SUSTAINABLE ENERGY SOLUTIONS (SDG7) FOR TOMATO VALUE CHAIN

SELCO FOUNDATION

german cooperation
DEUTSCHE ZUSAMMENARBEIT

Implemented by giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

IKEA Foundation

Good Energies FOUNDATION

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PREFACE

This report is based on key learnings from a program jointly conceptualised by APMAS and SELCO Foundation. The program is funded by GIZ, Green Innovation Centre, Good Energies Foundation and IKEA Foundation. The program aims to demonstrate decentralised sustainable energy solutions to all relevant stakeholders that can enable replication and scale. It also seeks to create synergies among ecosystem actors (technology manufacturers, financiers, trainers, markets etc.) to aid the adoption, dissemination and sustainable utilization of high impact, livelihood technologies within the tomato and allied value chains.

The report catalogues the context and need for the solutions, the technology specifications and the potential impact of such solutions. The insights captured here are largely based on experiences of testing and demonstrating solutions in the tomato-growing district of Chittoor (in Andhra Pradesh).

The Green Innovation Centres for Agriculture and Food Sector" (GIC) – India programme is part of the "ONE WORLD – No Hunger" (SEWOH) initiative of the German Federal Ministry for Economic Cooperation and Development (BMZ). In India the programme is working along the three value chains Tomato, Potato and Apple. Good Energies Foundation is focused towards empowering the primary producers with sustainable energy led solutions which improve their resilience to climate change. IKEA Foundation, together with SELCO Foundation, is focused towards ecosystems for scaling sustainable energy driven energy efficient technologies for agriculture and allied livelihoods.

ABOUT SELCO FOUNDATION

SELCO Foundation seeks to inspire and implement solutions that alleviate poverty by improving access to sustainable energy to underserved communities across India in a manner that is socially , financially and environmentally sustainable.

The organisation's efforts broadly include:

01 **Inclusive innovation** and implementation of holistic technology-finance-ownership models based on a clear understanding of end-user needs

02 **Ecosystem building** on aspects of appropriate financing, local skills and entrepreneurship development and practitioner-driven policy for interventions to be sustainable in the long run

03 **Incubation** of grassroots level clean energy enterprises and local technology enterprises to enable decentralisation of services at the last mile

04 **Replication of models and processes** based on learnings and sharing of knowledge across regions and contexts.

SELCO Foundation demonstrates the role of clean energy and energy efficiency across areas of well being, livelihoods, health and education.

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01 BACKGROUND:

1.1 SDG7 AND AGRICULTURE

The agriculture sector is essential to the overall development of rural economies, particularly in developing country contexts. Improvements in the sector with a focus on small and marginal farmers can contribute to improving productivity, increasing food security and incomes and enhancing service access, all of which are essential to end extreme poverty. The current challenges in agriculture are exacerbated by climate change- with increased heat stress, variable precipitation that shifts rainfall patterns, increased pest attacks and climate risks such as droughts and floods. Due to the dependency on already stretched and rapidly depleting soil and water resources, these farmers are extremely vulnerable to climate change and bear the brunt of catastrophic economic and social losses. In the absence of solutions that increase productivity, value capture and facilitate appropriate linkages to markets, farmers are highly at risk in these fragile, inequitable systems.

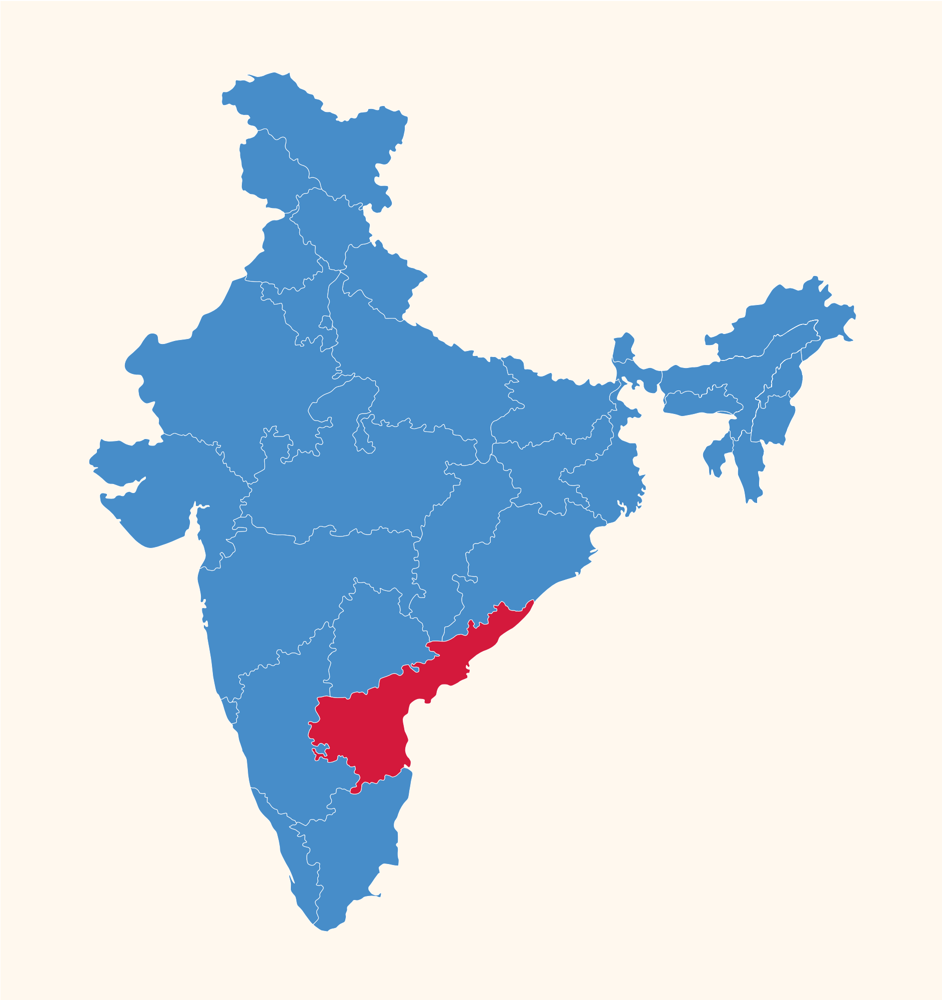
Small and marginal farmers with land holdings of less than 2 hectares are ill-equipped to deal with the vagaries of climate change and other systemic problems. The current narrative focuses on farmers having to produce enough food to feed the teeming billions with increasing demands. While this is a critical concern, it is equally important to understand what resources farmers have, and how we can optimise production using these resources to increase incomes and build resilience. This is a critical aspect of the innovations needed in agriculture from the perspective of the climate-energy nexus.

1.2. AGRICULTURE SCENARIO IN CHITTOOR

Around 70% of the lands in Chittoor district in the Southern state of Andhra Pradesh are dry lands, growing rainfed crops. The area was known for the cultivation of various dry crops such as millets, ragi, bajra, jowar, groundnut, red gram, cowpea, bean pea, horse gram etc. However, due to the poor remuneration for cereals and pulses, farmers have been primarily focused on cultivation of groundnut and tomatoes in the district.

Chittoor is predominately studded with hills. Traditionally, due to the absence of any major natural water resource, several chains of small tanks had been built for irrigation. The farmers in the central parts of the district grow paddy for one season and follow it up with two years of sugarcane. In the eastern taluks/ blocks, farmers opt for a cycle of paddy and groundnut in the Rabi season, while in the western taluks, farmers cultivate vegetables, especially tomatoes, with some others also cultivating mulberry (for silk). The alternative occupation of these small and marginal farmers is dairy, with a herd size of 2-5 cows, predominantly reared for local self consumption.[1]

Chittoor is connected to main markets such as Bangalore and Chennai (175 kms and 150 kms respectively). This could be one of the factors that has led to an increase in cultivation of vegetables like tomato, brinjal, beans and potato and floriculture which are all crops with relatively higher profit margins.



1.3. TOMATO VALUE CHAIN IN CHITTOOR: AN OVERVIEW

The state of Andhra Pradesh is known as the highest producer of tomatoes in India with an annual production of **5,962.21 thousand tons**, which contributes to about 35% of the total tomato production in India.[2] Within Andhra Pradesh, Chittoor district is the largest cultivator of tomatoes in the state. Specifically,

1 MAJOR AGRICULTURAL CROPS IN CHITTOOR DISTRICT,. R. Sarath Kumar,Dr. P. Subramanyachary,Indian Journal of REsearch,Issue : 5 | May 2015

2 Scenario of essential supply like Tomatoes from rural to urban areas, M.V. Durga Prasad and Vollance S Christian, January-June 2013_Special Issue on IDRC

the region of Madanapalle is considered one of the biggest tomato markets in Asia. It gathers tomatoes cultivated by small-scale and marginal farmers in the villages surrounding Madanapalle in Chittoor as well as Kadapa districts of Andhra Pradesh.

The tomato yard in Madanapalle holds about 1000 tonnes of tomatoes. The market is spread across 20 acres of land and it is located in the centre of the city. The tomatoes from Madanapalle are sold to local markets across states such as Maharashtra, Gujarat, Kerala, Tamil Nadu, Madhya Pradesh etc, as well as neighbouring countries such as Pakistan and Bangladesh.

02 NEED AND ROLE OF DECENTRALIZED ENERGY IN TOMATO VALUE CHAIN:

2.1 KEY CHALLENGES

Tomatoes are highly volatile crops that need to withstand various climate risks with constant fluctuations in market prices. In the absence of good infrastructure and logistics, farmers are pushed to undertake distress sales. The region experiences high glut during the year, where the cost of harvesting and transporting the crop to the market is much higher than the market price at which it would be sold. In such scenarios, tonnes of tomatoes go to waste resulting in income losses.

Typically a farmer has to invest anywhere between INR 30,000 to 50,000 per acre as inputs (such as manure, fertilisers, pesticides, irrigation, mulching paper, sticks and overall labour charge). Coupled with the most dynamic factor of fluctuating prices, farmers make speculative decisions and sell tomatoes out of distress.

Tomatoes are also water intensive crops which require timely irrigation throughout the cultivation cycle. Improper water management has been a major cause of the depleting water table in the region, which makes climate adaptation and mitigation strategies extremely critical for the region.

2.2 ROLE OF DECENTRALISED RENEWABLE ENERGY (DRE) FOR TOMATO FARMING

The issues at hand are diverse from production to processing of tomatoes; lack of reliable and affordable energy is one of the key issues that comes up at various stages within the value chain- from the use of soil testing facilities to powering on-farm equipment and irrigation solutions; and from enabling cold chains for storage to processing for preservation and value-add.

Presently the sector is dominated by large-scale, ill-fitted agricultural machinery (on farm, production and processing technologies) which are inefficient, use expensive traditional fuels and are unaffordable for small and marginal farmers. This scenario reflects a few critical points:

01 Existing innovations in the tomato value chain do not cater to the needs of these small and marginal farmers. With limited access to capital, they require smaller capacity machinery that do not add to their energy expenditure burdens.

02 Enabling access to inefficient machinery powered on traditional energy sources will only add to the carbon emissions and result in adverse environmental implications. In the past, adoption of inefficient machinery has led to extractive practices and natural resource depletion. Over the years with increasing heat stress and uncertain rainfall, groundwater tables in Andhra Pradesh have dipped down to levels of 1200 ft from 800 ft only a few years ago. With the state government supplying free electricity for pumping, most farmers in the region including small ones invested in inefficient, high capacity pumps and appear to have over-pumped water through deep borewells to grow water-intensive tomato crops, depleting the groundwater levels

03 Appropriate and efficient machinery- while extremely important- will alone not solve the issues for small and marginal farmers in the absence of reliable and good quality electricity access.

Decentralized Renewable Energy (DRE) can play an important role in powering equipment to address these energy gaps along the value chain in a reliable and efficient manner. Combined with appropriate and efficient equipment suited to the small farmer, the potential for DRE powered livelihood technologies is immense for the tomato and allied value chains. Reduced input costs and reduced post-harvest losses are some of the major impacts.

These solutions can contribute to better crop management and reduce the cost of inputs with technologies such as sprayers, water pumps, bio-fermenters etc and services such as soil testing. From a processing perspective, the glut in the market could be addressed by processing and creating value-added products such as pickles, sauces, dehydrated slices etc. using technologies such as dryers, slicers, pulpers and so on. These technologies combined with clean energy have the potential to reduce drudgery and increase farm incomes.

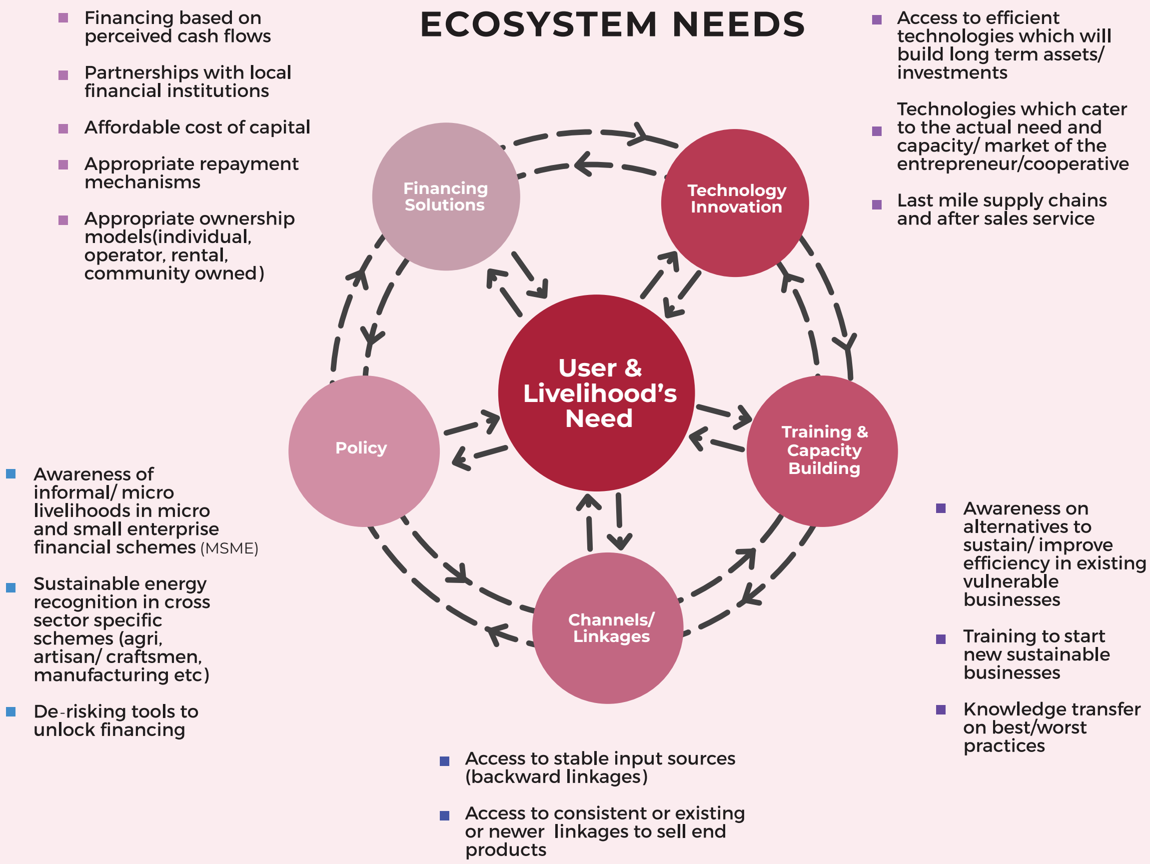
More efficient technologies powered on decentralised renewable energy, coupled with sustainable practices like drip irrigation, groundwater recharge, resuscitation of farm ponds can go a long way in meeting the broader agenda of improving livelihoods and incomes while also building climate resilience.

2.3 APPROACH TO SOLUTION BUILDING

The key aspects of the approach to identifying needs, designing and deploying holistic solutions are outlined below.

- **Decentralization:** Building decentralised productive assets is one of main ways to develop local economies and strengthen last mile resilience and sustainability. Within agriculture, efficient and need-based assets can help reduce drudgery, improve productivity, increase product diversification and contribute to greater wellbeing and higher incomes. Decentralisation presents the opportunity to maintain maximum value at a farm and farmer level and increase the benefit for small and marginal farmers.

- **Solution innovation:** Developing holistic solutions as a combination of technical, financial and ownership models is quintessential to the approach.
  - » **Technology Suitability and Efficiency:** Working with specific technology partners to implement and modify technologies that can better suit the needs of the farmers. This approach also helps to reach energy efficiency benchmarks thereby reducing energy consumption and energy expenditures.
  - » **Financing and ownership models:** Based on the nodal point, type of technology and usage, the ownership of the solution can be determined-whether at an individual level, group of FPO level. The energy system cost, business model/ expected cash flows and ownership will then determine the financing mix- percentage and terms of credit, gap financing and subsidy support, end-user contribution etc.
- **Ecosystem building:** This involves strengthening the ecosystem aspects to create conducive conditions for the deployment and sustainability of the solutions.



» **Linkages and capacity building:** Developing partnerships with grassroot organisations and FPOs to strengthen backward and forward linkages and build capacity on other aspects of the ecosystem can ensure optimum utilization to realize the impact of the technology. These aspects would include awareness on technology, training on usage, backward and forward linkages for the product, market and business development support.

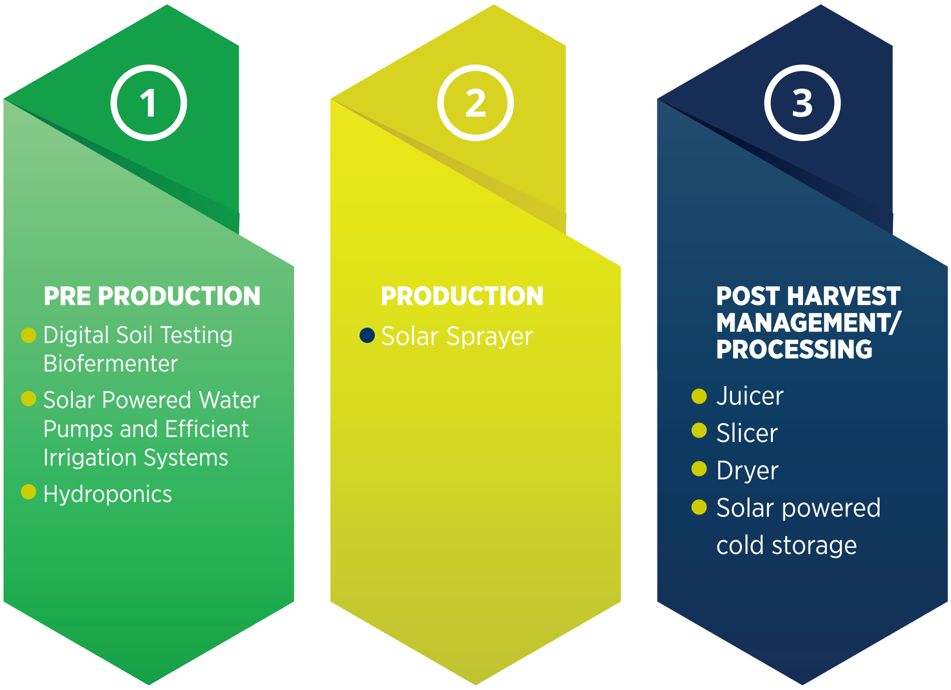
» **Unlocking credit and government programmes:** Proving financial feasibility, learning from the implementations and working actively with stakeholders to enable the creation of appropriate financial products, unlocking schemes and leveraging existing government programmes that seek to improve the impact for farmers in the tomato value chain.

This document aims to showcase the diverse solutions within the tomato value chain- on-farm, production and post harvest processing technologies- holistically designed with proven impact in agriculture and allied sectors. The technologies discussed here for on-farm and production phases could be adopted in the cultivation of all tomatoes, whereas post processing technologies are conducive only for the table varieties of tomato, such as *gewel, veerang*, emerald, *sakata, rishika etc*. which are among the many varieties processed in Madanapalle (in Chittoor district).

03 DRE-POWERED SOLUTIONS FOR TOMATO VALUE CHAIN

OVERVIEW OF TOMATO VALUE CHAIN

The various phases in the tomato value chain have been mapped and the energy nodes at each phase identified and illustrated in the graphic below.



3.1 PRE- PRODUCTION

3.1.1 Digital soil testing

Overview: Soil testing is the process of collecting soil samples and analysing the data on fertility in order to monitor the necessary quantities of fertilisers and nutrients for best yield. A soil test can determine fertility, i.e. expected growth potential of the soil with an indication of nutrient deficiencies, potential toxicities from excessive fertility and the implications of non-essential trace minerals or the lack thereof. The key challenges faced in the current systems for soil testing include:

- The soil testing centres are centrally located in Madanapalle. Typically, a farmer would have to travel between 90-110 km by public transport prior to every sowing season. The transaction costs can amount to INR 7,20,000/- per year for 1000 farmers (per FPO).

- The soil report itself can take anywhere between 1 to 4 weeks to receive from the agencies and follow ups by the farmers can drive up the transaction costs up by 1.5 times. More often the reports are received post the sowing season where there is an overuse of fertilisers in the absence of better insights resulting in increased cost of inputs for farmers.
- Lack of knowledge about soil or land exposes the produce to unknown dangers with the risk of income losses

A soil test helps optimise crop production, helps in diagnosis of plant culture problems and supports judicious utilisation of fertilisers and inputs.

Solution: Soil testing centres can be implemented through a Farmer Producer Organisation (FPO)-owned model or as an individual entrepreneur-owned service delivery model. The digital soil testing would require soil samples collected in the prescribed manner (dug from around 15-30 cm depth & collected in a zigzag manner from around 7-10 random spots) which will then be weighed and filtered at the centre. Following this, relevant chemicals are added to arrive at parameters like Nitrogen, Phosphate, potassium, zinc among others. The machine is then able to provide a report on the biochemical composition of the farmland and also helps in determining the nutrient gaps in the soil and the best ways to address them.

However, in both these cases it is important that the soil testing centre is complemented with training and schemes and policies that incentivise soil conservation, and provide awareness on cropping patterns, water conservation practices, biofertilizers etc.

Easy access to soil testing centres and faster access to reports can reduce the farmers transaction costs. It primarily leads to optimised farming, and thus savings on fertilisers, manure and pesticide used per acre. Regular soil testing, and responsible use of fertilisers, manure and pesticide can also (in the long term) contribute to improved soil health.

FPOs and individual entrepreneurs can generate revenues of nearly INR 50,000 per cropping cycle (assuming approximately 1000 farmers per FPO).

Technical specifications-

Energy system

Solar Module	Battery	Charge controller
100 WP	80 AH	10 A, 12 V

Efficient	**Appliance**
System type	AI based system to estimate biological, chemical and physical matter with automated sample preparation
Ease of use	One trained entrepreneur or operator
Detectable Parameters	Nitrogen (N), Phosphorus (P), Potassium (K), Boron (B), Zinc (Zn), Iron (Fe), Copper (Cu), Sulphur (S), Soil Organic Carbon, Electrical Conductivity, pH
Report delivery	<1 hour per test 10 test per day on average

CASE STUDY

Background: M- Tomato FPCL (farmers producer company) is a collective representing a group of 14 FPOs (Farmers Producer Organisations) around the area of Madanapalle, Andhra Pradesh.

An initiative was developed by APMAS to subsidise the cost of soil testing which can catalyse sustainable and economical farming practices and result in overall soil health improvements in Chittoor. There is awareness on the benefits of such practices amongst farmers, but the high transaction costs and delays in accessing reports prior to sowing season result in lower uptake.

Solution:

Solar powered Digital soil testing machine operated by an FPO appointed entrepreneur.

It was implemented in Oct 2021 with more than 200 tests done in a 6 month period upto March, 2022. Farmers approach the FPO for soil testing and purchase fertilisers and seeds along with their report in a span of 2.5 hours.

Impact:

Convenience: The unit has helped farmers in the surrounding area reduce travel and transaction costs. In addition, the device is portable and accessible to farmers in remote locations. The soil testing unit report can be accessed through mobile application as well as SMS.

Faster results: The conventional soil testing unit takes about 1 to 4 weeks to provide test results whereas the digital soil testing unit can initiate a report within 30-45 minutes, which is instantly shared with end users on their registered mobile phone numbers.

Customizability: The data provided can be calibrated across 11 parameters to any particular crop grown based on farmer insights on the specific nutrition requirements for that crop.

3.1.2 Bio fermenter

Overview and challenges:

Madanapalle produces about 500 litres of organic fertilisers like jeevamrutham and panchagavya on a weekly basis. Bio-fertilisers are typically stored in a 500L capacity tank (based on the need for landholdings of 2-3 acres for tomato) and requires 2 individuals continuously stirring the contents for 30 minutes a day. A farmer is required to employ daily wage labourers or family members in this manually intensive activity.

Solution:

A solar powered automatic bio-fermentor is intended to work as an agitator to supply oxygen during the process of fermentation. The solution comes with two tanks (a fermentation tank & a filtration tank), a battery powered motor for stirring and a timer controller unit. Some of the popularly known natural farming solvents brewed in this fermenter are jeevamrut, brahmastra, Agniastra, Amritpani, Dashparni, etc

The solution is intended to reduce drudgery, ensure stirring is uniform and improve output quality of the natural fertilizer. An automated stirrer is fitted into a fermenter- an enclosed vessel that maintains optimal conditions for the growth of microorganism to produce organic liquid bio-fertilizers. Filtered jeevamrutham is then applied on the farm using drip irrigation units.

The model can be implemented for an individual farmer for self consumption and for service provision within the community (which can generate revenues while providing services to other farmers). In the service model, farmers pay a nominal fee to buy the final product of Jeevamrutham while the entrepreneur bears the cost of raw materials. Typically, a 500 litre solution can cater to about 25-30 farmers with land holding between 2-3 acres for tomato crop.

Technical Specifications:

Energy system

Solar Module	Battery
60 WP	12V38 AH, 1 BATTERY

Efficient Appliance

Air pump	Motor	Filter
150 PSI (pound per square inch)	40W12VDC	6 STAGE

CASE STUDY

Background: Vishwanath Reddy is an organic farmer in Ramasamudram village. He owns 5 acres of land and cultivates tomatoes, and other horticulture crops like chilli, brinjal, cucurbits and roses. He has been involved in the preparation of organic fertilisers like *jeevamrutham* for over 20 years.

Preparation of the organic liquid manually proved to be a laborious task. The process involved frequently stirring the fertiliser in certain intervals of time which was not only time consuming but also exhausting. Uneven mixing of the liquid through this manual process also resulted in challenges during irrigation, like blockages in the sprayer nozzles.

Solution: Solar powered Biofermenter

"I need to produce 10,000 Litres of jeevamrutham in a year for my 5 acre land holding for tomato farming. This meant spending half an hour every day for 4-5 months a year in laborious activities that prevented my family and me from engaging in other tasks on the field"

Impact:

Time and energy saving: With the technology adopted, the process is completely mechanised with no requirement for manual stirring; this has significantly reduced drudgery and opened up the 30-60 minutes of time otherwise involved in preparation.

Better yield: The use of a biofermenter unit provides ample amounts of homogenous jeevamrutham that helps promote good microbial growth on the field and has added the necessary nutrition to his crops.

Entrepreneurship and farm income diversification: With the installation of the biofermenter, the farmer not only produces enough fertiliser for his own use but has also started selling it at a price of INR. 5-6 per litre in the market. On average, he generates a monthly income of INR 7000- INR 8000 from the sale of his own organic fertiliser.

3.1.3 Solar-powered water pumps for farm ponds (with efficient irrigation)

Overview:

Over 60% of India's farmers rely on rainfed agriculture, and contribute 55-60% of all agriculture GDP[3]. Rainfed agriculture covers over 55% of the gross cropped area in the country, contributing to large percentages of the country's production of rice, millet, pulses and oil seeds.[4] [5] Despite this significant contribution to overall food production and agriculture GDP, these farmers still lag behind in terms of income from farming compared to their counterparts who are able to irrigate[6].

On average, farm cultivation still contributes to nearly 50% of the average monthly income for the typical agricultural household in India[7].

3 https://www.business-standard.com/article/opinion/revamp-rainfed-farming-119120201507_1.html

4 https://www.rainfedindia.org/

5 https://www.thehindubusinessline.com/economy/agri-business/rainfed-farmers-are-the-most-neglected/article26272190.ece

6 https://www.business-standard.com/article/opinion/revamp-rainfed-farming-119120201507_1.html

7 NSSO report 576, Income , Expenditure, Productive Assets & Indebtedness of Agricultural households in India 2013,. 2. Figure 6, Key Indicators of Land and Livestock, Situation Assessment Survey of Farmers, NSSO Survey 70th Round, 2014

Kharif is the main cropping season and runs from June to October where there is typically a high dependence on rainfall for farming. Erratic rainfall and long dry spells significantly increase the risk of farming households solely dependent on rainfed agriculture for this single cropping season. Critical irrigation, thus, becomes an important way of ensuring good crop yields in this season. However, farmers face certain challenges in ensuring this critical irrigation.

Challenges:

- Limited water availability for irrigation: Erratic and unpredictable rainfall in drought-prone regions such as Madanapalle create a water crisis typically during the months when rainfed farming is undertaken. Increasing years of drought without appropriate water harvesting has pushed farmers to dig new borewells adversely impacting local water aquifers. This water stress reduces the ability to provide critical irrigation and can adversely affect crop yield and farmer income, not to mention the implications on groundwater levels.
- **Lack of reliable and affordable energy options for critical irrigation:** In Madanapalle, water storage is done through farm ponds of 20x15x10 cubic feet, from where it needs to be pumped to the field for irrigation. Those farmers who rely on the grid-based power to run the pump sets are affected by power outages or transformer outages. Those relying on diesel pumpsets experience high fuel expenditures and fuel shortages. In areas like Madanapalle, farmers also rent diesel pump sets but the high demand for these pumps from multiple farmers during the period of critical irrigation adds to the inconvenience and sometimes the cost of providing critical irrigation.

- **Implications of current practices on water use:** In the absence of water recharge and management interventions, farmers are forced to pump water from borewells (using farm ponds as storage options) to provide critical irrigation, resulting in a depletion of groundwater levels. Lower groundwater levels also increase fluoride content in the water causing a host of health-related challenges for local populations.

Solution:

Given the various inter-linkages, this complex challenge requires an integrated solution that addresses the needs of water, energy, soil to improve farmers' incomes and secure their livelihoods.

An **integrated solar-powered irrigation solution** includes the following:

- Need-based solar powered pumps that are appropriately designed to enable convenient irrigation as required without overuse of water.
  a. Submersible or surface pumps.
  b. Fixed small- medium sized pumps or micro-small pumps for portability
- **Replenishing water source:** Rainwater harvesting structures such as borewell recharge systems, farm ponds to store water
- **Efficient irrigation systems:** Drip, Sprinkler irrigation

These technologies and interventions should be combined with water-retentive, efficient cropping patterns and appropriate soil management practices.

Technical specifications (specifically for Solar water pumps for farm ponds)

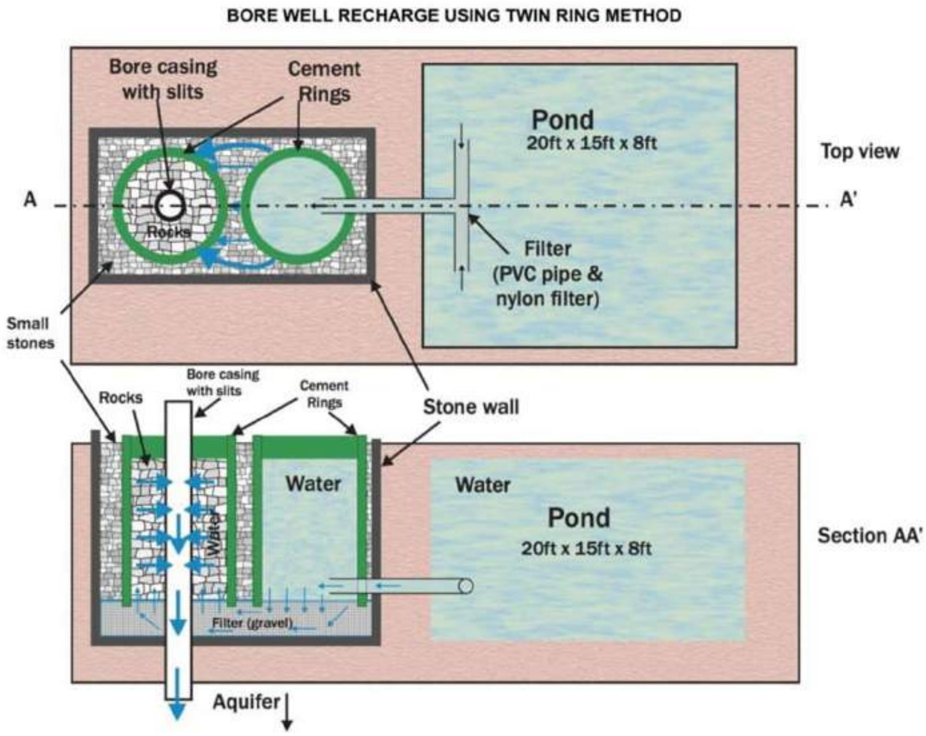
Energy system

Solar Module (range)
900-1500 WP

Efficient Appliance

Type	PMDC for farm ponds
Capacity (range)	1HP and 2 HP
RPM	3000
LPD (range)	1 to 1.5 lakhs
Max Head (Distance)	10 to 25 m

Water recharge and storage: Rainwater harvesting structures such as borewell recharge systems (to bring water back into borewells and openwells that have been overused and depleted groundwater levels), and construction of farm ponds (ideally without lining to allow for some percolation of water into the ground as well, overtime)



(Schematic on Borewell recharge mechanism: Credits- SRDS - NGO, Karnataka)

Delivery and ownership models:

Ownership/ Delivery model	Individual	Shared
Fixed	Suitable in areas where farm lands are far away from each other and individual farm ponds have been construction and/or for farmers with borewells and individual farm ponds who have larger areas of land (>2-5 acres) and interested in irrigation for more than one cropping season	Suitable for farm lands that are nearby, where: - a community farm pond has been constructed in fallow or common lands - same pump can be used to draw water from the large farm pond and divert to irrigate individual farm lands
Portable	Smaller and marginal farmers may have their own small areas of land for which they need to provide critical irrigation; they may need to pump water from their farm ponds to irrigate the land only a handful of times in the single cropping season. This may create an opportunity for an individual entrepreneur to own the pump, mount it on a portable structure and provide this water pumping service across multiple farm lands.	In cases where community cohesion is higher (for example- farmers belong to a single large family, or a single savings-lending group etc.), they may choose to have a portable pump through a shared, community ownership model. There would be an internal agreement about how many days each farm would need the pump and how they would share the payment towards capex and opex.

Impact on individual farmers:

01. **Improved income security and potential to increase income:** An integrated solution can enable dryland farmers to undertake irrigation, particularly critical irrigation for the first cropping season to improve crop yield. In addition, access to pumps and sustainable water sources can potentially increase the area under irrigation or add another cropping season to the farmer's yield and income

02. **Improved water access and efficient water usage:** contributing to longer term benefits for the farmland and rejuvenating land for future yield

03. **Reduced expenditure on irrigation in the medium-long run:** reductions in operational expenses incurred in fuel costs and maintenance of diesel-run pumps; Shared or rental models for solar water pumps also reduce capital expenditure incurred by each individual farmer on irrigation per cropping season.

Wider mitigation and adaptation related benefits:

01. **Contributing to improved groundwater levels:** farm ponds and rainwater harvesting techniques such as borewell recharge contribute to increasing ground water levels and restoring the flow of water to borewells, including those that may have dried up. Farm ponds help store water for critical irrigation post monsoons and can also be a way to reclaim and reuse fallow lands and reduce soil erosion. In the absence of lining, these farm ponds also facilitate percolation of water and act as a water recharge mechanism.

02. **Efficient irrigation and reduced water usage:** Efficient irrigation practices such as drip, sprinkler, etc. reduce water usage and wastage of fertilizers and deliver water and required nutrients directly to the roots, while also helping soil retain moisture for longer.

03. **Avoided CO2 emissions** from replacing diesel and grid-electricity powered pumps

CASE STUDY

Background: Sri Sevalal is a Farmer Producer Organization (FPO) located at Kadiri, Udumulakurthi village, Andhra Pradesh and consists of members across 5 Gram Panchayats. The FPO has been promoted by NABARD and Center for Sustainable Agriculture (CSA). The FPO works with small and marginal farmers with 2-4 acres, who predominantly cultivate paddy, mango, tomato, groundnut and jamun.

This is a drought-prone region, facing severe issues of water shortage. They were forced to transport water in tankers to the field for irrigation, spending INR. 800-1000 per trip for complete irrigation of their fields. APMAS has been promoting farm ponds as a means to store water and electric water pumps were used to irritate the fields from the ponds. However, most farmers also had issues with access to constant supply of electricity, which made electric pumps an unreliable option. Diesel powered pumps on the other hand resulted in high fuel expenses.

Solution: Solar powered portable water pump

A Surface Portable Solar Water Pump of 1hp capacity has been deployed to draw water from a maximum total dynamic head of 10-12meters. The solution is owned by the FPO which is utilised by 8 farmers in the region for a service charge of INR 100.

Impact:

User friendly: Solar pumps are easy to use, portable and don't need constant refuelling. With the use of solar power even farmers in extreme remote areas with no connection to the grid can irrigate their fields in a timely manner.

Savings: The use of solar pumps reduces the expenditure incurred for farmers-whether that is on transporting water in tanks for critical irrigation, whether it is on fuel for diesel pumps (approximately INR. 500 per day) and the associated maintenance costs (estimated at INR. 1000- 1500 every two months). All of these contribute to increased savings in comparison to the pre-intervention scenario.

Management of soil and water resources: The benefit of the solar-powered irrigation pump is best realised when supplemented with sustainable irrigation techniques and practices for soil and water conservation. Appropriate cropping patterns to avoid mono-cropping and ensure good soil health is critical to long-term sustainability of the solution.

3.2 PRODUCTION

3.2.1 Solar sprayer (centrally-powered)

Overview: Disease and pest infestations are a major challenge that can affect a farmers' entire harvest and result in adverse financial losses. Infestations can be avoided through efficient and judicious use of pesticides and fertilisers for weed, pest management and overall crop management to maximise yield. Efficient sprayers ranging in size, with options for portability can address this need.

In Madanapalle, battery-operated knapsack sprayers (of 20 litres capacity) are widely used. These are extremely heavy as the tank, the solar panel, battery and the sprayer components are carried on the farmer's back. Each battery needs to be charged for 6 hours to run the sprayer for 2 hours. This means farmers also spend time moving between the farm and the charging point (often in the house) which disrupts the flow of activities on the farm. The unreliability of electricity and untimely power cuts also add to the inconvenience.

Solution:

Solar powered stand-alone systems that de-link the sprayer (battery controller, motor etc.) from the solar panel and the nozzle can help alleviate the challenges outlined above. The systems would power on-farm (fixed) sprayers with a capacity of 400 litres and 4 hour run time covering <2 acres of land. Here, the sprayer unit (including battery and charge controller) can be placed in one location with the tank (liquid fertiliser/ pesticide etc.). The unit provides plug-and-play connections for input and output cables. The input cables connect the sprayer with the tank, and the output cables connect it to the nozzle. Long range pipes fitted with the nozzle allow for easy movement and spraying across the breadth of the farm. The different components are packed together and carried off-the-field by the farmer at the end of the day.

Technical specifications:

Energy system

Solar module	40 WP
Solar Controller	6/10 AMPS
Battery	12 V 12 AV
Motor pump set	60 W
Charger	12 V 1.7 A

Spraying Capacity (for single spray)	Operational time (for single spray)
400 LITRES	12 V 1.7 A

CASE STUDY

Background: Tulsiram Reddy is a farmer from Mudivedu cross, Chittoor district who grows primarily tomato and groundnut on his 8 acres of land. He previously used a petrol-fueled knapsack sprayer on his tomato field. He not only had to manually spray the field while carrying a heavy load on his back, but also had to make repeated trips to refuel the knapsack sprayer. He also incurred significant expenditure on petrol and maintenance requirements.

Solution: Solar powered fixed sprayer system.

Impact:

Ease of use: The sprayer is easier to use and requires lower maintenance when compared to petrol sprayers.

Reduced drudgery and time saved: The installed solar sprayer cuts down his drudgery substantially, as it ensures direct application/ spraying from the tank and has also helped optimise time used in spraying by eliminating trips to refill water or pesticides.

Savings: Tulsiram would spend nearly INR 300-350 of petrol for each cycle of spraying per acre which took place at least once or twice per week. He would subsequently also spend around INR 300 per day on labour for each cycle. These costs are avoided with the solar powered alternative.

3.3 POST HARVEST MANAGEMENT AND PROCESSING

Context:

Most farmers undertake 2 cycles of tomato cultivation per year, resulting in approximately 80 tonnes of tomatoes for each acre of landholding. Tomatoes have a short shelf-life once harvested and prices are volatile throughout the year ranging between INR 5 per kg to INR. 70 per kg. With value-added combinations of drying, slicing and pulping, the price per kg of products like tomato flakes or pulp starts at INR 150 and goes upward from there with appropriate market linkages. Find below the value capture via value addition of tomatoes:

- 20 kgs of raw tomatoes = 200 INR (INR 10 per kg)
- 20 kgs of tomatoes are required to produce 1.5 kgs of flakes
- 1.5 kgs of tomato flakes= 225 INR.

Small & marginal farmers are subject to drudgery when it comes to slicing of fruits or vegetables. Farmers incur losses due to price fluctuations, lack of logistics and infrastructure and poor market linkages.

Solution:

Solar powered, integrated micro-processing unit that powers equipment for slicing and pulping. A solar conduction dryer is also integrated into the processing unit; a small capacity solar panel is used to run the exhaust fans to prevent moisture and aid the conduction process.

SLICER

Slicer converts whole fruits and vegetables into thin and finer pieces. Slicing is a requirement prior to drying and pulping applications.

Slicing into thin pieces accelerates the drying time of tomatoes.

In a Self Help Group or Farmer group where 10 individual members come together to slice tomatoes, the time taken in this process can be optimised and used for packaging, marketing and other business promotion activities through mechanisation.

DRYER

The dryer is used to remove water content or moisture from fruits or vegetables. This removal of moisture from produce helps enhance shelf life via dehydration.

1kg of raw produce = 300 gms of dried produce

Dried tomatoes can be used in the manufacture of Tomato powders (sambar, rasam or spice mixes), Tomato Chips, Pickles and other food products. Labour is associated with drying, cutting, collecting and packaging activities.

Time taken to dry via traditional methods (10 to 12 days) is significantly reduced to 5 hours for 20-30 kg through the use of these dryers.

Unhygienic conditions associated with open, sun drying (such as dust and other pollutants) are also overcome through the solar drying option.

PULPER

The juicer or pulper helps extract juice and pulp from fruits or vegetables. It yields puree or juice which is further used to make food products.

1kg of raw produce = 850 g pulped produce

This provides a strong opportunity for farmers to add value to their harvested produce. The extracted juices or pulp also enables easy storage.

In the case of tomatoes, pulping/ juicing aids in the manufacture of products such as ketchup, tomato chutneys, pickles or juices.

Pulped tomatoes can also be stored for longer durations in the form of canned tomatoes.

Once pulped, FPOs can directly sell to the market.

Technical Specifications

3.3.1 Slicer (ideally implemented in combination with a dryer and/or pulper)

Energy system

Solar module	Battery	Inverter
300 WP X 1	200 AH X 2	1.5 KVA

Efficient Appliance

Type	Blade type
Motor HP	0.5 Hp
Operating Voltage	120 V Single Phase
Output Capacity	100-120 Kg/ hr

Juicer

Energy system

Solar module	Battery	Inverter
1.2 KWP 24 V	150 AH X 4	3 KW 4 KVA 48 V

Efficient Appliance

Tank volume	12 litres
motor	0.5 HP
Heater (optional)	1.5 KW
Pulping capacity	20 litres/ hour
Processing capacity (for ketchup)	3 litres/hour

Conduction-based solar dryer

Energy system for exhaust fans	40Wp solar panel with AC adapter
No. of drying fans	2
Size	6 ft x 3 ft
Per day drying capacity	25 Kg
No. of trays	8

CASE STUDY

Background: Mamtha Sosaya Sanga is a Self Help Group (SHG) aided by Grama Vikas located at Honnashettihalli, Kolar district. It consists of a group of 21 women who are involved in the production of a variety of pickles, tomato flakes, tomato juice and protein powder.

Prior to the intervention, members of the SHG sliced tomatoes manually which was time consuming. They would proceed to sun-dry these tomatoes using more traditional methods i.e., placing sliced tomatoes on towels for drying in the open over long durations. Challenges around labour availability coupled with time spent on the activity made the process tiresome.

Solution:

A conduction based solar dryer with a capacity of 25 kgs per batch, and a solar powered system to power the slicer and juicer (of 150 kgs and 25 kgs per hour capacity respectively) were installed.

Impact:

Reduced Drudgery: Typically for drying the produce, one or two women would have to sit and guard the tomatoes from animals, birds or pests while being subjected to direct heat in the open. With the installation of the dryer, this is no longer required. The combination of slicer and dryer have substantially reduced the drudgery involved in processing tomatoes.

Time saving: The implementation of a solar slicer has reduced the time involved in slicing 10 Kgs of tomatoes from 3-4 hours to 30 minutes. In the case of tomato drying, what previously took 4 days to 1 week, with the underlying condition of clear, sunny days, has now reduced to 1-2 days to obtain good quality tomato flakes under moderate to bright sunlight.

Improved quality: The slicer produces uniform tomato slices of any required thickness contrary to the uneven slices in manual slicing. The dryer eliminated mould that would previously form on a daily basis if the process was uneven in the open sun. The solar dryer ensures even drying of tomatoes for good quality.

Value addition: The production of tomato flakes helps in value capture for members of the group compared to the value of raw tomatoes. This enables a price of INR. 60-80 per kg through value addition over the INR 8-10 per kg for raw tomatoes. 1 kg of dried tomatoes which previously sold at INR 400 can now be sold at INR 600-800 (nearly double) due to the improved standards of quality and hygiene from solar drying.

3.3.2 Solar powered cold storage

Background:

Increasing temperatures and changes in rainfall patterns affect the quality of farmer produce and their ability to plan post-harvest processes and market linkage. In the absence of cold storage solutions, there is significant wastage particularly in horticulture produce- this can range from 5-16% in certain fruits and vegetables. Currently, the cold rooms available are grid powered but owing to the unreliability of electricity, they are forced to use diesel generators as a back-up. This not only adds to the operational expenditure but also contributes to GHG emissions.

Most of these are also centralised units, located far away from the farmgate. The farmer's access to cold storage is then contingent on being able to travel to the location, taking note of the amount sold at the farmgate and the surplus that needs to be stored. All of this affects the bargaining power of the farmer forcing them to accept lower prices or deal with wastage and losses.

Solution:

Solar-powered, decentralized cold storage solutions enable both pre-cooling and storage of perishable - thereby helping preserve their freshness and maximising their shelf life. Decentralized, sustainable energy powered cold storage solutions for agriculture can, in part, address the needs of farmers by:

- Increasing farming communities' abilities to store produce for longer, avoid wastage and distress sales and increase incomes.

- Maximising the use of low carbon, sustainable energy sources and reducing demand for fossil-fuel based electricity
- Reducing food losses and wastage resulting from a lack of post harvesting processes combined with the absence of cold storage at a decentralized level (thereby reducing income losses and methane emissions from food wastage)

Decentralized cold storage solutions for positive temperatures are available in capacities ranging from 2MT to 10MT and can be modular built to any capacity. These may be owned by individual aggregators, by FPOs/FPCs or SHGs, or by institutions for self-consumption. Cold storage solutions are run through a mix of business models including service-based (farmers are charged rent for storing produce) and trader-based (purchasing from farmers, storing and selling to the market).

Technical specifications

Energy System	Solar Module	7 kWp
	Aux. Battery	100 Ah, 48 V
	Aux. Inverter	3 kVA, 48 V

Cold storage features	**Product Dimension**	**20 ft x 8 ft x 9.5 ft**
	Storage Volume	750 CFT
	Temperature Range	4 - 20 degree Celsius
	Thermal Backup	Water/Ice
	Storage	Multi Chamber

CASE STUDY

Background: Murhu Nari Shakti Kisan Producer Company Limited- Khunti FPC promoted by CInI works with tribal communities in Khunti block of Jharkhand across 2200 farmers in the region. The FPO is also involved with trading agri-input like seeds, fertilisers, pesticides etc. The region is known for production of various vegetables, such as brinjal, cabbage, tomatoes, beans etc.

The farmers associated with the FPO were facing post harvest losses, and produce that was cultivated is often sold to middlemen at distress prices. The FPO realised the problem and addressed the opportunity at hand to capture value for the horticulture produce via a solar powered cold storage.

Solution: 5MT solar powered cold storage was adopted by the FPO to be run with the support of a local NGO, through a trader model. Here, the produce is bought from farmers at current market price and retailed by the FPO. For this, market linkages have also been developed and awareness built among farmers about the option to sell their produce to the FPO directly.

Impact:

Reduced wastage: On farm wastage has reduced significantly for farmers.

Improved market linkages: The FPO has established strong market linkages with Future group, that purchases 60-70% of the produce. The remaining is sold within the local markets of Khunti.

Product specific profitability: The FPO has reported to have procured tomatoes at INR 10 and within 3 days of storing the produce has realised an improved market price of INR 20.

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CONCLUSION

These interconnected nodal points along the tomato value chain- input, on-farm production and post harvest processing- can be powered with an array of decentralized, clean energy powered livelihood technologies. This report captures the key interventions for different nodal points and provides an insight into the technology, ownership models and the expected impact of these solutions.

Currently, in the focus region of Chittoor district, the activities within the tomato value chain are largely restricted to input and on-farm production. The interventions discussed here can play a key role in strengthening the overall value chain and increasing the value capture for tomatoes at the farm level and for end-user groups including FPOs and SHGs.

They can help in building safety nets for farmer groups by increasing incomes, reducing post-harvest losses and enabling product diversification. From a climate vulnerability perspective, they can help strengthen the climate adaptation capacities of last mile farmers in this drought-prone region, and reduce CO2 emissions from current and potential on-farm and processing activities.

The larger goal is to build on the learnings and evidence from these solutions to blanket the value chain with technologies that are efficient and run on sustainable energy, helping transform income earning capacities for farmers and farmer groups in the region.

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