Learning Brief

March 2022

How can increased access to solar milk chillers improve efficiency and smallholder incomes in the dairy value chain?

Insights from Inficold's experience in India

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Executive Summary

India is at the forefront of milk production, with huge opportunities for milk processing and cold chain innovations in the milk value chain. India is the largest milk producing nation, contributing to about 22% of global milk production[1] and producing 187.7 million MT in the year 2018-2019[2]. However, only 20% of the milk produced passes through the organised sector[3] which uses cold chain systems to ensure quality is sustained. The Inficold milk cooling solution can be installed as an add-on to the existing milk cooling infrastructure to address the shortcomings of milk cooling technology in India, which is affected by erratic power supply, high operational costs, and a prolonged and lengthy cooling process.

This report is based on a case study conducted on one milk chilling facility that is owned and operated by "Kamdhenu Dugdha Utpadak Samabay Samittee Ltd" dairy cooperative located in Nityananda village in the Barpeta district of Assam. The cooperative is owned and managed by 695 farmers. In the current system, milk is collected and aggregated from the nearby villages, and takes approximately two hours to reach the cooperative's milk chilling centre. The existing milk chilling system is primarily powered by diesel generators and takes 5-6 hours to chill the milk to the desired temperature. An assessment was conducted to understand the impact of a solar powered instant milk chilling system that has been installed as an add on to the existing chilling system to increase its efficiency.

Inficold solar instant milk chiller

The system installed by Inficold has been operational since January 2021 and is powered by 8 kWp solar panels to chill 3,000 litres of milk per day (LMPD). The system instantly chills the milk from 35^0C to less than 10^0C where the chilled milk is then transferred to the existing milk chilling system where it is further cooled to 4^0C. Inficold's innovative solution has brought multiple advantages in improving the socio-economic and environmental status of the community as the technology has improved milk quality, produced economic benefits at the household level, and reduced carbon emissions.

Benefits of adopting the system

The solution uses solar energy, thereby reducing the dependency on non-renewable energy sources. Based on energy consumption data collected over the past 18 months[4] from the milk chilling centre, the overall cost of electricity and diesel on milk cooling has decreased from 0.62 INR/L to 0.3 INR/L due to Inficold's solar instant milk chiller. The margins made as a result of reduced operational expenses after installation of the solar powered milk chiller provides an ROI of less than two years. As a result of using an alternative energy source, carbon emissions have been reduced by 1,099 Kg CO_2/month, totalling 10.1 tonnes CO_2 over a period of 10 months; effectively reducing carbon emissions by 30% from its business as usual (BAU) scenario.

The technology provided by Inficold has enhanced the capacity of the milk cooling infrastructure in the Nityananda village area, which has attracted additional farmers to join the cooperative, therefore increasing the overall amount of milk collected by 46% per day. In addition, all livestock

[1] https://www.nddb.coop/information/stats/across

[2] https://www.nddb.coop/information/stats/milkprodindia

[3] https://www.careratings.com/uploads/newsfiles/Indian%20Dairy%20%20Dairy%20Products%20Industry%20-%20June%202020.pdf

[4] 8 months prior to the system being installed and 10 months data after the system was installed

farmers who were interviewed during the study, confirmed that there were no disruptions in milk collection and processing at the cooperative during the covid pandemic lock downs.

Challenges faced by the cooperative

Access to finance and credit services has been identified as the main challenge for other dairy societies/cooperatives with regards to adopting solar powered milk chilling solutions. The system was provided to the cooperative of Nityananda village by Inficold through a grant received from the World Bank. Other cooperatives in the surrounding region are aware of the benefits that have been brought to the community by the Inficold solutions. However, the challenge associated with accessing sufficient finance to enable the purchase of a similar system has been the main roadblock for other cooperatives willing to go renewable and increase their income. The interviews conducted with the other cooperatives has revealed that they are keen to see a similar grant initiative or other financing arrangement from the World Bank to install a solar powered cold chilling facility such as the one established in Nityananda village.

Conclusion, recommendations and potential impact

A solar powered instant milk chiller installed as an add on to existing milk chilling facilities is a viable and cost-effective option for the existing 100,000 milk collection centres that are spread out across India. The solution can be fitted easily to existing milk chillers for quick results and impact. ‘Quick wins’ that could result from installing this system include improved milk quality, reduced diesel consumption and sustainable supply of energy, all of which result in improved household earnings and increased community resilience.

Rolling out similar systems at scale could produce economies of scale and generate tangible benefits for farmers in terms of their socio-economic status, as well as increasing the national GDP. However, the most significant barrier for this transformation to take place remains the lack of access to credit from financial institutions. The existing credit facility system in India is onerous and does not allow the cooling equipment itself to be considered as collateral, something which is commonplace in other sectors, such as the automotive sector.

Acknowledgement

1 Acknowledgements

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List of Abbreviations

BAU	Business as Usual
CAGR	Compound Annual Growth Rate
Co_2	Carbon dioxide
CRISIL	Credit Rating Information Services
FSSAI	Food Safety & Standard Authority of India
GDP	Gross Domestic Product
ISO	International Organisation for Standardisation
INR	Indian Rupees
KwP	Kilowatts Peak
Kg	Kilogram
Km	Kilometer
Kwh	Kilowatt Hour
Kva	Kilovolt-ampere
LPD	Liters Per Day
LPH	Liters Per Hour
LMPD	Litres Milk Per Day
MT	Metric Tonnes
NDDB	National Dairy Development Board
ROI	Return of Investment
US	United States
US$/D	US Dollar
WAMUL	West Assam Milk Producers Cooperative Union Ltd

1 Introduction

1.1 Dairy value chain in India

India has been the leading producer and consumer of dairy products worldwide for the past three decades – with 187.7 million MT produced in 2018-2019[5]. With a cattle population of over 300 million (the largest in the world) and an approximate annual milk production of over 187 million MT, the sector experienced a 6.4% CAGR (Compound Annual Growth Rate) in the past five years and remained the largest agricultural commodity in the country, contributing 5% to the national economy[6]. During 2019-2020, the average annual milk productivity in India was 1,777 kg per animal, which is far lower compared to the worldwide annual average of 2,699 kg per animal during 2019[7]. Furthermore, almost all dairy produce in India is consumed domestically, mainly in the form of liquid milk, suggesting a significant potential for value addition[8].

Key players in the dairy value chain

There are 210 dairy cooperative milk unions and five major milk processing companies in India (Figure 1). Together these cover about 186,000 villages, reaching 16.1 million milk producers and procuring about 44.2 million kg per day of milk[9]. Dairy farming is the major occupation for landless, small, and marginalised farmers, engaging 70 million rural households who play a major role in the rural economy. With a huge potential for its market, both public and private sector companies play a dominant role in the dairy industry. The National Dairy Development Board lists 27 major state-owned dairy cooperatives across India. In addition, there are aggregators at the village level who are farmer producers, milk unions, entrepreneurs, and local cottage processors etc who play a significant role in milk collection and processing.

Figure 1 Milk unions and major milk processing companies in India

Potential for growth

The growth of the dairy industry in India is essentially market-driven due to an increased demand for milk and milk products from the rising middle-income class and a shift in consumer preferences to hygienic and nutritious milk products. Rural milk procurement infrastructure and improved market accessibility play a crucial role in the dairy value chain. There is a need for investment in educating and training dairy farmers and providing better infrastructure for collection, transportation, and processing of milk to increase milk productivity and maintain its quality. With

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5 FICCI Paper on Development of Dairy Sector in India, July 2020

6 https://www.investindia.gov.in/sector/food-processing/dairy

7 https://pib.gov.in/PressReleaseIframePage.aspx?PRID=1707187

8 India Dairy Industry Report 2021: Market Size, Growth, Prices, Segments, Cooperatives, Private Dairies, Procurement and Distribution

9 National Action Plan for Dairy Development: Vision 2022

the tremendous potential for value addition and overall development, the dairy industry in India is projected to see a 5-6% growth, i.e., ~US$13bn sectoral revenue generation in 2021-22, as per CRISIL[10].

1.2 Inefficiencies in the milk value chain

The Indian dairy industry is characterised by the dominance of the informal milk distribution system, unlike developed nations where 90% of the surplus milk is distributed through formal organised channels. Of the total milk produced, only 20% of the milk sector is organised[3], with the remaining marketed through informal networks. To increase the share of organised milk handling, the government is trying to set up dairy cooperatives through the National Action Plan on Dairy Development[11]. An integrated approach towards milk production and processing which involves farmers as the key stakeholders in each node of the value chain from production, procurement, storage, transportation and processing and marketing is required.

The lack of an organised value chain is due to inadequate infrastructure at village level and higher operational costs incurred in milk processing. There is insufficient and inadequate milk cooling infrastructure to prevent contamination and spoilage at the village level. Based on estimates of the National Action Plan for Dairy Development (VISION-2022)[12], a shortfall of 350 MT of milk chilling capacity in the country is projected by 2021-22. In its gap analysis report, the department estimates that India requires 10,000 MT of value-added products per day to meet the demand. Adherence and compliance to international milk quality standards at each node of the value chain and interventions on designing efficient procurement and processing technologies is essential to reduce the total cost of production per litre, realise remunerative prices for the producers, maintain the highest quality milk produced and achieve maximum value addition.

1.3 Hypothesis – Need for Inficold solutions

Despite large production of milk, the cold chain potential in India remains untapped with only 20% of the total milk produced going through the organised sector[3]. One of the most important factors inhibiting the penetration of cold chain is irregular power supply in the rural areas of India, which makes the cost of owning and operating a diesel generator with bulk milk cooler high and increases the risk of milk spoilage. As well as this, lack of awareness about quality and handling perishable produce like lack of enabling infrastructure such as power, fuel stations and roads, adds to the issues. High initial investment (for refrigerator units and land) coupled with lack of access to finance for smallholders continues to be a barrier to improve the living standards of the households.[13].

The existing milk cooling centres have been established to serve a cluster of villages surrounding the facility. The milk produced by the smallholder farmers is collected and transported to the milk cooling centre. The time lag caused because of transporting the milk from the farm to the centre, and the additional time that the milk chillers take to cool the milk, directly affects the quality of the produce. The longer the time it takes the milk to cool to its ambient temperature of 4^0C, the higher the likelihood the produce will become an inferior quality. The time lapsed has been recognised as

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10 https://www.crisil.com/en/home/newsroom/press-releases/2021/05/dairies-to-log-5-6-percent-growth-this-fiscal-but-lag-pre-pandemic-level.html

11 India Dairy Industry Report 2021: Market Size, Growth, Prices, Segments, Cooperatives, Private Dairies, Procurement and Distribution

12 https://dahd.nic.in/sites/default/filess/Vision%202022-Dairy%20Development%20English_0_0.pdf : VISION-2022 by the Department of Animal Husbandry, Dairying & Fisheries, Government of India

13 https://www.coolingindia.in/challenges-in-food-cold-chain/

one of the main reasons for the low quality of milk in most parts of India. This challenge is further exacerbated as production of milk quite often happens during early morning and late evening, where the option to use solar energy to power the cooling centre is not viable and means the cooperatives have to use either a reliable electric supply (when available) or a diesel generator.

The innovative milk cooling solution developed by Inficold addresses these challenges directly through the provision of a simple but efficient technology that is fitted as an add-on to the existing milk cooling infrastructure. The technology uses solar and/or electricity to store energy in the form of ice to be used during the early morning and late evening hours to instantly cool milk collected from the farmers.

The power generated from solar energy means that the system is fully operational for most of the year. However, there is a need for a backup energy source – either from the grid or a diesel generator – during the rainy season. When reliable grid power is available, the additional power can be used to increase the volume of ice produced, effectively increasing the milk chilling capacity and directly increasing the number of milk producing farmers who can use the chilling system.

The Inficold instant milk chiller is designed to be installed as an add-on to existing milk chilling centres. It allows adoption of solar energy on existing systems without the need to replace existing hardware. The instant milk chiller system works by quickly cooling the fresh milk collected by the farmers from 35ºC to 10ºC, and the existing bulk milk cooler further reduces the temperature of the milk to 4ºC. This enables milk collected from farmers to be cooled in a relatively short period of time, as opposed to the prolonged period that it would otherwise take through the existing bulk cooler. Milk cooled in this manner is higher quality, fetches premium prices and the likelihood of milk spoilage is reduced.

Bulk milk coolers that were previously powered by diesel generators will also see a reduced run time as the cooling contribution of the bulk cooler has now reduced to 20% (10ºC to 4ºC). The impact of this technology is felt in reduced fuel expenses, an increase in profit margins by the chilling facility operator and reduced carbon emissions. However, while it is also possible to power the bulk milk cooler through solar energy, technically, milk chilling centres cooling 5,000L milk per day and above would require more than 30kWp of solar photovoltaic panel capacity. Installing a photovoltaic cell to generate 30kWp would require considerable land space, thus making solar power less viable to power most of the existing milk chilling centres without using the instant milk chiller as an add-on to the existing bulk coolers.

1.4 Objective of the study

Inficold milk cooling solutions are used by several dairy and horticulture service providers. The aim of the study was to better understand whether these cold chain solutions are yielding positive benefits to the primary producers and service providers. Hence, an assessment was conducted to study the following objectives:

- Assess to what extent cold storage can reduce post-harvest losses for smallholders
- Identify challenges in scaling the technology and provide recommendations to accelerate adoption of the technology.

2 Methodology

2.1 Approach

This report is based on a case study of a facility owned and operated by "Kamdhenu Dugdha Utpadak Samabay Samittee Ltd" dairy cooperative located in the Nityananda village in Barpeta district, Assam. The cooperative uses Inficold's solar instant milk chiller, with a 3,000 LPD chilling capacity, powered by 8kWp of solar panels.

2.2 Selection criteria

The Inficold solar instant milk chiller has been installed and operational in Nityananda since January 2021, giving the research team sufficient lead time to measure the impact of the initiative. During this period, the cooperative has been able to reach out to 695 livestock farmers selling milk produce to the cooperative within a catchment of 19 villages spread across a 45km perimeter. The large number of households involved and the wide catchment area made it an ideal case from which to analyse and measure the impact of the initiative.

2.3 Data collection and analysis

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

- Semi-structured key-informant interviews with cooperative members: This component was used to understand the cooperative level uptake of Inficold services as compared to the traditional solution.
- Existing data available from the cooperative on energy efficiency, price provided to farmers for their milk, quantity of milk processed etc, was collected for a comparative analysis of pre- and post- implementation of the Inficold solution.
- Semi-structured key-informant interviews with livestock farmers: Interviews were conducted for the 53 livestock farmers associated with the cooperative. Perspectives of the livestock farmers were collected to understand their socio-economic situation and their motivation to become involved and associated with organised milk cooperatives.

3 Background

3.1 Inficold

Inficold is a National Technology Award winning company making farm level cooling systems efficient and inexpensive to own and operate. The milk cooler is powered through solar photovoltaics during the day, where energy is stored in the form of ice to provide round-the-clock cooling to the produce. The technology developed by Inficold is suitable for both grid and off-grid areas to cool perishable commodities such as fruits, vegetables, poultry, flowers, milk etc in the most energy efficient manner and with reduced carbon emissions. Additional benefits from the cooling solution include reducing post-harvest losses, improving quality of produce, and increasing profit margins for the farmers.

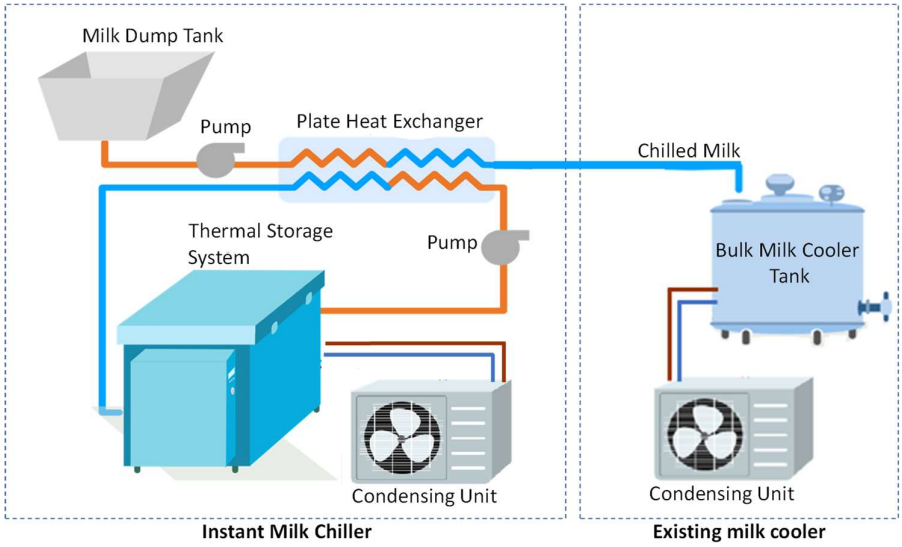
Instant milk chiller

The instant milk chiller by Inficold functions by converting solar or electrical energy to thermal energy storage. The technology uses energy from solar photovoltaic and/or grid electricity to power the vapour compression cycle in the chiller which converts it to thermal energy that is then stored

in the form of ice. The ice is later used to provide cooling (during early morning and late evening) without the need to continuously supply electrical energy from the grid or diesel generator. This is one of the main advantages of the instant milk chiller technology as it brings about immediate results by reducing operational costs, reducing carbon emissions and increasing the operational capacity of existing cold storage solutions.

The solar instant milk chiller is installed as an add-on system to existing milk chilling centres that are powered by either grid electricity or diesel generators. Fresh milk at 35ºC is instantly cooled to 10ºC by the instant milk chiller mainly using solar energy and supported by either grid or diesel energy when/if required. As the majority of the pulldown in milk temperature is achieved by the instant chiller, there is considerable savings in operational expenditure and carbon emissions at this stage, as the system cools the fresh milk from 35ºC to 10ºC. The milk at 10ºC is later cooled to 4ºC by the existing bulk milk cooler using grid or diesel electricity. As power generated by solar energy has reduced the temperature by 25ºC, the cooling operation becomes efficient and functions with a much-reduced energy requirement from non-renewables sources. However, during the rainy season when solar radiation is limited, the instant milk chiller is automatically powered through grid electricity. In case of prolonged power outages, the milk needs to be cooled by the existing bulk milk cooler, which in this situation is powered by diesel generators.

Figure 2: Schematic of the cooling infrastructure – Bulk milk cooler with Instant milk chiller as system add-on



The instant milk chiller is an add-on to the existing bulk milk cooler system as shown in Figure 2 above. The primary objectives served by the instant milk chiller are as follows:

- Milk is collected during the early morning or late evening when solar energy is at its weakest and there is an immediate requirement to cool the milk to ensure the quality is maintained. The solar instant milk chiller uses solar energy available during the afternoon to store thermal energy in the form of ice to provide the cooling of milk later during the evening, night and the morning before the system starts capturing solar energy again in the afternoon. This significantly reduces the energy consumed from the grid (where available) or the diesel generator (in off-grid areas).

- The design of a bulk milk cooler comes with inherent flaws as it requires a minimum of 15% of its available capacity to always be filled with milk before the cooling process can commence, otherwise there is a risk of ice forming at the base of the container. For example, a 5,000L milk cooler will require a minimum of 750L milk to start the equipment. As a result, until the cooler has is at 15% of its fill capacity, there is a risk that the milk will spoil in situations where farmers are unable to fill the cooler with enough milk to start the cooling process.
- Milk spoils quickly and easily when exposed to a temperature range of 10-35ºC for a prolonged period. Instant milk chillers significantly reduce the risk of milk spoilage by instantly reducing the temperature of the milk from 35ºC to 10ºC as soon as the milk is received, with no limitations around a minimum amount requirement. By comparison, a traditional bulk milk cooler will require more than two hours to bring the temperature of the milk to 10ºC.

Advantages of the instant milk cooler

- Improves milk quality ;
- Minimises energy requirements from the grid or diesel generator;
- Increases the capacity of the existing milk chilling centre without replacing the bulk milk cooler;
- In the event the existing bulk milk cooler malfunctions, the instant milk chiller is able to maintain the temperature of the milk at 10ºC, therefore avoiding the chance of immediate milk spoilage;
- Integrates solar energy without the need for net metering or electrical batteries.

3.2 Cooperative with installation of instant milk chiller

Kamdhenu milk cooperative society

Established in 2008, Kamdhenu Dugdha Utpadak Samabay Samittee Ltd is an agricultural cooperative situated in Nityananda village in the Barpeta district in Assam. Being owned and managed by marginalised and smallholder milk producer farmers, the cooperative enables an organised milk market linkage for 19 villages, encompassing 695 farmers in a catchment area of 43 km radius. The cooperative was established to support milk production, provide remunerative prices to the milk producers and improve the socio-economic conditions of the landless, marginalised and smallholder milk producers. The cooperative is primarily involved in the collection and cooling of milk at the designated collection centre and sells most of the milk to West Assam Milk Producers' Cooperative Union Ltd (WAMUL). The cooperative's major operations are classified in two business streams: milk trading and providing input services. Milk trading involves receiving produce from smallholder milk producers, testing the quality of received milk, sale of milk in the local market, dispatch of remaining milk to the milk federation, and payment and account keeping for the milk producers. Input services include animal health coverage, breeding, supply of cattle feed, fodder development, clean milk production and extension services to producer members. Besides the daily payment provided to the farmers against the milk delivered, the cooperative also shares dividends on paid up share capital at the end of the year. The net profit of the cooperative is paid in the form of a bonus to the farmers proportionate to the value of milk supplied by them during the year.

With a total membership of 695 farmers within the cooperative, 236 are female and 459 are male farmers. The cooperative sells 80% of the milk to WAMUL and the remaining 20% is sold to private vendors such as local shops.

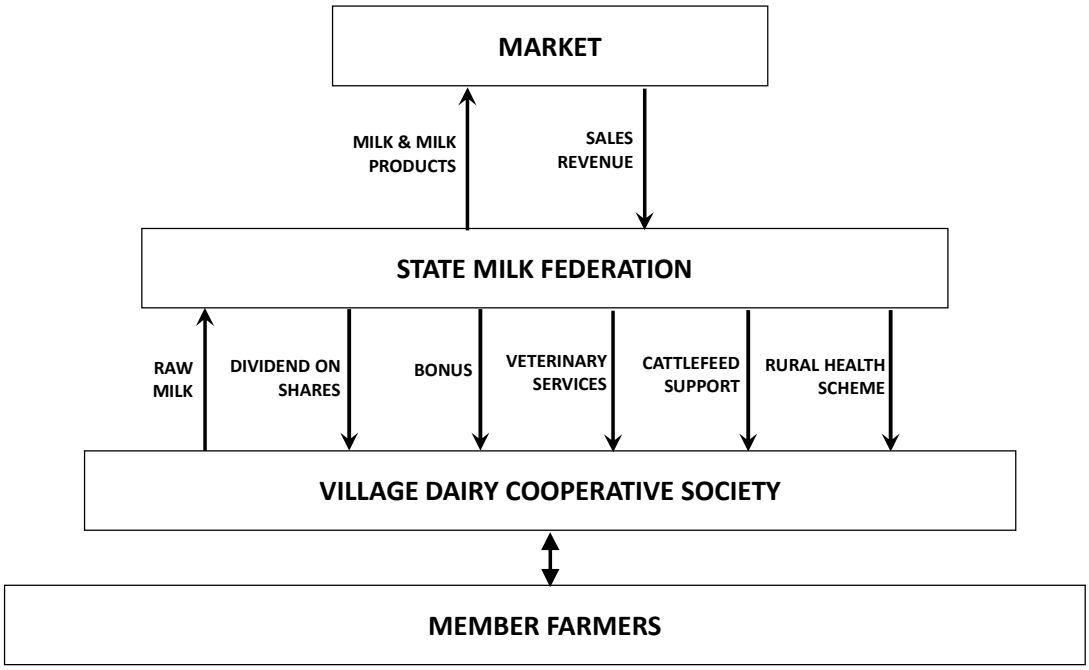
WAMUL – State Milk Federation

WAMUL was established in 1976 as a milk union of the Milk Producers' Cooperative of Nagaon, Morigaon, Goalpara, Nalbari and Kamrup districts of Assam.

WAMUL extends 80% of its annual profits to producers as a dividend and the remaining 20% is utilised for the cooperative's expansion and growth. The important functions of the union are:

- Marketing of milk and milk products;
- Managing production planning and State Milk Grid (movement of milk within the state);
- Coordination with state government, central government, NDDB and other agencies;
- Dividend payments to the farmer from the profits of WAMUL at the end of the year.

Figure 3: Structure of Dairy Cooperative and the transaction of benefits



Existing Milk Cooling Infrastructure at the Cooperative

The Kamdhenu milk cooperative uses traditional bulk milk coolers that are powered by grid energy but use a 35 kVA diesel generator as a backup. The cooperative has a total milk cooling capacity of 8,000 litres per day through three bulk milk coolers, each having a milk cooling capacity of 1,000L, 2,000L and 5,000L.

The primary data collected reveals that the operational cost of the traditional bulk coolers is 0.62 INR/Litre but fluctuates depending on the availability of grid energy. The frequent power fluctuations necessitate the need to use the diesel generator to keep the bulk milk coolers operational. During the period from May 2020 to December 2020, the milk cooperative chilled 97,963 litres of milk through 3,987 kWh of grid energy and 366 litres of diesel, which amounted to expenses of 0.62 INR/L. As the catchment area of the cooperative is greater than 40 km, it takes at least two hours for the collected milk to reach the cooperative.

As per the ISO 5708 Class 2 AII standard for bulk milk coolers, a bulk cooler can cool 50% of its capacity (for example, 500L milk in a 1000L bulk cooler) from 35^0 to 4^0C in three hours. Milk needs

to be cooled within three to four hours of its collection, which makes it difficult for the farmers, especially those from the peripheries, to reach the cooperative within the required time window. Therefore milk that reaches the cooperative after four hours of its collection will fail the test and be wasted.

Solar instant milk chiller as an add-on with the existing milk cooler

The solar instant milk chiller procured by WAMUL and provided to the Kamdhenu milk cooperative has a 3,000 LPD milk chilling capacity with 8 kWp of solar panels. It instantly chills the milk from 35ºC to 10ºC without the need for electricity. The chilled milk is then transferred to the existing/traditional bulk milk cooler where it is further cooled to 4ºC. The traditional bulk milk cooler is powered through grid electricity and/or diesel generator. The solar instant milk chiller automatically switches over to grid supply when/if available during non-solar hours to further minimise the diesel generator usage.

4 Findings

4.1 Sample socio-economic profile of the farmer members

A total of 53 farmer members from one village enrolled in the cooperative were interviewed for this study, of whom 50.9% are women. The average family size is four members. More than 80% of the farmers are educated up to higher secondary level and 60% are under 40. The assessment also revealed that almost 70% of the farmers own a single cow and 23% of the respondents own two cows. The average, maximum and minimum amount of milk supplied by the group of farmers interviewed is 2.7, 25 and 0.25 litres per day respectively.

Table 1: Socio-demographic profile of farmers interviewed

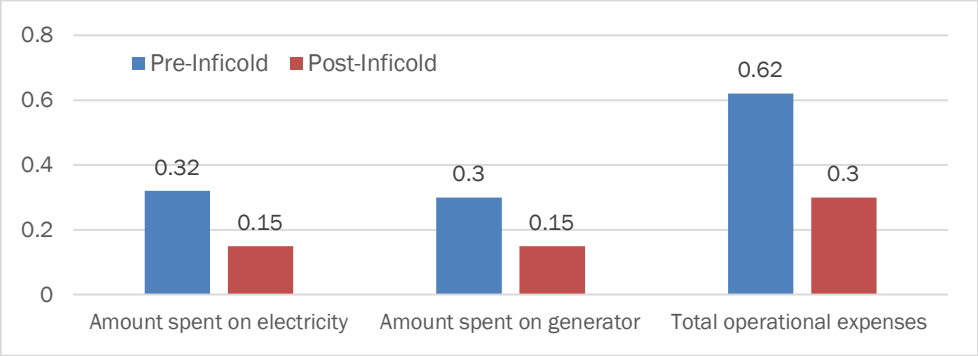
Parameter	
Gender	
• Male	49.1%
• Female	50.9%
Age	
• 18-30 yrs.	39.7%
• 31-40 yrs.	22.6%
• More than 41 yrs.	37.7%
Size of family	
• 2-4 members	54.7%
• 5-6 members	45.3%
Education	
• Illiterate	7.4%
• Below primary to secondary complete	11.4%
• Higher secondary and above	81.2%
Number of Cows owned	
• One	69.8%
• Two	22.6%
• Three to four	7.6%
Average milk supplied by each farmer, Litres/day	2.7
Number of farmers	53

4.2 Benefits of solar instant milk chiller

The Kamdhenu milk cooperative has been using traditional bulk milk coolers since its inception in 2008. Inficold's solar instant milk chiller was installed at the milk chilling centre in January 2021 and has brought about the following benefits:

- The Inficold solar instant milk chiller has the capacity to instantly cool 3,000 L of milk from 35ºC to 10ºC. The existing bulk milk cooler is now only required to reduce the temperature of the milk from 10ºC to 4ºC. The faster cooling reduces the chances of milk spoilage, improves milk quality, reduces energy demand, reduces its carbon footprint and increases profits. Since the installation and operationalisation of the instant milk chiller system, the Kamdhenu milk cooperative society has not received any complaints from the WAMUL cooperative about the quality of the milk it supplies.
- The operational costs of the milk chilling centre have reduced by 50% since the installation of the solar instant milk chiller (see Figure 4 below). The total saving made on energy bills over the 10 months since the system was installed has been INR 4,77,423. The capital cost of the solar instant milk chiller is INR 11,00,000. Therefore, the payback period is less than two years[14] assuming the average milk volume collected remains the same.

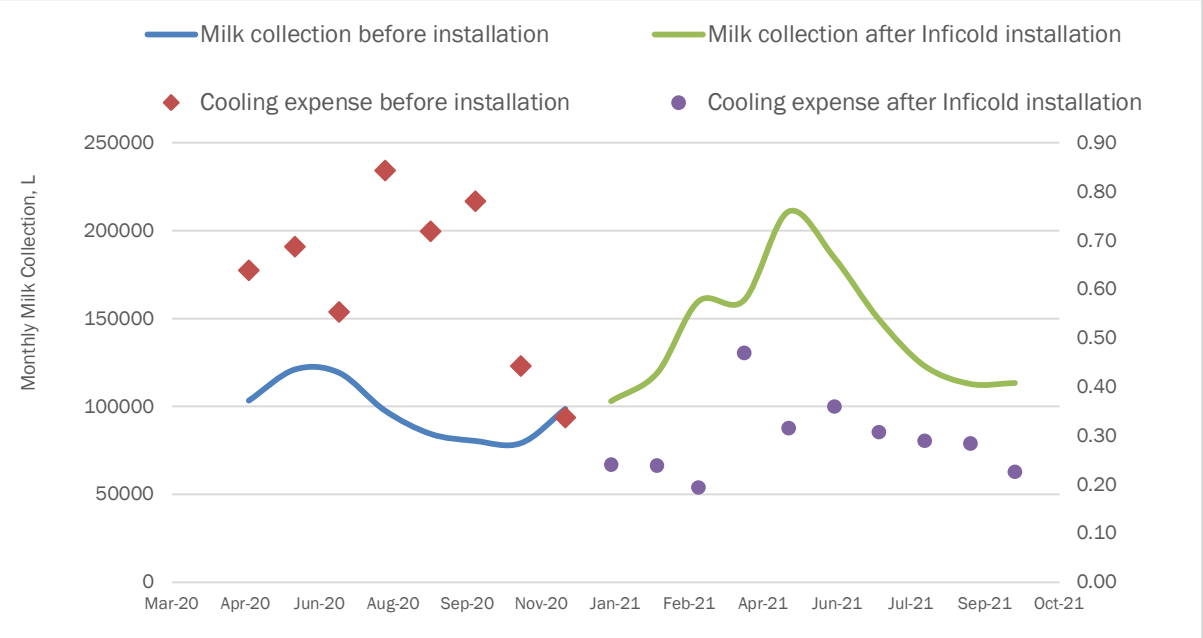
Figure 4: Impact of Inficold solution on operational expenses (cost in INR/L)



- The cooperative has increased its milk cooling capacity since the instant milk chiller was installed. As the milk cooling became faster, and therefore the chances of milk spoilage reduced, the cooperative was able to enrol additional villages in its catchment area.

[14] Payback period in months = (Cost of the system) / (Total savings in 10 months/10) = (1100000)/(477423/10) = 23 months

Figure 5: Milk collection and cooling expenses of milk chilling facility – Pre and post Inficold installation

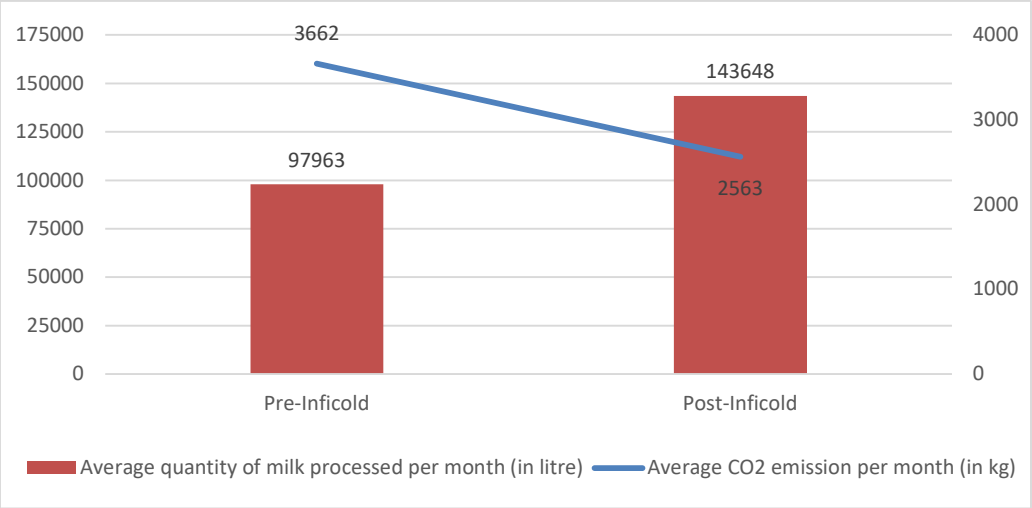


- Based on estimates from the US Energy Information Administration, one litre of diesel produces 2.63 kilograms of CO_2[15].Based on weighted average data of grid emission factor for the year of 2018-19, 1 kWh of grid electricity in India produces 0.82 kg of CO_2[16]. Using these references and the primary data collected on the amount of energy generated from the grid and diesel generator, this translates to 3,662 kg/month of CO_2 emissions. The Inficold instant milk chiller system has reduced emissions to 2,563 kg/month of CO_2 emitted, resulting in a total emission reduction of 1,099 Kg CO_2/month i.e. a reduction in carbon emissions of around 30% (see Figure 6). It should also be noted that since the system was installed, the cooperative has enrolled 150 additional farmers and increased its capacity to cool milk by 46%. Therefore installing the instant milk chilling system onto existing bulk milk coolers has made actual reductions in carbon emissions of around 45% of the base figures using linear extrapolation. This shows the potential benefits of the system if deployed at scale.

15 https://www.eia.gov/environment/emissions/co2_vol_mass.php

16 https://cea.nic.in/cdm-co2-baseline-database/?lang=en

Figure 6: Impact of Inficold solution on carbon emissions



- The covid-19 lockdown has been particularly difficult for those farmers in the village who were not associated with the cooperative as they were unable to sell milk to local shops and vendors during the lockdowns, resulting in a loss of income. However, farmers associated with the cooperative continued to supply their milk to the cooperative at a fixed price, thus ensuring constant earning with no impact on their livelihood.
- Qualitative data revealed that the cooperative has been able to increase its revenue because of using instant milk chilling solutions. Quantitative data validating this information however is not available as there was a hesitation by the union members to reveal the margins made.
- Triangulation of the primary data collected reveals that increased incomes because of reduced operational expenses was 0.3 INR per kg of milk, the dividend of which will be extended to the farmers at the end of each year. However, the increased profits of the milk union are shared amongst the farmers within the cooperative. Thus, the farmers currently working with the Kamdhenu cooperative have benefited from increased income as a direct result of using the solar powered Inficold chiller solution. The impact of this technology will be further extended to farmers when their respective cooperatives associated with the WAMUL milk union are also able to adopt similar solar instant milk chillers.

4.3 Challenges faced by the cooperative

The solar powered instant milk chiller that is installed at the Kamdhenu cooperative was funded by the World Bank and facilitated by the WAMUL union. The high capital investment and lack of access to credit remain the main challenges for cooperatives to adopt solar powered instant milk chilling solutions. The nearby cooperatives in the region are currently cooling milk through the traditional bulk milk coolers and mostly rely on diesel generators because of the unreliable grid energy. Some of these cooperatives who are aware of the Inficold's installation and its advantages are strongly in favour of getting the system for their own use, but have challenges accessing finance and are waiting for a similar credit facility to procure the system. Others who are not aware of such technology continue to use diesel generators for milk cooling in the most parts of India without being aware of the economical nor the environmental benefits of using solar powered systems. Greater awareness of the technology and the importance of off-grid solutions are required for the rapid adoption of the technology and reduce contributions to global warming.

5 Conclusion and Recommendations

The solar instant milk chiller has multiple advantages for smallholder farmers associated with milk cooperatives. Some of the advantages include:

1. Fast cooling leading to improved milk quality that fetches a higher value for the produce;
2. Reduced dependency on grid and diesel power, leading to cost competitiveness and reduced CO_2 emissions ;
3. Increased milk cooling capacity thus enabling additional farmers to benefit from more sustainable and increased incomes.

The Inficold technology, if implemented at scale, has the potential to improve the socio-economic status of the community, spur the local economy, and reduce CO_2 emissions, thus contributing to Goals 7 and 12 of the United Nations Agenda for Sustainable Development. There is a significant opportunity to bring smallholder farmers on board with the organised milk cooperative ecosystem in India, which calls for the need to generate more awareness at cooperative level around the adoption and replication of sustainable cooling solutions.

At the macro level, promoting energy efficient solutions is gaining prominence as a means to tackle climate change related challenges and our dependence on fossil fuels. With India's commitment to achieve Net Zero Emission by 2070, the country needs to look at all possible financing solutions to achieve this ambitious target. It is an opportunity to push off-grid solutions that are proven to provide a balance in serving people's livelihood needs without jeopardising the impact on the environment.