The Lab
Driving Sustainable Investment

Cooling as a Service (CaaS)

LAB INSTRUMENT ANALYSIS—INDIA REPLICATION
October 2021

DESCRIPTION & GOAL —
CaaS would enable smallholder farmers access sustainable cooling facilities through servitization.

SECTOR —
Clean cooling; Decentralized power generation; Energy access

FINANCE TARGET —
USD 200 million in cold room projects within four years of pilot

GEOGRAPHY —
For replication phase: India

The Lab identifies, develops, and launches sustainable finance instruments that can drive billions to a low-carbon economy. The 2021 Lab cycle targets three specific sectors: sustainable food systems; sustainable energy access; and sustainable cities, in addition to two regions: Brazil and Southern Africa.

AUTHORS AND ACKNOWLEDGEMENTS

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TABLE OF CONTENTS

CONTEXT

To better address food waste at the farm level, farmers—especially smallholder farmers—need access to efficient and clean cold storage solutions at affordable pricing.

India has pledged to reduce the carbon intensity of its economy by 33-35% over 2005 levels by 2030. Agriculture continues to be one of the largest emitters of carbon, contributing to about 15% of India's GHG emissions (UNFCCC India Biennial Report-3, 2021), besides consuming almost 80% of the country's water resources (Water and Agriculture in India, 2017).

According to FAO, more than 40% of food produced in India is wasted—cumulatively at the farm, transport, and retail level—before it reaches the customer(FAO Food Waste Index, 2021). One way to address the problem at the farm level is that farmers, especially smallholder farmers, are given access to efficient and clean cold storage solutions at affordable prices so that they can reduce food losses and sell products when market prices are more conducive.

Such a step would not only enhance India's food and water security but would also be in line with the Government of India's efforts at doubling farmer incomes. Our analysis suggests that farmer revenues can increase by more than 35% with the help of cold storage. Moreover, deploying clean and efficient cooling solutions, rather than those that use grid power, would also be in line with the targets set under the National Action Cooling Plan in 2019, as part of which India plans to reduce cooling energy requirements 25- 40% by 2037-38 (IEA, 2021).

Issues with India's existing cold storage ecosystem

The current cold storage capacity of India exceeds 37 million MT, according to the Ministry of Agriculture & Farmers Welfare (PIB India). However, a deeper analysis reveals that the quantum and nature of this cold storage is not conducive to either reducing food waste or empowering the small/marginal farmer. For instance:

- The current capacity is much lower than the optimal requirement. Despite being largely tropical and sub-tropical, India has only 6% of its food produced moving through the cold chain, compared to about 60% in developed economies (Ammonia21).

- Most of the cold chain storage in India comprises large-scale, centrally-located bulk storage facilities that are apt for single commodity storage. For instance, potato storage utilizes 70% of the capacity (Cold Chain Report, 2021). Moreover, such facilities are accessible to primarily wealthier farmers, aggregators, or retailers.

- In addition to the facilities, the expertise required to store and handle produce after harvest correctly to reduce food loss is also not accessible to smallholder farmers. Digital tools, such as mobile applications are often tailored to serve larger agriculture companies, instead of smallholder farmers.

- A significant portion of food waste occurs at the farm level, due to limited pre-cooling facilities (Shakti Foundation, 2019). Thus, the large cold storage warehouses are not well situated to intercept where most production-level food waste is occurring.

To significantly reduce food waste at the farm level, it is imperative to set up small-scale cold storage facilities at the farm gate and local markets.

How decentralized cold storage can address the shortcomings

Availability of decentralized, affordable cold storage at the farm gate can partly resolve the aforementioned issues:

- Decentralized cold rooms can increase smallholder farmer income through:
    - Reduced waste, leading to higher aggregate weight of sellable commodities.
    - Increased weight per commodity due to enhanced water retention and reduced wilting, leading to higher overall revenues
    - Higher rate/kg realization, due to better quality commodities at the time of selling (either at the mandi or outside)

- Decentralized cold storage can also assist in the diversification of commodities. India currently overproduces cereals such as wheat and rice, which consume large amounts of water, as farmers prefer to stick with cereals, given their low perishability and the fact that these commodities are covered under Minimum Support Price (MSP). Farmers are often hesitant to diversify beyond the 23 commodities covered within the MSP regime due to revenue assurance associated with such commodities. Decentralized cold storage can provide a safety net and encourage farmers to take on greater risk and cultivate commodities that are either outside the purview of MSP or more perishable – but which can potentially yield higher incomes.

- The proliferation of decentralized cold storage would augment India's cold storage capacity and make the overall cold chain infrastructure more robust and efficient. Such a cold chain can cater to different types of commodities based on their perishability, the desired storage duration, and end-use.

To address the challenge of food waste and limited decentralized cold stoage, BASE, a Swiss Foundation focused on developing innovative solutions in sustainable energy, and Empa, a Swiss research institute for materials sciences and technology, are creating 'Your Virtual Cold Chain Assistant' (VCCA), an open-source and data-driven mobile application as part of the data.org inclusive growth and recovery challenge. The app supports smallholder farmers in optimizing their post-harvest cold storage practices to reduce food loss.

CONCEPT

Cooling as a Service (CaaS) is a solution that aims to accelerate the uptake of clean energy-backed cold storage at the farm level through a servitization model. Through such a model, small and marginal farmers can pay for cold storage services on a pay-as-you-go basis. This would bypass the need for farmers to incur capital expenses on asset ownership – often the biggest hurdle in availing cold storage.

To enable and complement the CaaS solution, the proponents BASE and Empa are developing 'Your Virtual Cold Chain Assistant' (Your VCCA), an open-source and data-driven mobile application that supports smallholder farmers in optimizing their post-harvest cold storage practices. This assistant aims at addressing another hurdle that smallholder farmers face - even when cooling facilities are available, the expertise needed to effectively store is lacking. The app aims to be the missing post-harvest coach that guides farmers in reducing food loss and increasing their incomes.

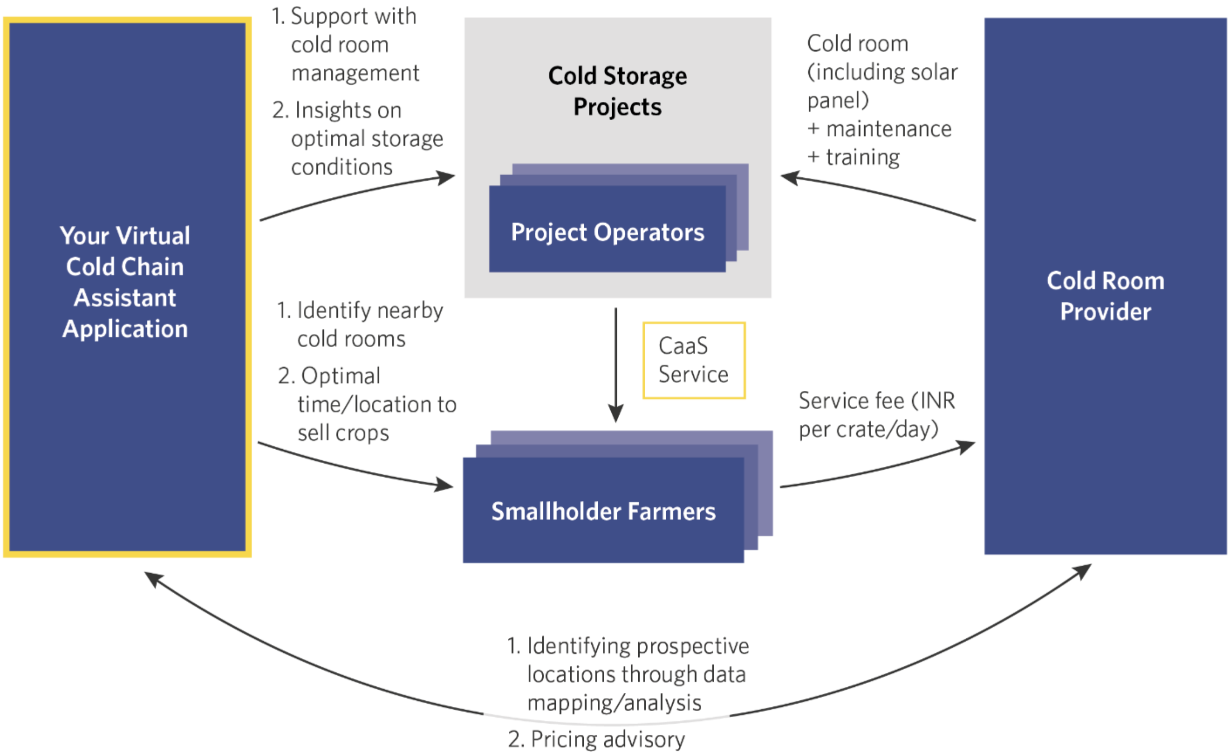
Featuring machine-learning and physics-based models, the application predicts the shelf life of stored crops and combines it with predictive price analytics of selected commodities as well as geographical and weather data. This application provides recommendations to users on optimal storage practices and when/where to sell to maximize revenue and minimize food loss.

1. INSTRUMENT MECHANICS

CaaS will ensure smallholder farmers make decisions on cooling based on lifecycle benefits, rather than upfront costs.

CaaS is a business model that enables farmers to gain access to the most efficient, reliable, and sustainable cooling while only paying for the weight of commodities they store (per kg-day) in the cold rooms, thus avoiding any need for upfront investment. Service providers own and maintain the cooling facilities, thereby covering the operational costs. Keeping the performance risk of the cold room with the service provider serves as an incentive for them to install the most energy-efficient equipment, and to perform high-quality maintenance to avoid downtime.

Figure 1: CaaS with VCCA instrument mechanics



The objective of CaaS with VCCA is to enable smallholders to gain access to cooling without upfront costs; have access to easy-to-use information so that they can make optimal decisions on produce and farm management and thus break the negative cycle of poverty - while also improving food security and minimizing the impact of food production on global climate.

Key Stakeholders

- **Idea implementers:** The app development is led by BASE and Empa. This work is part of the data.org challenge, which is a platform launched collectively by Rockefeller Foundation and the Mastercard Center for Inclusive Growth, to tackle society's greatest challenges and help people and communities thrive by harnessing the power of data science.

- **Farmer groups/Farmer Producer Organizations (FPOs):** As highlighted in Figure 1, service providers would need a cluster of farmers in a localized area who are keen to avail cold storage services, to generate enough revenues so as to make the project viable. Such farmers can be approached through FPOs or individually and then grouped in clusters.

- **Cold room service providers:** These are companies (often startups) that provide cold room services to farmers or FPOs in lieu of service charges. The companies may manufacture cold rooms in-house or procure them through third-party manufacturers. We only consider cold rooms that consume power produced through clean sources (e.g. solar or biomass), although the cold rooms could be connected to grids for additional power requirements. In addition to cold storage, cold room providers may also assist farmers by creating platforms that link sellers with buyers to expand market access and remove information asymmetry.

Value-add of CaaS

CaaS with VCCA offers value-add to key stakeholders, including farmers, cold room service providers and cold room operators. This is summarized in Table 1.

Table 1: Caas with VCCA value-add

CaaS with VCCA value-add		
For farmers	Cold room providers	Cold room operators
• Identify nearby available cold rooms. • Access to clean cooling through a servitization business model. • Real-time instructions on optimal cold storage conditions to maximize shelf life and minimize food loss. • Instructions guiding farmers on the optimal time and location to sell their produce to maximize revenue,	• Identify prospective cold room sites through multi-factor analysis based on data including climate/weather, net sown area, marketplace locations, commodity production, and yields, among others • Advice on pricing analytics and pricing strategy	Cold rooms may be operated directly by FPOs or by employees of service providers (who may also function as sales agents). CaaS with VCCA plans to provide cold room operators with: • A digital cold room management system for an overview of which crops enter and leave the room. • Insights on optimal storage conditions

based on predicted shelf life, predictive market analytics, and other factors that impact net profit.		• A digital payment system that facilitates CaaS payments

Possible financial structures of the CaaS business model

There are several ways for smallholder farmers to benefit from cold storage on a pay-per-use basis. Three representative examples are:

- The service provider owns the cold room. The operator of the room is an employee of the service provider. The full project risk lies with the service provider.
- The service provider sells the cold room to an FPO, which takes the commercial risk by offering CaaS to farmers. The service provider is still responsible for proper maintenance of the cold room.
- The service provider leases the cold room to the FPO and includes maintenance in the agreement. The FPO offers CaaS to farmers and takes on the commercial risk.

The three structures are summarized in Table 2.

Table 2: Possible structures for CaaS

Structure name	Which entity maintains cold room and takes technology risk?	Asset owner	Entity responsible for: (a) Operating and (b) Collecting payments
Direct CaaS	Cold room provider	Cold room provider	Employee of cold room provider (can also be hired from FPO)
CaaS via FPO	Cold room provider	FPO (FPO self-finances or finances with the help of a bank loan)	FPO
CaaS via FPO with lease	Cold room provider	FPO (FPO leases cold room from service provider)	FPO

2. TARGET COMMODITIES AND OPTIMAL STORAGE DURATION

It is prudent to have a flexible approach to identify commodities that are suitable for decentralized cold storage.

Given India's varied landscape and a wide range of climatic conditions, it produces a large number of commodities, which vary widely when it comes to perishability, market prices, seasonality, and regions they are cultivated in. Therefore, it is prudent not to have one-size-fits-all approach to identify commodities that are suitable for decentralized cold storage. We provide a framework for screening commodities suitable for decentralized cold storage, depending on their inherent properties related to perishability, seasonality, and other characteristics related to market pricing.

I. Medium (2 weeks to 1 month) and long-duration cold storage (1-4 months)

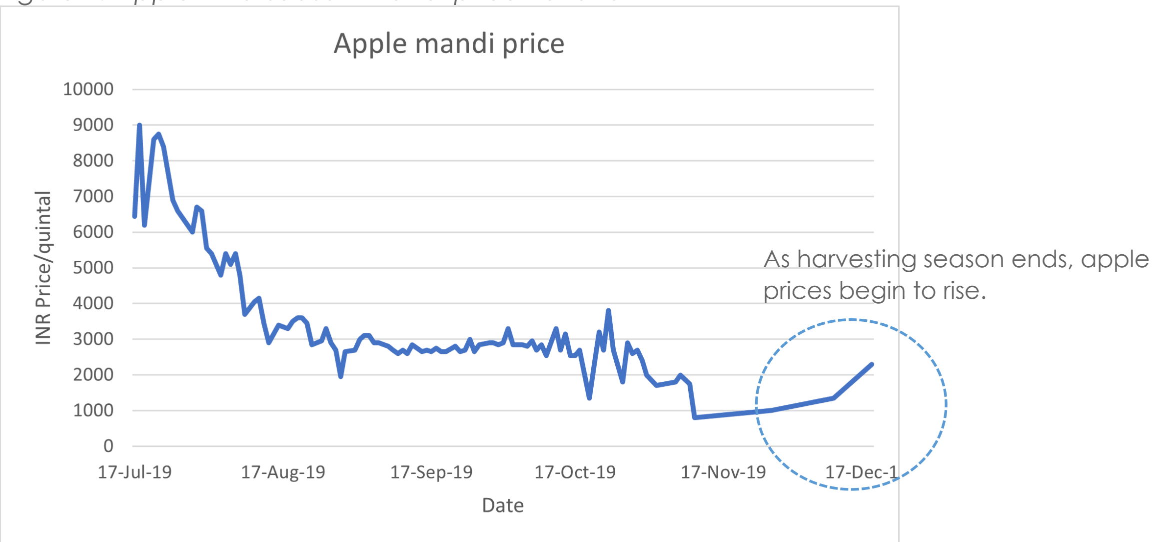
Medium and long-duration cold storage is applicable for commodities exhibiting the following characteristics:

- Low perishability: commodities that can easily be stored up to 2-3 months in cold rooms. Certain commodities may be stored for up to 4 months. (UC Davis)
- Seasonality of cultivation/harvesting, leading to a predictable and seasonal variation in prices, determined largely by supply.
- The magnitude of price variation (both intra-season and inter-season) is large enough to absorb cold storage service costs.
- Commodities that do not have external reference prices or minimum support prices. The absence of downside price protection incentivizes farmers to utilize the cold rooms.

Examples include: Strawberries, lychees and cherries for medium duration storage, while apples, pears, citrus fruits, grapes can be stored for a medium as well as long duration.

Illustrative Example
The following price chart illustrates the predictable and seasonal price variation for apples:

Figure 2: Apple intra-season mandi price variation



Data extracted from Agmarket.gov.in
State: Himachal Pradesh; District: Kullu; Market: Bandrol
Apple variety: Delicious; Grade: Medium

The majority of apple harvesting takes place in India between July and November (apeda.gov.in). As supply increases in the initial harvesting months (e.g. July/August), apple prices at the mandis decline before plateauing once the supply stabilizes. As the supply starts to decline at the terminal end of harvesting season, apple prices begin to rise again.

- **For medium duration storage**, farmers can store for <1 month (e.g. November-end) and profit from the intra-season price variation.

- **For long-duration storage**, a farmer can store the apples for several months to profit from the inter-season price variation. The farmer can sell the apples at a time when they would compete with the higher priced imported apples (e.g. Washington apples, whose retail price is typically 2-3x that of a domestically produced apple).

II. **Short-duration cold storage (typically less than 2 weeks)**

Farmers are able to absorb the cost of cold service not only through reduced waste (hence higher selling mass and lower rejection rates), but also from increased price realization as a result of higher commodity quality enabled through cold storage. The short duration cold storage is applicable for commodities exhibiting the following characteristics:

- High perishability
- Commodities that do not have external reference prices or minimum support prices Combined with high perishability, farmers are often forced to crash sell, or destroy harvest when prices are abnormally low

Examples of commodities suitable for short-duration cold storage include tomatoes, broccoli, mushrooms, spinach, sweet corn, cabbage, beans, mint, other leafy vegetables. Even the commodities mentioned in the medium/long-duration storage can also be stored for a shorter duration. Farmers may use cold rooms simply for pre-cooling activities and ensure higher commodity quality before selling, without looking to exploit any inter-season price variations.

The above framework may only be used as a guide for identifying and screening commodities that can be targeted for cold storage services. Whether or not a business case exists depends on a large number of local factors, such as the cluster of willing farmers in a region (cold room service providers need a critical number of users to generate optimal returns), distance and transportation costs till marketplaces (mandis), inter-cropping patterns (certain inter-cropping commodities may not complement well with the commodities suitable for cold storage), the nature of commodities (certain commodities bloom in the third or the fourth year and may not need cold storage in specific years), the depth of market linkages within a region (so that the farmer is in a capacity to benefit from seasonal price change), how developed the existing cold chain infrastructure is in the region, the level and certainty of subsidies that can be availed for cold room purchase, the region's electricity tariff, the regional government's policies and subsidies on irrigation water, among other factors.

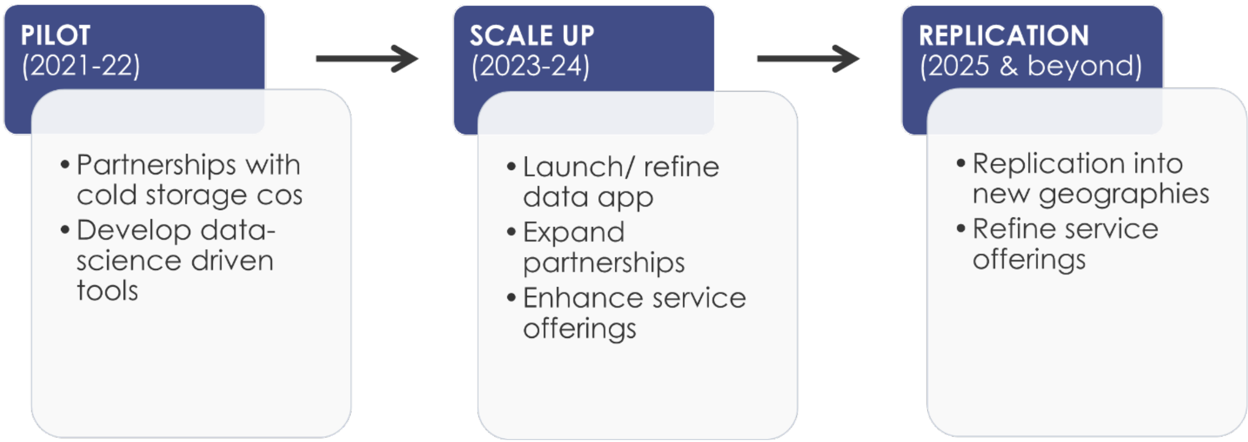
MARKET TEST AND BEYOND

3. IMPLEMENTATION PATHWAY AND REPLICATION

CaaS with VCCA will pilot in India during 2021-2022, demonstrating the economic viability of the CaaS business model and the value add of the VCCA app.

The proponents BASE and Empa plan to pilot CaaS with VCCA in two states, Bihar and Himachal Pradesh, during 2021-2022, after which they will expand partnerships, enhance service offerings, and enter new regions. The pilot will serve to demonstrate the economic viability of the CaaS business model and the value-add of the VCCA app, after which the proponent expects more cooling service providers to partner, given the open-source nature of the app. The process followed for scale-up is shown in Figure 3.

Figure 3: Implementation pathway and replication process



A tentative timeline on how the company plans to achieve its targets, along with the corresponding activities is depicted in Figure 4:

Figure 4: Timeline for scaling up and replication

	Pilot		Scale Up		Replication
	Year 1	Year 2	Year 3	Year 4	Year 5
Cold storage partnering firms	3	8	18	25	40
States covered in India	5	10	18	22	>25
Cold rooms deployed (cumulative)	10	100	1,000	5,000	15,000
Farmers benefited (cumulative)	1,000	10,000	100,000	500,000	1,500,000
Countries covered	1 (India)	2 (+ Nigeria)	6 (+ Kenya, Rwanda, and 2 countries in Latin America)	12	18

Services provided for partnering firms

From Year 1 to Year 5:
- Business model advisory
- Pricing advisory

From Year 3 to Year 5:
- Cold room management support
- Insights on optimal storage conditions
- Predictive shelf-life + physics-based modeling
- Predictive market analytics
- Optimal time/location to sell recommendation
- Cluster location identification for providers
- Cold room identification for farmers

3.1 UPCOMING PILOT PROJECTS

BASE and Empa are seeking to implement the following pilots in the 2021/22 harvesting season:

- **Apple cold storage in Himachal Pradesh (Medium/Long term)**
  - Implementing partner: CoolCrop
  - Pilot description: CoolCrop will implement a cold room to store Apples for up to six months, from October to March, to enable between 200-500 farmers in Himachal

Pradesh, organized under an FPO to sell their Apples when their market value is up to three times higher (INR 40/kg on October vs INR 120/kg in March).

- Expected number of farmers that would benefit: 200-500

- Technical specifications of cold rooms: solar-driven cold rooms; temperature range: 0-18°C, humidity range 65-100% RH.

- Pricing model: CoolCrop will own and operate the system, and charge users per box of apples stored.

- Purpose of the pilot and role of the proponent:

  (i) The pilot would help to test the viability of the CaaS business model for medium/long-term storage in the apple supply chain.

  (ii) The pilot will also help to translate data into actionable recommendations that allow farmers to identify the best time to sell their produce. The proponent is developing physics-based digital twins of different fruits, including apples. Using the measured real-time sensor data, the digital twins will predict the mass loss and expected shelf-life of the stored fruit, as these twins age in real-time along with the real produce, but inside a computer.

  (iii) The proponent would also test the effectiveness of key components of the VCCA app, including an image-based machine learning model to grade fruits after harvest and gauge their receptivity among farmers. Current solutions that grade fruits are not tailored to the limitations that smallholder farmers face. For example, farmers can take images with baic smartphones instead of high-end cameras.

- **Multi-commodity cold storage in Bihar (Short term)**
  - Implementing partner: Oorja

  - Location: Nevra Bazaar, Muzzaffarpur, Bihar

  - Expected number of benefiting farmers: ~ 500

  - Technical specifications: 5MT solar-driven cold room with thermal storage, supplied by Ecozen. Smart controls for set points and exhaust fans for cooling.

  - Pricing model: membership fee + fee per crate

  - Purpose of the pilot and role of the proponent: The CaaS team would collect hygrothermal and usage data, with the intention to upcycle data and provide insights on optimal storage conditions and expected shelf-life of crops. In conjunction with Oorja, the CaaS team will test an interactive map that helps identify promising cold room storage locations throughout India. Such an exercise is key to identify where a cold storage facility could help save most food.

Additionally, the BASE and Empa teams are currently exploring the implementation of pilot projects with several other clean technology providers in India. The CaaS business model and several components of the VCCA app are to be developed and tested on a number of commodities.

4. FINANCIAL IMPACT AND SUSTAINABILITY

Our analysis suggests that farmer revenues can easily increase by more than 35% with the help of cold storage.

4.1 QUANTITATIVE MODELING

To illustrate the economic viability of a cold storage project, we developed a financial model to compute the expected returns, based on reasonable assumptions that are detailed in Table 3. This model is built for apple farmers in the Himachal region, who would store apples for up to 3 months and sell them at a time when market prices are high. The financial model exercise suggests that cold room providers can easily generate returns in excess of 25% at the project level, if reasonable levels of price realization and capacity utilization of cold rooms can be attained.

Table 3: Financial model assumptions and related information

Project assumptions and information		Comments
Size and cost of cold rooms:		
Cold room size	15 MT	• 3 solar-powered cold rooms of 5 MT each • Typically one cold room is used for pre-coolling while the other two for cold storage
Cost of each unit	INR 0.2 millon/MT	• This cost includes solar panels, transporation and installation • This cost does not include any subsidy
Manufacturer margin	15%	This metric is applicable if the cold room service provider is the same entity that manufactures the cold rooms
Capital assumptions		
Debt:Equity	50:50	
Project duration	10 years	
Loan tenure	7 years	
Cost of debt (%)	11% per year	
Project duration	10 years	
Cost of equity (%)	16% per year	
Operational costs		
Power units consumed by each cold room (units; 1 unit = 1 Kwh)	900 units per month (or 60 unit/MT for a 15 MT project)	Power is consumed primarily for pre-cooling activities, due to higher difference between the field temperature and optimal storage temperature. Pre-cooling refers to the removal of field heat from commodities immediately after harvesting.

		Once commodities reach optimal storage temperature, they are shifted to cold rooms.
Average power tariff (INR/unit)	INR 7/unit	
Average annual increment in power tariff (%)	3%	
Land rental and O&M costs related to cold rooms (INR)	INR 150,000 per year	
Annual increment in land rental and O&M costs (%)	3% per year	
Staff cost (INR)	INR 240,000 per year	This assumes the cost of 1-2 full-time employees for a 15 MT project.
Annual increment in staff cost (%)	4% per year	
Revenue assumptions (*Note: Project revenues = capacity utilization*cold room capacity*average revenue*365)*		
Capacity utilization (%)	50%	Utilization rates for cold rooms will vary during different seasons. Service providers may also transport cold rooms to different locations to realize higher capacity. This figure assumes the average value of capacity utilization comes to be 50% annually.
Average revenue realized (INR/kg/day)	INR 0.5/kg/day	Revenue charged/kg/day would depend on: (a) Duration of the storage – shorter duration will naturally have a higher price/kg/day; and (b) Overall demand for cold storage, which depends on harvesting patterns.

Based on these assumptions, the following returns are expected:

Table 4: Expected returns for a cold storage project

Return Type	Expected return (%)	Comments
Project IRR	22.5%	
Equity IRR	31.1%	
Project IRR (manufacturer)	27.2%	This scenario assumes the manufacturer is the same entity as the cold room service provider and is able to realize a margin prior to the provision of cold room
Equity IRR (manufacturer)	43.2%	

		services, which adds to overall returns.

As highlighted in Table 3 and Table 4, the financial models illustrate the economic viability of cold room projects if providers are able to realize a certain level of revenue and capacity utilization. While the expected return values are fairly high, one must take into account that these returns are at a project level. Actual returns, after taking into account corporate expenses, would be lower.

Increase in farmer revenues

To estimate the increase in farmer revenues, we compared two scenarios for apple farmers – with long-term cold storage and without cold rooms. Our analysis suggests that farmer revenues can easily increase by more than 35% with the help of cold storage. This is summarized in Table 5. For more details on assumptions and methodology regarding the two scenarios, please refer to Annex 1.

Table 5: Increase in farmer incomes through cold storage

Metric	Without cold storage	With cold storage
Yield/acre (kg/acre)	10,000	10,000
Wastage (%)	25%	5%
Farmer selling price (INR/kg)	40	88
=> Revenue/acre (INR/acre)	300,000	836,000
Commission agent fees	20%	20%
=> Farmer income/acre (INR/acre)	240,000	668,800
Cold storage costs	0	342,000
=> Effective farmer income/acre	240,000	= 668,800 - 342,000 = 326,800
% increase in farmer incomes/acre through cold storage	=(326,800 -240,000)/(240,000) **= 36%**	

5. ENVIRONMENTAL AND SOCIO-ECONOMIC IMPACT

Within four years of launch, CaaS with VCCA can benefit more than 1.5 million farmers, abate 100,000 units of CO2, and mobilize USD 200 million into decentralized cold room projects.

Through reduced food waste, better quality commodities, and by enabling farmers with the duration and tools to decide when to sell, CaaS empowers smallholder farmers. We estimate the following impact generated directly by CaaS as it scales up.

Table 6: Expected environment and socio-economic impact through CaaS

Year	Pilot (2021-22)	Scale up (2023-24)	Replication (2025 and beyond)
Expected increase in farmer incomes	25-35%	25-35%	25-35%
GHG Abated (MTCO2e) (Cumulative)	650	33000	100,000

Number of farmers benefited ('000) (Cumulative)	10	500	1500
Expected food reduction waste (MT) (Cumulative)	400	20,000	60,000
Capital mobilized (USD Million) (Cumulative)	1.4	67.6	202

Beyond the direct impact, CaaS with VCCA would address numerous SDGs, such as SDG-2 (Zero Hunger), SDG-7 (Affordable and Clean Energy), SDG-12 (Responsible Production and Consumption) and SDG-13 (Climate Action).

6. NEXT STEPS

As immediate next steps, CaaS with VCCA would focus on implementing pilots listed in Section 3.1. The pilots would help to collect data that would feed into the Machine Learning algorithm, which would then set the stage for launching the VCCA app in 2022. The learnings from the pilots would also help to understand farmer behaviour, market price analytics, shelf-lives of different commodities, and inform the overall scale-up and expansion strategy.

Access to affordable decentralized cooling holds potential to transform India's agriculture and supply chain. If the model is successfully replicated by market players (including those who may not partner with CaaS with VCCA), then the impact can be significant and contribute to achieving the following outcomes:

- Enhancing India's food security and nutrition through lower food waste and a more balanced diet for the populace.
- More efficient use of land and precious natural resources such as water.
- Reduced reliance on cereal-dominated agriculture through crop diversification, and an increased contribution of horticulture within the overall agriculture. India currently overproduces cereals such as wheat and rice, which consume large amounts of water (Grainmart.in). This has led to a significant deterioration of the water table in North Indian states. Farmers prefer to stick with cereals, given their low perishability and the fact that these commodities are covered under Minimum Support Price. Decentralized cold storage can mitigate risks of price volatility and higher perishability, and can nudge farmers to cultivate horticulture commodities.

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7. ANNEX 1 – FARMER REVENUE ASSUMPTIONS

Our analysis suggests that farmer revenues can easily increase by more than 35% with the help of cold storage. To estimate the increase in farmer revenues, we developed two scenarios for apple farmers – with long-term cold storage and without cold rooms. We first computed expected revenues without using a cold room and then with a cold room. The details are provided in Table 7 and Table 8.

Table 7: Farmer incomes without cold storage

Metric	Without cold storage
Yield/acre (kg/acre)	10,000
Wastage (%)	25%
Farmer selling price (INR/kg)	40
=> Revenue/acre (INR/acre)	300,000
Commission agent fees	20%
=> Farmer income/acre (INR/acre)	240,000

Thereafter, we estimated the farmer revenues with cold storage, summarized in Table 8:

Table 8: Farmer revenues with cold storage

Metric	With cold storage
Productivity and wastage assumptions	
Yield/acre (kg/acre)	10,000
Wastage (%)	5%
Apple selling price	
Usual farmer selling price without cold storage (INR/kg)	40
Difference in market selling price due to off-season (INR/kg)	80
Farmer share in market selling price differential (due to off-season)	50%
=> Farmer selling price during off-season (INR/kg)	=40 + 50%*80 = 80
Premium realized due to better water retention (higher weight) and higher quality commodity as a result of pre-cooling	10%
=> Effective farmer selling price	=80*1.1 = 88
=> Revenue/acre (INR)	= (100-5)%*88 = 836,000
Commission agent fees	20%
=> Farmer revenue/acre (INR)	=836,000*(1-20%) =668,800
Cold storage costs	
Cold storage duration (days)	90
Cold storage cost/kg/day	0.5
Discount factor due to long-term storage	0.8
=> Effective cold storage cost/kg/day (INR/kg/day)	=0.5*0.8 =0.4
=> Total cold storage costs (INR)	342,000
Farmer revenue after incurring cold storage costs	
Effective farmer revenue (INR)	= 668,800-342,000 = 326,800
% increase compared to no cold storage scenario	=(326,800/240,000-1) = **36%**