Background Note – Distributed Renewable Energy for Sustainable Development Conference

February 2024

CLIMATE POLICY INITIATIVE

POWER FOUNDATION OF INDIA

CONTENTS

1. INTRODUCTION

India has set ambitious targets as part of its climate change mitigation commitments. In its revised Nationally Determined Contribution (2022), the country committed to reducing its emission intensity (volume of emissions per unit of GDP) by 45% from 2005 levels by 2030. It also set a target of having 50% installed power generation capacity from non-fossil-fuel-based energy sources by 2030.[1]

India's current per-capita power consumption of 1,255kWh per year is far below the global average of 3,541kWh per year.[2] However, significant growth in power demand is likely considering the country's pace of economic growth (7.3% in FY2023-24)[3] and urbanization (1.34% year-on-year),[4] paired with improved electricity access.

While concerted efforts will be required to achieve its climate-related targets, India has made steady progress to date. By December 2023, around 44% (188.5GW)[5] of the country's total installed power generation capacity (428 GW)[6] pertained to non-fossil-fuel-based sources, comprising 134 GW for renewable energy (RE), 47 GW for hydropower, and 7.5 GW nuclear capacity. With this growth, India has become the world's third-largest producer of RE.[7]

Most of this RE capacity has been achieved through large utility-scale wind power installations (~45 GW) and ground-mounted solar (~58 GW); the capacity from other Distributed Renewable Energy (DRE) sources such as rooftop solar, off-grid solar, small hydropower, biomass, and waste to energy cumulatively amount to only 24% (~32 GW) of total RE capacity.[8]

To increase the share of DRE sources in the energy mix, the Government of India has launched multiple schemes. These include the Pradhan Mantri Kisan Urja Suraksha evam Utthaan Mahabhiyan (PM-KUSUM; Prime Minister's Farmer Energy Security and Development Campaign), Grid Connected Solar Rooftop Programme, the Solar Energy Scheme for Power Looms, and DRE targets under Renewable Purchase Obligation (RPO). The Hon'ble Prime Minister also announced the launch of the PM Surya Ghar Muft Bijli Yojana rooftop solar scheme for free electricity in January 2024. With an investment of over INR 75,000 crore (USD 9.1 Billion[9]), this scheme aims to light up 1 crore (10 million) households by providing up to 300 units (300 kWh) of free electricity every month using solar rooftop solutions.[10]

1 https://pib.gov.in/PressReleaseIframePage.aspx?PRID=1987752#:~:text=In%20August%202022%2C%20India%20updated,enhanced%20to%2050%25%20by%202030. (as on 19 Feb 2024)
2 https://cea.nic.in/dashboard/?lang=en (as on 19 Feb 2024)
3 https://pib.gov.in/PressReleaseIframePage.aspx?PRID=1993550#:~:text=INCOME%2C%202023%2D24-,Indian%20economy%20is%20to%20grow%20by%20a%20robust%207.3%25%20in,double%20digits%20growth%20of%-2010.7%25. (as on 19 Feb 2024)
4 https://www.globaldata.com/data-insights/macroeconomic/urbanization-rate-in-india-2096096/#:~:text=India%20had%20an%20urbanization%20rate%20of%201.34%25%20in%202021.,2011%2C%20between%202010%20and%202-021. (as on 19 Feb 2024)
5 https://cea.nic.in/dashboard/?lang=en (as on 19 Feb 2024)
6 https://cea.nic.in/dashboard/?lang=en (as on 19 Feb 2024)
7 https://pib.gov.in/FeaturesDeatils.aspx?NoteId=151141&ModuleId%20=%202 (as on 19 Feb 2024)
8 https://mnre.gov.in/physical-progress/(as on 19 Feb 2024)
9 At conversion rate of 1USD = INR 82
10 https://pib.gov.in/PressReleaseIframePage.aspx?PRID=2005596 (as on 19 Feb 2024)

Such government policies and schemes have the potential to foster a more favorable regulatory environment, scalable business models, and innovative financial structures to unlock the potential of DRE projects in the country. Through this paper, the Power Foundation of India and Climate Policy Initiative examine the different DRE technologies and solutions, along with the benefits they offer, the barriers to achieving scale, and potential solutions. The paper also examines the role DRE solutions could play in achieving the Sustainable Development Goals.

2. DEMYSTIFYING DRE

DRE is critical to India's sustainable growth; however, the lack of a universally accepted definition of this term creates ambiguity. At its core, DRE encompasses various technologies and solutions that enable decentralized electricity generation, benefiting local communities, households, and businesses.

The Forum of Regulators defines DRE as "The electricity fed into the electric system at a voltage level of below 33 KV using rooftop solar PV system [or such other forms of renewable sources as may be approved by the Commission from time to time or as recognized by the Ministry of New and Renewable Energy, Government of India]" [11].

In India, DRE also covers the Productive Use of Renewable Energy for livelihood generation. The Ministry of New and Renewable Energy (MNRE) has identified multiple technologies and solutions under DRE with an emphasis on livelihood generation. According to the MNRE, DRE[12], [13] livelihood applications are those powered by RE to support livelihoods. These technologies include solar dryers, solar mills, solar or biomass-powered cold storage/chillers, solar charkha (spinning wheels) and looms, small-scale biomass briquette/pellet-making machines, etc.[14] Some of these technologies and associated solutions are discussed in the subsequent sections.

11 https://forumofregulators.gov.in/Data/Reports/DMR-for-GIDRES-08-05-19.pdf (19 Feb 2024)
12 https://india-re-navigator.com/public/tender_uploads/rooftop_policy-6049fa415e0da.PDF (as on 19 Feb 2024)
13 https://www.investindia.gov.in/team-india-blogs/distributed-renewable-energy-india (as on 19 Feb 2024)
14 https://india-re-navigator.com/public/tender_uploads/rooftop_policy-6049fa415e0da.PDF (as on 19 Feb 2024)

3. DRE TECHNOLOGIES AND SOLUTIONS

3.1 MINI AND MICROGRIDS

Mini- and micrograds are decentralized energy systems, typically operating in challenging-to-serve locations. These differ in terms of generating capacity, with mini-grids typically exceeding 10 kW and microgrids falling below this threshold.[15] These are generally served by relatively small, location-specific, load-dependent, DRE generation sources.

The technology behind these mini and microgrids – often solar, wind, or hydro – is decided based on location, and is often complemented by battery-based energy storage systems. The mini and microgrid solutions can be off-grid or connected to the wider state/regional grid. With the expansion of the electricity grid, these solutions are moving beyond their traditional role of providing last-mile connectivity, to empower communities by enabling reliable 24/7 electricity supply, aligning with India's vision for a transformed power sector.

3.2 SMALL HYDROPOWER PROJECTS

In India, sub-25 MW hydropower generating stations are classified as small hydropower projects. Small hydropower is further classified into mini, micro, and pico based on capacity (as shown in Figure 1). These small projects are built on runoff streams and often do not require relocation of communities or deforestation. Economically feasible with a relatively low gestation period, these plants are well-suited to powering villages and remote areas in the Himalayan and Western Ghat belts of the country.

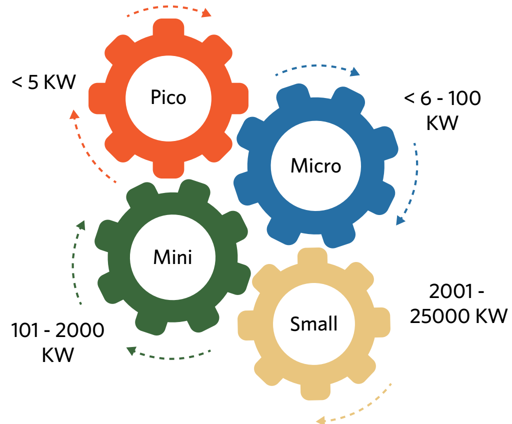

Figure 1: Capacities of Small Hydro Projects

According to the MNRE, India has the potential to generate 21 GW from small hydropower from around 7,133 sites. Currently, 1,167 plants contribute 5 GW with an additional 102 plants in various stages of completion.[16] Although it requires relatively higher investment, small hydro projects have a long lifespan with minimal operation and maintenance costs, efficiency ranging from 70% to 90%, and dispatchability where pondage is available, making them suitable for complementing other variable renewable generation sources.

3.3 SOLAR AGRI PUMPS

Agriculture is a major contributor to the Indian economy. Agriculture and its allied sectors collectively accounted for 18.3% of the gross value added within the total economy, as of

15 https://cstep.in/drupal/sites/default/files/2022-02/An%20Introduction%20to%20Mini%20Grids.pdf (as on 19 Feb 2024)
16 https://cdnbbsr.s3waas.gov.in/s3716e1b8c6cd17b771da77391355749f3/uploads/2023/08/2023080211.pdf (as on 19 Feb 2024)

2022-23.[17] These sectors employed 46.6% of the workforce in 2022.[18] Agriculture also holds strategic importance in ensuring the country's food security.

India's monsoon season plays a prime role in the irrigation of arable land. However, pumps are often used either as a primary or complementary source of irrigation, given the erratic nature and uneven geographic spread of the seasonal rains. Irrigation pumps are typically powered by diesel gensets, creating recurring costs for farmers as well as emitting pollutants and greenhouse gases into the environment. Solar-powered agricultural pumps offer a viable environmentally sustainable alternative that is low maintenance, scalable, and adaptable to off-grid areas, and save on forex by avoiding the use of diesel (predominantly refined from imported crude).

Keeping this in consideration, the Government of India through the PM-KUSUM scheme has targeted the installation of solar-powered irrigation systems and solarization of grid-connected agriculture pumps. The scheme targets setting up 34,800 MW by March 2026 with a total central financial support of INR 34,422 crore (USD 4.2 Billion[19]).[20]This includes 10,000 MW of decentralized ground/ stilt mounted grid-connected solar or other RE, installation of 14 Lakh (1.4 Million) stand-alone solar agriculture pumps, and solarization of 35 Lakh (3.5 Million) grid-connected agriculture pumps including feeder level solarization.[21]

3.4 SOLAR COLD STORAGE

India ranks second globally in terms of fresh produce, with an estimated production of over 107 million metric tonnes of fruits, and nearly 205 million metric tonnes of vegetables in FY2022-23.[22] However, a substantial portion of this is lost due to a lack of cold chain infrastructure. An estimated 30% of fruit and vegetables are lost or wasted each year and total post-harvest food loss amounts to around INR 14,93,000 crore (USD 182 billion[23]) annually[24].

The availability of reliable electricity supply is a barrier to the development of the requisite cold chain infrastructure. Solar-based cold storage solutions provide an opportunity to address challenges associated with post-harvest food management, particularly in remote and off-grid areas. Recognizing this potential, the Government of India has established the National Center for Cold Chain Development (NCCD) as a dedicated nodal agency. The NCCD promotes several subsidy schemes for setting up cold chain elements in India.[25] To address the need for capital, dedicated funds including Agriculture Infrastructure Funds have been established which support collateral-free term loans for cold storage establishments. These initiatives intend to significantly reduce capital costs and enhance accessibility for entrepreneurs and farmers seeking to invest in solar cold storage solutions.

17 https://www.pib.gov.in/PressReleasePage.aspx?PRID=1909213 (as on 19 Feb 2024)
18 https://www.niti.gov.in/sites/default/files/2023-02/Discussion_Paper_on_Workforce_05042022.pdf (as on 19 Feb 2024)
19 At conversion rate of 1USD = INR 82
20 https://pmkusum.mnre.gov.in/landing-about.html (as on 19 Feb 2024)
21 https://pmkusum.mnre.gov.in/landing-about.html (as on 19 Feb 2024)
22 https://apeda.gov.in/apedawebsite/six_head_product/FFV.htm#:~:text=As%20per%20National%20Horticulture%20Database,million%20metric%20tonnes%20of%20vegetables. (as on 19 Feb 2024)
23 At conversion rate of 1USD = INR 82
24 https://aeee.in/wp-content/uploads/2022/08/scaling-up-investment-in-clean-and-efficient-cold-chain-in-india.pdf (as on 19 Feb 2024)
25 https://www.nccd.gov.in/ (as on 19 Feb 2024)

3.5 DISTRIBUTED ENERGY STORAGE

The intermittent availability of RE sources prompts the need for energy storage systems that are capable of storing excess generated power for on-demand distribution. These systems enhance flexibility and reliability, enabling enhanced integration with the electricity grid. Distributed energy storage (DES) can be in the form of pumped storage capacity, battery energy storage systems, and even thermal storage systems (for cold chain applications).

In contrast to centralized systems, DES minimizes transmission and distribution losses by facilitating energy transfer near generation and consumption points, thereby enhancing efficiency. In addition, the modular nature of technologies like battery energy storage systems make them suitable for deployment and scaling in remote areas.

Falling costs of storage technologies combined with the rise of solar rooftop technology are spurring the adoption of DES. With further expected decline in the cost of storage technologies, distributed renewable storage could potentially become cost-competitive with other grid-based electricity supply options. Research suggests that this could initiate the process of energy independence for consumers and communities with the potential for them to eventually become grid-independent and *Aatmanirbhar*.[26] Therefore, the growth of DES is expected to be in tandem with the growth of DRE in the country.

26 https://www.sciencedirect.com/science/article/pii/S2589004223004923 (as on 19 Feb 2024)

4. BENEFITS OF DISTRIBUTED RENEWABLE ENERGY

Aside from reducing greenhouse gas emissions, DRE solutions offer a wide range of benefits. Some of these are detailed below:

4.1 TECHNICAL BENEFITS

a) ***Resource diversification potential:*** DRE solutions can combine multiple resources (e.g., solar, wind, and hydro) depending on their availability in a given geographic location, coupled with DES to smoothen out intermittency and provide reliable supply.

b) ***Increasing resilience:*** The small and modular nature of DRE systems distinguishes them from centralized generation systems and associated transmission infrastructure, which could face longer outages in case of breakdowns. This resilience is critical in remote areas with vulnerable grid infrastructure.

c) ***Minimizing transmission and distribution losses:*** By generating electricity close to the point of consumption, DRE reduces transmission and distribution losses. This is especially important in countries like India, where technical losses are on the higher side.

4.2 SOCIETAL BENEFITS

a) ***Creating economic opportunities:*** DRE systems catalyze sustainable growth by fostering new economic opportunities in rural areas, nurturing the expansion of local businesses engaged in the sale and installation of RE systems. They also facilitate the establishment of new industries dependent on a consistent and affordable energy supply, strengthening resilience in rural communities.

b) ***Enabling energy self-reliance:*** The shift towards decentralized energy generation is likely to accelerate, driven by the falling cost of RE technologies, especially solar PV, and the government's thrust on DRE solutions. This will empower consumers to become prosumers, who not only generate and consume electricity but also can trade it on the local grid (net metering, gross metering, and peer-to-peer trading).

c) ***Improving agricultural earnings:*** Erratic monsoons, high diesel costs, and limited cold storage capacity are some of the challenges affecting India's agricultural sector. Schemes such as PM-KUSUM would provide support to farmers for setting up solar pumps, thereby reducing irrigation-linked issues. Solar chillers, dryers, and other productive use solutions close to the point of production can prolong the shelf life of produce, thereby enhancing agricultural earnings.

d) ***Supporting a just transition:*** DRE projects generate job opportunities at the local level, contributing to economic growth and extending the benefits of the low-carbon energy transition to grassroots communities. This generation of localized employment can help to reduce migration from rural to urban areas, preserving the social fabric of rural communities and reducing pressure on urban infrastructure.

5. BARRIERS AND POTENTIAL SOLUTIONS

Learnings from DRE experience (see Annexure 1 for illustrative cases) underscores several impediments to their adoption and scaling, as well as potential solutions to overcome these challenges. Some key financial and technical barriers, and potential solutions, are detailed hereunder:

5.1 FINANCIAL BARRIERS

a) ***High capital expenditure:*** The high capital expenditure required to set up DRE solutions remains a notable obstacle to their broader adoption. While these technologies may be financially justified based on the levelized cost of electricity (LCOE) or lifecycle analysis, their upfront capital expenditure can render them unaffordable, especially for consumers with capital constraints.

Solutions:

- Targeted capital subsidies, soft loans, and incentives such as interest subvention schemes can reduce the capital expenditure burden.
- Business solutions such as pay-as-you-go models, which convert upfront capital costs into longer-term operational costs can help to increase consumer uptake.

b) ***Improper tariff comparison:*** One important reason for limited support for DRE among distribution companies is improper tariff comparison. DRE tariffs are often compared to these companies' average cost of supply (ACOS) and are deemed uncompetitive. However, a fairer comparison would be with the cost-to-serve.

Solutions:

- Evaluate the cost competitiveness of DRE based on cost-to-serve rather than ACOS, factoring in technical losses incurred for a fair comparison.
- Factor in the savings accrued from the deferment of distribution infrastructure augmentation considering a reduction in distribution load growth due to DRE solutions.

5.2 TECHNICAL BARRIERS

a) ***Variability:*** Certain DREs, such as distributed solar and small wind turbine technologies, grapple with variable or intermittent outputs, thereby affecting their applicability as primary electricity sources affecting their uptake.

Solutions:

- Supplement variable DRE sources with other, more dispatchable generation technologies like small hydro or biomass-based capacity.
- Use electricity storage solutions like battery energy storage systems and pumped hydropower storage systems.
- Implement demand response programs to align consumption with variable DRE generation.

b) ***Grid integration:*** Most electricity distribution systems were designed for unidirectional electricity flow. The introduction of grid-connected DRE solutions, which can intermittently feed electricity into the distribution system, may necessitate hardware modifications and operational adjustments to ensure grid stability. Given that centralized generation still dominates most electricity systems, utility and system operator familiarity with grid-connected DRE solutions remains limited.

Solutions:

- Capacity building of system operators to better understand grid-connected DRE solutions and handle bidirectional power flows.
- Revision of standard operating procedures factoring in DRE systems for ensuring system reliability.
- Investment in smart grid infrastructure.

c) ***Lack of a technically trained workforce:*** Installation, operation, and maintenance of DRE systems requires technical expertise. The scarcity of local experts in remote areas impedes adoption and creates concerns regarding maintenance services for DRE adopters. In most cases, organizations budget to bring in external technical support to remote locations, resulting in increased costs and extended downtime. Inadequate maintenance, partially attributed to the lack of skilled personnel, contributed to the failure of numerous DRE projects.

Solutions:

- Develop standardized training modules for various DRE technologies to facilitate capacity building.
- Offer training at subsidized rates in local industrial training institutes to develop a talent pool.
- Redesign policy and incentive frameworks that not only enable the setting up of DRE capacity but also incentivize the operation and maintenance of these assets.

6. THE WAY FORWARD

India is taking bold steps towards sustainable growth and reducing its carbon emissions. DRE solutions offer a pathway to help achieve the country's ambitious emission reduction targets while ensuring the energy security and independence of the country. DRE also plays a critical role in achieving the UN SDGs (see Annexure 2), by addressing energy poverty, enhancing food security, improving health and education, promoting gender equality, fostering economic growth, supporting sustainable infrastructure, and contributing to climate action.

This background note would be developed into a detailed conference paper based on the proceedings and discussions of the DRE Conference. Considering the importance of DRE for India, the Power Foundation of India, and Climate Policy Initiative are planning a series of papers on different aspects of these solutions. These papers will cover perspectives from industry, government, and end-use beneficiaries, as well as international examples to support the Government of India in accelerating the adoption of DRE and enabling a low-carbon transition.

ANNEXURE 1 – DRE CASE STUDIES

Case 1 – Ladakh, India: Micro Hydro Powered Clean Energy

Ladakh is known for its mountain passes and clear sky, however extreme weather conditions make remote villages inaccessible for three to four months of the year. One such village is Udmaroo, which is situated on the bank of River Shayok in Nubra Valley of Leh District, about 150 km from the town of Leh.

The village has 90 households and a total population of about 540. Neither clean energy sources (e.g., electricity) nor natural had adequately reached this village via state agencies, creating a major dependence on fossil fuels. These polluted the atmosphere and endangered health of people and the fragile ecosystem of this region.

Solution highlights:

- Micro hydro has been installed with a capacity of 32 kVA which generates 20–25 kVA electricity in 2008.
- The unit is managed and maintained by the village electricity committee.
- Most households each contributed INR 1,000 (USD 12.2[27]) towards the capital cost of the system, with some villagers contributing in-kind through unpaid labor for its installation.
- Villagers have also taken the initiative to install a carpentry saw machine, a flour machine, and an oil expeller, making use of the electricity generated at the site.

Value proposition:

- This community initiative has led to cleaner air and the safeguarding of fragile ecosystems.
- Installation of machines by local entrepreneurs has created additional income for the community and provided livelihoods to many families, along with a reduction in drudgery of manual household and farm work.

Case 2 – North India: Powering Hinterlands Using Husk

The company Husk Power Systems has pioneered the use of rice husks as a biofuel to generate electricity. The electricity generated is often used to power communities and/or villages with a population of less than 500. Rice husk is abundant in North India and has a high calorific value (3,410 Kcal/Kg).

For its initial project, Husk Power System created a 35-kW plant, based on the generator set size available in the market. A single plant under this model powered three to four villages on average, which accounted for roughly 60% to 70% of capacity.[28]

27 At conversion rate of 1USD = INR 82
28 https://isbinsight.isb.edu/case-summary-husk-power-systems/ (as on 19 Feb 2024)

Solution highlights:

    - Directly reaches individual households, bypassing the grid, to power around 500 households/shops across three villages

- **Benefits:** Stable electricity demand and efficient plant operation.
- **Cost-effective:**
    - Plant cost: ~USD 32,000
    - Jobs created: 3-4 per plant
    - Installed per KW cost: USD 80 to USD 90 per kW (lower than comparable technology)
    - Electricity sales revenue: USD 800 to USD 900 per month per plant
- **Sustainability:**
    - Rice husk ash is sold to concrete manufacturers
- **Financial viability:**
    - Break-even point achieved in three years
    - Positive net present value achieved in four years (from electricity revenue alone)

Value proposition:

- The use of rice husk as fuel was selected based on the local environment.
- The use of indigenous methods such as using bamboo poles in the distribution network kept the initial project costs in check.
- Project sizing was according to the needs of communities.
- Monetization of rice husk ash waste materials by selling to concrete manufacturers provides additional sources of revenue.

Case 3 - Mentawai, Indonesia: Rural Electrification Using Decentralized Biomass-based Power Generation System

A bamboo-based community power plant was created in a pilot study in the Mentawai Islands Regency, Indonesia. The community supplies bamboo and the state utility buys the power and subsidizes village energy costs through a 20-year agreement. This arrangement benefits 1,181 households and providing electricity activities like cold storage for agriculture.[29]

Solution highlights:

- 700 KW capacity installed across three villages
- Serves 1,181 households and 456 non-residential connections

Value proposition:

- The use of bamboo as fuel was selected according to the local environment.
- The power purchase agreement and agreement on feedstock uptake demonstrate a citizen-centric approach of the project.
- The project is expected to benefit the overall development of the region.
- Buy-in from federal and state government agencies and the community indicates the convergence of various stakeholders to create an impact.

29 https://powermin.gov.in/sites/default/files/uploads/Decentralised_Renewable_Energy.pdf (as on 19 Feb 2024)

ANNEXURE 2 – DRE CONTRIBUTION TO SDGs

DRE contributes to and interacts with the UN Sustainable Development Goals (SDGs):

- **SDG 1: No Poverty:** DRE projects create job opportunities and alleviate poverty in both urban and rural areas.
- **SDG 2: Zero Hunger:** Productive use applications such as solar cold storage help to reduce food wastage.
- **SDG 3: Good Health and Well-Being:** DRE solutions reduce reliance on polluting energy sources and also enable the operation of medical facilities, refrigeration for vaccines, etc.
- **SDG 4: Quality Education:** Reliable electricity from DRE sources enables access to educational resources and lighting for study.
- **SDG 5: Gender Equality:** DRE projects under productive use application empower women by providing income-generating opportunities.
- **SDG 7: Affordable and Clean Energy:** DRE solutions promote access to affordable and clean energy.
- **SDG 8: Decent Work and Economic Growth:** DRE creates local employment opportunities and contributes to economic growth.
- **SDG 9: Industry, Innovation, and Infrastructure:** Investments in DRE drive technology and business model innovation.
- **SDG 11: Sustainable Cities and Communities:** Urban areas benefit from DRE through rooftop solar installations.
- **SDG 12: Responsible Consumption and Production:** DRE promotes responsible consumption, minimizes wastage, and reduces environmental impacts.
- **SDG 13: Climate Action:** The transition to RE is a key strategy for mitigating climate change.
- **SDG 17: Partnerships for the Goals:** Collaboration between governments, private players, and local communities is key for successful DRE deployment.

www.powerfoundation.org.in
www.climatepolicyinitiative.org