S4S Technologies: Addressing India's Energy Trilemma with Productive-use Decentralised Renewable Energy

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1.1 India's energy trilemma

Energy security is a critical issue in many areas and communities in emerging economies, including India. Despite 97% of Indian households having access to electricity, reliability and supply issues persist.[1] These access issues disproportionately affect rural Indian households, with the International Energy Agency (IEA) estimating that 53% of rural households in India face more regular and longer power cuts than urban households.[2]

Energy unaffordability compounds this. Indian consumers pay up to 3-4 times the cost of electricity generation due to ineffective infrastructure and practices by power distribution companies. This leads to tariff rates that are higher than those in Malaysia, Vietnam, and even China.[3]

In 2021, India set a target of achieving net zero emissions by 2070.[4] Transitioning away from fossil fuel-based energy generation is an important lever in the fight against climate change. However, today 70% of India's electricity grid is derived from fossil-fuel heavy sources.[5] Diesel and biomass are used as alternate sources of energy, especially during times of grid blackouts, which in rural India can be up to 8 hours a day.[6]

Addressing this energy trilemma, of security, affordability and sustainability, remains critical for India's green development.

1.2 What are decentralised renewable energy (DRE) approaches?

A potential solution to India's energy trilemma is the use of decentralised renewable energy (DRE) approaches. DRE approaches differ from traditional energy generation approaches in that they localise energy production facilities to the site of consumption, where energy is typically generated off the main grid, reducing transmission and distribution inefficiencies.[7] These approaches tend to make use of renewable energy sources, such as biomass and solar.

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[1] Agrawal, Shalu, Sunil Mani, Abhishek Jain, and Karthik Ganesan. 2020. State of Electricity Access in India: Insights from the India Residential Energy consumption Survey (IRES) 2020. New Delhi: Council on Energy, Environment and Water. Accessible here: https://www.ceew.in/sites/default/files/ceew-research-on-state-of-electricty-access-and-coverage-in-india.pdf.

[2] India Energy Outlook 2021, International Energy Agency. February 2021. Accessible here: https://www.iea.org/reports/india-energy-outlook-2021.

[3] N. Banerjee, "Why are Indians paying three to four times the cost of generating electricity", National Herald, 25 July 2020. Accessible here: https://www.nationalheraldindia.com/india/why-are-indians-paying-three-to-four-times-the-cost-of-generating-electricity.

[4] Climate Action Tracker. Accessible here: https://climateactiontracker.org/countries/india/net-zero-targets/#:~:text=Target%20year%20%E2%80%93%20India%20aims%20to,Government%20of%20India%2C%202022a.

[5] India Energy Outlook 2021, International Energy Agency. February 2021. Accessible here: https://www.iea.org/reports/india-energy-outlook-2021.

[6] "These Indian states are on the brink of power outage amid heatwaves, increased demand" Livemint, 29 April 2022. Accessible here: https://www.livemint.com/industry/energy/power-cut-delhi-punjab-uttar-pradesh-kerala-haryana-maharashtra-are-on-brink-of-power-outage-amid-heatwave-increased-demand-coal-shortages-11651192917644.html.

[7] https://www.unescap.org/sites/default/files/14.%20FS-Decentralized-energy-system.pdf.

DRE approaches have been used for almost two decades across India, and are often led by small enterprises, startups and local communities.[8] They can serve as an effective tool in plugging the reliability gap that plagues many rural communities by using renewable energy sources. To date, the DRE solutions deployed in rural areas in India have been primarily for consumer-use, that is driven by consumer demand. Examples include solar microgrids that provide households with off-grid energy and quality of life solutions, such as solar lights and cookstoves. While a valuable source of reliable, renewable energy, their adoption is often constrained by affordability challenges in maintaining such systems.

The question of affordability of consumer-use DREs has led to the rise of productive-use DRE solutions, which focus on supplying DRE-powered equipment for productive work that can directly lead to additional revenue or cost savings for users.

Examples of the leading productive-use DRE solutions are given below in **Table 1**.

Table 1: Examples of productive-use DRE solutions

Cold Storage	Food Processing	Irrigation	Textiles
Chillers Solar refrigerators Cold rooms Dryers	Rice and millet milling Crushers and processors Solar dehydrators	Solar surface and subversive pumps	Solar rooms Solar sewing machines

1.3 The role of productive-use DRE approaches in addressing the energy trilemma

Productive-use DRE approaches have the potential to address the three elements of India's energy trilemma.

The primary difference between productive-use and consumer-use DRE solutions is the potential for livelihood generation. In addition to being a cheaper energy source than fossil fuel-based energy, renewably-powered, productive-use DRE solutions enable users to generate income through the use of their DRE products, thereby addressing the affordability issue of consumer-use DRE solutions.[9] For instance, a farmer utilising a solar dehydrator increases their income through the sale of value-added outputs (the dehydrated produce) and reduced spoilage (the wasted produce). This can, in turn, improve quality of life for rural users of productive-use DREs. An increase in income generation and improvement of livelihoods for consumers tackle the critical adoption challenge faced by consumers (i.e., paying capacity).

In addition, DRE systems connected to microgrids can be used as a source of energy for others. This allows owners of DRE systems to sell excess power to other users of the grid or microgrid, plugging local energy supply gaps and helping to address energy security issues.[10] DRE systems can serve as back-ups that address energy supply gaps, or provide reliable energy generation off-grid.

Finally, productive-use DRE solutions can also help to address the environmental impacts associated with traditional energy sources in India. They primarily generate energy from renewable sources, such as solar and biomass, thereby increasing the share of renewables in an individual's or business's energy mix. In addition, productive-use DRE solutions are also likely to drive the growth in funding and financing for DRE

[8] This insight is based on S4S's experience working in this space. For example, DRE solutions such as solar microgrids, have been in place since the early 2000s.
[9] https://www.germanwatch.org/sites/default/files/germanwatch_renewable_energy_africa.pdf.
[10] https://youmatter.world/en/decentralised-renewable-energy-systems/.

needed to support India's net zero targets. A Climate Policy Initiative (CPI) Report identified that India would need to see a 10x increase in its annual DRE investment to USD 18 billion by 2024.[11]

There have been various successful pilots of productive-use DRE adoption in sectors such as agriculture, fishing and agro-processing. A case study example of the successful adoption and use of S4S's productive-use DRE-powered agricultural dehydrators can be found in section 1.5 of this report.

1.4 S4S Technologies

S4S Technologies is an India-based business providing decentralised agricultural processing technology to over 800 female entrepreneurs working in the agricultural sector across 290 rural Indian villages. As well as setting up village-level collection centres that source processing-grade produce and establishing market linkages to sell the dehydrated foods, S4S installs micro-processing units near smallholder farms. The micro-processing units have the capacity to dehydrate and process over 45 different ingredients and increase the shelf-life of produce by up to 12 times. S4S's dehydrator and micro-processing units are an example of a productive-use DRE solution, where energy drawn from captive renewable sources, specifically solar energy, is used to power equipment for productive work that can lead to additional revenue or cost savings for users.

The use of solar energy to power the dehydration systems is a matter of necessity as well as an opportunity for S4S Technologies to incentivise clean energy use for rural electrification. Rural areas in large parts of India are poorly electrified, as explored in section 1.1. This makes electric dehydrators ineffective and potentially under-utilised when powered using grid electricity, which is dominated by fossil-fuel energy sources.

S4S's DRE-powered, electric micro-processing unit generates greenhouse gas emission savings in 3 ways, by:

- Simplifying logistics and logistics cost by removing water and reducing weight of the produce by up to 10x at the farm-gate;
- Using solar energy for food processing saving fossil fuel-based emissions;
- Reducing food loss, where 7kg CO2 equivalent is saved for every kilo of food loss avoided.

S4S's products currently process 25,000 tonnes of food annually which helps to realise a greenhouse gas emission saving of around 68,750 tonnes of CO2eq, in addition to the indirect emissions savings through the use of DRE-powered micro-units instead of units powered by traditional energy sources.

The productive-use DRE solutions S4S employs focus on increasing incomes for rural communities as well as minimising the climate impact of food processing. Wider adoption of these systems, however, is needed to tackle India's energy trilemma.

1.5 Lessons and opportunities to address barriers of DRE adoption in India

Despite examples of successful uptake of productive-use DRE approaches in India, they are still only being deployed at a local level, cover a small fraction of the productive energy usage in the country, and face barriers to wider adoption.[12] The DRE sector is nascent and faces key structural challenges such as weak electricity infrastructure, a lack of skilled manpower for installation and repair, and ineffective financing options. These need to be addressed to realise the products' full potential.

[11] https://www.climatepolicyinitiative.org/publication/the-future-of-distributed-renewable-energy-in-india/.
[12] https://mnre.gov.in/img/documents/uploads/file_f-1644909209115.pdf.

S4S have identified four key opportunities that DRE solutions should focus on, which if strengthened, can be catalysts for mainstreaming DRE solutions in the sector.

1. DRE solution-providers need access to financing that enables them to make products more affordable for customers

External capital is often needed to manufacture and develop these products. Grant capital from philanthropic institutions and incubation funds helps to provide first investments that primarily go towards research and development of products to ensure they are market-ready. Debt and non-dilutive capital are also important instruments especially used for production and sale of DRE solutions that are hardware-based and asset-heavy. Despite the availability of capital, adoption of solutions can be slow as products are too expensive for customers to purchase. DRE solutions need to be engaged in financing approaches that make adoption for customers more affordable and accessible.

S4S Technologies works to address the problem of affordability by providing a productive-use DRE solution. A key part of S4S's approach is providing dehydrators to farmers to extend the life of produce, reduce food wastage and increase incomes. To overcome the cost barrier, S4S Technologies worked with a financing entity to develop a performance-based asset financing instrument, where customers did not need to pay for the cost of the equipment, but instead only pay monthly instalments that were linked to the income generated in using the dehydrators. The instrument was designed in such a way that in low yield periods, customer pay-outs will be lower than in higher yield periods, making it more affordable given the income and cash flow cycles of smallholder farmers.

As women farmers have no land ownership and no bank accounts, they are not included in the formal banking system. S4S has developed a unique financing model where women farmers do not have to invest any initial capital cost. For example, the company has partnerships with nationalised banks (State Bank of India, Indian Overseas Bank, Maharashtra Gramin Bank) and government to leverage financing for women farmers - who are all new to credit with no evidence of credit history. Through bank partnerships across the country, S4S works toward financing, which is available without any collateral, no upfront payment, and at an affordable rate, ensuring rapid scalability of DRE products.

2. DRE-solution providers need to enable market linkages for the outputs customers create

Outputs from rural-based, productive-use DRE solutions tend to be intermediary products, such as food produce and textile yarn. These need value additions to be made into products that generate revenue, but such value additions are often not located near rural areas where outputs are produced. Rural customers are often unable to sell to such value-added markets, for example selling cotton yarn to apparel companies, or dehydrated vegetables to food producer companies. Yet, selling productive-use DRE equipment to customers is often not enough. Companies need to also work vertically across their value chain to create market linkages for these outputs. This has an additional benefit to DRE system producers of creating additional revenue streams beyond selling DRE equipment.

S4S Technologies has adopted a market-linkages approach. They deploy their solar dehydrators (that are purchased by smallholder farmers and groups through financing approaches as described above) to increase the amount of food produce that the organisation can access and sell to food producer organisations. That is, they buy the produce output that farmer groups make from S4S's solar dehydrators, among other sources. In effect, S4S Technologies has transitioned from a supplier of productive-use DRE solutions to an enabler of supply, as solar dehydrators sell more food produce to value addition markets. This is demonstrated by the term through which S4S labels their operations: a full-stack food processing platform.

3. The DRE-jobs ecosystem needs to be more collaborative and made more attractive to overcome the skilled worker gap especially for rural areas

There is a lack of skilled workers and accessibility to talent in the productive-use DRE ecosystem, primarily during the installation process and after-sale service support in rural areas. Technicians often have to travel long distances to reach the rural areas where customers are located, where the lack of quick resolution can be a negative experience for rural consumers, affecting DRE adoption. Skilled workers are estimated

to account for 71% of employment in the DRE sector in India, around 56,000 people, but given the increasing electrification, there is a need to reskill workers towards supporting commercial and industrial productive-use DRE applications.[13]

There is an opportunity to train and develop skills of individuals in rural areas where job options are limited, but this requires collaborative engagement between DRE companies.[14] Especially at the early-stage, it can be expensive for an organisation to hire multiple skilled technicians, but the related nature of technology across DRE solutions can create collaboration opportunities between DRE providers. An example of this collaboration could include shared job boards where skilled technicians in specific geographic clusters can work across DRE providers, for faster resolution of issues, which helps to improve customer experience.

S4S Technologies works towards creating an ecosystem for skill development in a concentrated geography. It started with several technical universities in its geography of operations by providing internship opportunities and exposure visits for students pursuing technical courses. It also encourages the setting up of maker rooms for students to do product experimentation and organises regular special training sessions conducted by experts in the field. This creates a strong and skilled network of technicians and engineers in Tier 2 and Tier 3 cities.[15] S4S hires from this talent pool, thus making technical resources readily available to serve women entrepreneurs during machine breakdown.

4. Improve capacity building and product training for customers to address servicing and repair gaps

Even with the improvements in accessibility and resolution that a collaborative approach for skilled workers can offer, rural customers will continue to have service and repair experience gaps and issues. This makes it important for DRE-solution providers to design solutions and support that enables and empowers customers to maintain and perform basic servicing where necessary, instead of having an exclusive reliance on technicians.

Capacity building for customers can be adopted in many ways. It begins with how products are designed to allow for ease of servicing and maintenance. Education and knowledge sharing are also critical factors. User manuals, guides, and demonstrations should be easily accessible, and importantly available in local languages where the solutions are deployed so that such capacity building and training support is effective. Capacity building should be involved in the sales process, which can often be a repeated process to build the confidence of rural customers in being able to do these activities on their own.

S4S is developing an impressive array of digital tools that would enable faster communication and solutions for any breakdown. With a learning management system, minor challenges can be repaired at the women farmer's end with assistance from our technician. Furthermore, enabling the iotization of the machines will create historical data and enable technicians to make data-based decisions.[16]

[13] https://www.powerforall.org/resources/reports/renewable-energy-jobs-sub-saharan-africa-and-india-2022-power-all.
[14] DRE companies have country or regional sales offices. Distributors are also common.
[15] As per the government, cities having a population size ranging between 50,000 and 100,000 are categorised as Tier 2 cities in India while cities with population size ranging between 20,000 and 50,000 are known as Tier 3 cities.
[16] Iotization refers to the process of connecting products to the internet, such as mobile device and the Cloud.

Box 1: Food waste case study

A case study example of the impact of S4S's DRE solutions in practice is that of Anita Kholte, who is a smallholder farmer from Bhavadi village in Maharashtra. Before the introduction of S4S's electric, solar-powered dehydrating and processing unit, her income from selling vegetables was inconsistent due to market price volatility, and a lack of access to premium markets and cold storage – thus forcing her to throw away her produce at the end of the day.

She would sell her vegetables to the first of up to eight middlemen who ultimately sell her produce to one of India's 270,000 food processing units, often located in centralised clusters far away from Anita's farm, to be made into FMCG and food service products for India's growing population to consume.

From this work, Anita used to earn an average of INR 40,000 a year. She needed to sell her produce quickly, often at lower prices, to ensure that her harvested crops did not spoil and that she could extract some value from them.

A full-stack food processing platform, S4S works with smallholder farmers and farmer groups to source food produce, which it then processes through DRE-powered dehydrators into shelf-stable, nutrition-rich, and convenience foods, and sells them to industrial kitchens and packaged food companies. Ever since becoming an S4S-supported micro-entrepreneur, Anita has increased her income by 50% to INR 60,000 a year; an income amount that is steady, unlike her previous way of earning. She has also been able to significantly reduce the 15% loss of food that is usually experienced at post-harvest stage, due to being able to process the harvest herself and extend the lifetime of the produce. The processing is done using the DRE-powered processing unit, which is cost-effective, reliably powered and has a minimal climate impact compared to fossil-fuel powered units.

1.6 Conclusions and looking forward

S4S's approach has highlighted the potential of productive-use DRE systems in addressing India's trilemma of energy security, affordability, and climate impact, and has drawn out lessons from its work to identify four key opportunities that DRE solutions should focus on in order to promote wider DRE adoption in the agriculture sector. These include the need to access financing that enables providers to make products more affordable for customers, the need to enable market linkages for the outputs customers create, the need for the DRE-jobs ecosystem to be more collaborative and attractive in order to overcome the skilled worker gap, especially in rural areas, and the need to improve capacity building and product training for customers to address servicing and repair issues.

S4S is creating a new food ecosystem that mitigates the increase in agricultural greenhouse gas emissions while meeting the world's food needs. S4S's renewable energy solutions and the integrated food-energy system can directly advance energy and food security, while also contributing to job creation, gender equality, and climate resilience and adaptation. The company's vertically integrated approach, *Forward Market Linkages and Affordable Financing Solution for Farmer*s, make S4S services an ideal solution with a promising path to scale. S4S's agri-processing systems, with one of the highest energy efficiencies in the world, are a reliable and cost-effective alternative to fossil fuels, promoting decentralised infrastructure, and reducing labour-intensive activities.