumped Storage Hydropower. Pumped Storage Hydropower Capabilities and Costs. Page 11. September 2021. Based on 1000MW/10hr.

example, in BESS, battery life is about 10 years, thus needing a periodic CAPEX infusion to maintain project capacity.

- **Longer duration:** PHS offers longer energy storage of more than six to 12 hours, significantly longer than BESS, which is financially unviable for storage of more than four hours. Thus, PHS is well suited for energy-shifting applications, wherein excess renewable energy generation can be shifted to peak demand periods of late evenings.
- **Policy Support:** The Indian government has placed equal emphasis on developing BESS and PHS capacity. BESS will enable grid resiliency and frequency stabilisation, while PHS will play a key role in long-duration energy shifting. In April 2023, the Ministry of Power issued a pumped hydro policy to catalyse the growth of the PHS market. Other policy support to PHS includes a waiver on transmission charges and the inclusion of PHS in ESO.
- **Low dependence on imports:** PHS project infrastructure is similar to a hydropower plant. Thus, with India already having a significant presence in hydropower, most PHS project components can be sourced locally. This is in high contrast to BESS, wherein battery cells, a key project component, still need to be almost wholly imported.
- **Finance availability:** The long project life of PHS ensures a stable and consistent cash inflow for more than 40 years. This healthy cash-flow profile enables favourable project financing arrangements for PHS, such as lower loan rates and a higher debt-equity ratio.

In 2023, about 19GW of PHS tenders were issued, accounting for about 59% of the total requests-for-selection (RFS) issued in the ESS Market. In addition to tendering, several state governments have announced PHS projects through MoUs with IPPs. With this growth spurt in PHS tendering, India is well poised to attain its PHS potential. While CEA suggested a minimum of 18.9GW PHS capacity for optimum energy mix in 2030, this target will likely be easily surpassed.

## Comparison of PHS vs BESS

| Parameters | Pumped Hydro Storage (PHS) | Battery Energy Storage System (BESS) |
|---|---|---|
| **Definition** | PHS consists of two reservoirs at different elevations with a turbine and a pump between them. The energy is stored as potential energy in the water of the upper reservoir. | An ESS is any technology solution designed to capture energy at a particular time, store it, and make it available to the offtaker for later use. |
| **Capital Cost** | Pumped storage plant costs can range from US$1,700-2,500/kW.[14] (Cost can vary depending on the type of project.) | Lithium-ion battery storage plants can range from US$1,400-2,000/kW[15] (for a four-hour storage solution). |
| **Operating cost** | Lower operating cost | Higher operating costs due to replacement of batteries after every few years. |
| **Lifetime** | Up to 50 years | Typically 10-20 years |
| **Response Time** | Ten to 15 seconds from half to full production capacity; under two minutes from standstill to full production capacity | Battery storage facilities exhibit quicker response times (in milliseconds) compared with pumped storage plants, making them more suitable for applications requiring swift reactions, such as grid 18 stabilisation or frequency regulation. |
| **Environmental Impact** | Pumped storage plants need substantial reservoirs and can lead to environmental consequences, such as habitat destruction and changes in water flow downstream. | As large-scale battery storage becomes more prevalent, the disposal of batteries poses a growing concern. Without careful management, these batteries may end up in landfills, posing risks of corrosion, flammability, and environmental contamination. |
| **Duration of storage** | More than six hours | Up to four hours |
| **Commissioning timeline** | Commissioning time is longer due to the lack of suitable sites. | Much shorter commissioning time than with PHS |

*Source: Industry articles, JMK Research*

[14] National Hydropower Association. 2021 Pumped Storage Report. Page 18. 2021.
[15] NREL. Cost Projections for Utility-Scale Battery Storage: 2023 Update. June 2023.

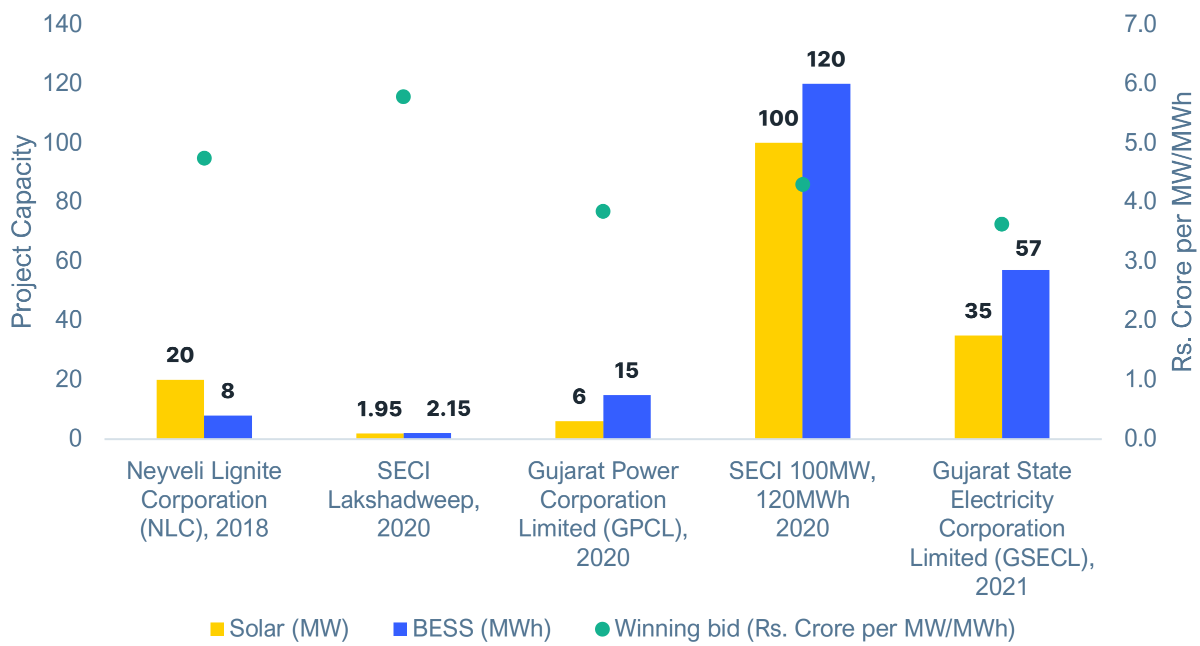
# Utility ESS Tender Auction Analysis

As of November 2023, a cumulative grid-scale ESS capacity of 8GW has been awarded. More than half of this capacity (5GW) was awarded in 2023. The capacity awarded varies from small-scale solar + BESS EPC tenders to GW-scale allotment under peak power supply, RTC, standalone ESS and FDRE tenders.

## Solar + BESS

Neyveli Lignite Corporation (NLC) issued and awarded the first grid-scale solar + BESS tender in 2018 to address diesel abatement efforts in the Andaman Islands. The EPC tender of 20MW solar and 8 megawatt-hour (MWh) BESS was awarded to Larsen and Toubro (L&T) for about Rs1.33 billion (US$15.96 million). This NLC tender,[16] along with the Gujarat Power Corporation Ltd (GPCL) tender of 6MW/15MWh are two of the prominent grid-scale ESS tenders that have been commissioned until 2023 in India.

**Figure 9: Auction Results of Solar + BESS Tenders in India**




*Source: JMK Research*

On a per MW/MWh basis, the winning bid cost of solar + BESS tenders has generally decreased over the years, in sync with the trend of falling solar module and battery prices. The per MW/MWh price (winning bid cost/sum of solar and BESS capacity) for the NLC tender in 2018 was Rs47 million

[16] NLC. Installation of 2 x 10 MW (AC) Solar PV Power Project integrated with 8 MWhr. BESS at Andaman. February 2018.

(US$560,000), which fell by 23% to Rs36 million (US$430,000) in 2022 in the tender by Gujarat State Electricity Corporation Limited (GSECL).

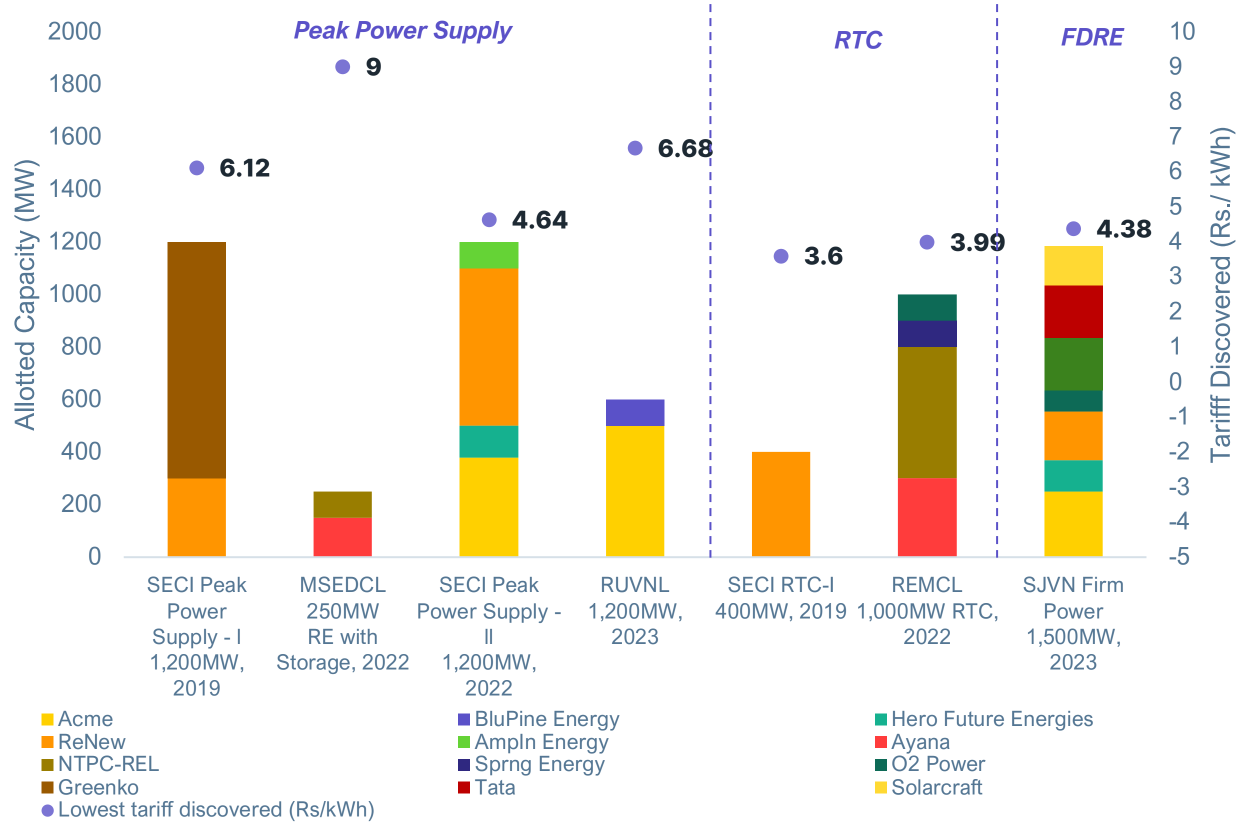
## Peak Power Supply, RTC, FDRE

Tendering authorities introduced both peak power supply and RTC tenders to enhance the availability, reliability and dispatchability of renewable energy sources. In 2023, SECI introduced FDRE tender in order for renewable energy to match the firmness and dispatchability of conventional sources of power. While RTC aims to provide year-round availability of power from renewable sources, peak power supply aims to ensure the availability of renewable energy in the most critical hours of peak demand.

SECI issued its first peak power supply[17] and RTC tender[18] in 2019, with bidding for both tenders concluded in 2020. Both projects are under construction and will likely be commissioned by early 2024. SECI concluded its second iteration of the peak power supply tender in 2023 wherein the discovered peak hours tariff at Rs4.64(US¢5.6)/kWh was 24% lower than the tariff of Rs6.12(US¢7.3)/kWh discovered in peak power supply-I concluded in January 2020. The key reason for this decline was the reduction of peak hours from six to four in peak power supply-II vis-à-vis the first tender.

[17] SECI. RTC 400 MW. March 2020.
[18] SECI. Peak Power Supply 1200 MW. January 2020.

**Figure 10: Auction Results of Peak Power Supply and RTC Tenders**




*Source: JMK Research*

*Note: 1. For peak power supply tenders, the peak tariff is shown. The off-peak peak tariff for SECI Peak Power Supply-I is Rs2.88/kWh. For MSEDCL 250MW, the off-peak tariff is Rs. 2.42/kWh. There is no provision for off-peak tariff in SECI Peak Power Supply-II and RUVNL tenders.*
*2. For the RTC-1 Tender, the tariff shown is the levellised tariff over the project tenure. The bidding tariff was Rs 2.9/kWh vis-à-vis the first year of the Power Purchase Agreement (PPA).*
*3. SJVN 1,500 MW FDRE tender, whose tender conditions are similar to a peak power supply, has an annual minimum CUF requirement of 40%.*

The tariff discovered in peak power supply tenders depends significantly on the quantum of peak hours specified, clarity in terms of energy and capacity utilisation factor (CUF) requirements, location and tendering agency.

The first FDRE tender to conclude was SJVN 1,500MW in November 2023. The tariff discovered was Rs4.38(US¢5.3)/kWh, which was marginally higher than the RTC tenders.

For future FDRE tenders, with stricter power supply requirements in terms of demand fulfilment ratio, at minimum 90% of the demand profile monthly, the tariffs are expected to be higher, about Rs5(US¢6)/kWh.

Figure 10 shows the discovered tariff in RTC tenders is lower than any peak power supply tenders, even though RTC tenders ensure higher availability and supply of renewable energy. This trend is due to the higher utilisation rate of ESS in the case of RTC tenders, leading to lower tariffs.

**Table 2: RTC Tenders Issued in India to Date**

| | Railway Energy Management Company Ltd (REMCL) RTC | Adani RTC | SECI RTC | REMCL RTC | SECI Thermal + Renewable Energy RTC | SECI 400MW RTC |
|---|---|---|---|---|---|---|
| **Tender Issuance Date** | Sep 2023 | Dec 2022 | Sep 2022 | July 2022 | Mar 2020 | Oct 2019 |
| **Project Capacity** | 750MW | 1,500MW | 2,250MW | 1,000MW | 2,500MW | 1,260MW |
| **Technology Mix** | Renewable Energy with or without ESS | RE with or without ESS | RE+ESS | Renewable Energy with or without ESS | Thermal RE+ESS | Renewable Energy + ESS |
| **Capacity Utilisation** | 90% at the end of 10 years<br>80% at the end of 25 years | | | | Minimum 85% | Annual: 80%<br>Monthly: 70% |
| **Tariff Structure** | Single Tariff | Single Tariff | Single Tariff | Single Tariff | Single Tariff | Single Tariff |
| **Business Model** | Build Own Operate (BOO) | BOO | BOO | BOO | BOO | BOO |
| **Storage Component** | Optional | Optional | Mandatory | Optional | Mandatory | Mandatory |
| **Peak Availability** | 75% (First three years)<br>85% (Rest of contract) (annual)<br>50% (block availability) | 90% (annual) | 90% (annual) | 75% (First four years)<br>85% (Rest of contract) (annual)<br>50% (block availability) | - | - |
| **Tender Winners** | Request for selection (RFS) Issued | RFS Issued | Tender Cancelled | NTPC (500MW), Ayana (300MW), O2 Power (100MW), Sprng Energy (100MW) | Tender Cancelled | ReNew Power (400MW) |
| **Lowest Tariff Discovered (Rs/ kWh)** | - | - | - | 3.99 | - | 2.9 |

*Source: JMK Research*

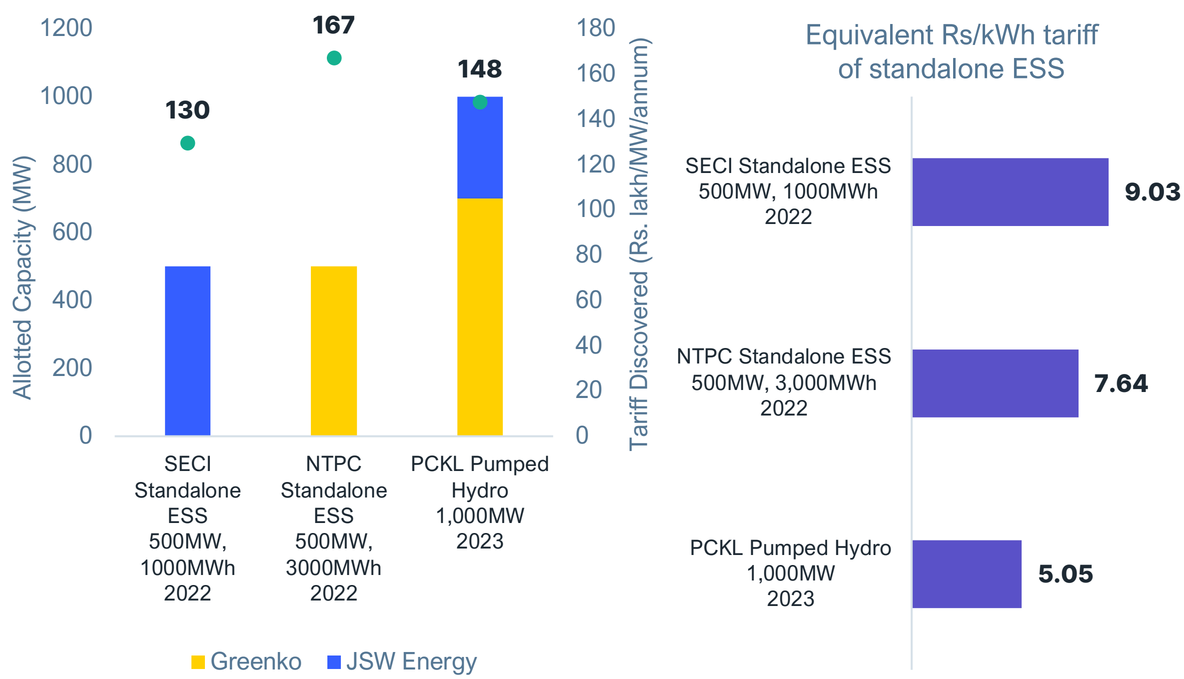
## Standalone ESS

Standalone ESS tenders enable the offtaker to utilise the ESS on demand. The scope of charging and discharging the ESS is completely decoupled from the developer. Moreover, the bids in these tenders are quoted based on contract capacity (MW or MWh) rather than the actual energy supplied.

SECI issued its standalone ESS 500MW/1,000MWh tender in April 2022. It was a pilot project designed to be widely replicable to inform future standalone ESS tenders. Bidding concluded in August 2022, with JSW Energy emerging as the winning entity with a tariff of Rs1.083 million (US$12,997)/ MW/month for 12 years.[19] Other concluded standalone ESS tenders include NTPC 500MW/3000MWh at Rs2.79 million (US$33,483)/MWh/pa and the Power Company of Karnataka (PCKL) 1000MW pumped hydro tender at Rs14.75 lakhs (US$176,995)/MW/pa.

In terms of the ESS technology, SECI's tender is for BESS, while PCKL's tender is for PHS. Although NTPC's tender was technology agnostic, the requirement of six hours of energy supply ultimately favoured PHS, which the winning bidder, Greenko, aims to supply from its under-construction GW-scale Integrated Renewable Energy Storage Projects (IRESP) in Andhra Pradesh.

**Figure 11 : Auction Results of Standalone ESS Tenders**




*Source: JMK Research*

*Note: Equivalent Rs/kWh tariff only includes ESS per unit cost. It does not include the cost of energy for charging the ESS.*

[19] PV Magazine. JSW Energy wins SECI tender for 1 GWh of battery energy storage systems. August 2022.

Based on the daily energy output requirements of these projects, an equivalent Rs/kWh project tariff can be estimated. Both the PHS-based tenders from NTPC and PCKL incur lower equivalent Rs/kWh tariffs compared with the SECI standalone ESS tender.

SECI's tariff at Rs9/kWh is the highest, primarily due to BESS being a relatively expensive technology vis-à-vis PHS on a per kWh basis. SECI, which has contracted 60% of the capacity from this project, aims to provide grid support and ancillary services. Of the capacity contracted by SECI, 30% of the project capacity will be earmarked to Power System Operation Corporation Limited (POSOCO)/Grid India.[20] Arrangements for utilisation of the remaining 40% capacity will be at the ESS developer's discretion.

An additional factor influencing the tariff is the project tenure. For the tenders from SECI, NTPC and PCKL, the tenures are 12, 25 and 40 years, respectively. Falling ESS costs (especially for BESS) and sustained cash flow over a longer duration enable ESS developers to quote lower tariffs.

While the standalone storage tariff is more than the tariffs in the other ESS tenders, these projects offer remarkable flexibility and provide value to the system in terms of different applications offered, and thus remain competitive with other sources of flexibility.

## Status of Grid-scale ESS Projects Under Development

Projects allotted under grid-scale ESS tenders are in various stages of implementation. SECI peak power supply-I and RTC-I projects are nearing completion, and are likely to be commissioned by mid-2024. Greenko aims to use its under-construction PHS at Pinnapuram, Andhra Pradesh, for both peak power supply and standalone ESS projects. Project components of RTC-I include solar, wind and BESS. ReNew is setting up these across Rajasthan, Maharashtra and Karnataka. Tata Power is also constructing India's largest grid-scale Solar + BESS project in Rajnandgaon, Chhattisgarh, of 100MW/120MWh capacity.

[20] SECI. RfS for setting up 500MW/1000MWh standalone BESS. April 2022.

**Table 3: Prominent Grid-scale ESS Projects Under Development**

| Name | Capacity | Developer | Location | Project Solution | Status |
|---|---|---|---|---|---|
| **SECI Peak Power Supply-I** | 1200MW | ReNew Power (300MW), Greenko (900MW) | Andhra Pradesh, Karnataka | Greenko<br>Solar – 1500MW, PHS – 350MW<br>ReNew<br>Solar – 81MW, Wind – 322.5MW, BESS – 150MWh | Under Construction Commissioning: Greenko: March 2024, ReNew: March 2024 |
| **RTC-I** | 400MW | ReNew Power | Rajasthan, Maharashtra and Karnataka | Solar – 400MW. Wind – 900MW, BESS – 100MWh | Under construction, commissioning by mid-2024 |
| **SECI 100MW, 120MWh** | 100MW | Tata Power | Chhattisgarh | Solar – 160MW peak, BESS – 40MW/120MWh | Under construction, commissioning by March 2024 |
| **NTPC Standalone ESS** | 500MW/3000MWh | Greenko | Pinnapuram, Andhra Pradesh | Entire capacity – PHS | Greenko's integrated renewable energy project (IREP), under construction, will be commissioned by 2025 |

*Source: JMK Research*

# FDRE and the Evolution of Grid-scale ESS Tenders

As discussed in previous sections, ESS tendering in India is continuously evolving in terms of design, of which FDRE is the latest mutation. On 9 June 2023, the Ministry of Power issued "*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*".[21] The guidelines provide a detailed framework to enable FDRE procurement on a "demand-following" basis, thereby creating a truly viable alternative to coal, hydro and other dispatchable power-based technologies.

Based on these guidelines, SECI issued four FDRE tenders in 2023 of capacities 500MW (Punjab), 1,500MW (Punjab, Madhya Pradesh), 800MW (Haryana) and 1,260MW (Delhi, Gujarat). After issuing peak power supply, RT) and standalone ESS tenders in the past, these FDRE tenders are SECI's latest attempt to find the ideal tender design for ESS development in India.

[21] Ministry of Power. Guidelines for Tariff Based Competitive Bidding Process for Procurement of Firm and Dispatchable Power. June 2023.

**Table 4: Features of SECI 1,500MW FDRE-II Tender, Issued in July 2023**

| Tender Attribute | Condition |
|---|---|
| **Project Size** | • Cumulative contracted project capacity: 1500MW<br>• Developers can quote capacities from 50MW to 750MW, with a minimum allowed increment of 10MW. |
| **Location of Generation Sources** | • The project location or its components can be located across pan India, with the only condition being a connection to the ISTS Network at a minimum voltage level of 220kV. |
| **Scheduled Commissioning Date** | • Two years from the effective date of signing the Power Purchase Agreement (PPA). |
| **Project Tenure** | • 25 years from the scheduled commencement of supply date (SCSD). |
| **Selection of Project Technology** | • Solar, Wind and Energy Storage<br>• The selection of Energy Storage Technology is entirely in the developer's scope.<br>• The selected technology solution can be modified/amended at any time during the project tenure. |
| **Tariff Design** | • Fixed tariff applicable for the entire project tenure of 25 years. |
| **Offtaker of Energy** | • Punjab State Power Corporation Limited (PSPCL), Madhya Pradesh Power Management Company Limited (MPPMCL)<br>• The developer can sell the excess power generated to PSPCL/MPPCL (having first right of refusal until contracted capacity) or to third-party/merchant markets. |
| **Project Scope of the Developer** | • Renewable Power developer (RPD) will build, own and operate (BOO) the plant during its entire tenure of 25 years.<br>• Responsible for delivering FDRE power on a "demand-following" basis. |
| **Bidding System** | • Two-stage bidding: e-bidding followed by e-reverse auction.<br>• E-bidding will comprise separate technical and financial bids. |
| **Main Technical Requirements** | • Solar modules used in the project should be on the Approved List of Models and Manufacturers (ALMM).<br>• Wind turbines used in the project should be in the Revised List of Models and Manufacturers (RLMM).<br>• Demand Fulfilment Ratio (DFR) of at least 90% on a monthly basis. |

*Source: SECI*

The key differentiator of FDRE tenders from previous variations, such as RTC tenders, is the enhanced clarity for the project developers on the quantum, duration and schedule of the injected power requirement for the entire project tenure of 25 years. These characteristics will aid the developers in efficiently sizing the system and accurately modelling the future realised revenue, leading to correct tariff discovery. Industry stakeholders assert that these "demand-following" FDRE tenders will showcase the actual cost/tariff of renewable sources. For a summary of key FDRE tenders issued to date in India and their status, see Table 5.

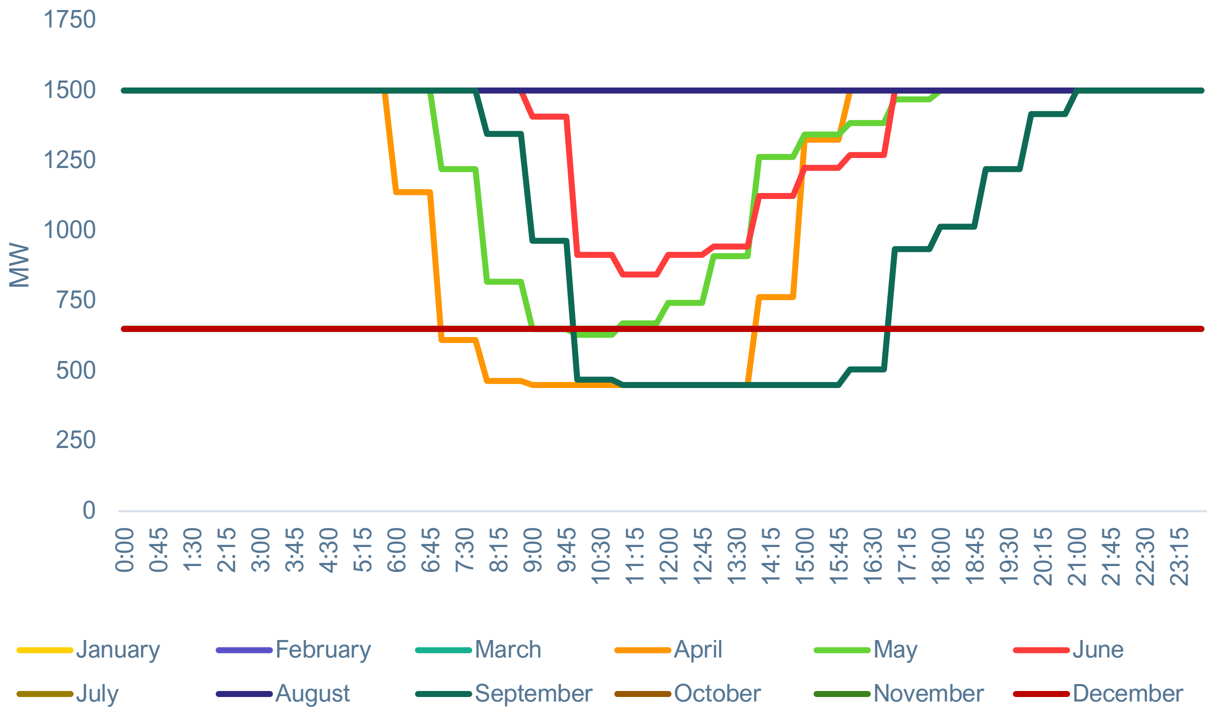
**Table 5: Features of FDRE Tenders Issued to Date in India**

| Tenders | SJVN Firm Power | SECI FDRE 1 (HR) | SECI FDRE 2 (Punjab, Madhya Pradesh) | SECI FDRE 3 (Haryana) | SECI FDRE 4 (Delhi) | NHPC Firm Power | NTPC FDRE |
|---|---|---|---|---|---|---|---|
| **Project Capacity** | 1,500 MW | 500MW | 1,500MW | 800MW | 1,260MW | 1,500MW | 3,000MW |
| **Tender issuance date** | June 2023 | July 2023 | July 2023 | August 2023 | September 2023 | October 2023 | October 2023 |
| **Technology Mix** | Renewable Energy+ESS | Renewable Energy+ESS | Renewable Energy+ESS | Renewable Energy+ESS | Renewable Energy+ESS | Renewable Energy+ESS | Renewable Energy+ESS |
| **Capacity Utilisation** | 40% (annual) | 90% (Demand fulfilment ratio) (annual) | 90% (Demand fulfilment ratio) (annual) | 90% (Demand fulfilment ratio) (annual) | 90% (Demand fulfilment ratio) (annual) | 40% (annual) | |
| **Tariff Structure** | Single Tariff | Single Tariff | Single Tariff | Single Tariff | Single Tariff | Single Tariff | Single Tariff |
| **Business Model** | BOO | BOO | BOO | BOO | BOO | BOO | BOO |
| **Peak requirement** | 4 Hours | - | - | - | - | 4 Hours | - |
| **Storage Participation** | Mandatory | Mandatory | Mandatory | Mandatory | Mandatory | Mandatory | |
| **Peak Availability** | 90% | - | - | - | - | 90% (annual) | |
| **Tender Winners** | ACME (250MW) Juniper, Tata (200MW), Blupine (150MW), O2 Power (80MW), Hero (120MW) | RFS Issued | RFS Issued | RFS Issued | RFS Issued | RFS Issued | RFS Issued |
| **Lowest Tariff Discovered (Rs/kWh)** | 4.38 | - | - | - | - | - | - |

*Source: JMK Research*
*Note: Both SJVN and NHPC FDRE tenders deliver firm power, having tender conditions similar to peak power supply tenders.*

Under FDRE tenders, SECI has introduced a new parameter to gauge the project performance, i.e., Demand Fulfilment Ratio (DFR). According to SECI, this parameter (which is essentially "scheduled injection of demand/actual required demand")) comes closest to what distribution companies (DISCOMs) truly expect from renewable energy + ESS projects. In prior similar tenders, such as RTC, the critical performance parameters were capacity utilisation factor (CUF) and project availability.

**Figure 12: Project Load Demand Profile for SECI FDRE-II (Monthly, Entire Tenure)**




*Source: SECI*

*Note: 1. The demand profile shall be followed by the individual RPD on a pro-rata basis, i.e., for a Contracted Capacity of "A" MW, the respective demand for hour 1 January shall be calculated as [650/1500 x "A"] MW*
*2. The load profile in the figure above is based on 15-minute time block load profile data from the tender document.*

According to Ministry of Power guidelines, FDRE power includes configurations such as assured peak power, RTC renewable energy with firm power delivery at rated capacity at any hour of the day as per demand specified by DISCOM, and renewable energy projects with firm delivery of power for fixed hours. Hence, FDRE is also a blanket term encompassing various renewable energy + ESS tender designs issued in India. In future, all renewable energy + ESS tenders in India will likely refer to these guidelines for tender document formulation.

FDRE guidelines allow clubbing as offtakers of more than one DISCOM as well as open access (OA) consumers, which will enhance the utilisation of ESS and hence lower discovered levellised cost of energy (LCOE). Most FDRE tenders are being planned with two separate offtaker states having complementary seasonal demand profiles. For example, in the SECI FDRE-II, Punjab will be the energy offtaker for the summer months of April to September, corresponding with its agricultural load profile. Madhya Pradesh will be the offtaker for the rest of the winter months. Doing this will ensure optimum utilisation of energy resources across the entire year. Similarly, FDRE-I and FDRE-IV also have two separate entities as energy offtakers.

The bidding process for FDRE tenders is based on contracted capacity. However, the actual project capacity will be much higher than the contracted capacity. Roughly, each 100MW of firm power will require about 200MW of solar, 160MW of wind and 100/400MWh of BESS.[22] Thus, setting up firm power capacities will result in much higher renewable energy and ESS capacity additions.

As the load profile is already determined for the entire project tenure of 25 years, it can be argued that the latest SECI FDRE tenders are not truly "demand-following". However, with these tenders, SECI aims to strike an optimum balance between DISCOM requirements and renewable projects' power delivery capabilities. In future, FDRE tenders may incorporate more complex and detailed demand profiles spanning the entire project tenure. The response to these FDRE tenders will be crucial in developing this newest grid-scale ESS tender market segment.

## Key Participants (Indian Grid-Scale ESS Market)

Indian grid-scale ESS market is still in its initial years of development. In the past few years, even though the energy storage push has accelerated significantly, there are still only a few market participants at the grid-scale ESS level.

Original equipment manufacturers (OEM) for grid-scale ESS are almost all based outside India. Samsung and LG Chem are the leading Li-ion manufacturers in the world. Indian battery manufacturers, such as Exide and Exicom, only assemble the battery packs after importing the battery cells, primarily from China.

Akin to renewable energy development, SECI is also leading the efforts in the grid-scale ESS market. Other prominent tendering agencies active in grid-scale ESS include NTPC, Maharashtra State Electricity Distribution Company Ltd (MSEDCL), Railway Energy Management Company Ltd (REMCL) and Rewa Ultra Mega Solar Ltd (RUMSL).

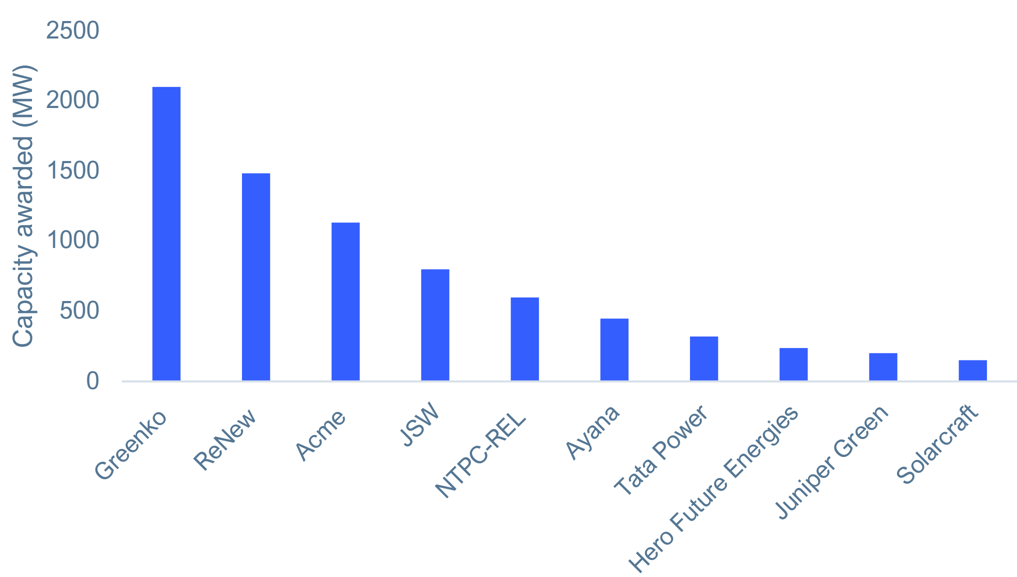
[22] International Solar Alliance, Page 53 of RenewX Special Issue. Surging Demand Growth a Challenge But Also Opportunity for DISCOMs. Page 53. March 2023.

**Figure 13: Key Participants in the Indian Grid-scale ESS Market**


*Source: JMK Research*

As of November 2023, in terms of capacity won, Greenko is the largest grid-scale ESS developer in India, with a total allotted capacity of more than 2GW. ReNew Power, Acme Solar, JSW Energy and NTPC-REL have each secured grid-scale ESS capacities of more than 500MW.

**Figure 14: India's Grid-scale ESS Market Leaders, by Capacity Awarded (as of November 2023)**




*Source: JMK Research.*

# Challenges and Risks to ESS Market Growth

ESS is an emerging technology in the power sector. Hence, in this transitionary period, ESS faces a host of challenges ranging from technical, procurement, execution as well as post-execution. We covered some of these still relevant challenges in a previous report titled *Evolution of Grid-Scale Energy Storage System Tenders in India*, published in July 2022.[23] In addition, developments since then have emphasised other challenges and risks the ESS market will need to overcome in the short to medium term.

## Suboptimal T&D Infrastructure

To fully realise the grid security and balancing benefits of grid-scale ESS, the entire grid transmission and distribution (T&D) infrastructure must be robust and in sync. However, industry stakeholders note that most of India's T&D infrastructure is decades old and needs a significant overhaul to accommodate additional renewable energy and ESS capacity. A major upgrade is imperative, especially of ISTS T&D infrastructure, given that projects under most grid-scale ESS tenders can be set up in pan India. In fact, integrating ESS to support grid strength at the Intra-STS (InSTS) and ISTS grid level should be mandated across the country, thereby enabling the development of a virtual transmission system.

Over the years, the government has issued schemes to promote the growth of T&D infrastructure, mainly to support the increasing penetration of renewable energy in the grid. To develop the renewable energy evacuation infrastructure of InSTS in leading renewables states, the government launched two iterations of the Green Energy Corridor (GEC) scheme in 2015 and 2022. To develop the ISTS infrastructure, CEA issued the National Transmission System Plan by 2030, which aims to set up infrastructure to evacuate 181.5GW of renewable energy and ESS capacity by 2030.[24]

[23] IEEFA-JMK Research. Evolution of Grid-Scale Energy Storage System Tenders in India. 4 July 2022.
[24] CEA. Transmission system for integration of over 500 GW RE capacity by 2030. December 2022.

**Figure 15: Major Transmission Infrastructure Augmentation Schemes in India**


*Sources: MNRE, CEA, JMK Research*

An added challenge is that the time required to set up power evacuation T&D infrastructure is much longer than concurrent renewable energy/ESS capacities. Hence, it is crucial that the augmentation of T&D infrastructure is planned much further in advance and takes centre stage in all the renewable energy development plans.

## Lack of Domestic BESS Manufacturing

Self-sustenance in manufacturing requirements is a crucial component under the aegis of the government's Atmanirbhar Bharat (Self-Reliant India) campaign.[25] However, akin to solar, the domestic ESS industry (especially BESS) majorly relies on imports. Other ESS components, such as battery/hybrid inverters, specialised control systems and software, are also all provided by non-Indian companies.

India has a Li-ion battery pack manufacturing capacity of about 5.2GWh/pa. However, battery cells, the most critical battery pack components, are largely imported, mainly from China. In contrast, the annual battery demand in India, including all sectors such as electric vehicles (EV), stationary storage and consumer electronics, is more than 30GWh.

Given its ambitious ESS targets, India will need to augment its BESS manufacturing capacity significantly to insulate itself from any future global supply chain shocks in battery supply. In 2021, the government initiated its PLI scheme to set up a 50GWh manufacturing capacity of ACC in India.[26] The Ministry of Heavy Industries awarded PLIs to four beneficiaries in March 2022: Ola (20GWh),

[25] Government of India. Atmanirbhar Bharat Abhiyan. June 2020.
[26] Ministry of heavy industries. The Production Linked Incentive scheme, National Programme on Advanced Chemistry Cell (ACC) Battery Storage. May 2021.

Hyundai Global (20GWh), Rajesh Exports (5GWh), and Reliance New Energy (5GWh).[27] In August 2022, Hyundai Global pulled out of the scheme, and the government is looking to reallocate this 20GWh capacity.

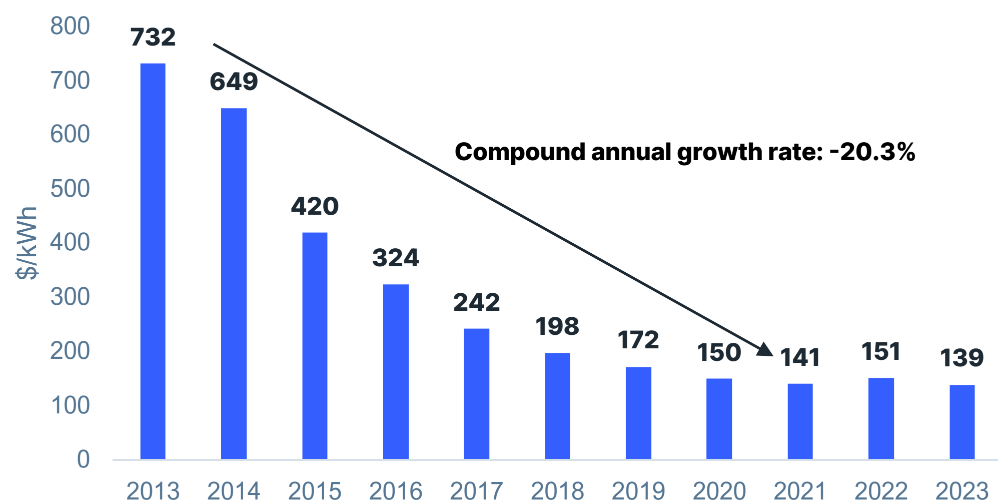
Annual battery demand in India is poised to exceed 100GWh by 2030. Hence, India will need to supplement the PLI-commissioned capacity from other sources. Growth of domestic BESS manufacturing will require a sustained push from the government in the form of manufacturing incentives and policy support, such as tax rebates, lower GST, concessional land rates for setting up factories and possible inclusion of the BESS project under the domestic content requirement (DCR) initiative.

## Fluctuations in CAPEX

High initial CAPEX is one of the major inhibitors of ESS adoption in India. Some grid-scale ESS technologies, such as PHS, are so capital-intensive that few developers can afford to enter this space. Scale is also significant, wherein only large GW-scale PHS projects can justify the investment.

In BESS, Li-ion battery prices fell steadily from 2013 (US$732/kWh) to 2021 (US$141/kWh). All industry stakeholders had expected this trend to continue and battery prices to fall below US$100/kWh by 2024. However, bucking the trend, battery prices have marginally increased in the past couple of years, mainly due to supply chain constraints in 2021 and a rise in the cost of input metals in 2022 (Figure 16).

**Figure 16: Li-ion Battery Pack Price Trend**




*Source: BloombergNEF*

[27] PV Magazine. Ola, Hyundai, Reliance and Rajesh Exports emerge winners in 50GWh battery cell tender under PLI Scheme. March 2022.

This trend reversal has put pressure on ESS market participants, who would have factored a continuous decline in battery prices into their financial calculations of project viability.

However, in a positive development, Li-ion battery prices fell to a record low of US$139/kWh in 2023.[28] Even though prices are expected to continue to decline in 2024,[29] this fluctuation in battery prices indicates that extra caution is imperative from all stakeholders while bidding for grid-scale BESS tenders, at least in the near term.

# Expectations for ESS

Energy storage is becoming the next disruptor in the renewable energy renewable energy sector. This decade, the ESS market will attract the highest investment of all emerging renewable energy sectors, concurrent with the increasing penetration of renewable energy in the electricity grid. Another key driver for the surge in ESS capacity will be the decline in costs. Maturity in grid-scale ESS tender design and growth of ESS trading on power markets are other expected developments.

> **Energy storage is becoming the next disruptor in the renewable energy renewable energy sector.**

## FDRE Tender Design to Dominate

FDRE "demand-following" tenders are the culmination of SECI's efforts to find a suitable ESS tender design for India over the years. By clearly specifying the quantum and schedule of power delivery for the entire project duration, these tenders create a win-win scenario for developers and energy offtakers alike. Even before the bidding commences, the tendering authority already has a verbal power sale agreement (PSA) with the energy offtaker, generally the state DISCOMs. This will help reduce the long turnaround time to conclude grid-scale ESS tenders. In the case of SECI FDRE 1, 2 and 4, the respective DISCOMs already have in-principle approval of SERC before conveying consent to SECI for floating the tender on their behalf. Therefore, PSAs for these tenders are already assured, subject to rational tariff discovery.

[28] BloombergNEF. Lithium-Ion Battery Pack Prices Hit Record Low of $139/kWh. 26 November 2023.
[29] BloombergNEF. Lithium-ion Battery Pack Prices Rise for First Time to an Average of $151/kWh. 6 December 2022.

**Table 6: Time Taken to Conclude Bidding for Grid-scale ESS Tenders**

| Tender | Capacity | Gap between tender issuance and bidding | Status |
|---|---|---|---|
| **SECI Peak Power Supply-I** | 1,200MW | 5 months | Project under construction |
| **RTC-1** | 400MW | 7 months | Project under construction |
| **RTC-2** | 2,500MW | 19 months | The auction was not successful. Only 250MW capacity was allotted, as bidders were unable to match the L1 price. Also, the PPA and PSA for 250MW are yet to be signed. |
| **Standalone ESS (SECI)** | 500MW/1,000MWh | 4 months (10 months if counted from issuance of draft RFS) | JSW Energy won the entire capacity. Winning tariff: Rs10,83,500/MW/month (US$13,099.83/MW/month). |
| **Standalone ESS (NTPC)** | 500MW/3,000MWh | 11 months | Greenko won the entire capacity. Winning tariff: Rs27,92,308/MWh/year (US$33,759.81/MWh/year). |
| **REMCL RTC** | 1,000MW | 9 months | The entire capacity was awarded to four developers: NTPC-REL, Ayana, Sprng Energy, and O2Power. The winning bid was by Spring Energy at Rs3.99/kWh. |
| **SECI Peak Power Supply-II** | 1,200MW | 5 months | The entire capacity was awarded to 4 developers: Acme, ReNew, Hero, and Ampln Energy. The winning bid was by Ampln Energy at Rs4.64/unit. |

*Sources: JMK Research, SECI, NTPC*

The demand profile of a specific FDRE tender can be modelled for either RTC or peak power supply. For example, the demand profile under a given FDRE tender can be set so as to supply the maximum quantum of power during the peak demand hours, thus emulating the peak power supply tender design. Thus, most grid-scale ESS tenders will likely be modelled under the FDRE framework. However, standalone ESS, a wholly unique and separate tendering solution that can target multiple applications, will continue to exist in tandem.

According to state DISCOMs, the power supply profile of FDRE tender comes closest to matching the firmness and dispatchability of thermal power. Hence, FDRE tenders will ultimately be crucial to reducing dependence on coal and other conventional power sources. Punjab State Power Corporation Limited (PSPSCL), being an offtaker in both SECI FDRE-I and FDRE-II, is already assessing the FDRE tenders to retire some of its coal capacity.

## ESS Trading on Power Markets

Many projects under these tenders are significantly oversized to cater for the strict requirements of power delivery under ESS tenders. Hence, most new grid-scale ESS tenders allow the developer to sell excess power generated from the project to a third party or on the power markets. A vibrant power market segment catering to ESS power is also imperative to fulfil grid-scale demand surges in peak periods of the year.

In August 2022, the Ministry of Power mandated that Indian power exchanges introduce a separate product to the day-ahead market (DAM), the High Price-Day Ahead Market (HP-DAM), which caters to high-cost power from specific categories of generators.[30] The Indian Energy Exchange (IEX) initiated its HP-DAM market segment (with BESS generators among the eligible sellers) in March 2023, with Power Exchange India Limited (PXIL) and Hindustan Power Exchange (HPX) expected to follow in 2024. In June 2023, IEX added this high-price vertical under its real-time market (RTM) and contingency market segments.

**Table 7: Features of HP-DAM**

| Parameter | Description |
| --- | --- |
| **Product name** | High Price-DAM under DAM |
| **Eligibility criteria** | The following categories of generators are eligible to participate in HP-DAM:<br>• Gas-based power plants using imported RLNG and Naphtha<br>• Imported coal-based power Plant using only imported coal<br>• Battery Energy Storage Systems (BESS) |
| **Auction Methodology** | Uniform price step double-sided auction |
| **Bid price range** | Floor Price: Rs0/kWh<br>Forbearance Price: Rs20/kWh |
| **Status** | IEX has been operating HP-DAM since March 2023. PXIL and HPX are listing HP-DAM, due to start in 2024. |

*Sources: Ministry of Power, IEX*

Unfortunately, HP-DAM, active since March 2023 on IEX, has had very little activity.[31] This indicates an inferior liquidity of buy and sell bids for HP-DAM. However, with several large grid-scale ESS projects commissioned within the next few years, high price power markets will likely spark a flurry of activity. Obligated entities aiming to fulfil their ESOs in the coming years will also be a key driver for developing these ESS-based power markets.

## Outlook for ESS Technologies

PHS has been used in the power grid for decades as an ancillary and backup support. However, in the past few years, there has been an unparalleled emergence of BESS.
A strong demand for batteries, especially in the electric vehicle (EV) market, has contributed to the steep reduction in their price, leading to a significant inflow of investments in BESS.

[30] Ministry of Power. Seeking comments of proposal on High Price Market Segment for Day Ahead Market (HP-DAM). August 2022.
[31] Moneycontrol. High Price Day Ahead Market at power exchanges had no trade for over a month since launch. 27 April 2023.

PHS provides long-duration, grid-scale energy storage (more than six hours) at a significantly lower cost than BESS. However, PHS has a considerably larger lead time of more than 36 months (compared with BESS). This is partly due to several associated regulatory clearances related to environment and construction. On the other hand, BESS is a modular solution and can implement a wide array of ESS applications, ranging from energy shifting to frequency regulation. However, beyond a discharge time of four hours, the financial viability of BESS (especially Li-ion) is adversely affected.

True long-duration storage (weekly or seasonal) can only be achieved through green hydrogen. In green hydrogen-based ESS, excess electricity can be stored physically through the production of green hydrogen. This green hydrogen can be stored for weeks or months and converted to electricity through fuel cells when required. India, along with several other countries around the world, is in the process of setting up massive green hydrogen infrastructure, such as electrolysers. The economy of scale, both in manufacturing capabilities and actual production, will be a crucial factor in driving down the levellised cost of hydrogen (LCOH), leading to green hydrogen ESS attaining financial parity with other forms of storage.

In the near term, large grid-scale ESS will favour PHS, mainly due to it having the lowest levellised cost of energy (LCOE). However, with the likely decline in battery prices, BESS may overtake PHS as the most financially viable option to implement grid-scale ESS. In the long term, with green hydrogen-based ESS possibly attaining parity with PHS and BESS, green hydrogen may become the dominant grid-scale ESS technology.

# Conclusion

Renewable energy has made significant strides over the years. However, the rising penetration of variable renewable energy (solar/wind) in the electricity grid has exposed new risks regarding grid stability and resilience. Energy storage will play a crucial role in ensuring the firmness and sustainable growth of RE in the electricity mix.

According to the optimum power generation mix study conducted by CEA in April 2023, India will require at least 41.7GW/208GWh of BESS and 18.9GW of PHS in FY2029-30. The same year, the study estimated the variable renewable energy capacity at 392GW (292GW solar, 100GW wind), half of the installed power capacity. A concerted effort by all stakeholders is imperative to attain this ESS target.

ESS is still an emerging sector in India, and grid-scale ESS tendering will play a crucial role in its initial development. The tendering in India has shifted from vanilla solar or wind tenders to more complicated tender designs with equal emphasis on power quality and scale. Storage is slowly gaining prominence as a crucial component to enhance or maintain this power quality. Even the projects under usual wind solar hybrid tenders are allowed to install some ESS component to maintain their annual minimum CUF commitment.

The focus on PHS to implement grid-scale ESS is rising swiftly. PHS-specific grid-scale ESS tenders accounted for more than 56% of all ESS tender issuance in 2023, contrary to prior years wherein no ESS tender was exclusively specified for PHS. The PHS tender issuance in 2023 is more than 19GW, already greater than the PHS capacity the CEA estimated for FY2029-30.

Tendering agencies, led by SECI, have worked diligently for years to find the ideal grid-scale ESS tender design for India. These include tender designs such as solar + BESS, peak power supply, RTC and standalone ESS. FDRE is the latest iteration in this evolution. SECI claims that FDRE addresses all the issues in previous ESS tenders and will likely be the dominant tender type in future.

FDRE tenders mandate the developers to supply power in line with a fixed demand profile of the energy offtaker, thereby creating a "win-win" scenario for both developers and energy offtakers. Apart from the five FDRE tenders SECI issued in 2023, other tendering agencies have also issued FDRE tenders recently, such as National Thermal Power Corporation (NTPC), National Hydroelectric Power Corporation (NHPC) and Rewa Ultra Mega Solar Limited (RUMSL). Industry stakeholders point to the firmness and dispatchability of power under FDRE tenders as comparable to conventional sources. With similar power quality and declining costs of renewable energy and ESS, FDRE can potentially replace thermal, a situation FDRE offtaker DISCOMs are already exploring.

**With similar power quality and declining costs of renewable energy and ESS, FDRE can potentially replace thermal, a situation FDRE offtaker DISCOMs are already exploring.**

The design of the FDRE tenders will have a major impact on tariff discovery. The tendering authorities must aim to design the FDRE tenders with multiple offtakers having complementary seasonal load profiles. In addition, the demand profile must be carefully set considering the daily and seasonal load requirements, unlike the FDRE-III (Haryana) tender, wherein there is just one offtaker, and the demand profile is static throughout each time block at 800MW.

In 2030, BESS, PHS, and green hydrogen will be the most prominent ESS technologies in India. The development of green hydrogen infrastructure will represent another pivotal shift in the ESS market. Green hydrogen produced during the excess power availability can be physically stored as a fuel for an extended period or transported where required. The high calorific value of hydrogen (about 150,000 kilojoules (kJ)/kg) will enable a large amount of energy to be stored in a relatively much smaller space.

The outlook of ESS has improved, wherein it has taken centre stage in all power sector developments rather than as an afterthought. However, there are still some challenges that need to be addressed. Firstly, the planned GW-scale ESS projects will need a robust supply chain infrastructure in India, which will need time to develop. Fluctuations in project costs, driven by an unexpected rise in battery costs in 2022 and then its subsequent fall in 2023, demand caution from stakeholders bidding on BESS projects. To support the development of renewable energy and ESS, T&D infrastructure will need to be concurrently strengthened, which the government aims to do through its national transmission plan by 2030.

In ESS's initial years of development, the government must support the industry through targeted incentives. One is to reduce the applicable tax and duty rates until the domestic manufacturing ecosystem develops. ESOs, introduced in 2022 by the government, should also be strictly enforced. To increase the proliferation of ESS among corporate consumers, SECI may act as a demand aggregator and set up a centralised "ESS as a service" grid-scale project.

While there is no requirement for indigenisation in ESS systems in India, a policy similar to DCR can be formulated for ESS once ample domestic manufacturing is set up. Hence, ALMM can also include batteries or any other critical ESS components in the future.

It can take five to 10 years to commission a pumped hydro project. Thus, it is imperative to reduce this lengthy gestation period. To address this, the approval process for PHS projects must be sped up and streamlined. Another option can be identifying potential PHS sites and their preliminary study by government agencies even before tendering.

In conclusion, ESS is the link that bridges the power quality between variable and intermittent renewable energy and conventional energy sources. Renewable energy capacity additions to grid infrastructure cannot sustain long-term without a concurrent equivalent rise in grid-scale ESS system capacity. Thus, widespread deployment of large-scale ESS in support of its renewable energy capacity will be crucial for countries to meet their decarbonisation and net zero greenhouse gas emission targets.

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# About JMK Research & Analytics

JMK Research & Analytics provides research and advisory services to Indian and International clients across Renewables, Electric mobility, and the Battery storage market. www.jmkresearch.com

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