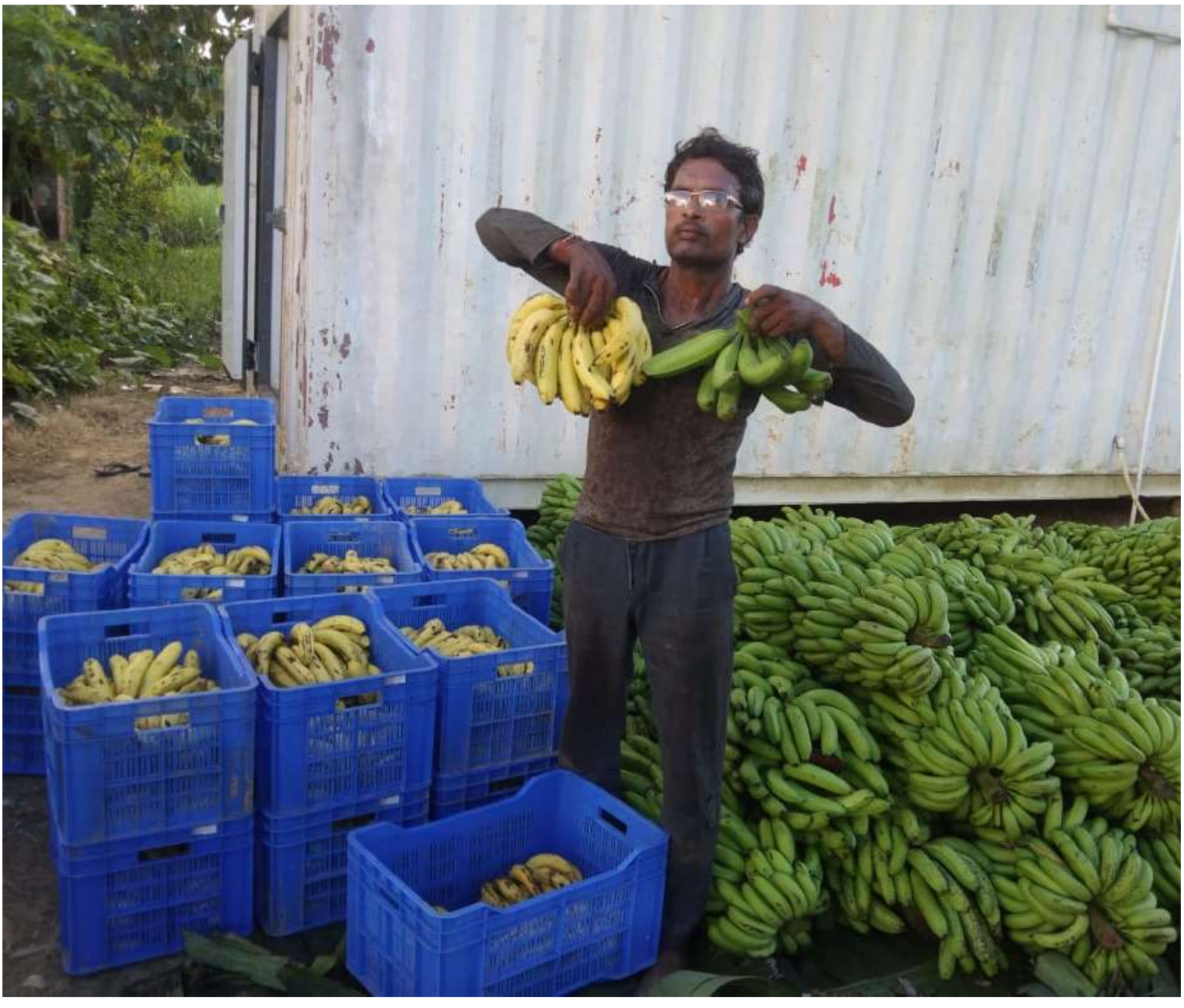
Learning Brief

March 2022

How can increased access to solar cold storage improve efficiency and smallholder income in the banana value chain?

Insights from Inficold's experience in India



Executive Summary

India is the largest producer of bananas in the world, with a production of 29.7 million MT per year. However, of this only around 0.65% of the total produced (0.19 million MT) is exported and around 16.8% (5 million MT) is lost to wastage(2019-20)[1,]. Bananas are harvested raw and ripened artificially at controlled temperatures inside cold storage. The ripening process is energy intensive and requires a continuous supply of energy to maintain the 14^0 to 20^0C temperature that is required to ripen the fruit. In areas where grid power is unreliable, running a diesel generator to power the cold storage unit directly increases the operational costs of the system, making it economically unviable. Lack of cold storage facilities – coupled with unreliable grid infrastructure in rural areas – results in the farmers selling raw bananas to traders with no value addition to the produce. The traders purchase the green bananas from the farmers at a discounted price, transport them to the nearest urban ripening centre (adding value to the produce) and then return the ripened bananas to the villages to be sold at higher margins for local consumption. This inefficiency has resulted in a high degree of wastage, poor-quality control, lost earning opportunity, inflated cost of purchasing produce and increased carbon emissions. According to a report prepared by NABARD consultancy services (NABCONS) in 2015, the current available ripening infrastructure in India is sufficient to handle only 10% of the total production[2].

Technology – Inficold cold storage solution

Inficold solar powered cold storage system provides uninterrupted cooling that is fit-for-purpose for those places that are off-grid or have unreliable grid connectivity. The system is modular with a storage capacity to expand from 5 to 100 MT and designed with an option to integrate the cold storage system to an existing facility. The operation of the cold storage is fully automated, requiring minimal training, with an option for the system operator to monitor its performance remotely via web enabled devices.

The Inficold system stores solar energy in thermal storage, which provides a 24/7 energy efficient cold storage solution. A 5 MT capacity system is powered through 7 kWp solar photovoltaic panels, which has enough cooling capacity to ripen 100-200 MT bananas per annum when installed in completely off-grid locations.

Impact of cold storage solution

Solar powered cold storage makes banana ripening viable at village level, which helps to reduce food wastage and provides economic opportunities to the farmers by enabling them to sell ripened bananas in place of green ones which adds value to their produce. The installation of Inficold solar cold storage at Nayanagar village in Uttar Pradesh, India has improved the livelihoods of at least 10 farmer families who have doubled their income to INR 7,00,000 (~US$9,333)[3] per annum, reduced their carbon footprint by 27 MT per annum and avoided food wastage of around 5 MT per annum. Additional benefits of having the solar powered cold storage solution include affordable and higher quality bananas for the local consumers.

Challenges

Lack of access to finance is the major challenge for banana farmers willing to have a cold storage facility installed in their vicinity. The current system installed by Inficold solutions has the capacity to ripen only 0.5% of the total bananas produced in the Nayanagar village and its surroundings.

[1] https://theprint.in/india/andhra-is-going-bananas-how-indias-largest-producer-of-the-fruit-is-breaking-own-record/622466/

[2] All India Cold-chain Infrastructure Capacity Assessment of Status & Gap https://nccd.gov.in/PDF/CCSG_Final%20Report_Web.pdf

[3] Assuming exchange rate of 1 USD = 75 INR

There is a huge unmet demand for a cold storage solution as there are large number of farmers in the region who are cultivating bananas and require cold storage facilities for ripening.

Conclusion

The market opportunity to provide cold storage facilities in India is significant but access to finance remains a bottleneck in terms of getting the technology installed at scale. However, addressing the market opportunity using off-grid systems comes with additional benefits. These benefits include a reduction in carbon footprint and affordable fruits to the end user, which will directly translate to monetary savings, improved nutrition and better health. Savings can also be made by reducing the operational costs of transporting bananas from the farm to urban areas – and back – for consumption. Therefore, leveraging the market opportunity to provide solar powered cold storage systems in the banana market has the potential for job creation and improved environmental status.

Acknowledgements

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Co2	Carbon dioxide
CAPEX	Capital Expenditure
Ha	Hectare
INR	Indian Rupee
Kg	Kilogram
KWp	Kilowatt Peak
MT	Metric Tonnes
NABCONS	NABARD Consultancy Services Private Limited
NGO	Non-Governmental Organisation
OPEX	Operating Expenditure
PANI	People's Action for National Integration
PFA	Prevention of Food Adulteration
PV	Photovoltaic
US$/D	US Dollar

1 Introduction

1.1. Banana value chain in India

Bananas are a popular fruit not only due to their low price but also that they a rich source of carbohydrate and vitamins – particularly vitamin B. They are also a good source of potassium, phosphorus, calcium and magnesium, free from fat and cholesterol and easy to digest. Bananas can help reduce the risk of heart disease when eaten regularly and are recommended for patients suffering from high blood pressure, arthritis, ulcers, gastroenteritis and kidney disorders. Processed products of banana include chips, puree, jam, jelly, juice and baby food.

Bananas are a perennial fruit crop that grow quickly and can be harvested all year round. India is the largest producer of bananas in the world, with a volume of 30.5 million tonnes per annum – accounting for 25% of the world's banana production[4].

The fruits are ripened by exposing them to ethylene, a natural plant hormone that accelerates ripening by converting the starch it stores into sugar – a process that would take 4-5 days at a temperature of 15^0 to 17^0 C. Uniform temperature and circulation of air is required inside the cold storage throughout the ripening process. Cold storage facilities for ripening bananas and for further storage need to be built near the consumption centres to avoid wastage during transportation and handling, as the shelf life of ripened bananas is minimal.

The rural community of India accounts for 69% of the total population[5] so the market opportunity dictates for cold storage facilities to be built within the vicinity of these rural consumption centres. However, lack of both reliable grid energy and access to finance has meant that many cold storage facilities have been built within urban centres where there is reliable grid energy coupled with a private sector that is better capitalised than in rural communities. This has led to fruits being ripened in the cities and transported back to the villages at higher cost, with increased wastage and reduced quality produce.

In the absence of cold storage infrastructure, local traders at the rural level use calcium carbide to artificially ripen the bananas, a substance that is banned under PFA Rules, 1955 and under Food Safety and Standards (Prohibition and Restrictions on Sales) Regulations, 2011[6]. Fruits ripened with calcium carbide have the potential to cause cancer as it contains traces of arsenic and phosphorous hydride.

The lack of cold storage ripening facilities has been the main reason for a high degree of banana spoilage, low quality of fruit and higher costs for end consumer, with no opportunity for farmers to participate in the ripening-based value addition of their produce. Solar powered cold storage that can be installed in rural locations can help reduce banana wastage, improve the quality and reduce the cost of fruit for the end consumer. Therefore, building on the existing market opportunity through incentivising smaller businesses is important for the local economy as it is critical to both gross and net job growth, an important factor in driving local economic growth and development.

1.2. Inefficiencies in the banana value chain

A study conducted by NABARD Consultancy Services Private Limited (NABCONS) in 2015 states the ripening capacity of the country is limited to only 8,120 MT per day. The same report suggests that the required ripening infrastructure is almost 12 times higher than the current capacity. Apart

[4] https://www.freshplaza.com/article/9299457/india-has-great-potential-when-it-comes-to-bananas/

[5] https://censusindia.gov.in/2011-prov-results/paper2/data_files/india/paper2_1.pdf

[6] https://fssai.gov.in/upload/uploadfiles/files/pfa-acts-and-rules.pdf

from the limited ripening capacity, the main issue lies in the location of these ripening facilities which are only located in major cities. The lack of ripening facilities at local village level results in higher retail pricing, greater wastage due to transportation of ripened bananas, lower product quality and promotion of hazardous chemicals. The end consumer pays the highest prices because of the inefficient value chain. Traders and the ripening centre owners are the biggest beneficiaries of the current ecosystem with the maximum profit margins levied on the rural farmers.

1.3. Hypothesis of the need for Inficold solutions

Cold storage facilities are required close to consumption centres in order to reduce spoilage, wastage and deliver fresh fruit to the end user. Setting up cold storage facilities in rural settings that are powered by diesel generators is not considered cost effective due to the high operational costs. Furthermore, when grid power supply in the rural settings is available, it is not reliable.

As a result, there is a good rationale for solar powered cold storage units in these areas, to bridge the gap of unreliable electricity and provide uninterrupted and consistent power supply to cold storage facilities. Inficold's solution addresses these shortcomings and provides solar powered cold storage solutions in off-grid areas to ripen and store ripened bananas. It serves as a one-stop solution to the banana value chain challenge at the village level that is predominantly affected by erratic power supply, high operational costs and inefficient handling of produce. The Inficold solution has the potential to increase smallholder famers' income and reduce banana wastage by minimising transportation requirements, improving the efficiency of the overall value chain and reducing its carbon footprint. Availability of solar facilities at the farm level will increase the efficiency of the value chain in terms of delivery of ripened bananas, which will reduce the likelihood of traders using hazardous chemicals for ripening.

1.4. Objective of the study

Inficold cold chain solutions are used in numerous horticulture and dairy service applications with a potential to build the resilience capacity of farmers as well as reduce carbon footprint at the local level. In order to better understand the implications of the solar powered cold storage technology at the local level, an assessment was conducted with the following objectives:

- Assess the impact of the technology to reduce post-harvest losses and improve income for farmers
- Identify challenges in scaling the technology and provide recommendations for scaling.

2 Methodology

This report is based on a case study of a 5 MT capacity solar powered cold storage facility that was installed in Balrampur district, Uttar Pradesh. It is one of the first solar cold storage facilities that was installed by Inficold Solutions to ripen bananas in India.

A mixed methods approach using quantitative and qualitative data was used for the study. It included the following methods:

- Semi-structured key informant interviews with the operator/owner: These were used to understand the institutional level uptake of solar cold storage as compared to the traditional solution.
- Collation and review of available data on energy efficiency, rates provided to farmers, benefits of using the cold storage, challenges, gaps, and improvements needed etc.

- Semi-structured key informant interviews with farmers: Interview with 10 farmers using the solar cold storage system and an additional 10 interviews with farmers with no experience using the system was conducted. The perspective of the farmers was collected to understand the effectiveness of the solar cold storage, knowledge about solar cold storage, changes in income levels and other individual level impacts.

3 Background

3.1 Inficold and solar powered cold storage technology

Inficold is a National Technology Award winning company making farm level cold storage efficient and inexpensive to own and operate. The solar powered cold storage technology is powered through photovoltaic (PV) cells from which energy that is generated is stored in the form of ice. Solar powered cold chain solutions are a necessity in India, a country that is one of the largest producers of milk, vegetables, fruits, flowers, fish and eggs, all of which are perishable commodities. Off-grid solar cooling solutions directly address inefficiencies that are primarily caused by unreliable grid energy supply. In rural areas, solar powered solutions are necessary to extend the shelf life of perishable goods by reducing spoilage. This enables farmers to sell ripened bananas which adds value to their produce and increases their income. It also avoids glut periods and reduces transportation requirements, thereby reducing the carbon footprint that comes with the process.

Inficold's innovative solution uses solar energy to convert water to ice, and maintains a continuous ambient temperature of 4^0-15^0C within the storage room. Using ice to maintain the ideal temperature required for the bananas to ripen during non-solar hours eliminates the need to use diesel generators or lead acid batteries as a backup system. Traditional grid powered cold storage facilities on the other hand require a continuous supply of electricity to maintain the ambient temperature of the cooling chamber. At the farm level, traditional grid based cold storage facility is not practical, mainly because of unreliable grid electricity.

Inficold cold storage facilities provide the option to store produce in either containerised units or indoor cold rooms. The containerised units are quickly deployable, require minimal civil work at the site and can be mobilised and re-installed at other locations during the off-season. The solar integration technology for cold storage was jointly developed in partnership with the National Institute of Solar Energy, the autonomous institute under the Ministry of New and Renewable Energy, Government of India.

The advantages of Inficold solar cold storage include:

- Flexibility of site selection without the need for grid electricity;
- No need for large electric battery banks which have expensive recurring costs and are also an environmental challenge to dispose of;
- Grid electricity or diesel generator can be used as an alternative source of power to operate the solar cold storage in case of prolonged rainy season when sunshine hours are much lower than the average;
- Retrofittable solution for existing cold storage facilities;
- Modular design of ice-backed cooling results in system size flexibility in the range of 5-100 MT.

3.2 System ownership

The solar cold storage supplied and installed by Inficold is owned and operated by People's Action for National Integration (PANI). The NGO is headquartered in Faizabad district, in Uttar Pradesh, with 360 members, a ratio of 5:1 female to male and a ratio of 10:1 of people below and above 35. The NGO's catchment villages are within an average distance of 12 km. PANI supports farmers there with education, awareness about latest technologies, improved crop mix to increase their incomes and extension support to link them to the right markets. PANI's aim is for farmers to be able to collaborate with government and peers in order to achieve economic, social and environmental sustainability.

3.3 Farmers and system usage

Funded by the Sustain Plus Energy Foundation at a total cost of around INR 14,00,000 (~US$ 20,000)[3], the solar powered Cold Storage facility has been installed in Nayanagar village located in Balrampur district, in Uttar Pradesh by Inficold solutions. Around 700-800 acres of land in nearby villages are covered by banana plantations, translating to a total of 18,000 MT of annual banana production in the area. The average land holding of a single farmer is one acre, yielding around 25 MT of bananas per farmer per annum.

Nayanagar is faced with frequent and long lasting power outages that can last from a couple of hours to several days, particularly during rainy season storms and resulting erratic power supply that frequently breaks equipment. The nearest cold storage facilities are in cities such as Kanpur, Faizabad – around 100-150 km away. In the absence of a cold storage facility near the village, farmers sell green bananas to the traders. These bananas are then ripened in the urban cities using traditional cold storage which is powered by grid electricity and backed by diesel generators.

The cluster of villages near Nayanagar produce about 18,000 MT of bananas per annum with no cold storage facilities within 100 km. PANI commissioned Inficold to install the first solar powered cold storage facility in the village and trained an operator on banana ripening techniques using ethylene. The Inficold team provided operational training and the system is now fully powered by solar and rented to the farmers by the NGO. The NGO provides ethylene for free but charges the farmers 0.25 INR/kg-day to use the cold storage facility to ripen their bananas.

The solar powered cold storage became operational at the end of July 2021 and has been running fully off-grid since then. Since becoming operational, 10 farmers have been using the cold storage services for the past four months. These farmers were early movers mainly because of their entrepreneurial nature and the fact that they were willing to take the risk. As well as this the early adopters had prior experience of ripening bananas in makeshift rooms cooled through ice blocks and so were aware of the advantages in selling ripened bananas.

4 Findings

4.1 Profile of farmers

As a part of the assessment, a total of 20 farmers, of which 20% were women, were interviewed in the village. 10 farmers are currently using the solar cold storage for ripening whereas the remaining 10 farmers sell their green bananas directly to traders. The average family size consists of six members. More than 40% of the farmers are educated up to higher secondary level and 80% are under 40. 60% of the farmers own less than an acre of land for banana plantation whereas 40% of the respondents own between 1-1.5 acres of land. The average, maximum and minimum banana production per annum by the group of farmers assessed is 21, 50 and 5 tonnes per annum respectively.

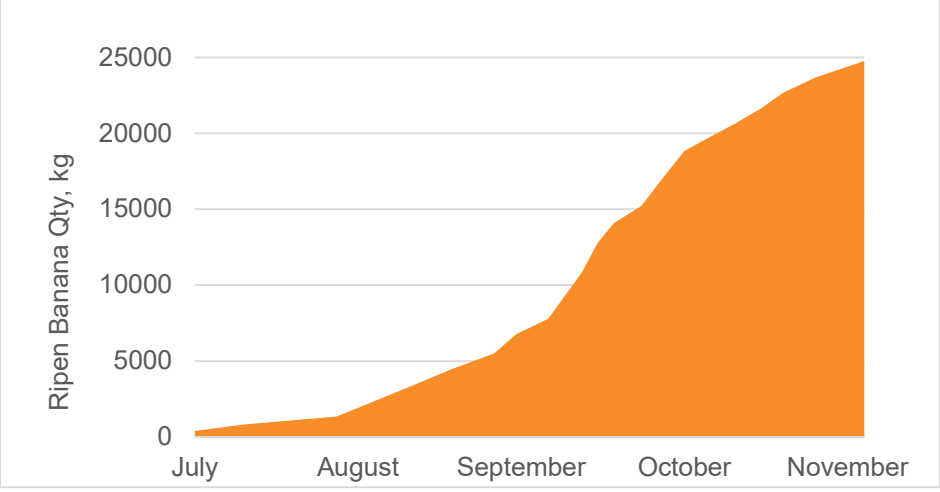
Table 1 Socio-demographic profile of farmers interviewed

Parameter	% Farmers
Gender	
• Male	80
• Female	20
Age	
• 18-30 yrs.	50
• 31-40 yrs.	30
• More than 41 yrs.	20
Size of family	
• 2-4 members	15
• 5-6 members	30
• More than 6 members	55
Education	
• Illiterate	10
• Below primary to secondary complete	30
• Higher secondary and above	60
Landholding of farmers	
• Less than 1 acre	60
• 1 acre to 1.5 acre	40
Average banana production by each farmer, Tonne/year	21
Number of farmers	20

4.2 System usage data

The solar cold storage was first used for banana ripening on 31 July 2021. Figure 1 shows that the total quantity of bananas ripened through the cold storage after four months reached 25m kg.

Figure 1 Monthly ripen banana throughput of solar cold storage



4.3 Benefits of the solar cold storage

The following advantages have been identified since operationalising the solar cold storage:

- The average selling price of green bananas is 10-12 INR per kg, whereas the average selling price of ripened bananas is 20-25 INR per kg. The cost of ripening is 1 INR/kg, hence enabling the farmers to make a profit of 9-14 INR/kg by selling the ripe bananas instead of green bananas. Over a period of four months, the total profit generated by the farmers using solar cold storage for banana ripening was 2,47,000 INR. Assuming the same level of utilisation throughout the year, it would take less than two years to return the total cost of purchasing and installing the cold storage facility at the village level which is around INR 14,00,000.
- There is no ripening facility nearby in the region – ripened bananas were bought by the local retailers from the nearest city. The transportation of ripened bananas from the cities to the consumption centre led to price inflation by about 2-3 INR/kg (20-30% of the raw bananas) at the consumption stage. This is the amount the farmer would be out of pocket directly to the traders due to inefficient market systems. Furthermore, in order to off-set the cost of transportation, traders transport ripened bananas in large volumes, of which 5-10%[7] is spoiled and/or wasted owing to its shorter shelf life and fragility as interviewed farmers reported. The ripening of bananas using solar cold storage at the farm level near the consumption centre has reduced the overall wastage of bananas from an average of 7% to less than 1%. Furthermore, the bananas reaching the farmers are much better quality due to their freshness.
- Establishing cold storage solutions at scale in the village that use ethylene for ripening will reduce the likelihood of bananas being ripened with calcium carbide. Calcium carbide is carcinogenic and cheaper than ethylene. In the absence of a cold storage facility, local traders are using ice cooled makeshift storage using calcium carbide for ripening, producing low quality bananas that have a shorter shelf life and come with significant health risk. Solar cold storage solutions are fit for purpose for the village and have provided the local traders and farmers with a cheaper alternative to ripen bananas and also removed the associated health risk.
- Assuming seven hours of power outage in a day[8] and 75 MT banana ripening per annum, the grid powered cold storage with diesel generator backup would have generated 17 MT CO2[9] in excess as compared to the solar cold storage per annum.
- Considering that solar cold storage is used for ripening of 75 MT bananas per annum, it will help reduce wastage by 5.25 MT per annum. This reduction in food wastage prevents emissions of 10 MT CO2 per year[10].
- Installation and use of Inficold systems in the village has led to increased awareness amongst farmers around the costs of ripening bananas in the chambers. As a result, they have become cautious of the costs involved and have leveraged this knowledge to negotiate a better deal with the traders when purchasing ripened bananas. If supported and organised properly, the cost-benefit awareness created presents an opportunity for the farmers to establish themselves as unions or small and medium sized enterprises which might enable them to obtain a loan from a finance institution to purchase and install a solar powered storage facility within their vicinity.

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7 Data is based on key informant interview collected from farmers

8 https://www.ceew.in/sites/default/files/ceew-research-on-state-of-electricty-access-and-coverage-in-india.pdf

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10 https://watchmywaste.com.au/food-waste-greenhouse-gas-calculator/

- Rural localities within the grid that previously could not be considered for the establishment of cold storage facilities due to their unreliable power supply can now be considered through solar powered facilities.

4.4 Challenges

Lack of access to finance serves to be a major barrier to the adoption of solar cold storage solutions, given the high capital investments and lack of access to credit for farmers. PANI was able to establish the solar powered cold storage facility through grant funding received from Sustain Plus organisation. The capacity of the storage unit built only caters for 0.5% of the total banana production in Balrampur district, with a huge unmet demand for the cold storage solution. This unmet market demand has translated to the farmers selling their green bananas to traders at lower margins.

Considering the margins the farmers are making from ripening and selling bananas at the consumption centre, a careful economic analysis of the capex and opex cost of owning and running the ripening operation in off-grid areas against volume of consumption and margins has the potential to make solar powered cold storage facilities viable in some localities. However, this assumption comes with limited available data and would require the data to be collected and analysed over a prolonged period of time.

5 Conclusion and Recommendations

India is the largest producer of bananas in the world with 29.7 million tonnes produced from an area of 0.88 million hectares[11]. In India, more than 85% of total a total of 146.5 million farmers are smallholders and more than 100 million farmers (68.5% of total) operate on an average 0.38 hectare (ha) land[12]. Due to the lack of technological intervention, absence of viable value addition or processing facilities and the ineffective cold-chain at the producer level (largely comprised of smallholder farmers), the post-harvest wastage is unusually high and the product quality is poor – generating lower returns for the smallholder farmers in the domestic market, while the produce quality is substandard to export. A study conducted by NABARD Consultancy Services Private Limited (NABCONS) in 2015 showed the ripening capacity of the country is limited to 8,120 MT per day. The same report suggests that the required ripening infrastructure is almost 12 times bigger than the current capacity. Moreover, the current installations of cold storage in the country are mainly located in urban centres with almost zero penetration to rural/semi-urban areas. Lack of cold storage facilities in rural areas is attributed to operational challenges associated with irregular grid supply and the lack of access to finance for installing solar powered cold storage solutions.

The installation of a solar powered cold storage facility in Nayanagar has revealed that the system can function fully in areas with limited and unreliable supplies of grid energy. The successful implementation of the facility resulted in an increase of farmer incomes by 9-14 INR/kg with an approximate payback period of less than two years. It translates to about a 100% increase in the income associated with banana cultivation. This was directly attributed to the sale of ripened bananas at the consumption centre as opposed to selling raw bananas to traders. The study also found that there was a 7% reduction in post-harvest losses due to a reduction in transportation distance and fewer number of stages to handle ripened bananas.

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11 https://pib.gov.in/Pressreleaseshare.aspx?PRID=1520827#:~:text=India%20is%20the%20largest%20producer,production%20is%2025.58per%20cent.

12 https://www.niti.gov.in/sites/default/files/2021-03/NaturalFarmingProjectReport-ICAR-NAARM.pdf

In addition, a primary challenge at the village level preventing widespread adoption of cold chain equipment is high financing cost for equipment purchase and prohibitively expensive operational cost of grid based cold storage. Grid based cold storage are twice as cheap than off-grid solar cold storage. The off-grid solar makes the system capital intensive as the farmers do not have access to credit facilities for upfront payments to buy the system. However, the short payback period (less than two years) makes a strong business case, and if the financing facility was available to farmers, there could be a higher uptake of the cold chain in rural settings. Inficold also provides grid powered but diesel free cold storage solution which provides cooling backup with thermal storage.

It is predicted that with ever-increasing demand for cold storage facilities, 60 million tonnes of bananas will be required to meet the domestic demand by 2050. There is also a considerable scope to export bananas and its by-products, which further enhances the demand. To promote ripening chambers for higher value addition and reduced post-harvest losses, it is essential to generate accessible financing options for the farmers. Financial institutions risk averseness and lack of understanding of solar powered technology puts the farmers at a disadvantage, as they are required to use their land as collateral to access finance to purchase the cold storage systems. However, it is much easier to access finance from the same institutions to purchase grid based cold storage units backed by diesel generators, which are less capital intensive but have significant operational costs. This creates a market system with high operating costs, which makes it less competitive in the long term, inefficient, not sustainable and is anchored on a system that has a high degree of carbon emissions. The right technology and accessible financing could change the landscape of the Indian agricultural industry and the farmers associated with it by reducing post-harvest losses, increasing farmers' profit margins, and improving the overall quality of produce for end consumers and their environment.

In addition to bananas, there is huge potential to use the same technology to ripen other fruits such as papayas, mangos, custard apples etc. India is the largest producer of mangoes with an annual production of around 24 million tonnes. The value addition of ripening mangoes brings higher returns as compared to bananas. The assessment conducted by the Ministry of Agriculture in 2013 shows that 99% of the mangoes harvested in India are ripened by using Calcium Carbide, which is a toxic chemical and extremely hazardous.

Based on the assessment conducted in 2015 by the National Centre for Cold-Chain Development – an autonomous body of the Ministry of Agriculture and Farmers Welfare, Government of India – the installed capacity of ripening chambers in India is capable of providing ripening for only 10% of the total annual fruit production. There is therefore a minimum market potential to install 150 million tonnes capacity of cold storage chambers to ripen fruits in India.