Rural Cooling Needs Assessment
Towards designing Community Cooling Hubs

November 2020

SHAKTI SUSTAINABLE ENERGY FOUNDATION

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Rural Cooling Needs Assessment: Towards designing Community Cooling Hubs

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Centre for Environment Education
Centre for Environment Education (CEE) was established in 1984 as a Centre of Excellence of the Ministry of Environment and Forests, Government of India. As a national institution, CEE's mandate is to promote environmental awareness nationwide. CEE develops innovative programmes and educational material and builds capacity in the field of Education for Sustainable Development (ESD). It is committed to ensure that Environmental Education (EE) leads to action for sustainable development. It undertakes field projects that demonstrate and validate the role education can play in sustainable development. With partners including State Governments, Foundations and Corporates through CSR funding, CEE has undertaken projects in rural and urban development, waste management, biodiversity conservation, quality improvement in school education, marine conservation and others.

MP Ensystems Advisory Pvt. Ltd.
MP Ensystems is a niche energy and environmental sector consultancy and advisory firm. Established in 2012, MP Ensystems provides a bridge between policy-making and clean energy project implementation, by providing solutions at both the product levels as well as the process levels. These include the entire energy value chain: generation, transmission, distribution and consumption, and especially design, implementation and evaluation of demand-side management and energy conservation programs.

Shakti Sustainable Energy Foundation
Shakti Sustainable Energy Foundation seeks to facilitate India's transition to a sustainable energy future by aiding the design and implementation of policies in the following areas: clean power, energy efficiency, sustainable urban transport, climate change mitigation and clean energy finance.

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Abbreviations

AC	Air Conditioner
AC	Asbestos Cement
AI	Artificial Intelligence
ANM	Auxiliary Nurse Midwife
APMC	Agriculture Produce Market Committee
ASHA	Accredited Social Health Activist
BAIF	Bharatiya Agro Industry Foundation
BCG	Bacilli Calmette Guerin
BQ	Black Quarter
CCH	Community Cooling Hubs
CDX-ENS	7 CORDEX South Asia multi-RCM Ensemble Mean
CDX-REA	7 CORDEX South Asia multi-RCM Reliability Ensemble Average
CEE	Centre for Environment Education
CFL	Compact Fluorescent Lamp
CHC	Community Health Centre
CMH	Cubic Meter per Hour
CRM	Customer Relationship Management
CSA	Consumer Support Agriculture
DB	Dry Bulb
DPT	Diphtheria Pertussis Tetanus
DVS	District Vaccine Stores
eNAM	National Agriculture Market
eVIN	Electronic Vaccine Intelligence Network
FGD	Focused Group Discussions
FMCG	Fast Moving Consumer Goods
FMD	Foot and Mouth Disease
FPC	Farmer Producer Company
FPO	Farmers' Producer Organization
GHG	Greenhouse Gases
GI	Galvanized Iron
GMSD	Government Medical Store Depots
HFC	Hydrofluorocarbon
HIV	Human Immunodeficiency Virus
IBR	Infectious Bovine Rhino tracheitis
ICAP	India Cooling Action Plan
IEA	International Energy Agency
ILR	Ice line refrigerator
IoT	Internet of Things
IPD	In Patient Department
IPV	Inactivated Polio Vaccine
LAQSHYA	Labour Room Quality Improvement Initiative
LED	Light Emitting Diode
MoHFW	Ministry of Health and Family Welfare
MGNREGS	Mahatma Gandhi National Rural Employment Guarantee Scheme
MR	Measles and Rubella
MRI	Magnetic Resonance Imaging

MSEDCL	Maharashtra State Electricity Distribution Company Limited
MSL	Mean Sea Level
MT	Metric Ton
NA	Not Applicable/Available
NASSCOM	National Association of Software and Services Companies
NCCD	National Centre for Cold-chain Development
NCCRC	National Cold Chain Resource Centre
NCCVMRC	National Cold Chain and Vaccine Management Resource Centre
NGOs	Non-governmental Organization
NT	Nomadic Tribes
OBC	Other Backward Castes
OPD	Outpatient Department
OPV	Oral Polio Vaccine
PHC	Primary Health Centre
PMAY	Pradhan Mantri Awas Yojana
PPM	Part Per Million
PVC	Polyvinyl Chloride
RCC	Reinforced Cement Concrete
RCP	Representative Concentration Pathway
RE	Renewable Energy
RH	Rural Hospital
RVS	Regional Vaccine Stores
SC	Scheduled Castes
SDGs	Sustainable Development Goals
SNF	Solids Not Fat
ST	Schedule Tribe
SVS	State Vaccine Stores
TR	Tonnage of Refrigeration
TT	Tetanus Toxoid
UHC	Urban Health Centre
UIP	Universal Immunization Programme
UNFCCC	United Nation Framework Convention on Climate Change
VVM	Vaccine Vial Monitor
WHO	World Health Organization
ZP	Zilla Parishad

Rural Cooling Needs Assessment: Design of Community Cooling Hubs

Executive Summary

As average temperatures increase to extremely hot and unbearable conditions, India faces the dilemma of meeting the increased needs for cooling for human well-being without increasing greenhouse gas emissions. Rural India's cooling requirements are mainly for the domestic, commercial, agriculture and medical sectors. Clean cold chain is an integrated solution to meet the increasing cooling demand whilst taking energy efficiency into account.

Community Cooling Hubs (CCH) are envisaged as facilities that are highly accessible to villages or village clusters, managed by local entities, that meet diverse local cooling needs in an aggregated manner to enhance well-being while optimizing energy and resource management, and potentially bundling multiple revenue streams. Long-term outcomes expected include improved incomes, resilient livelihoods, reduced emissions and wastage in the food supply chain.

A Cooling Needs Assessment was conducted in three village clusters in Satara and Nashik districts of western Maharashtra, using an exploratory mixed-methods research design. The results of the surveys and discussions were used to develop the design briefs for cooling solutions, and guiding principles for potential business and governance models. The major findings were:

- **Rural Cooling Needs -** Improving cooling solutions may result in higher yields, increased work productivity, lower food losses, higher incomes
- **Access to healthy, nutritious (and socially acceptable) food -** Cooling solutions would allow households to access food from their own farmlands and kitchen gardens
- **Rural livelihoods -** An accessible and affordable community cooling hub could help in reducing vulnerabilities faced by landless labourers and small and marginal farmers
- **Agriculture -** Accessible and affordable cold storage facilities near the village will help farmers reduce losses, increase bargaining power and fetch more profit
- **Opportunities for new market connectivity and enhanced incomes -** Access to markets in neighbouring cities is preferred as demand is high, but requires cold storage and transportation
- **Dairy -** Bulk milk coolers in villages would lower the risk of milk spoilage and enhance incomes
- **Meat -** Affordable cold chain services could enable the supply of hygienic, trackable, packed meat to nearby urban markets, though local practices of consumption of fresh meat only appear currently sustainable and introducing cooling may have unintended consequences
- **Animal shelters -** Setting up cooling in animal shelters would reduce stress to animals, which directly affects egg and milk production, feed efficiency and animal reproduction
- **Local Veterinary care -** Vaccines used in veterinary care require a cold chain to preserve efficacy
- **Animal Breeding -** Cooling for Artificial Insemination can be used in breed improvement to improve yield, heat stress tolerance and disease resistance, though traditional methods of breed improvement may be continued in keeping with local cultural practices

- **Thermal comfort for living, learning, working and connectivity -** An approach combining active cooling services and products, with passive cooling and traditional practices will lower the adverse impact of extreme heat on health, and there is a need to enhance awareness about the impact of extreme heat on human and animal health
- **Human Health Services -** Wastage of vaccines can be reduced by setting up active cooling points closer to the villages
- **Passenger transport -** More than half of all respondents in most villages expressed a desire for air-conditioned passenger transportation, while the basic public transport services also need improvement.

The design of the CCH was developed to meet local needs, with Sustainable Development Goals as a guiding framework. Multiple options of business models to run CCHs have been developed, including Farmer Producer Organisations (FPOs), Government, Cooperatives and Private ownership. The CCH operations need to be supported with information on pricing, demand, weather forecasts. Physical design principles for the CCH in the selected village clusters have been developed, along with standards, guidelines, siting and building layout.

Based on our extensive examination of the cooling sector over the past 12 months, there is a strong need for investment to tackle these challenges specifically at the last-mile end of the supply chain. The report presents robust cases for the establishment of CCHs and identifies areas for further work in this sector.

1. Introduction

Cooling is needed for human well-being

Cooling is inter-linked with several aspects of human health and wellbeing. In a warming world, protection of fresh and nutritious food, safe medicines and protection of the population from extreme heat are essential. Cooling is directly related to work conditions, economic productivity of the working population, and income generation. Due to extreme heat, the Indian economy is estimated to lose productivity worth $450 billion by 2030 (Kjellstrom et al., 2016)

Cooling needs are increasing

Considering temperature projections for the next 50 years and India's geographical location in the tropical region, sector-wise cooling demand is likely to increase manifold. The aggregated nationwide cooling demand, in Tonnage of Refrigeration (TR), is projected to grow around 8 times by 2037-38 as compared to the baseline of year 2017-18 (India Cooling Action Plan 2019, 2019)

Cooling without warming is an imperative

Enabling universal access to clean cooling solutions is a multifaceted challenge as fulfilling cooling needs for human well-being may lead to an increase in energy demand and carbon emissions in order to meet these needs, and cause ozone depletion due to the type of refrigerant used by the technology.

For example, according to the International Energy Agency (IEA), refrigeration and air conditioning (RAC) causes 10 percent of the global CO_2 emissions and this will increase manifold with increasing refrigeration and air conditioning demand (*Global CO_2 Emissions in 2019*, 2020). The Montreal Protocol and Kigali Amendment regulate the use of refrigerants in cooling technologies and aim at phasing out the use of Hydrofluorocarbon (HFC) by year 2028. The protocols also recognize the link between refrigerant transition and energy efficiency of air-conditioning equipment. If environment friendly passive cooling solutions and energy efficient active cooling solutions are provided, the energy demand for cooling in each sector can be reduced by 25-30 per cent. And if these interventions are not implemented, the energy demand for cooling may increase more than five times by 2050 (*Global CO_2 Emissions in 2019*, 2020).

As average temperatures increase to extremely hot and unbearable conditions, India faces the dilemma of meeting the increased needs for cooling for human well-being without increasing greenhouse gas emissions.

Integrated cooling solutions may help

Cooling technologies, products and services are spread across different sectors of the economy such as residential and commercial buildings, cold chains for vaccines, agriculture produce, food products, household and commercial refrigeration and transportation.

The India Cooling Action Plan (ICAP) of the Ministry of Environment, Forest and Climate Change has the vision is to provide sustainable cooling and thermal comfort for all while securing environmental and socio-economic benefits for society. This is sought to be achieved through integrated solutions with synergies in actions towards providing cooling solutions across sectors (India Cooling Action Plan 2019, 2019).

Exploring rural cooling

To address the challenge of meeting increasing cooling needs in an integrated manner, and without warming, or with minimal emissions increase, a first step is to assess current and future cooling needs.
A study of rural cooling was taken up by Centre for Environment Education (CEE) in partnership with MP Ensystems, support from Shakti Sustainable Energy Foundation and technical guidance from University of Birmingham and Heriot-Watts University. The study was implemented with BAIF and Yuva Mitra in western Maharashtra. This study builds on the findings of the earlier research published by Shakti Foundation and MP Ensystems, 'Promoting Clean and Energy Efficient Cold-Chain in India' in 2019, and delves deeper into assessing rural cooling needs and the possibility of developing integrated rural cooling solutions.

This report presents the methodology and findings of the study, carried out in 2019 and 2020 in three village clusters in Nashik and Satara districts, Maharashtra.

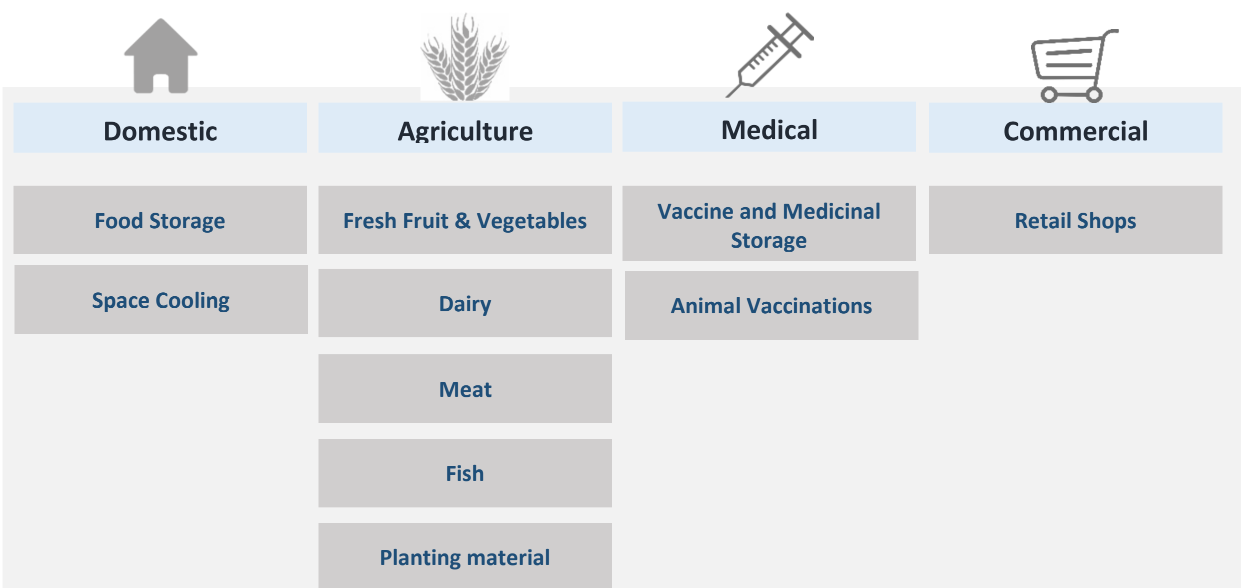


Figure 1 - Rural cooling sectors

2. Rural cooling and the concept of Community Cooling Hubs

Rural cooling needs

Cooling is needed in many sectors such as, agriculture (food production, livestock, fisheries), post-harvest produce management (refrigeration, transport, food processing), health (vaccine storage, space cooling and comfort) and transport. Space cooling needs for humans and animals are needed not only for comfort, but also because at extreme temperatures, susceptibility to diseases increases, work productivity decreases. The productivity of milch animals also reduces during the summer season leading to economic loss to the owner. It is estimated pf the 4 million metric tons of fruits and vegetables produced in India, about 30-40 per cent produce gets wasted resulting in loss of around INR 920 billion (Kumar, 2016, Ministry of Agriculture and Farmers Welfare, 2017). Storage of animal and human vaccines which are highly temperature sensitive requires cooling. At the country level about 300 million vaccine doses are needed for the Universal Immunization Programme. In animal husbandry, artificial insemination is used for the production of animals at a large scale and cooling is need for preservation of semen.

Community Cooling Hubs

The concept of 'Community Cooling Hubs' has been developed by Professor Toby Peters of University of Birmingham, Heriot-Watt University, and Prof Pawanexh Kohli, Former Director, (to confirm with Prof Kohli about inclusion here) National Centre for Cold-chain Development (NCCD), Government of India (Kohli, 2019; MP EnSystems Advisory Pvt Ltd et al., 2019)

Community Cooling Hubs (CCH) are envisaged as facilities that are highly accessible to villages or village clusters, managed by local entities, that meet diverse local cooling needs in an aggregated manner to enhance well-being while optimizing energy and resource management, and potentially bundling multiple revenues streams.

The expectation is that Community Cooling Hubs can support farmers and fishers in reducing post-harvest food loss, protecting quality and value of produce, providing new market connectivity, whilst ensuring that communities have continuing access to life-saving vaccines, domestic cooling, and properly cooled health facilities and community services. Through access to cooling in a rapidly warming world, the long-term outcomes expected include improved incomes, resilient livelihoods and other well-being dimensions for rural communities, reduced emissions and wastage in food production, transport and storage.

Cooling also has an intertwined relation with SDGs – end poverty, zero hunger, good health and wellbeing, affordable and clean energy, decent economic growth, industry, innovation and infrastructure; reduce inequality, sustainable cities and communities; responsible consumption and production and climate action.

CEE and MP Ensystems, with support from Shakti Sustainable Energy Foundation (SSEF) have taken forward this radical new approach to rural cooling provision, from a conceptual level to the first steps of assessing rural cooling needs. The results of the assessment would help to design integrated solutions to meet a broad portfolio of a community's cooling needs in an efficient, affordable and sustainable way.

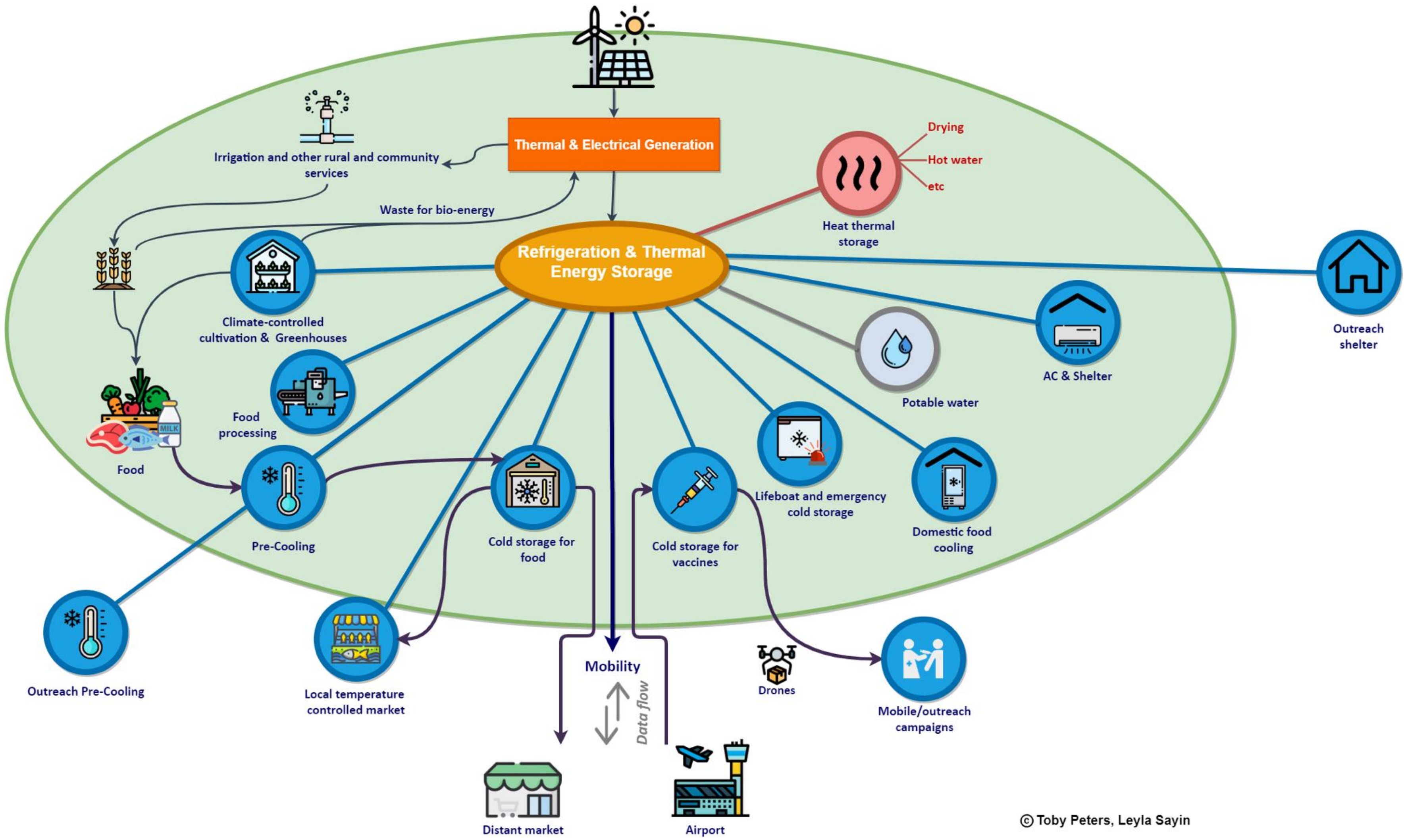


Figure 2 - The concept of the Community Cooling Hub

Towards designing Community Cooling Hubs: Cooling Needs Assessment

The first step in designing such a cooling model is to understand the sector wise cooling needs and quantum of those needs. This needs assessment study was conducted by the Centre for Environment Education, Pune and MP Ensystems Advisory Pvt Ltd. with technical advice and research guidance from University of Birmingham and Heriot-Watt University with financial support from Shakti Sustainable Energy Foundation. This study aimed to calculate sector specific cooling needs of rural communities in India. The needs assessment included their quantum of cooling demand, current use and different ways in which the communities seek to maintain or enhance this level of cooling to meet their health, economic and comfort needs. The portfolio of cooling needs (for food, health and thermal comfort) identified through this study will be utilized to develop a cooling solution catering to the demand, aggregate cooling provision and harness localized waste and renewable sources of thermal energy to provide environmentally friendly and affordable cooling for all.

The immediate outcomes expected were:

1. Preparation of the Community Cooling Hub Design Package, which would include guidance materials and templates for the following.
    a. Needs and resource mapping at the village level.
    b. Designs for CCH for 2 sites.
    c. Business cases for FPOs or entrepreneurs to establish CCHs.
    d. Design for a Fork to Farm information platform through a crowd sourced solution method.
    e. Process documentation in video and other formats.
2. A demonstration of the approach and model to policymakers, peers and key stakeholders in rural development and agri-business.
3. Presentation of the approach to other developing markets e.g. other Asian and Africa countries.

3. Study Methodology

Conceptual Framework

Presently, the cooling pathways involved in providing cooling to domestic, agricultural, vaccinations sectors work in isolation. The cooling needs of the community are addressed in a fragmented manner or sector wise as the governance of the sectors rests with multiple departments of state governments. For example, post-harvest agriculture needs are addressed through farm produce cold storages/ pack-houses and vaccine preservation needs are addressed through providing deep freezer and vaccines carriers at primary health centres. The community cooling hub concept envisions understanding a range of different cooling needs related to agriculture and post-harvest, animal husbandry, health, building comfort, transport and others, to enable the design and management of integrated and synergistic solutions of governance, enterprise, economy, energy and materials. The premise is that by estimating cooling needs more accurately and developing cooling solutions for different needs in an integrated manner, it is possible to enhance the associated well-being with minimal increase in greenhouse gases (GHG) emissions and carbon footprint.

As the first step to developing a Community Cooling Hub, this study set out to develop and test a methodology for Cooling Needs Assessment in a rural context. The methodology was refined in partnership with two non-profit organizations, Bharatiya Agro Industry Foundation (BAIF), Pune and Yuva Mitra, Nashik which have several years of experience in the rural development sector, especially agriculture and animal husbandry. Both organizations have long standing work experience in the region.

Study Area

Three clusters were selected to conduct a needs assessment study, two were from Nashik district while one was from Satara district of state of Maharashtra. BAIF has been working in the first cluster i.e. Koregaon block since the last ten years, Yuva Mitra has been working in Sinnar block of Nashik district since last fifteen years while it has recently started working with farmers producer companies (FPCs) in Yeola block of Nashik district. All the three village clusters are located in western Maharashtra.

Table 1 - Study Sites

Cluster	**Village**	Households by village	Households by cluster
Koregaon, Satara	Randullabad	394	1119
	Karanjkhop	725	
Sinnar, Nashik	Lonarwadi	275	1358
	Bhatwadi	217	
	Sonambe	866	
Yeola, Nashik	Patoda	1299	1940
	Dhulgaon	641	
Total households		4417	

The criteria for choosing these clusters for site studies included:

1. Field presence of BAIF and Yuva Mitra enabling data collection to be done with ease
2. Population size and village area such that they can, currently or in the near future, fully utilize cooling infrastructure with sizes based on recommendations by NCCD.
3. A local culture amenable to innovation and experimentation, with the presence of the non-governmental organizations (NGOs) and experience of a range of developmental interventions over the past several years.

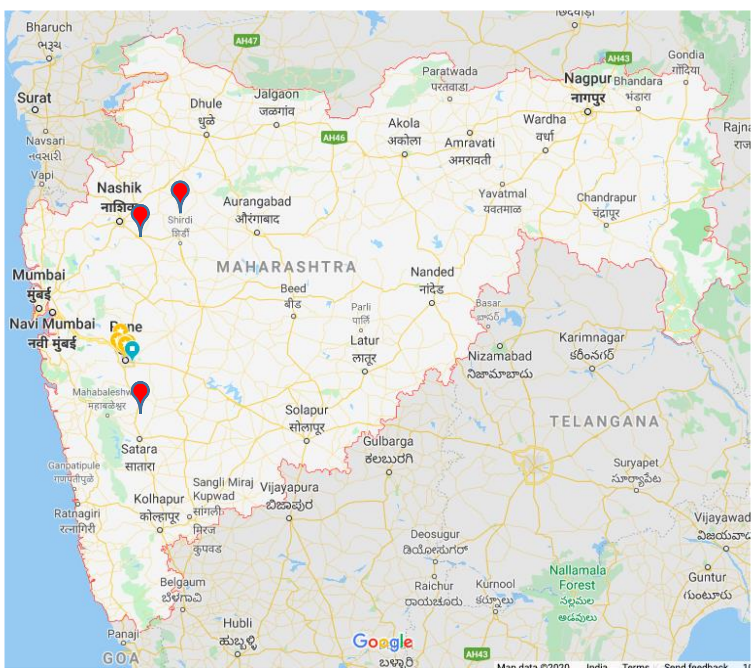


Figure 3 - Locations of Study Clusters

Study Objectives

The objectives of the study were to:

1 Identify the different sectors at present and prospective sectors in the future which require cooling in the context of rural communities in India; taking the clusters identified as test cases.
2 Understand the different cooling needs at present and projected needs in the future across these sectors in the context of rural communities in India.
3 Identify mechanisms and instruments through which these demands have been met and the extent to which these demands have been met.
4 Explore and estimate social, economic and environmental impact due to lack of cooling in the rural context (e.g. health implications, food losses, income losses etc) and the potential for increase in socio-economic well-being in case appropriate cooling is provided.
5 Understand drivers and barriers in addressing cooling demands, including ease of operation, relevance of different technologies, local capacity and resources, financing, costs and willingness to pay.
6 Develop the methodology to estimate the sector-wise cooling needs
7 Provide the data to support the design of Community Cooling Hub, development of cooling solutions using a merit order of intervention, develop options for 'fit for purpose' business / financial and governance models of cooling services provision.

Research Questions

Overview Questions

1 What are the different sectors at the present and sectors in future in the rural context which will require cooling?
2 What are the cooling needs (at present and in future) across sectors at the local (rural context) and national level in India?
3 What are the current methods, mechanisms and instruments through which Indian rural sector cooling demands have been met and extent to which these demands have been met?
4 What is the social, economic and environmental impact due to lack of cooling in the rural context (health implications, food losses, income losses etc.) and the potential for increase in socio-economic well-being in case appropriate cooling is provided?
5 What are the different drivers and barriers in addressing cooling demands in rural context?
6 What can be the appropriate methodology to understand cooling needs of a particular community?
7 What data is required to develop a fit to purpose design of a community cooling hub?

Questions related to cooling sectors

a) Food security, connectivity and rural incomes
- To what extent does the population have access to the food they need to achieve a healthy, nutritious (and socially acceptable) diet?
- How much food is lost between farm, beach / inland fishery and market?
- Are agricultural and fisheries incomes sufficient to keep workers out of absolute and relative poverty?
- Is there missed opportunity for new or more distant market connectivity and enhanced incomes?
- Does the supply chain meet commercial customers' product management demands, such as quality, timeliness, price etc (domestic and international)?

b) Thermal comfort for living, learning, working and connectivity
- What do people regard as the minimum acceptable level of thermal comfort for living, studying and working?
- How do people seek to maintain or enhance current levels of cooling and how might they do so in a warming world?
- To what extent does the population have access to the space and mobility cooling that is considered by the scientific evidence base to be adequate to maintain safety and productivity, at home, in education and in the work environment and whilst moving between each?

c) Health services including safe storage and transportation of vaccines and medicines
- Are national vaccine programmes reaching their target population?
- Is there sufficient unbroken cold-chain to ensure provision of medicines and healthcare products?
- Are health infrastructure buildings equipped with the cooling they need to deliver existing health services?

Study Methodology

Research Design

The first step of the study formulation was to bring findings from prior studies, and the field experiences of BAIF, Yuva Mitra and CEE to reflect on the nature of rural cooling needs, and whether and how these are addressed, including through traditional passive techniques, and seasonal changes in lifestyle and diet etc. One hypothesis was that the current mechanism of addressing cooling needs using cooling equipment may be sector-specific, such as agriculture produce related needs have been addressed through cold storage facility, household needs through fans or refrigerators. Another reflection was that there may not be immediate recognition of current and future increases in extreme heat events and the impacts on health, productivity, incomes etc. Different data collection tools have been used to probe this aspect and understand the perception of the communities.

An exploratory, mixed-methods research design has been used for this study. A mixed-methods design was thought to be appropriate given the multiple dimensions to be studied, which would help in developing a holistic understanding of the community cooling needs. The mixed-methods approach enabled us to draw upon the strengths of quantitative and qualitative data collection methods.

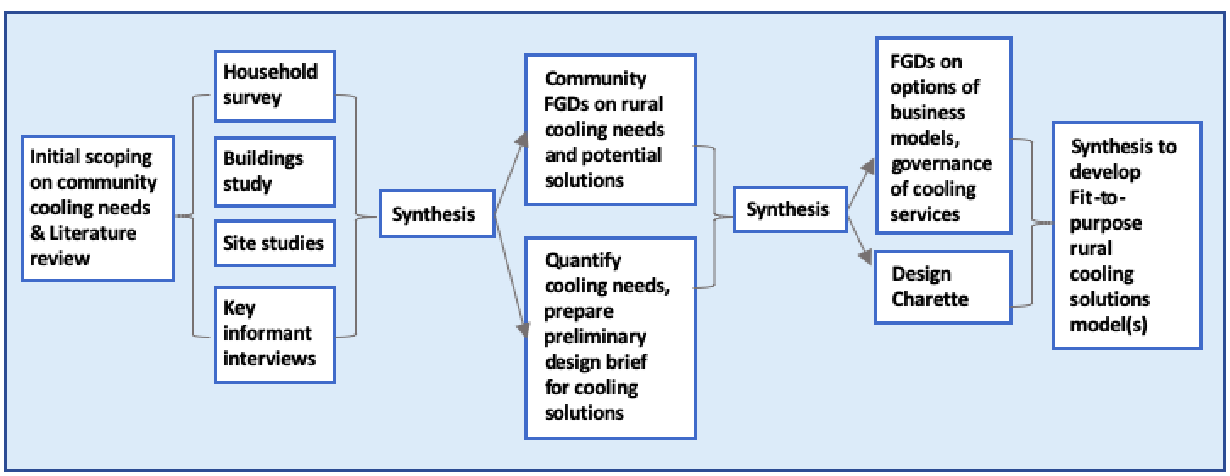


Figure 4 - Mixed-methods approach to studying rural cooling needs and developing solutions

The early qualitative exploration and reflection among the research team helped to formulate further quantitative and qualitative tools.

Data collection tools

The primary data collection tools included

- Household survey
- In-depth interviews of key informants
- Focus Group Discussions
- Social mapping
- Building Typology Study

The household survey tool included both quantitative and qualitative questions. It helped to quantify community cooling needs, losses due to absence of cooling and demand for cooling at household and community level. Qualitative questions were included in the interview schedule to fill gaps in quantitative data. They mainly addressed the 'why' and 'how' question, to understand the processes around cooling needs and how they are met (or not), at present.

Key informant interviews and site observations, which are qualitative tools, were deployed in parallel with household surveys. In-depth interviews have been conducted with key informants from the village such as Sarpanch (Head of the village), Auxiliary Nurse Midwife (ANM), Dairy owners etc.

The findings from the household survey, key informant interviews, and study of building and thermal comfort were synthesized to develop the discussion content and guidelines for the next step of focused Group Discussions (FGDs), a qualitative tool.

The content analysis of the FGDs was to be used develop the next steps of the research process, towards developing the design briefs for cooling solutions, and the guiding principles that may be used to explore potential business and governance models. The initial round of FGDs were planned along with social mapping and were aimed at understanding community cooling needs in detail, mapping of the resources available with the community and exploring possible mechanisms of governance of cooling hubs. Some FGDs were also planned with specific groups to understand sector specific cooling needs. The second round of FGDs were aimed to be conducted with an objective of sharing the findings of the need assessment survey, to share the design options aspects of community cooling hub / solutions that are developed in the design studio workshop, and to understand desired merit order of cooling solutions, governance of cooling solutions, local capacity and resources needs, financing options, costs and willingness to pay. The social mapping exercise was planned along with the first round of FGD to map community resources, cropping patterns, other sector specific needs and draw farm to fork market processes.

As the FGDs and social mapping exercises could not be carried out due to COVID 19 epidemic, the staff and field workers of BAIF and Yuva Mitra were interviewed on video calls to discuss some of the findings and ideate on the questions of governance, management and business aspects of rural cooling solutions.

Figure 5 - Glimpses of discussions with partner organizations and villagers

Sample sizes

The sample sizes for the different methods of data collection are as presented below.

Census, and ***reduced sample sizes***: For the household survey, the census method was applied at Randullabad and Karanjkhop villages, Koregaon block, Satara District. Data collectors were instructed to re-visit any houses that were found locked. In some cases, households were found locked permanently, for reasons such as families shifting to cities or other villages, or seasonal migration for work. In some cases, respondents refused to participate in the study. Due to these reasons the final sample size is lesser than the sample size aimed for in Karanjkhop and Randullabad.

Table 2 - Household Survey Samples

Name of cluster	Village name	Number of households	Sample size (% of total)	Cluster wise sample (% of total)
Koregaon, Satara	Randullabad	394	248 (62.94)	712 (63.62)
	Karanjkhop	725	464 (64.00)	
Sinnar, Nashik	Lonarwadi	275	53 (19.27)	210 (15.46)
	Bhatwadi	217	32 (14.75)	
	Sonambe	866	125 (14.43)	
Yeola, Nashik	Patoda	1299	162 (12.47)	240 (12.37)
	Dhulgaon	641	78 (12.17)	
Total		4718	1162 (24.63)	1162 (24.63)

Sample survey Sinnar and Yeola cluster: The household surveys in these clusters faced some difficulties due to a perception created that the survey may lead to changes in the public buildings and sopces. As one objective of the study is to propose appropriate methodologies to assess community cooling needs, it was decided that in the Sinnar and Yeola clusters, a stratified sampling approach would be used. The COVID 19 pandemic imposed some restrictions on mobility of data collectors. The stratification was done on the basis of landholding data obtained from the Land Records office. Ten per cent representative samples have been selected from each of the strata i.e. landless, small farmers (up to 3 acres), medium farmers (3 to 5 acre) and big farmers (more than 5 acres), as presented in Table 3.

Table 3 - Stratified random sampling of Sinnar and Yeola block study villages					
Village	Land holding in acres				Total
	Landless	Up to 3	3 to 5	More than 5	
Bhatwadi	6	25	2	1	32
Lonarwadi	6	42	4	3	53
Sonambe	17	83	14	12	125
Patoda	1	96	42	25	162
Dhulgaon	1	51	27	1	78

Building typology assessment

This component aimed to understand the prevalent building construction practices and preferences in Karanjkhop and Sonambe, including materials used for construction, reasons for selection of particular materials, sizes and techniques. The study included:

- Case studies of selected public and residential building, including basic information, demographic details, physical drawings, the orientation of the building, construction technique adopted, material usage, the study of the openings provided, sections to understand topographical conditions
- Surrounding Area Analysis, including documentation of natural & built features surrounding the selected case, line drawings including roads, pathways, etc., orientations, climatic analysis, identifying nearby natural resources, ground condition mapping, climate enhancing feature mapping
- Village level analysis, including a studying of the built fabric, roofing material and green cover analysis.

In addition, a more detailed study of the Anganwadi building was done, to propose ways to enhance thermal comfort.

The building typology assessment was done by a team of architects. Due to resource constraints, this study was conducted in only two villages.

Challenges

The tool was extensive and at times it was challenging for data collectors to keep respondents engaged while conducting household surveys.

Setting up recall periods for certain kinds of data such as household consumption of food items, thermal comfort in households and at the workplace was a challenge. In order to avoid this error, a recall period of one week was recorded and this quantity is extrapolated to monthly requirements. The unit of measurement varied for different clusters and varies from person to person. For example, farmers measure quantities in numbers of gunny bags, plantation areas etc. and this posed a challenge to data collectors to convert them into quantities in kilograms. The data collectors were trained to probe more with respondents to understand quantities in kilograms.

To obtain participants' consent for the study, meetings were done initially with a few community members, and political representatives and the purpose of this study explained in advance. Written consent from gram panchayat ward members was taken at the beginning of the study. During the household surveys, data collectors were asked to briefly explain the objective of the study and obtain the verbal consent of participants.

The progress of the survey was interrupted several times due to reasons such as houses being locked, families migrating temporarily to nearby towns and cities and people being busy in farming activities. The survey in Sonambe village was interrupted as the perception spread that the aim of the study is to restructure the built up area of the village, as mentioned earlier. This was because the survey team conducted a detailed study of selected public buildings like the gram panchayat office and the anganwadi. Senior colleagues of Yuva Mitra attempted to again communicate the objectives of the study to the villagers but they remained resistant to participating in the survey. Finally, responses from a representative sample of households was taken from this village (10 percent sample).

The Building Typology assessment team found it challenging to enter some of the houses for measurements as outsiders are usually not permitted to enter rooms where women are present.

Due to the COVID 19 pandemic, the research team could not conduct the final set of focus group discussions with the community, though this was an important step in the research design. The methodology was adapted and discussions were continued with the staff of the partner organizations who have been working in the study villages for a long time and hold nuanced understanding of village situation. The staff members were interviewed online. The interview guides used for these interviews are placed in the Appendix.

Figure 6 - Village level meetings in Randullabad and Bhatwadi

Reflections on the methodology and data needs

The rural cooling needs assessment had the following stages

June – July 2019	Initial discussions among partners, including introduction to the concept of the community cooling hub
August – October 2019	Literature review Methodology and tool development Formalization of study partners' contracts
November 2019	Partner discussions continued towards site selection and initial visits
December 2019	Survey team orientation
January – February 2020	Data collection
March – May 2020	Preliminary analysis of data Data collection continued Methodology adaptations in light of lockdowns
June – August 2020	Analysis and report writing (with some disruptions due to lockdowns)
September – October 2020	Reviews of findings

The multidimensional nature of the data to be collected, as well as the iterative nature of the methodology has meant that the time taken is more than originally anticipated. The pandemic struck just as we were about to begin the process of focus group discussions to share the initial findings with different community and stakeholder groups.

While some discussions did take place with the NGO teams, the big next step is still a number of discussions with the communities to chart a course for the future. Besides this one key point, reflections on the appropriateness of the methodology and tools, and learnings for future work are:

1. Easy to understand - The methodology was largely well understood by the NGO teams and local surveyors after a detailed orientation.

2. Orientation - Orientation of the study team is necessary as there is limited exposure to rural cooling needs. While climate change is much discussed, the implications for diverse cooling needs are not well understood.

3. Future-oriented discussions require systems understanding - Visualizing future growth and requirements in various sectors requires systems understanding and ability to handle statistical information which may not be readily available locally

4. FGDs and feedback on needs assessment and future scenario building is an important step in the methodology which could not happen due to the COVID 19 situation

5. Information on skill sets and human resource availability - Though generic education data has been collected, more refined questions will be needed to explore readiness to learn new skills and assume leadership and entrepreneurship roles

6. Assessing thermal comfort inside buildings should ideally be done with temperature measurements and interviews with occupants over different seasons and ambient temperature conditions. However, this methodology was not adopted as the time period decided for the overall study for a broad based understanding of cooling needs, was quite short and took place during the winter.

7. Focus on well-being of the poorest - Given that the ambition of the CCH intervention is inclusive well-being enhancement, the focus on the poorest and most marginalized, and approaches to how wellbeing would in fact be enhanced requires more thought

8. Need for policy dialogue – Certain key aspects require policy dialogues, which have not been possible due to the pandemic situation, but which need to be taken up as next steps:
   - Ecosystem for climate responsive rural building construction, retrofits and repairs
   - Storage of vaccines and medical supplies at the village cluster level
   - Human resource and cold chain enhancement for animal healthcare

9. Disaster and disruption preparedness – At the conceptual level it has already been envisaged that a CCH could help mitigate the disruptions caused due to disasters, including the current pandemic; this aspect needs further exploration to

10. Participatory approaches may be possible – Given the understanding that the study team now has about rural cooling needs, in the future, the methodology could be evolved with well thought out communication materials and processes that help the study teams, the village communities and other stakeholders carry out participatory action research.

4. Findings and Discussion

Rural Cooling Needs – current and in the future

Human induced climate change in India is expected to continue in the 21st century, with impacts that include 'rise in average temperature; a decrease in monsoon precipitation; a rise in extreme temperature and rainfall events, droughts, and sea levels; and an increase in the intensity of severe cyclones, alongside other changes in the monsoon system' (Krishnan & Dhara, 2020). Studies by the Indian Institute of Tropical Meteorology (IITM) show a significant increase in the number of warm days and nights, especially over the past 30 years, and indicate that these will increase further in the coming years. (See Box 1)

The 2030 Agenda, the Sustainable Development Goals and targets and a consideration of the impacts of climate change on rural life and economy help provide a framework for current and future sectors of rural cooling. These frameworks, in combination with the country context and the findings of the study can help formulate a localized agenda for improving cooling infrastructure and services, that must be further deliberated upon by the village community, and by individual households and stakeholders. These include the role of cooling in food and nutrition, livelihoods, health, work productivity, sustainable production and consumption etc. A detailed list of the intersection of cooling with the SDGs is presented in Box 2 - Cooling and the SDGs

The Covid 19 pandemic and lockdowns in India have also highlighted the need for robust emergency care, disaster preparedness, strengthening of localized supply chains, information systems, as well as health care systems. The shocks and stresses to various economic and societal systems due to Covid 19 have also given pointers for the potential role of adaptive, versatile, localized cooling facilities for improving resilience in the future. An overview of Current and Future Rural Cooling Needs is presented in Box 3.

The next sections discuss the findings of the study in relation to the questions on cooling needs for food, incomes, health, shelter, and quantification of such needs for exploring the possibilities of cooling solutions, especially in the form of a community cooling hub.

Box 1 - Increasing number of Warm Days and Nights

To assess current and future cooling needs, it is necessary to understand climate change projections. Extreme heat is projected to increase over the next few years. The recently published report 'Assessment of Climate Change over the Indian Region' by the Ministry of Earth Sciences, Government of India evaluates surface air temperature changes between 1986 and 2015, and includes these key messages:

- The frequency of warm extremes over India has increased during 1951-2015, with accelerated warming trends during the recent 30-year period 1986-2015 (*high confidence*).
- The frequency and intensity of ward days and warm nights are projects to increase over Indiain the next decade, while that of cold days and cold night will decrease (*high confidence*).
- The pre-monsoon season heatwave frequency, duration, intensity and areal coverage over India are projected to substantially increase during the twenty-first century (*high confidence*).

The graphs in Figure 7 depict a number of warm days and warm nights across different seasons between years 1951 to 2015 and between years 1986 to 2015. Both graphs show that there is an increase in the number of warm days and warm nights compared to the respective base year. But the graph of the last 30 years shows that the warm days and warm nights are increasing rapidly and warm nights are increasing more rapidly than those in the last 65 years. It is noteworthy that the increase in warm days in winter and monsoons is higher than in other seasons.

Source: Krishnan R., Sanjay J., Gnanaseelan Chellappan, Mujumdar Milind, Kulkarni Ashwini, 2020

Figure 7 - Projected changes in daily extreme temperature

Box 2 - Cooling and the SDGs

1. No Poverty

- Improve income of small holder farmers by cold storage infrastructure and creating cold chain to improve access to the market.
- Reduce vulnerability of rural poor by reducing food waste and boosting incomes of small and marginal farmers. Reducing agriculture market volatility by supplying food when demand is high.
- Create community cooling spaces, creches, workspaces and schools where risk of heat illness and hospitalisation is reduced for the old, infirm, pregnant and children. Demonstration of passive cooling techniques to improve housing better fit for extreme heat.

2. Zero Hunger

- Reduce harvest and post-harvest loss of fish, milk, fruit, vegetables and grain, improving food availability in the country.
- Enhance the usable life of food, retarding loss of freshness, sustaining nutritional value and extending the value chain system beyond traditional regions.
- Cool storage facilities for local varieties of seeds and cryopreservation of local breeds of cattle sperm, to maintain agricultural biodiversity. Indigenous varieties local to regions can be preserved and promoted.
- Investment in cold storage to reduce food waste, and less waste of inputs such as water, electricity, fertilizers.
- Improved market access allowing farmers to improve productivity, income, livelihood; improved linkages between farmers and institutional buyers, retailers and consumers with cold chains including pack-houses, reefers etc can boost farmers' profitability.

3 Good Health and Well-being

- Reduction in maternal mortality by providing blood, other medical services and Operation Theatres in temperature-controlled medical centres.
- Reduction in infant mortality by storing vaccines and medicines at the required temperatures. Health facilities with temperature-controlled treatment rooms, Operation Theatres, blood and other medical services. Safe, comfortable environments for Integrated Child Development Services (ICDS), primary healthcare, immunization, health check-ups and referral services for children under 6 and their mothers.
- Reduction in mortality and improving local health outcomes and life expectancy by transporting and storing vaccines and medicines at the required temperatures.
- Cooling services for medical buildings, health services and medicines will improve overall treatment.
- Provide sexual and reproductive health-care services, including for family planning in temperature-controlled medical centres and information and education in temperature-controlled community centres.
- Reduction in mortality and improving local health outcomes and life expectancy by transporting and storing medicines and vaccines at the required temperatures, temperature-controlled medical centres, blood storage, other medical services, Operation Theatres.

4 Quality Education

- A temperature-controlled, safe and comfortable school environment will improve educational outcomes by boosting productivity hours.
- Providing temperature-controlled safe and comfortable creche and preschool environment. Provide a space for Integrated Child Development Services (ICDS) services, including primary education to children under 6.
- Provide a temperature-controlled safe and comfortable environment for students to access the following Government programs including for disadvantaged and vulnerable children: Sarva Shiksha Abhiyan, Umbrella ICDS, Umbrella Programme for Education of SC, OBC and vulnerable group students, Umbrella Programme for Education of ST students, Umbrella Programme for Education of minorities students
- Providing a temperature-controlled safe and comfortable school environment, where students can access Government programs, including those for disadvantaged and vulnerable children. Attendance rate lost due to heat stress can be reduced.

5 Gender Equality

- Create additional jobs - especially for women - within the rural community, for foods that require cooling, chilling or freezing in processing.
- Provide safe, comfortable community spaces where socio-political business is enacted- enabling greater participation of women.
- Through cooling, provide a safe and productive environment in the home and workplace, as well as at community spaces where socio-political business is enacted- enabling greater participation of women.
- Ensure women’s full and effective participation and equal opportunities for leadership at all levels of decision-making in political, economic and public life; Proportion of women in managerial positions
- Undertake reforms to give women equal rights to economic resources, access to ownership and control over land and other forms of property, financial services, inheritance and natural resources.

6 Clean water and sanitation

- Providing cool, filtered drinking water at community spaces, schools, creches and medical centres.
- Local participation and management of temperature-controlled community spaces that provide water and sanitation services. Additionally, improve hygiene awareness.

7 Affordable and clean energy

- Using decentralised renewable energy to provide cooling services off-grid for space cooling as well as cold storage. Clean energy system designs can meet the large electricity demand for cooling. Additional clean energy generated can be used for other uses in the communities.
- Using energy efficient clean cold chain, following energy efficient building practices, using low carbon and passive cooling vernacular architecture practices to reduce energy consumption.
- Using star-labelled energy efficient fans and air conditioners will reduce the energy consumed, while providing communities with a comfortable environment.

8 Decent work and economic growth

- Create additional jobs within the rural community, for post-harvest processing before cooling, chilling or freezing, with innovative business models with economic and environmental approaches in rural cooling.
- Promote a resilient community especially for women through cooperative engagement by creating Self Help Groups, Micro Small and Medium Enterprises (MSMEs), Farmer Producer Organisations (FPOs) for post-harvest processing before cooling, chilling or freezing, selling to markets.
- Decentralised renewable energy, star-labelled energy efficient fans and air conditioners, energy efficient, low carbon, passive cooling vernacular architecture practices to reduce energy consumption.
- Investment in cold storage leads to reduced food waste, and less waste of inputs such as water, electricity and fertilizers. Improved market access allows farmers to improve productivity.
- Improving thermal comfort to increase number of productive hours, enhancing economic value.
- Creating additional jobs within the rural community- especially for unemployed youth through Self Help Groups and Micro Small and Medium Enterprises (MSMEs) for post-harvest processing before cooling.
- Improving work productivity and reduce risk of heat-related illnesses, with cooled work spaces/ shelters to address heat stress, particularly for outdoor workers, considering India lost 75 billion hours of work due to extreme heat in 2017, over 80% of these losses were in the agriculture sector.

9 Industry, innovation and infrastructure

- Provide cool and safe conditions for workers, schools, caregivers and providing cold storage for agricultural produce. Cooling improves overall human well-being by reducing risks of heat stress and illness.
- Creating additional jobs for women, unemployed youth, landless labourers within the rural community through Self Help Groups, Farmer Producer Organisations and Micro Small and Medium Enterprises (MSMEs) for post-harvest processing before cooling.
- Financial models such as pay-as-you-go, cooling as a service, etc can provide affordable access to cooling services. Storage of agricultural produce will help deepen linkages with markets and value chains and help

provide access to affordable finance.

- Using energy efficient appliances, following energy efficient building practices, using low carbon and passive cooling vernacular architecture practices to reduce the energy consumed. Investment in cold storage leads to reduced food waste, and less waste of inputs such as water, electricity and fertilizers.
- Meeting cooling needs of data centres, internet infrastructure
- Strengthen cold chain through efficient data management and supportive supervision through upgraded MIS and mobile based applications to capture real-time data from the field, which includes cold chain, communication as well as operations.

10 Reduced inequalities

- Use cooling to enhance incomes per capita among the bottom 40 per cent of the population
- Provide safe, comfortable community spaces where socio-political business is enacted- enabling greater participation of women, minorities and disadvantaged groups.

11 Sustainable cities and communities

- Provide space cooling to reduce risk of heat-related ailments, with energy efficient building practices and appliances, using low carbon and passive cooling vernacular architecture practices and distributed renewable energy, for homes, work places, schools and community spaces, particularly for women, the elderly, children and persons with disabilities.
- Provide cooling in public and private transport to prevent serious health impacts on vulnerable groups.

12 Responsible consumption and production

- Reducing harvest and post-harvest loss of fish, milk, fruit, vegetables and grain, reducing use of ozone-sensitive refrigerants with preference to natural refrigerants and Phase Change Materials.
  Reduced food waste leads to lower use of inputs such as water, electricity and fertilizers.
- Providing cooling, storage and transportation from first mile, warehouses, ripening chambers, reefer vehicles, particularly in states that do not have these facilities, to reduce post-harvest losses significantly.
- Reduce loses of harvested agricultural produce, due to inadequacy of cold storage and supply chain management, that are as high as 40% in India

13 Climate action

- In the past 50 years, heat waves killing more than 100 people have become twice as likely to occur during hot summers in India. Providing space cooling for homes, work places, schools and community spaces, can lower the risk of heat-related ailments, particularly for the poor, elderly, children and the disadvantaged.
- Using Low-GWP refrigerants will be an integral part of sustainable cooling, reducing GHG emissions.
- Provision of cold warehousing and cold chain for emergency supplies, health care products. e.g. medicines, vaccines, blood banks for disaster preparedness and risk reduction.
- Using health infrastructure buildings equipped with cooling.

14 Life Below Water

- Providing cooling, storage and transportation of fish will expand markets for fishing communities, reducing wastage and losses. Access to organised buyers who require fish caught using sustainable practices will also provide a demand push for fishermen to maintain the health of the ocean.
- Providing cooling, storage and transportation for fishing communities will maintain the safety, quality and quantity of fish and extend the value chain beyond nearby markets.

17 Partnerships for the goals

- Building partnerships between local and state governments, farmers, builders, technology providers, schools, community leaders, agricultural produce purchasers, final consumers and other stakeholders in buildings, storage, space cooling sectors.

Box 3 - Overview of Current and Future Rural Cooling Needs	
AGRICULTURE and HORTICULTURE and FISHING/AQUACULTURE	
Storage of seeds, sperm, etc.	Maintain vitality of seeds, cryogenic storage essential for sperm
Mushroom cultivation etc.	Some produce, e.g. mushrooms, require cold environments
'Coolhouses'	As global warming raises the temperature, some horticultural and agricultural produce may need temperature-controlled environments or 'coolhouses'
Animal vaccines	Increase productivity of smallholders' animals (goats, sheep, etc.) Reduce the risk of livestock farmers
Animal heat stress	Address loss of productivity (e.g. dairy cows) and health 'Cool sheds' for the housing of cattle, pigs, chickens etc
POST-HARVEST	
First to Last Mile Cold Chain incl. mobile cooling	Reduce food loss, improve market connectivity Increase farmers' and fishers' (especially small and marginal) incomes Maintain the safety, quality and quantity of food
Food processing	Dairy - Milk, cheese, butter, yogurt, ice-cream production
	Secondary economy/ jobs for rural or fishing communities that require cooling/ chilling/ freezing in processing with secure, affordable, sustainable cold chain
MEDICAL SERVICES	
Human vaccines and medicines	Reduce the loss of high-value products and mortality from preventable diseases – improve local health outcomes and life expectancy.
Medical centre and services	Blood (e.g. Zipline drones for surgery, maternity) and other medical services Temperature-controlled buildings, hospitals *(equipment such as MRI scanners, cryogenic treatments etc. are not included)*
FOOD	
Domestic refrigeration	Improve nutrition Avoid food loss and food poisoning Store food to avoid shopping every day
Retail incl. food markets/stalls	Avoid food loss, quality loss, food poisoning Boost food lifespan Avoid unsafe preservatives (e.g., chemical preservatives including formalin)
School mid-day meal supply chain	Improve nutrition Avoid food loss and food poisoning
Workplace meal provision	Avoid food loss and food poisoning, at the farm, fishing boat etc
SAFE / PRODUCTIVE ENVIRONMENTS *Reduce risk of heat illness/ hospitalization, accelerated mortality for infirm, elderly, less able as well as those suffering from respiratory, cardiovascular and other chronic diseases (i.e. renal diseases)*	
At home	Old, young, pregnant; and especially for sleep for all
At work (indoor and outdoor)	Productivity and safety (e.g., accidents; fainting or heat collapse; heatstroke)
Community services – crèche	Safe environments
Community spaces	Common spaces for community recreation Public spaces for local government functions and public meetings
At school	Productivity and improved educational outcomes.
Care-givers	Safety and productivity
MOBILITY AND TRANSPORT	
Public and private transport modes	E-mobility and charging/ range Adequate cooling in public and private transport can help avoid severe health impacts during travels on vulnerable groups: elderly, babies and young children
EMERGENCY – local Life Support systems	
"Cool lifeboats" at time of heat stress for old, young, etc. within a community	Avoid/ reduce mortality Reduce pressure on hospitals from heat stress and dehydration
Forward warehousing for supplies for emergency	Speed and cost of accessing essential temperature-sensitive supplies for natural or other disasters
ENERGY	
Clean, efficient, sustainable energy solutions	

Access to healthy, nutritious (and socially acceptable) food

A report by IFPRI has noted that between 45-64% of the rural poor cannot afford a nutritious diet, and recommends improving the affordability of the full range of nutritious food groups and diversification of cultivation (Raghunathan et al., 2020). UNICEF has highlighted that India has a triple burden of malnutrition – undernutrition, hidden hunger and overweight (UNICEF, 2019). According to the Comprehensive National Nutrition Survey 2016-2018 (CNNS), anaemia, one of the parameters of malnutrition, was a moderate or severe public health problem among pre-schoolers in 27 states, among school-age children in 15 states, and among adolescents in 20 states (Ministry of Health and Family Welfare, Government of India et al., 2019). According to this report, prevalence of anaemia is a moderate to severe public health problem among children and adolescent in Maharashtra.

1. **Extent of access to healthy nutritious food**

   In the Satara cluster, most households, including landless households, stated that they have nutritious food in sufficient quantity. About 4.7% of the landless households said they have enough food quantity but not diverse foods, and they had concerns about the adequacy of food through the year. Under-nourishment was reported among children and mothers in a few families, that number less than ten. Some households expressed that they have access to regular vegetarian diets throughout the year, but meat, fish, and fruits are unaffordable. As such, households did not report food scarcity or malnourishment at the time of the survey.

   While the surveyed households in the Satara cluster have not reported high levels of malnourishment or food scarcity, national nutrition surveys have pointed out the high degree of undernutrition and hidden hunger (inadequate micronutrients), as well as lack of awareness about malnourishment.

2. **Current methods of sourcing food**

   In the study area, food for household consumption, including major crops, vegetables and fruits, is primarily sourced from the market, and only partially from farmlands and kitchen gardens. For the Satara cluster, the Pimpode weekly market, which is about 7 km from Karanjkhop, is the most popular for buying food grains, vegetables, meat and fish.

Table 4 - Food items purchased from the market

Items	Respondents (Satara)	
	Number	Percentage
Coriander	540	74
Onions	643	84
Lemon	433	85
Vegetables	509	89
Potato	626	97
Tomato	506	97
Meat, eggs	315	98.5
Fruits	384	99.5

Table 5 - Number of households with kitchen gardens

Karanjkhop		Randullabad		Patoda		Dhulgaon	
Number	Percent	Number	Percent	Number	Percent	Number	Percent

25	5	47	19	3	2	6	8

Table 6 - Source of vegetables and fruits (percent of total)									
Food item	Summer			Monsoon			Winter		
	Home	Barter	Market	Home	Barter	Market	Home	Barter	Market
Satara cluster									
Vegetables	10.58	3.93	84.56	25.16	7.29	67.03	26.72	7.41	64.70
Fruits	7.41	2.82	87.31	8.76	4.03	84.11	8.81	3.86	84.15
Yeola cluster									
Vegetables	22.09	0.82	77.52	26.79	0.95	75.34	23.89	1.29	74.03
Fruits	11.20	1.12	87.48	12.44	0.73	85.46	12.39	0.73	85.46

Table 7 - Source of meat, fish, eggs, milk and milk products			
Food item	Homes	Barter	Market
Satara cluster			
Meat and Fish	1.78	0.03	95.41
Egg	6.65	0.15	90.39
Milk	31.50	0.69	65.85
Milk products	12.05	0.24	83.45
Yeola cluster			
Meat and Fish	1.52	0.00	98.51
Egg	1.34	0.34	98.37
Milk	42.82	0.11	57.58
Milk products	18.71	0.00	80.74

Most households in the Satara cluster buy vegetables and fruits from the market. About 33 to 36% households consume vegetables from their own fields and backyard gardens in the monsoon and winter. About 90 to 95% households purchase meat, fish and eggs from the market, while about 65% buy milk from local livestock keepers, or packaged milk from the market. Yeola has a similar pattern. Sale and purchase of milk for local consumption takes place directly and not through the cooperative or private dairies where milk is aggregated at the village level for further processing and sale. About 40 per cent of the milk produced in the cluster villages is consumed locally.

As regards consumption of dairy products, 61 percent households have a daily milk demand of 1 to 3 litres. The households that consumed relatively lesser quantities of milk were more dependent on purchasing milk, as compared to households that required larger quantities.

Buttermilk and curd are usually prepared at home. 171 households in the Satara cluster said they bought milk products from the market – Branded packaged curd (46.2%), Butter (21.6%), sweets (14.0%), Cheese (9.9%), Buttermilk (4.1%), Paneer (2.3%), Local shop curd (1.8%).

Table 8 - Milk purchase patterns in Satara cluster						
Quantity of milk	Karanjkhop			Randullabad		
	No. of households	Avg % bought	Avg % Wastage	No. of households	Avg % bought	Avg % Wastage
1 to 3 litres	129	79.9	1.16	80	65	0
3 to 5 litres	116	66.38	0.35	10	70	0
5 to 10 litres	100	50	0.2	18	50	5.56
Over 10 litre	11	36.36	0	6	33.33	0

	356			114		

3. **Mid-day meals**

The household survey shows that most parents are satisfied with the meals provided at the schools and anganwadis. In the Satara cluster villages, in Karanjkhop, two anganwadis get freshly cooked food from local Self Help Groups (SHGs). In other anganwadis, the gram panchayat appoints a helper at every anganwadi to cook food daily. The government provides INR 8 per child/ day to provide an average of 50 gm of morning snacks and 250 gm of a cooked meal.

Though the community sometimes provides vegetables for these meal, the menu of the morning snacks and cooked meals at both the anganwadi and the school in the Satara cluster does not include fruits, vegetables, eggs, meat. The main reason is that these institutions do not have a refrigerator to store these. In Yeola, the cook at the school does add leafy and other vegetables into the standard menu. However, there are some interruptions in providing midday meals due to delays in supplies and due to the absence of the cook. Teachers struggle to buy the daily essentials and cook the meals. The school principals were considering shifting to centralized kitchen facility, as is the practice in some urban areas. The logistics of addition of vegetables are likely to become more complex with centralized kitchens as the tendency is to provide dry rations rather than fresh hot cooked meals. The anganwadi at Yeola also does not generally provide fruits, vegetables, eggs or meat, and there is no cooling facility to store these ingredients.

The training manual for anganwadi workers as well as the mid-day meal scheme document advise setting up a backyard garden to cultivate local vegetables. The district administration encourages anganwadi workers to prepare matka fridges using earthen pots and sand to store vegetables. The difficulties in developing such food gardens in the school or anganwadi include inadequate space and lack of protection from stray animals. The teachers and anganwadi workers buy a few vegetables (curry leaves, coriander, onion, potatoes etc) from the market. They find it quite inconvenient to use earthen pot cooling as the size is not appropriate and it is tedious to pour water at regular intervals.

Table 9 - Daily snacks and meal menu			
Anganwadis in Satara cluster			
Meal	**Day**	**Menu**	**Ingredients**
Morning snack	Tuesday, Wednesday, Thursday, Saturday	Murmura Chivada	Puffed rice (25g), Pulse (10 g) Oil (10 ml) , Groundnut (5 g)
	Monday and Friday	Murmura Laddu	Puffed rice (30 g), Jaggery (30 g)
Hot cooked meal	Monday and Friday	Waran Bhat	Rice (40 g), Mung dal (10 g), Oil (10 g)
	Wednesday	Khichdi	Rice (40 gm), Soyabean (10 g) Peas/ lentils (10 g), Oil (10 g)
	Thursday	Usal Bhat	Rice (40 g), Sprouts (10 g), Oil (10 g)
	Tuesday and Saturday	Sweet Lapsi	Wheat (50 g), Jaggery (20 g), Soyabean (5 g)
Mid-day Meal menu of schools in Satara cluster			
Mid-day mean	Monday	Pigeon pea dal curry and rice	
	Tuesday	Sprouts curry and rice	
	Wednesday	Chickpea pulav and Rajgira ladoo	
	Thursday	Mung dal curry and rice	
	Friday	Chickpea curry and rice	
	Saturday	Mung dal Khichadi	

UNICEF (2019) has noted that the findings of the CNNS have informed India's ambitious child nutrition programmes, such as POSHAN, and also provide the basis for potential new policy recommendations, including scaling up dietary diversification. Considering the findings of the CNNS 2019, the recommendations of the mid-day meal scheme and anganwadi guidelines, there is a clear need and a policy and programmatic direction for including more nutritive foods in the mid-day meals, and for setting up the required cooling facility.

4. Current methods, mechanisms and instruments of cooling food and water for domestic use

Over 40 percent of the households use earthen pots, covered with wet cloth, while 1.3 percent use metal containers covered with we cloth. About 17 percent of the households of the cluster own a refrigerator. One retail shopkeeper in Karanjkhop has two deep freezers that can keep products cool up to 4 hours during power outages.

Table 10 - Refrigerator ownership in Satara cluster			
Refrigerator	**Karanjkhop**	**Randullabad**	**Cluster**
Number of refrigerators	59	70	129
Number of households that own a refrigerator	59	68	127
Percentage of households that own a refrigerator	12.7% (59/ 464)	27.4% 68/ 248	17.8% 127/712
Average age of equipment	4.32	3.29	3.81
Average price in INR	14435	10764	1260
Average volume	118 lit	101	110
Number of households that wish to buy a refrigerator	31.7% (147/ 464)	29.4% (73/ 248)	29.68% 220/ 712
Number of households that stated refrigerator is not required	66.3% 317/464	173/248	490/712

Table 11 - Methods of cooling water, Yeola cluster		
Cooling Method	Patoda	Dhulgaon
Earthen Pot	80	85
Refrigerator	17	10
Earthen Pot and Refrigerator	2	5
Metal container covered with wet cloth	1	0.00

5. Impacts due to lack of cooling

The IFPRI report notes that, among other reasons, lack of cold chain and market links is an important barrier in diversification of cultivation, which in turn impacts what is grown and used for self-consumption. Since women are often responsible for the nutrition of the entire households, their access to income is also likely to affect access to nutritious diets for the whole family (Raghunathan et al., 2020). It has also been noted that mid-day meals at schools and anganwadis must provide a more nutrient dense diet, and not only cereal-based diets. The lack of cooling facilities at the schools and anganwadis in the study cluster is clearly a factor in that vegetables and fruits are not much included in the midday meals.

Products retailed in the village shops include milk, milk products, cold beverages, ice cream, etc. These products are affected by frequent power cuts. Shopkeepers reported losses of up to INR 2000 in the past year due to lack of cooling facilities and regular power supply.

6. **Potential for enhancement if cooling is provided**
   In the light of the findings of our study, and other national studies and recommendations, cooling solutions could help improve nutrition in a number of ways. For this, cooling solutions need to be carefully linked to outcomes of nutrition improvement and planned for:
   - Diversification of cultivation
   - Making nutritious foods available in mid-day meals
   - Improved incomes for women (including from improved incomes from reduced losses, better prices for agri-produce, new types of agri-produce, such as mushrooms, and from management of the cooling hub) may enable the purchase of more nutritious foods for the family, given gender roles.

Rural livelihoods

India is among the world's largest producers of food. Among the producers of food, about 70% of rural households depend primarily on agriculture for livelihood, of which 82% are small and marginal farmers. The projected increases in average temperatures, decreases in precipitation and rise in extreme temperature may impact agriculture and the food production sector in many different ways:

1. **Lower yields**
   Agriculture systems may have about 4 to 4.6 lower yields in irrigated fields in Kharif and Rabi respectively, and 7 to 7.6% percent lower crop yields in rainfed fields, in Kharif and Rabi respectively, when a district is significantly hotter. (Ministry of Finance, Department of Economic Affairs, Economic Division, 2018). Livestock systems are projected to be adversely affected by rising temperatures. Increases in temperature may lead to decreased milk production in high producing dairy cows and lower meat production in ruminants (Mbow et al., 2019, pp. 454–455). Pest and disease pressures among livestock are also likely to change, and robust strategies for pest and disease mitigation are advisable (Mbow et al., 2019, p. 458).

2. **Reduced work productivity**
   Heat stress is projected to reduce the hours people can work by at least 25% in a scenario of 2°C increase in global temperatures, in occupations like agriculture that rely on manual labour (Dunne et al., 2013).

3. **Potentially higher food losses**
   Higher temperatures may impact the quantum of food losses and increase risks in food safety, though the exact ways of change are not well understood (Mbow et al., 2019, p. 463); food losses are already very high in India, with losses in perishables at 4.6 to 15.9% in fruits, 5.2% in inland fish, 10.5% in marine fish and 2.7% in meat and 6.7% in poultry (ASSOCHAM, 2018).

4. **Lower incomes**
   Lower yields and greater food losses mean lower incomes for farmers. With a 3 to 4°C rise, farm incomes may decline 20% to 25% especially in unirrigated areas, and in a year when temperatures are 1°C higher, farmers' incomes would fall by 6.2% in unirrigated districts (Ministry of Finance, Department of Economic Affairs, Economic Division, 2018).

Income increases and reduction in risk through improved cooling within supply chains, storage, processing, diversification etc become more relevant given climate change and projected variation and fluctuation in weather patterns.

These may lead to increases in summer temperatures, possible increase in aridity of the landscape, increase in rainfall with extreme events and the likely increase in pest and disease incidence for humans, livestock, and crops, reduction in yields in field crops, low production in animal husbandry. These increase risks and vulnerabilities, and increase spoilage or losses of produce.

Technical strategies based on improved cooling solutions need to be part of an overall adaptive approach for farmers and livestock holders in semi-arid regions like the western Maharashtra and the Deccan plains, that may include:

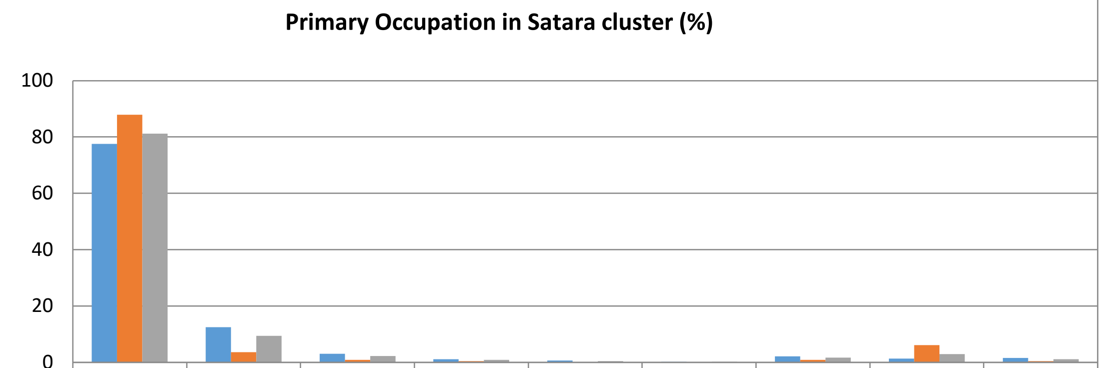
- Landscape level – Address increasing aridity through soil and moisture conservation, water harvesting, agro-ecological approaches to farming and supporting integration of livestock and farming systems.
- Farming – crops and farming systems that are able to withstand heat and water scarcity, mixes of field crops supplemented with vegetables, mushrooms, fruits grown under controlled conditions, such as 'coolhouses'
- Livestock breeding thrust – Selecting for breeds and species which have Heat stress tolerance and disease resistance
- Animal shelter improvement – Small-scale shelters with improved cooling, disaster proofing to avoid spread of disease and ability to withstand extreme heat and weather even
- Healthcare – Strengthen natural immunity by free-range practices, strengthen pest and disease management combining traditional and modern systems, strengthen vaccination systems of manufacture and delivery

Improving cooling solution may mitigate some of the currently experienced and anticipated risks and impacts, while recognizing that technical approaches need to be well-integrated into, and work alongside governance, social and behavioural approaches of improving resilience. This section explores the current context and potential for cooling solutions in the study sites, with regard to agriculture and related livelihoods.

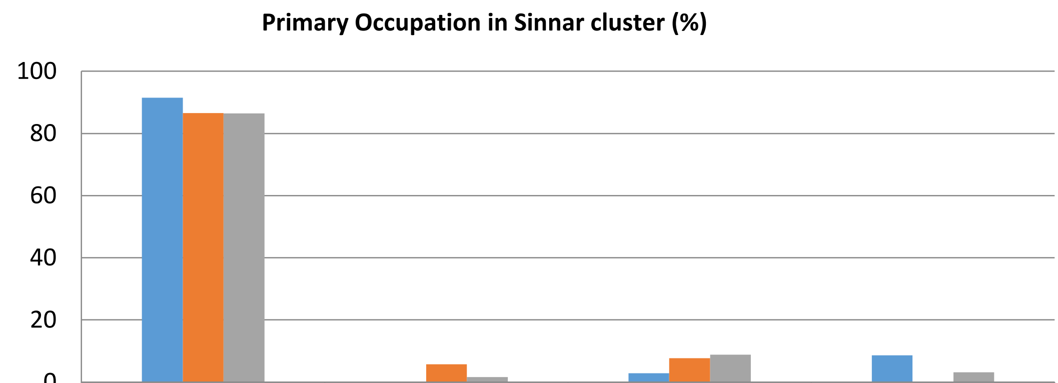
1. Sufficiency of agricultural and fisheries incomes to keep workers out of poverty

The economy of the villages and employment is largely based on agriculture. Over eighty percent of households in the Satara and Yeloa cluster have agriculture as their primary source of income. Work as agricultural labourers is a key source of income for the landless and a supplementary source for smallholders. Very few are engaged in businesses or employed in government or private jobs.

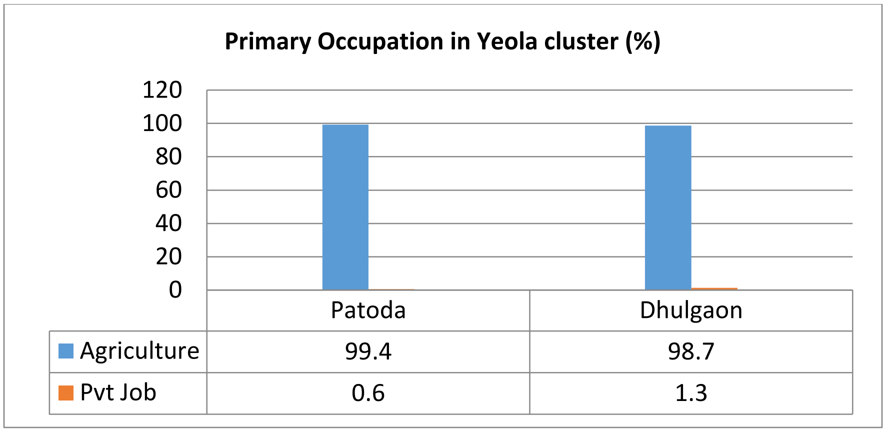
Figure 8 - Primary Occupations in the study clusters



	Agriculture	Agriculture Labour	Private Job	Government Job	Animal Husbandry	Fishery	Business	Other	None
Karanjkhop	77.6	12.5	3.0	1.1	0.6	0.2	2.2	1.3	1.5
Randullabad	87.9	3.6	0.8	0.4	0.0	0.0	0.8	6.0	0.4
Cluster	81.2	9.4	2.2	0.8	0.4	0.1	1.7	2.9	1.1



	Agriculture	Agri Labour	Pvt Job	Business
Bhatwadi	91.4	0.0	2.9	8.6
Lonarwadi	86.5	5.8	7.7	0.0
Sonambe	86.4	1.6	8.8	3.2



As presented in Table 12, about 10.13 and 6.05 per cent of surveyed households have got work under the MGNERGS, for about 32 days and 1.8 days on average, in Karanjkhop and Randullabad respectively. About 3 per cent of surveyed households of Karanjkhop and Randullabad had demanded work but did not get any. Out of 19% of landless individuals who applied for work under MNREGS, 14% got work under this in the last one year. The nature of work under MGNREGS mainly includes road construction, construction of buildings and agriculture ponds, land development and tree plantation.

Table 12 - Work access under MGNREGS (response percentages)		
MGNREGS work status	Karanjkhop	Randullabad
Worked under NREGS	10.13	6.05
Applied but did not get work	3.02	3.23
Scheme is not operational	37.93	2.02
Don't need work under this scheme	48.92	88.31

The average annual household income in the Satara cluster villages is INR 69000, while most households have an income of about INR 50,000, with very few households with incomes much higher than average incomes. At least 70% of the households in Karanjkhop and 31% in Randullabad reported per capita incomes less than INR 50,000. About 30.65 per cent of families in Randullabad reported incomes of INR 50,000 to 1 lakh. Less than 1% of households in the Satara cluster have incomes over INR 5 lakh.

The recent NABARD All India Financial Inclusion Survey (NAFIS) puts the average annual income of rural households at about INR 96000, or USD 1305, with that of agricultural households being, on average, slightly higher at INR 107172, or USD 1446. (NABARD, 2018). Compared to these figures, most households of the Satara cluster are well below the average rural income. About 65% of the households in the Satara cluster are landless, marginal or smallholder farmers, and about half of them practice rainfed farming, as is also indicated by pump ownership data presented in Table 18. In the Yeola cluster too, 58% and 65% of the farmers and marginal or smallholders.

Table 13 - Annual Family Income in Satara cluster				
Income bands	**Karanjkhop**		**Randullabad**	
	No. of families	**Percentage**	**No. of families**	**Percentage**
Less than 10000	23	4.96	5	2.02
10,000-50,000	303	65.30	73	29.44
50,000 to 1 lakh	110	23.71	76	30.65

1 lac-5 lakh		14	3.02	21	8.47
More than 5 Lakh		3	0.65	2	0.81
Didn't Reply		11	2.37	71	28.63
Total		464		248	
Mean, mode, median					
Annual Family Income	Mean	Maximum	Minimum	Mode	Median
	68939	2400000	5000	50000	50000

Table 14 - Landholding in Satara cluster				
Land holding Bands (acres)	**Karanjkhop**		**Randullabad**	
	No. of families	Percentage	No. of families	Percentage
Landless (0)	82	17.15	25	9.50
Marginal (Up to 1 acres)	128	26.78	49	18.63
Small (1.1 acres-3 acres)	154	32.21	94	35.74
Medium (3.1 acres-5 acres)	55	11.50	52	19.77
Large (>5 acre)	59	12.34	43	16.35
Total	478	100	263	100

Table 15 - Landholding in Yeola cluster, Nashik				
Land holding Bands (acres)	**Dhulgaon**		**Patoda**	
	No. of families	Percentage	No. of families	Percentage
Landless (0)	1	1.25	1	0.62
Marginal (Up to 1 acres)	7	8.75	16	9.94
Small (1.1 acres – 3 acres)	44	55.00	77	47.83
Medium (3.1 acres – 5 acres)	27	33.75	42	26.09
Large (>5 acre)	1	1.25	25	15.53
Total	80	100	161	100

Table 16 - Well ownership by landholding size in Satara cluster						
Land holding Bands (acres)	**Number of Farmers who own a dug well or bore well**					
	Karanjkhop		**Randullabad**		**Cluster**	
	Dug Well (%)	**Borewell (%)**	**Dug Well (%)**	**Borewell (%)**	**Dug Well (%)**	**Borewell (%)**
Marginal (Up to 1 acre)	46 (35.94)	12 (9.38)	12 (24.90)	9 (18.37)	58 (30.42)	21 (13.88)
Small (1.1 acres – 3 acres)	94 (65.73)	30 (20.98)	45 (45.45)	0 (0.00)	139 (55.59)	30 (10.49)
Medium (3.1 acres – 5 acres)	41 (73.21)	15 (26.79)	37 (71.15)	1 (1.92)	78 (72.18)	16 (14.36)
Large (>5 acre)	37 (84.09)	7 (15.91)	13 (56.52)	0 (0.00)	50 (70.31)	7 (7.96)

Table 17 - Rainfed and irrigated cultivation in Satara cluster		
Water Source	**Randullabad**	**Karanjkhop**
Rainfed	33%	11.8%
Irrigated	66%	72.8%
Both	1%	15.4%

Table 18 - Pump ownership				
No. of pumps owned	Number of farmers			
	Satara cluster		Yeola cluster	
	Karanjkhop	Randullabad	**Dhulgaon**	**Patoda**
	280	195	4	10
1 motor pump	169	50	76	142
2 motor pumps	12	2	0	9
3 motor pumps	3	1	0	0

The UNDP Multidimensional Poverty Index (MPI) tracks deprivation across three dimensions and 10 indicators: health (child mortality, nutrition), education (years of schooling, enrolment) and living standards (water, sanitation, electricity, cooking fuel, floor, assets). The household survey shows that 81.1 per cent families have BPL and Antyoday ration cards and at least about 10 to 15% of the households face various types of scarcities and deprivations, including inadequate access to nutrition, clean energy, assets and adequate shelter.

Table 19 - Agriculture and household assets in the cluster villages									
Sr	**Agriculture equipment**	Karanjkhop		Randullabad		Dhulgaon		Patoda	
		No. of families	Percent age	No. of families	Percent age	Number	Percent age	Number	Percent age
1.	Motorcycle	259	55.82	160	64.51	73	91.25	141	87.58
2.	Bullock cart	31	6.68	15	6.05	6	7.50	11	6.83
3.	Car	29	6.25	35	14.11	4	5.00	11	6.83
4.	Cycle	42	9.05	39	15.73	14	17.50	28	17.39
5.	Generator	0	0	1	0.40	1	1.25	3	1.86
6.	Radio	4	0.86	11	4.44	1	1.25	2	1.24
7.	Smartphone	301	64.88	213	85.89	65	91.67	134	80.77
8.	Television	378	81.47	215	86.69	65	81.25	124	77.02
9.	Tempo/ Truck	8	1.72	1	0.40	2	2.50	2	1.24
10.	Tractor	22	4.74	8	3.23	23	28.75	59	36.65
11.	Trolley	18	3.88	9	3.63	19	23.75	49	30.43

In the Satara cluster at least 6% do not use clean cooking fuel while another 10% use LPG in a very limited way. Of the 710 households that responded to the question on fuel for cooking and heating water, at least 43 households (6%) reported no usage of LPG, while another at least 74 households (10%) appear to use LPG very minimally.

Table 20 - Usage of LPG			
Hours of use	Summer	Monsoon	Winter
0	43	48	48
Up to 0.5hr	89	75	74
0.5 -1hr	277	252	248
1 to 2hr	259	273	269
2 to 3hr	31	44	48
3+ hours	11	17	19
	710	709	706

Due to shortfalls in incomes, households in these villages tend to take loans. About 36 percent of the households in Karanjkhop and Randullabad have taken loans. The average of loan amount in these villages is INR 1,62,770 and it varies from INR 5000 to 15,15,000.

Farmers were also asked if they think agriculture is profitable these days, to which around 16 per cent households replied that agriculture is no longer profitable while about 54 percent farmers felt that agriculture is still profitable. However, there are shortfalls and losses in agriculture produce due to a range of factors such as scarce water resources, relatively low production and productivity of largely rainfed cultivation on small holdings, unpredictable weather conditions, fluctuations in market prices, lack of storage and transport facilities.

In summary,

- A significant number of households are landless or with marginal landholdings, and work available under MGNREGS is also scarce.
- Between sixty five to seventy five percent of the households are landless, or small and marginal farmers and the average household incomes in Satara cluster are well below the national average incomes in rural households
- About 10 to 15 percent of the households face a range of scarcities and deprivations

These add up to a high degree of vulnerability to shocks and stresses. A facility such as a highly accessible and affordable community cooling hub could help in reducing some of these vulnerabilities.

Box 4 - Impact of lockdown on farmers

Ravindra*, a 34-year old from Randullabad, Satara is a small-holder farmer who grows tomatoes and potatoes. Like most other farmers, he had cultivated tomatoes in bulk along with potatoes and a few other crops. The freshly-grown tomatoes were ready for harvest. But due to the nationwide lockdown amidst the coronavirus pandemic, the produce had to be put on hold. As APMC markets and other mandis were closed, the entire supply chain was disrupted. Commodities like tomatoes perish in a couple of days. To add to interruptions, a second lockdown was announced in Pune, resulting in unavailability of transport. Ravindra had no choice but to sell the produce at extremely nominal prices in local markets of Pimpode or Wai. Even so, local markets have a fairly limited demand and capacity to sell. Hence, most of the tomatoes remained unsold.

Ravindra says, “Around 300 crates of tomatoes remained unsold, equating to a total loss of approximately INR 1,50,000 (around $2000)”. This is 3 times average annual income of families in the cluster.

Due to the lockdown, demand for produce has declined drastically. “We used to sell to Pune markets where much of the demand for tomatoes came from hotels”. In the case of potatoes, disruption was caused by erratic rainfall in the month of August 2020, resulting in INR 20-25,000 worth of produce wasted. The facility of cold storage could have played a major role in reducing the losses faced. “If I had access to a cold storage, I could have stored the excess tomatoes until restrictions were lifted”, says Ravindra.

This shock has meant that Ravindra has made no savings this year. He has resorted to crops such as kidney beans as they need less investment. This will mean lower profit margins as compared to tomatoes. A lot of work on the farm has been held up as his savings were used up. Earlier, he was planning to spend on tractor maintenance and well repairs. He has applied for the state government’s subsidy for relief but has received no reply.

In terms of the household, the family’s wellbeing has been hit as well. He says, “We are just going to survive this year by cutting down spending.” It has also been difficult to meet the family’s health expenses. His mother suffers from knee joint pain and the doctor has recommended a knee replacement surgery. However, Ravindra is unable to afford the treatment.

**Name changed to protect identity*

Agriculture and cooling

As has increasingly been highlighted in recent years in India, the agriculture sector faces a significant amount of food losses and wastage. Around 40% of harvested produce is lost in the farm to fork supply chain (Committee for Doubling Farmers’ Income, 2017). Cold storages for the agriculture sector have been set up through government schemes such as Pradhan Mantri Kisan Sampada Yojana, implemented by Ministry of Food Processing Industries; Mission for Integrated Development of Horticulture, implemented by Department of Agriculture, Cooperation & Farmers Welfare (Press Information Bureau, 2019). According to a 2018 study by AEEE, India has had a capacity of 35 million MT of cold storage by 2017. Yet, key aspects of the cold chain such as reefer vehicles and ripening chambers are still missing from the current infrastructure (NCCD, 2015). Due to the recent economic downturn after the Covid-19 outbreak, an “Agri-Infrastructure Fund” is being set-up for projects at farm-gate and aggregations points including cold chain to provide support to farmer producer organisations, agricultural co-operative societies, etc (Essential Commodities (Amendment) Act, 2020, 2020).

The most prominent social impact for farmers is vulnerability due to lack of cooling facilities. Farmers are compelled to sell at extremely low prices at local markets. Additionally, there are environmental impacts of lack of cooling facilities in agriculture. Food waste is responsible for 6% of global greenhouse gas emissions (Poore & Nemecek, 2018). The uptake of input resources such as water, energy needed to pump water and other resources like fertilizers comes at an environmental cost.

Energy-efficient cold chains can play a crucial role in reducing wastage in the food supply chain. As mentioned earlier, clean cold chain as an integrated solution to meet the increasing cooling demand whilst taking energy efficiency into account. Appropriate cooling technologies provision can gain a number of socio-economic benefits. Access to cooling can improve the resilience of farmers as they become more equipped with infrastructure to grapple in times such as a pandemic, or effects of climate change. Farmers will have the option to store during off-season, increasing their negotiating power and overall income opportunities. There can be a boost in employment opportunities not on in the cooling services but also in the aggregation services and post-harvest activities.

There are many drivers to addressing agricultural cooling demands. Cold chain development can improve the create wider marketing channels by aggregating produce and selling to farther markets. Farmer groups and cooperatives can enable a swift streamlining of cooling facilities along with other agricultural activities such as food processing. Having a strong community can enable exchange of crucial information such as market volatility, weather and irrigation management amongst the clusters, strengthening the overall farm to fork supply chain. On the other hand, a few barriers to cold chain development include the lack or minimal access to energy for operating large scale cold centres; there are limited financial options for addressing cooling demands.

1. Current status of cooling for seeds and farm produce

Current practices of avoiding heat stress in agriculture produce on fields include:

- Harvest produce late in the evening or early in the morning to avoid exposure
- Cover produce in wet gunny bags, store under sheds avoiding exposure to direct sunlight
- Transport produce packed in crates and covered with gunny bags
- Dry certain types of produce such as common beans under sunlight to sell in dried form.

In the Satara cluster, eight cold storage facilities were identified within 100 km of the cluster, of which four are close to Pune and situated near highways. The cold storage facilities in the vicinity of the cluster are primarily used by traders and milk and milk product companies. Less than 5% of the farmers reported using cold storages facilities. Fifteen farmers had stored 1 ton of potatoes, while two farmers stored 4 tons and one farmer stored 10 tons. A small quantity of potatoes is usually stored as seeds for next year's sowing while most of the potato produce is stored in anticipation of getting better market prices. The average cost of potato cold storage is INR 2.60 per kg per month. One farmer had also stored 800 kg of green pea at a cost of INR 1.95 per kg per month.

The farm produce is usually transported without any refrigeration to Pune and Satara markets that are at one to two hours distance by motorized vehicles. Only seven farmers reported having used reefer vehicles to transport farm produce. Farmers have expressed interest in exporting fruit crops such as strawberries, grapes and pomegranate if reefer vehicles are easily available with established market linkages.

Table 21 - Current usage of cold storages in Satara cluster

Current utilization of cold storage	Karanjkhop		Randullabad	
	Number	Percentage	Number	Percentage
Yes	5	1.08	12	4.84
No	428	92.24	235	94.76
Not aware of such facility	31	6.68	1	0.4

Table 22 - Potato quantities in cold storages and average reported cost

Quantity of potato stored	No. of farmers	Avg. Cost per Kg per month
Up to 250 Kg	1	6.94
250-500 Kg	10	2.78
500-1000 Kg	4	1.72

More than 1000 Kg	2	0.14

Box 5 - Potato Storage for Planting Material

Potato is a major crop in this region. However, currently, very few farmers in the cluster sow potatoes. The potato area is about 62 acres totally in the cluster. The reasons are multi-dimensional.

The cost of transportation and seeds adds to the cost of external inputs for potato farming. Farmers may be able to use their own seed potatoes, if they could store part of their annual potato produce for seed for the next year. This would be possible if an affordable cold store were available nearby. Currently, only one farmer produces seeds locally and preserves them for next year sowing.

About 38 farmers in this cluster collectively buy potato seeds sourced from Punjab and Indore from the market in Manchar (150 Km away). Seeds of varieties cultivated in Punjab may be less suitable for local conditions in cluster villages. The farmers in this cluster report that the locally grown seeds are well adapted to the local climatic conditions, so they have more productivity and resistance to pest attacks and require less fertilizers.

Some farmers in the cluster are contract farming with Pepsico. Pepsico under its collaborative farming initiative supplies potato seeds of high yielding varieties, fertilizer and soft loans to farmers. Pepsico then buys back these potatoes at pre-agreed prices. Initially, farmers did earn fair profits through this arrangement. Later production started declining and buy back prices were much lower than market prices.

Cold stores may be used to safely store a proportion of the potato harvest as planting materials seeds in the next year. Currently, the cold stores are quite far from the cluster. The nearest cold store is 70 km away, and the cost of storage is high.

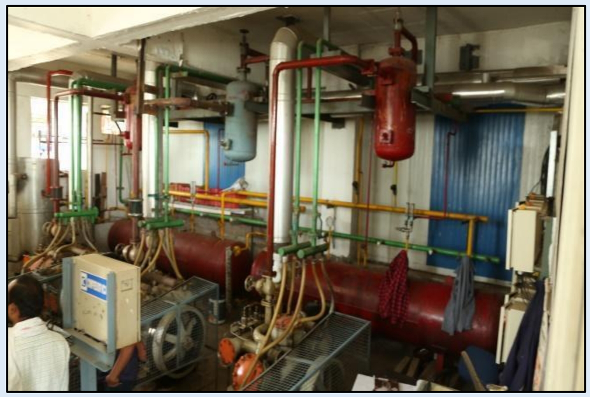
Around 800Kg of potato seeds are required in an acre of land. This indicates a current total requirement of 49 tons of potato seeds for the cluster. This demand may rise in the future if an affordable cold store near the villages is available, as more farmers may again switch to potato farming and may also store their own seed potatoes.

Box 6 - Deccan Cold Storage Pvt Ltd

The facility is primarily used by traders of certain agricultural commodities like coriander seeds and turmeric as the low temperature helps to preserve the colour of the produce, and agencies trading in milk, milk products. According to the manager of this facility, reasons behind underutilization could be cost of storing, awareness about benefits, accessibility, convenience and transportation. These cold storage facilities usually have large compartments as units. The farmers have to rent entire unit, this might increase the cost of storage per Kg of produce for farmers if they cannot fill the whole space. The cost of storage per unit reduces for larger quantities. Though the utilization of cold storages is low, most of the farmers are aware of this facility and know that it may help fetch better prices for their farm produce.

Visit to Deccan Cold Storage, Satara

Cooling plant at cold storage facility



Discussion with staff at Deccan Cold Storage

Study team at Deccan Cold Storage

2. Loss of Produce

Extreme weather conditions are impacting agriculture production and produce. Around 34 farmers have experienced that standing crop is burnt due to intense sunlight while 21 farmers feel that extreme summers cause a drought-like situation and scarcity of water for agriculture. About 69 percent said they tried to sell their produce immediately after harvest even if this meant lesser bargaining power, as intense heat spoils the perishable produce. See

"I have sown red cabbage, bok choy, broccoli, celery in my 3 acres of land. At present there is no demand for these vegetables in the market so the trader told me to not to send these harvested vegetables to his shop. I have no option now but to either bury these vegetables in the farm or to feed them to animals".

Baburao Sangale, Farmer, Sinnar cluster

Table 23.

The household survey and subsequent discussions revealed that farmers incur substantial losses of farm produce due to lack of storage facilities, lack of transport facilities and limited market demand for particular produce. In Karanjkhop for example, farmers reported losses of over 57 metric tons, worth INR 0.4 million or about USD 54000. Some farmers have reported losses of up to 43% of their total produce of a crop. A correlation analysis was done between landholding and nature and quantum of losses.

Within the sample of farmers who have incurred loss due to lack of storage, lack of transport and due to fluctuation in market rates, marginal farmers have incurred more loss due to lack of transport as compared to big farmers. Marginal and small farmers reported more loss in terms of quantity and cost.

Due to lack of storage facilities, small farmers (land<3 acre) incurred losses of up to 36% in terms of quantity while medium and large farmers (land>3 acre) have lost 14% of their produce due to lack of storage facility. Similarly, small farmers have incurred loss of 25.33% of their produce due to lack of transport and while medium and large farmers have lost 24.47% of their produce.

Table 23 - Measures to avoid losses

Measures	Randullabad		Karanjkhop		Cluster	
	Number	Percentage	Number	Percentage	Number	Percentage
Pack and store in shade	30	17.75	20	4.32	50	7.91
Dry and preserve	1	0.6	146	31.53	147	23.26
Immediate sale	138	81.66	297	64.15	435	68.83

Table 24 - Loss of produce by land holding size

Landholding Bands (acres)	Lack of storage (column %)		Lack of transport(column %)		Volatile market prices (column %)	
	Quantity (%)	Value (%)	Quantity (%)	Value (%)	Quantity (%)	Value (%)
Marginal Up to 1 acre	129261 (22.08)	784250 (17.61)	6870 (16.23)	266300 (21.80)	5301 (22.93)	70001 (9.85)
Small 1.1 - 3 acres	292380 (49.94)	2183050 (49.01)	14220 (34.43)	560100 (45.86)	6000 (25.95)	284000 (39.94)
Medium 3.1 - 5 acres	81160 (13.86)	611000 (13.72)	6190 (14.99)	165000 (13.51)	1200 (5.19)	50000 (7.03)
Large >5 acre	82640 (14.12)	876000 (19.67)	14025 (33.95)	230000 (18.83)	10620 (45.93)	307000 (43.18)
Total	585441	4454300	41305	1221400	23121	711001

Table 25 - Loss of produce due to lack of storage reported by farmers in Karanjkhop, Satara

Crop	No of farmers	% loss out of total production	Quantity (kg)	Cost (Rs)
Potato	5	3.82	3300	262000
Common Beans	75	32.17	38280	1615050
Sorghum	6	2.01	2570	89050
Bengal Grams	1	0.95	400	20,000
Groundnut	1	24.74	600	30000
Onion	3	43.70	7600	110000

Green Peas	41	0.05	525700	1425000
			578450	3,551,100

Table 26 - Loss of produce due to lack of transport reported by farmers in Karanjkhop, Satara				
Crop	No of farmers	% loss out of total production	Quantity (Kg)	Cost (Rs)
Potato	5	2.92	2525	83000
Common Beans	10	3.64	4330	226000
Green Peas	27	4.16	4810	266600
Lima Beans	1	3.70	80	3500
Wheat	1	0.50	400	8000
			12145	587100

Table 27 - Correlation between landholding size and loss of produce					
Reasons	**Loss**	**Pearson Correlation**	**Sig (2-tailed)**	**Number who reported loss**	**Mean and Standard Deviation**
Lack of storage	Quantity In kg	0.015	0.717	151	Land M=2.9acre; SD=2.9 Loss in Kg M=1641.9; SD=4382.6
	Value in INR	0.107	0.190	151	Land M=2.9acre; SD=2.9 Loss in Rs M=39704.6; SD=55988
Lack of transport	Quantity In kg	0.347	0.014	50	Land M=2.8acre; SD=2.8 Loss in Kg M=1045.7; SD=1786.2
	Value in INR	0.261	0.067	50	Land M=2.8acre; SD=2.8 Loss in Rs M=23816; SD=26388.1
Fluctuations in market rates	Quantity In kg	0.179	0.437	21	Land M=3.8acre; SD=2.1 Loss in Kg M=1109.5; SD=1430
	Value in INR	0.232	0.311	21	Land M=3.8acre; SD=2.1 Loss in Rs M=33857.1; SD=32763.2

3. Potential for enhancement if cooling is provided

Around 85 percent of the farmers in the cluster are of the opinion that accessible and affordable cold storage facilities near the village will help them to increase their bargaining power and fetch more profit. Around 7 percent are unsure of the benefits of such a facility while 4 percent feel that it will not add to their net income.

Table 28 - Farmers' views on the need for cold storage in Satara cluster				
Need cold storage?	Karanjkhop		Randullabad	
	Number	Percentage	Number	Percentage
Yes	377	81.25	229	92.34
No	24	5.17	7	2.82
Can't say	38	8.19	9	3.63
Yes, if affordable	25	5.39	3	1.21

The projected increase in incomes if cooling is provided include the avoidance of loss of produce as well as the possibility of a better market price. The cost of storing and the delay in obtaining the income from sales partially offset the earnings. The income may be calculated as follows:

Increased income = Price at *n* days – ((*n* days) * (Cost of cold store for *n* days)) – distress price

Table 29 - Projected increase in income with better market prices					
Produce	Increased income per kg in INR	Price at end of October, November	Price per kg (at the end of Kharif season, October)	Number of days in cold store	Cost of store per kg per day (at present) in INR
Potato	4	40	15	30	0.7
Beans	6.5	90	25	30	1.95
Green Pea	6.5	90	25	30	1.95
Marigold	32.5	65	12.5	30	1.5

4. **Drivers and barriers in relation to cooling in seed storage, post-harvest practices and supply chains**

The reasons for low usage of cold storage facilities by farmers include:

- Cost of cold storage
- Only whole units are available for hire even if a lesser volume is needed
- Accessibility, convenience, and cost of transport
- Lack of awareness of costs and benefits

Around 85 percent of the farmers in the cluster are of the opinion that accessible and affordable cold storage facilities near the village will help them to increase their bargaining power and fetch more profit. Around 7 percent are unsure of the benefits of such a facility while 4 percent feel that it will not add to their net income.

5. **Socio-economic and environmental impact in relation to cooling in agriculture, field crops**

Harvesting season usually varies by about 15 days. As supply is high during this time, rates are low. If storage is provided near villages, it will enable farmers to hold their produce for some more days. It will enable them to sell produce when demand is high (during festive season and during summer vacations when demand for vegetables is high). Recent amendments to the Essential Commodities Act, 1955 have allowed stocking and holding of agriculture produce. Traders can now legally stock commodities and sell when prices are high. However, farmers do not have storages, so they have to sell their perishable produce immediately. Cold storages near villages will enable to store produce and hold for few days. It will also increase bargaining power of farmers.

Potato seeds can be locally produced and stored. Local varieties, adapted to the local soil, water and climate ecology are more likely to withstand changes in local climatic conditions, pests attacks, and soil composition. With reduction in losses during transport with a precooling facility and with cooled transport, farmers will be able to explore more distant and profitable markets. Micro and small food processing industries could be set up, providing opportunities to enhance incomes.

If consciously planned for and monitored, the benefits of a pack-house and cold storage facility for agri-produce may include:

- Higher incomes with
  - the ability to wait for better prices
  - better produce quality with fresher fruits and vegetables
  - New business and employment opportunities from cooling services, aggregation services, post-harvest activities
- Better nutrition from greater crop diversity
- Greater equity with avoidance of losses that marginal farmers face

However, these positive outcomes are neither automatic not guaranteed. On the other hand, changing cropping patterns due to improved market linkages enabled with access to cooling services may have certain negative impacts observed elsewhere, if not consciously addressed. For example, increase in the cultivation of exotic crops that have high market demand is likely to result in increased abstraction of ground water. Colleagues from BAIF have observed a shift from Jwari (sorghum) millets-based mixed farming system to vegetable and other cash crop farming which are economically more remunerative. This trend is expected to grow. In a report on the status of groundwater levels in 2019, nine out of eleven talukas in Satara district and twelve out of fifteen talukas in Nashik district are recorded with ground water depletion of 1 m or more (Groundwater Survey and Development Agency, Govt of Maharashtra, 2019).

Inorganic farming practices coupled with increased groundwater based irrigation may result in increased use of fertilizers, pesticides and weedicides. This potentially will have adverse impact on soil and above ground biodiversity, natural soil carbon and water quality. In turn this can also adversely impact human health. Mitigation of these impacts is possible locally with adoption of precision and organic farming methods.

Contract farming or farm pooling to take advantage of cooling facilities may reinforce existing disparities between small and large farmers, unless consciously planned to preferentially and equitably benefit the more marginalized households. With pre-cooling and cooled transport, produce can last longer, but this also lengthens supply chains and adds food miles. With changes in cropping patterns, and a shift to commercial and horticulture crops, local varieties may slowly become unpopular further eroding the regional agrobiodiversity.

Currently, organic farming is not popular among the farmers of this region. The few who do so, use the produce for household consumption and distribution to relatives. Though most farmers are aware about organic farming and certification, they are reluctant to practice it due to broken market linkages and financial buffers needed to make the transition. A gradual shift to organic farming may be explored, in conjunction with a cooling facility that could help to shore up resources, though this will require further deliberation with the farming community.

Dairy and Cooling

1. **Current practices of dairy-related cooling**
   Like in other parts of rural India, animal rearing is a part of the local economy and livelihoods in this cluster too. The villagers rear animals such as bullocks, buffalo, hybrid cows, goats, sheep and chicken. For some farmers, it is their main livelihood while for others it is a supplementary income. Marginal, small and medium-holder farmers own more cattle and goats as compared to farmers with large land holdings. Those with marginal land holdings own more goats as compared to other categories.

Table 30 - Ownership of livestock in Satara cluster

Land holding Bands (acres)	No. of Cows & Oxen (No. of families)	No. of Buffaloes (No. of families)	No. of Goats (No. of families)
Marginal (Up to 1 acres)	99 (48)	34 (24)	225 (20)
Small (1.1 acres – 3 acres)	204 (79)	52 (28)	30 (9)
Medium (3.1 acres – 5 acres)	75 (32)	33 (15)	2 (2)

Large (>5 acre)	53 (21)	17 (9)	6 (1)

The majority of the milch animals are cows and buffalo. Hybrid varieties such as Holstein Friesian, and Jersey are very popular in the Satara cluster - in the surveyed households in Randullabad, out of 179 cows, only 13 cows are of local breed while remaining all cows are hybrid.

The milk of local cow breeds is neither consumed by the household nor sold in the market. As the milk yield is low, farmers prefer to let the calves feed so that they grow into healthy oxen to be used for draught power later on. Villagers prefer hybrid cows over local breeds for dairy milk enterprises, as they yield about 1.5 times more milk than local breeds. Milk production and yields depend upon several factors such as the stage of the reproduction cycle, food intake and weather conditions.

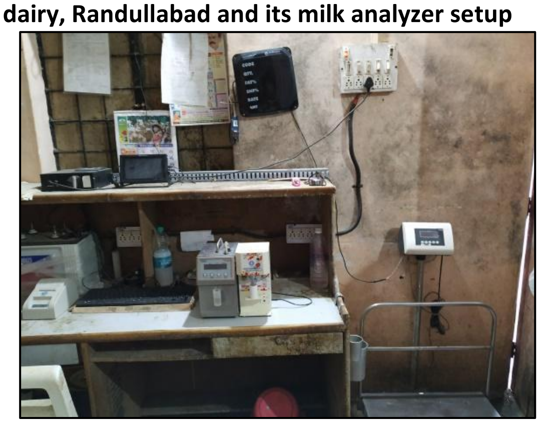
The animal holders can earn INR 31 per litre of cow milk (3.5% fat, SNF 8.5 %) at the first point of sale and INR 1 per litre bonus at the end of the year, when they sell to a dairy aggregator. In an average around 2500 lit milk is collected daily in this study cluster.

Four private dairies in Karanjkhop and two co-operative dairies in Randullabad procure the milk produced in this cluster as well as from farmers in neighbouring villages. These dairies only procure hybrid cow milk and not that of buffalo or local cow breeds. They function as aggregators, analyzing the milk brought by farmers for fat, Solids-not-fat (SNF) and Lactose, and cooling and storing it at 5^{o}C.. The aggregators earn INR 1 per litre of milk for these services. They also transport the collected and cooled milk on to larger companies like Baramati Agro and Govind Milk & Milk Products Pvt Ltd that process and package milk and milk products for bulk and retail supplies. On an average around 2500 litre milk is collected daily in Satara study cluster.

Table 31 - Quantity of milk production in cluster villages

Village	Animal	Number of animals	Daily average production (Lit)	Litres sold to dairies	Dairy	Daily average collection (Lit)
Karanjkhop	Cow (Hybrid)	512	2142	1875	Prayatna	350
	Cow (Local)	59	886		Sanchita	225
	Buffalo	201	1173		Sant Krupa	950
Randullabad	Cow (Hybrid)	166	400	2700	Waghajai	350
	Cow (Local)	13	60		Hanuman	1200
	Buffalo	33	38		Datta Digambar	1500

Figure 9 - Datta Digambar Co-operative milk dairy, Randullabad and its milk analyzer setup



2. **Losses in Dairy**
Both dairies in Randullabad have bulk milk coolers installed. Earlier, the milk was collected in the morning and transported to the nearest cooling facility later in the day. As milk collected in the morning was mixed with that collected in the evening, there were high chances of milk getting spoiled. Now the milk producer companies have provided bulk milk coolers near the village and this collected milk is transported in insulted tankers to dairies for packaging. The collected milk is stored in bulk milk coolers at around 5^{o}C. Milk producer companies have also provided generator facilities that are used to keep the chillers running during power failures. Milk dairies in Karanjkhop do not have bulk milk cooler facilities. Milk is collected early in the morning before 9 am and transported to the nearest cooling facilities in Pimpode village which is at a distance of 7 Km from Karanjkhop. At Pimpode, the milk is cooled to 5^{o}C and then transported to dairies in Titave village.

Milk spoilage is higher in private dairies, as compared to cooperative dairies, because the bulk milk coolers operated by them are located away from the village, in Pimpode. The cooperative dairies have set up bulk milk coolers in the village itself.

"In our village we have daily collection of about 750 litres of milk. One day there was a power cut, and our generator had some problem. All 750 litres stored in the bulk milk cooler got spoiled and we had to discard it in the gutter"
Vijay Deshmukh, Secretary, Hanuman Co-operative dairy, Randullabad

Weather conditions do have an impact on the quantum of production of milk. The nature of animal shelters and the potential for improved cooling in livestock shelters is discussed later in this section.

3. **Social, economic and environmental impact due to lack of cooling in dairy**
There is a need to provide bulk milk coolers in villages like Karanjkhop. The presence of a bulk milk cooler would lower the risk of milk spoilage and enhance incomes. Considering that the average annual income in this cluster is about INR 50000, for a household that maintains 2 hybrid cows, producing 20 litres of milk totally, the loss of the day's earning of INR 640 is very substantial.

4. **Potential for increase in socio-economic well-being in case appropriate cooling is provided**
There is a potential to enhance incomes by avoiding spoilage, if milk cooling facilities are developed at Karanjkhop village. If a milk cooler is made available, there is a possibility of increasing the number of milch cattle to enhance incomes. However, the decision to increase the number of livestock is related to the availability of space, shelter, water, feed, healthcare, human resource, and local demand and market linkages, besides the financial investment needed.

The investment needed is INR 150000 for a bulk milk cooler and the average monthly cost of electricity is around INR 12000. The current demand for milk cooling and insulated transport is for about 1875 litres, which is the total daily hybrid cow milk collection by four private dairies in Karanjkhop, which includes milk aggregated from a few neighbouring villages other than Randullabad.

5. **Drivers and barriers in addressing cooling demands for dairy**

At the moment, the bulk milk coolers at neighbouring Randullabad and at the collection centre in Pimpode are adequate. Among the barriers in setting up a milk cooling facility at Karanjkhop are

- Lack of conscious consideration of the benefits of cooling and costs of not having cooling facilities within the village itself
- Lack of collectivism and community mobilization in Karanjkhop where a milk cooperative has not been formed so far and the business is conducted through private milk dairies.

Box 7 - A success story of goat rearing by a women-owned farmer producer company

The Deccan has traditionally been a goat rearing region. In 2016, Yuva Mitra started a dialogue with women goat farmers to understand the needs related to goat farming. High mortality rates and lack of adequate fodder. There was no clear market for goat milk, the farmers were just adding goat milk to cow or buffalo milk for sale.

The Savitribai Phule Goat Farmer Producer Company Ltd (SGFPCL) a women-owned goat farming company was registered in 2016 for live goat trading, goat milk processing, and manure preparation. Yuva Mitra helped identify markets for goat milk, cheese and meat, started extensive veterinary services, including vaccinations to goat farmers in the region, and conducted training on fodder production.

As demand for goat milk grew, the company established a sophisticated goat milk processing plant that started operations in June 2019 in Harsule village of Sinnar block. Nabkisan Finance Ltd provided a loan of INR 7.715 million for this milk pasteurization and cheese making facility while part of the finance was raised through shares. The total cost of the project is INR 12.7 million.

The company collects milk from three villages Shaha, Mithasagar and Pangave, that are at a distance of 33 km from the plant but have been chosen for milk production because of the presence of rare breeds such as Kathiawadi, and cross bred local and Kathiawadi animals that produce milk in large quantities. These three villages collectively produce around 3000 litres of goat milk in a day, but only 500 litre per day is processed as the plant has limited capacity. The SPFPCL sells goat milk under its brand 'Sahaj'.

Yuva Mitra also strengthened marketing of live goats in the region. Previously, live goat traders and middlemen used to trade goats by number of goats and not by weight of the goats. Yuva Mitra conducted meetings of women and created awareness about the sale of goats based on weight. Apart from that women used to sell the goats whenever they were in need of money and hence traders used to exploit them by bargaining for lower prices. To avoid this, Yuva Mitra set up a goat rearing centre, which buys goats by weight. Now women get money at the rate of Rs180-220 per kilogram for 60 percent of met weight, and depending on the breed. The rearing centre sells the goats at the rate of INR 250 per kilogram. The centre also periodically conducts training of women and youth in the region and orients them about different breeds of goats, their milk and meat productivity, fodder production, animal husbandry and care. The SFFPCL now has a paid-up share capital of INR 2.27 million, with 1600 shareholders.

Milk collection process

The women farmers bring goat milk to the collection centre situated at Mithsagar village by 8 am. The milk is purchased at the rate of INR 32 per litre. The other costs are INR 2 per litre for collection and INR 1 per litre for transportation of the milk to the processing plant. The collection centre at Mithsagar village has one bulk milk cooler of 500 litre capacity. Milk is tested to check for traces of antibiotic. Milk is cooled to 5^0C in the bulk milk cooler and by 9 am dispatched to the milk processing plant. The milk is again tested at processing plants for total fats, Solids not Fat (SNF), proteins, lactose, water content and salt using equipment called 'Lactosure'.

Processing of the milk

Processing starts with segregation the required quantities of milk for pasteurization and cheese preparation.

Pasteurized milk is sold to customers in Mumbai and Nashik. The current demand is about 60 litres per day. This milk is transported through a normal transport vehicle in an insulated box which contains ice and salt. The milk is sold at the rate of INR 90-120 per litre. The remaining milk is processed to produce feta, blue, cream and camembert cheese, priced at INR 2500 per kg on average. Cheese is supplied to Kodai Dairy Products, Tami Nadu, that bears the cost of transportation and provides a reefer to pick up the cheese produced.

Meat and Cooling

1. **Current practices**

   In India traditionally, people prefer to buy fresh meat. This suits the rural context very well, as demand is predictable. The Satara cluster has three meat shops that sell both meat (mutton and chicken) and eggs. In keeping with the practice of eating meat on specific days in the week, meat is not regularly available in these villages. The traditional practice for mutton sale is that meat shopkeepers usually assess the amount of mutton required a day in advance and only the required numbers of animals are butchered. This is a good practice for the local context as the demand in the villages is predictable and waste is avoided. The meat shopkeepers buy goat and sheep locally from the same villages or from Pimpode, Wai, Wathar. Around 400 goats and 500 sheep were being reared in the cluster villages at the time of the survey. Goat and sheep are sold locally as well as in distant markets.

   People usually buy broiler chicken and fish from Pimpode or Wathar when they visit the weekly market. Randullabad has one poultry farm of broiler chicken of 6000 capacity. These chicken are supplied directly to Baramati Agro Pvt Ltd. At the time of the survey there were around 239 chickens of local breeds being reared by 28 households in the cluster. Customarily, women rear chicken and the income from the sale of chicken and eggs also goes to the women. Local breeds of chicken are preferred in rural areas due to the use of antibiotics and hormones in industrial poultry farms.

2. **Losses or spoilage of meat**

   Currently, hardly any loss or spoilage of meat was reported with the prevailing practice of demand-based supply.

3. **Social, economic and environmental impact due to lack of cooling in meat**

   However, there are hardly any enterprises or cooperatives producing local breeds, avoiding the use of hormones and antibiotics, and selling these in urban markets as an income generating activity. Another characteristic of sale of live animals is that the prices are approximate and not based on actual weight. Farmers have low bargaining power and may be exploited by butchers and other vendors.

4. **Potential for increase in socio-economic well-being in case appropriate cooling is provided**

   The need for setting up hygienic, advanced slaughterhouses near villages and transport of meat to urban markets through effective cold chains may emerge more clearly if consumer preferences could be assessed.

   In the authors' view, the current practice of supplying fresh meat for local consumption aligned to a culturally aligned, known steady demand seems highly appropriate and should consciously be continued and encouraged. Increasing the marketability of meat by cooling may have unintended consequences of waste management and pollution unless it is systematically addressed.

5. **Drivers and barriers in addressing cooling demands for meat**
   There may be a potential demand in urban markets for hygienic, trackable, packed meat with increasing urbanization and the pandemic situation. Awareness about and the technical and financial capacity to set up a modern slaughterhouse, processing unit, cold chain and market links are key barriers for such enterprises.

Animal Shelters

The livestock sector, including dairy and meat, are likely to be affected both directly and indirectly by climate change. Stress to animals caused by changes in temperature-humidity index directly affect egg and milk production, feed efficiency and animal reproduction, and is one of the leading causes of decreased production and fertility during summer months.

In milch cattle, when the environmental temperature goes beyond the upper critical temperature (24°-26°C for exotic and crossbred cattle and 33°C for Zebu cattle and 36°C for buffaloes), the body is unable to maintain the core body temperature through sweating (NDDB, n.d.). Research indicates that stress from heat can cause decline in milk yield in the range of 10 to 30 % in first lactation and 5 to 20 % in second and third lactation, and that both the heat waves and cold waves can cause short to long term cumulative heat effect on milk production in cattle and buffaloes, as well as impact animal reproduction adversely (Rath, 2017). Crossbred / exotic animals are more prone to the heat stress losses as compared to indigenous cattle (P Belsare & Pandey, 2008). Indirect effects include feed and water availability being impacted by adverse climate events (Rath, 2017). Following exposure to heat, cattle appear to acclimatise within 2-7 weeks. The most effective practice is for cattle to wallow in a pond. For animal heat stress management, adaptation options include water management, breeding animal and forage species for resistance to drought, heat and harsh environments, providing cooling or shading and implementing on- and off-farm diversification (FAO, 2018). Indigenous breeds have genetic traits that help them to survive with in harsh climates, pursuing breeding policies that encourage an appropriate mix of breeds that can adapt to the region in which they are to kept should be the most important element in our adaptation strategy. Under National Dairy Plan (NDP) I – a programme under implementation by NDDB, indigenous breed development programmes for eleven breeds – Kankrej, Rathi, Gir, Sahiwal, Hariana and Tharparkar breeds of cattle and Murrah, Mehsana, Nili Ravi, Jaffarabadi and Pandharpuri breeds of buffaloes are being implemented in their respective native tracts through a scientific selection programme (Rath, 2017). Experts also recommend simple modifications in feeding practices such as hydration of dry straws, incorporation of good quality green fodder when available, replacing poor quality roughage with concentrate, feeding properly chaffed dry fodder etc. Animal shelters that have appropriate design, height and orientation, choice of roofing material, provision of open space for ventilation and space per animal can help in creating a cooler microenvironment for animals. Water can be used to bring down the micro-environmental temperature within the animal shelters and increase the evaporative heat loss from animal body (Rath, 2017).

In poultry too, heat stress among layer and broiler chicken affects feed intake, thereby affecting growth rate, meat quality, and egg production and quality. The typical optimal temperature is 22C to 30C, and severe stress sets in at 40C. General strategies to address heat stress in poultry include heat conditioning, open sheds, cooling systems, feed modifications, as well as breeding to improve heat stress tolerance (Nawab et al., 2018; Wasti et al., 2020). Other studies also highlight the higher mortality rate of due to heat stress during transport of birds from the bird rearing sites to processing facilities. Early life conditioning and genetic selection are relatively newer approaches. Among the various strategies, good shelter with space, ventilation, light and protection from weather and predators, has an important role in small scale and commercial poultry. Though animals do naturally adapt, with increase in the intensity of summer and number of hot days and nights, attention to cooling provisions in animal shelters and practices assume importance. Traditional methods may need to be supplemented to address extreme weather conditions.

1. **Current practices for managing heat stress of livestock**

   In the Satara cluster, animal keepers traditionally use different shelters, spaces and practices for different seasons for cattle like a shed with a roof for the monsoons, open pens for the winter so that the animals can bask in the sun, or covering the animals with wet jute/ cloth, frequently bathing them in the summer and installing fans, showers etc. to cool them down. Traditional practices such as covering animals with wet jute/ cloth (248 farmers), covering the shelter roofs with straw (250 farmers) or giving frequent baths to animals (301 farmers) are prevalent currently in the cluster villages. Very few farmers are use fans (6 farmers) or showers for animals. At the one poultry farm in Randullabad, tungsten lamps and tarpaulin covers are used during the winters for warming the space, and the roof is painted white during the summers to protect chicken from extreme cold and heat. Tungsten lamps are installed in goat and sheep shelters as they easily catch pneumonia in the monsoon and winter. Table 32 presents the prevalence of different practices in the cluster villages of managing thermal conditions in animal shelters.

Table 32 - Cooling / heating measures in animal shelters

Measures	Karanjkhop	Randullabad	Patooda	Dhulgaon
Fan	3	3	1	2
Shower	1	2	2	4
Tungsten lamp	75	88	1	1
Bathe the animals	177	124	8	0
Cover shelter with straw	148	102	80	56
Place wet jute/ cloth on animal	236	12	66	45

2. **Losses due to heat stress**

   Milk collection data in two dairies of Karanjkhop and Randullabad shows that during summer there is less collection of milk compared to milk collection in other seasons. Heat stress in summer has an impact on the production of milk. The summer to winter milk production ratio of Prayatna Dairy is 0.8 while that of Hanuman dairy is 0.92, indicating an 8 to 20% reduction in yield in the summer.

Table 33 – Seasonal variation in daily milk production

	Satara cluster			Yeola cluster		
	Summer	Monsoon	Winter	Summer	Monsoon	Winter
Buffalo	206.5	267	266.5	54	57	57
Cow (Local)	47	60	60	1424	1431	1423
Cow (Hybrid)	1469.5	1839.3	1829.5			

Table 34 - Seasonal variation in daily milk collection

Name of the dairy	Average milk collection per day in litres		
	Summer	Monsoon	Winter
Prayatna Dairy	240	350	300

Hanuman Dairy	1100	1250	1200

The household survey also shows the same trends. Milk production in lowest in the summer and highest in winter. The summer to winter milk production ratio for cluster villages is 0.77 for buffalo, 0.78 for local breeds of cows and 0.80 for hybrid cows. The heat stress impact on milk production is almost equal on buffaloes, local breeds of cows and hybrid breeds of cows. Heat stress can also lead to a decrease in the number of days of lactation. However, interviews with staff in the cooperative dairy said that this has not been observed locally.

The study also revealed that in the Satara cluster villages, in the past year, about 87 animals died due to extreme weather conditions such as heavy rain, high and low temperature. Goats are more prone to pneumonia during the rainy season. About 79 goats died because of heavy rain while six cattle died due to extreme summer and winter. In the Yeola cluster, 3 cows and 3 goats died due to weather conditions. However, discussions with poultry keepers indicated that there was no significant change in egg laying quantities due to heat stress.

3. Social, economic and environmental impact due to lack of cooling in animal shelters

Considering that the reduction in total yield is about 8% to 20% less for hybrid cattle, and the average yield per day as 2500 litre in the Satara cluster (only Randullabad and Karanjkhop), the loss of income due to heat stress may range from INR 6200 to INR 15500 per day for the whole cluster.

The loss of an animal can be quite substantial, as the price of a single animal may range from 5% to almost 40% of an average annual rural income. The average prices of animals in the cluster villages are as follows:

Buffalo	INR 39000
Cow	INR 38000
Ox	INR 38000
Goat	INR 5000

Box 8 - Contract farming of broiler chicken

Through an agreement made between the farmer and a poultry aggregator company, the chicks, feed, medication (including a veterinary doctor) and technical assistance are provided by the aggregator. The number of birds supplied depends on the area available in the shed of the famrer, considering 1.2 sqft/bird. One farmer from Randullabad has around 3,200 birds worth around 10 tonnes. The company collects the birds after 42-45 days when the weight is about 2.5-3 kg.

The disadvantages of the contract is that during recession, the company does not collect birds even if the weight has reached 4kg. While there is some mortality among the chicken due to extreme heat, the company only bears 5% losses of birds. Farmers have to bear the remaining losses. Approximately 250 deaths have taken place, over the last one year.

The farmer has installed micro-sprinklers on the shed roof. However, micro-climate management for poultry needs a strategy that does not increase relative humidity, as high humidity can increase heat stress.

4. **Potential for increase in socio-economic well-being with improved cooling for livestock**

Appropriate shelters that provide protection against extreme weather would help in reducing the yield losses, and adverse health impacts of heat stress on livestock. This is especially relevant for stall fed exotic or cross bred cattle and even stall fed rearing of local goat breeds such as Osmanabadi. Avoidance of diseases related to heat stress, would help reduce expenditure on animal healthcare.

5. **Drivers and barriers related to improved cooling in animal shelters**

Some barriers to modifying animal shelter practices including installing active cooling measures may include:

- Inadequate awareness about the changes in climate – currently, while there may be general awareness about the impact of warm days and nights, it may not be perceived as acute enough for active measures beyond traditional practices.
- Inadequate realization of the quantum of loss – while there is awareness about reduction in milk yields, there may not be a realization of (and even research or documentation of) whether the trend of more number of warm days and night, and more extreme temperatures has led to further reductions in milk yields
- Additional work – such as the need to bathe the animals more frequently
- Additional expenses – such as for a fan or cooler, which may be difficult to afford.

In the future, livelihood support schemes related to animal husbandry should take climate change considerations into account for management practices and shelter designs, as well as in animal breeding programmes for tolerance of heat stress.

Currently, when support has been facilitated to individual households for animal husbandry, the support may not necessarily include appropriate shelter. In Sinnar, as part of the effort to promote goat rearing, a central goat shed has been developed by Yuva Mitra, and is designed in accordance with guidelines for ventilation and sunlight. However, assistance to individual households may only include the animals, and not also the expenses of a shelter. Under Navinyapurna Scheme, the Govt of Maharashtra is providing cows/ buffaloes/ goats/ chicken to beneficiaries. The scheme budget includes provisions for the cost of the animals, sheds, fodder cutting machines, sheds for storing fodder, and insurance. For 6 cow / buffalos, INR 30,000 are provided for a cattle shed of size 33ft X 35ft and INR 25,000 for shed for storing food. In case of goat scheme, INR 15750 are provided for a goat shed of 225 ft, 2 for 11 goats. Support of INR 2,00,000 is provided for bird shed, store room and electrification in poultry schemes.

6. **Areas for further research**

Areas for further research may include:

- Documentation and research on the threshold levels of heat stress of different breeds of animals, changes in daily yields and the number of days of lactation, and trends thereof
- Breeding for heat stress in addition to milk yield. For example, Maldhari communities in the western Indian plains have crossbred local varieties with Gir cows from Brazil, that are descendants of Gir animals originally from Gujarat exported to Brazil some generations ago[1].
- The possibility of developing modern common facilities of animal sheds built with appropriate materials, designs for thermal comfort, ventilation and hygiene, as well as active cooling as

[1] Dr Nitya Ghotge, personal communication, 6 March 2020

needed, extending and contextualizing the traditional practice of collective animal shelters such as ‘panjra pol’ in Gujarat and Rajasthan.

Local Veterinary Care

Animal healthcare has been a crucial driver for animal husbandry and the agriculture sector. India has a large livestock population of 512 million, making healthcare a priority for livelihoods that depend on it (Chand, 2019). As part of the economic recovery after the Covid-19 outbreak, the Government announced a package of INR 20 lakh crores (USD 265 million). The economic package will cover the cost of a National Disease Control Programme for animals. Vaccines are primarily manufactured by central and state government institutions. Each state produces as per its state requirements. At present, animal vaccination market values at INR 1,300 crores, but is expected to grow to INR 7,500 crores (Jayakumar, 2020).

Livestock farmers, mainly smallholders, suffer from limited access to health services, training, quality management (Leitch et al., 2020). This includes ineffective cold chain services for animal vaccinations. This results in low livestock productivity, high levels of mortality and thus reduction in income opportunities for farmers. There is little to no cold chain logistics provided at the village level by district veterinary systems. Farmers are compelled to rely on private practitioners, resulting in higher costs. The sector faces key constraints and challenges which create a gap in the infrastructure effectiveness. Due to the remote areas of the market share, health services are not able to achieve economies of scale. Cold chain services needed for vaccine maintenance requires high costs. Since distribution becomes disaggregated and fragmented at delivery points, last-mile delivery is not profitable. The sector requires investment to tackle these challenges specifically at the last-mile end of the supply chain.

1. **Current practices in local veterinary care related cooling**

   People use government as well as private animal healthcare facilities. A government veterinary hospital situated in Karanjkhop caters to the needs of five villages namely Karanjkhop, Moreband, Sonake, Jagtap Nagar and Chawaneshwar. Traditional medicines and healthcare practices for animals are prevalent and help to a certain extent. However, with climate change, the patterns of spread of diseases among domesticated animals are also changing. For example, Bluetongue disease is quite recent and there may not be any locally known traditional medicines to treat it (N. Ghotge, personal communication, 6 March 2020; Saminathan et al., 2020).

   Several vaccines used in veterinary care require a cold chain to preserve efficacy, other than some like the vaccine for Newcastle disease which is thermostable. However, unlike the human vaccine cold chain in India, the cold chains for animal vaccines in the country are generally managed by the private sector, and may not be very robust at the village levels. Another difference between human and animal vaccination programmes is that human vaccination has universal coverage but vaccines are administered to animals only if there is an outbreak of a particular disease in that region.

   Vaccines are available in local medical shops and farmers have acquired knowledge of administering vaccines. Vaccines are usually carried in vaccine carriers for administration in field sites, but in practice, may be carried on person, in clothing pockets. The prevalent practice is for animal keepers to buy vaccines from local medical stores and administer these themselves. For these short distances, typically a vaccine carrier is not used. When the vaccine refrigerator at the veterinary hospital is not working, as was the case in one of the clusters studies, the practice is to store these in domestic refrigerators. Antibiotics used in veterinary care generally do not need cold storage.

2. **Losses in livestock due to inadequate cooling in local veterinary care**

There have been deaths of 60 animals in cluster villages due to diseases which could have been avoided by vaccination. In the Satara cluster, some animals died despite being treated while a few died due to non-treatment. The reasons for non-treatment include non-availability of doctors, and incurability of the disease.

Table 35 - Animal deaths from vaccine preventable diseases in Satara cluster in the last year		
Animal	Karanjkhop	Randullabad
Buffalo	14	0
Cow	33	5
Ox	4	0
Goat	85	3
Chicken	44	0

3. **Social, economic and environmental impact due to inadequate cooling in local veterinary systems**
As mentioned earlier, it is projected that pest and disease pressures among livestock would change in the coming decades, with global warming. As a risk mitigation measure, it is important to strengthen veterinary healthcare services and animal vaccine cold chains.

4. **Drivers and barriers in addressing cooling demands in veterinary care**
Barriers underlying the development of cold chain facilities for animal vaccines
   - Inadequate awareness about vaccine preventable diseases among livestock keepers
   - Inadequacy of licensed veterinary care staff as a veterinary license is needed to stock, sell and administer vaccines
   - Inadequacy of cold chains for animal vaccines
   - Logistics of vaccine administration, including among migratory populations

The curriculum[2] and legislations for Animal Health Workers are currently being developed. Once these are notified and the skilling courses and testing systems implemented, the shortage of trained and licensed veterinary care staff is expected to be addressed over time.

Box 9 - Common vaccine preventable diseases in livestock		
Name of disease	Animals	Storage temperature
Foot and Mouth Disease (FMD)	Bovine, sheep, goat	2-8°C
Haemorrhagic Septicaemia	Bovine, sheep, goat	2-8°C
Black Quarter (BQ)	Bovine, sheep	2-8°C
Brucellosis	Bovine, sheep, goat (female calves, non-pregnant non lactating)	2-8°C
Theileriosis	Bovine, sheep, goat	2-8°C
Anthrax	Bovine, sheep, goat	2-8°C
IBR	Bovine	2-8°C
Rabies	Bovine, sheep	Room temperature
Blue tongue disease	Sheep, goat, bovine	2-8°C
Enterotoxaemia	Sheep, goat	2-8°C

[2] https://nsdcindia.org/sites/default/files/TR-AGR-Q4804-Animal_Health_Worker.pdf

PPR	Sheep, goat	2-8^{o}C

Animal Breeding

Though India has a large population of milk producing animals/ cattle, milk production per animal is considered low, in comparison to varieties in temperate climates. The focus of state-supported animal breeding programmes in India in recent decades has largely been to increase milk yield among cattle, and effectiveness of conversion to meat among chicken, while acknowledging the hardiness, heat tolerance, disease resistance and other adaptations to local conditions among indigenous breeds.

Under the breed improvement program, using modern techniques of artificial insemination, cattle productivity is sought to be increased by cross breeding local breeds of cows and buffalo with exotic breeds such as Holstein, Friesian and Jersey. Semen production centres have a bull station where bulls of high milk producing varieties such as pure breed animals of Holstein, Friesian, and Jersey, as well as indigenous varieties such as Khillar, Sahiwal, Gir, Dewani, Amritsari, Lal Kandhari, Dangi are reared and their semen collected. The collected semen is tested and processed in the laboratory and preserved for at least one month. After a month, random checks of semen quality are done and quality-approved semen is loaded into preservation tanks. The temperature required for semen preservation is -196^{o}C which is maintained using liquid nitrogen. The temperature is brought down in a stage wise manner to avoid temperature shock to sperms. The liquid nitrogen containers are of capacity of 3 to 500 litres. Nitrogen is supplied to artificial insemination centres by external vendors from liquid nitrogen depots set up at cluster level. Transporting containers, also called nitrogen goblets, can contain 100-120 canisters. Each canister contains around 6-7 straws, classified by breed and colour-coded for easy identification. In order to preserve the semen straw for longer duration, it is required to maintain the nitrogen level till the neck of the goblet hence it needs refilling after two days. Conception rate with preserved semen is 50-60 percent.

Semen straw

Wide mouth AI liquid Nitrogen Container

1. **Current practices in animal breeding for heat stress tolerance and cooling needs**

   The current animal holding in the cluster villages shows that hybrid cows are more than 5 times the number of desi cows.

Table 36 - Cattle and buffalo population in Satara cluster		
	No. of animals (No. of families)	
Type of animal	**Karanjkhop**	**Randullabad**
Oxen	73 (42)	0 (0)
Cow (Hybrid)	237 (120)	166 (70)
Cow (Desi)	34 (21)	13 (5)

Buffalo	116 (71)	33 (9)

AI services in Satara are partly provided by BAIF and partly by the government veterinary hospital. People prefer services by private veterinary doctors as they believe that the semen provided by the government hospital is not of high quality. In the Satara cluster, about 40% of livestock holders utilize AI services, while other continue with traditional methods of breeding. The artificial inseminations performed by Karanjkhop veterinary hospital are as follows.

Table 37 - Number of artificial inseminations at Karanjkhop Veterinary Clinic

	April 19	May 19	June 19	July 19	Aug 19	Sep 19	Total
Exotic breeds	7	3	9	47	2	1	69
Cross breeds	36	67	41	3	54	48	249
Local breeds	6	2	7	1	1	7	24
Buffalo	4	4	8	1	2	4	23
Total	53	76	65	52	59	60	365

2. Social, economic and environmental impact due to lack of modern animal breeding

There are different views about both the ethics and relevance of AI. On the one hand is the view that the lack of adequate AI facilities has meant the perpetuation of non-descript varieties of livestock, that have low yields. The presence of an AI centre can help to rapidly reach out to animal keepers for breed improvement programmes and transform non-descript cattle to improved herds in their next generations.

On the other hand, apart from the ethical dimension of AI, is the view that the low production levels of such cattle are linked with the scarcities of water, fodder and other resources, and the limited ability for investments in animal husbandry by small scale farmers and animal keepers. In such conditions, the hardiness of the animals is of paramount importance. The hardiness of local breeds, though low yielding, is in itself a very important adaptation measure.

Breed improvement, whether by AI or by traditional methods, may not by itself lead to greater resilience, especially without the concomitant strengthening of the agro-ecosystem through soil and moisture management, agro-biodiversity enhancement and animal husbandry practices. It may in fact lead to further losses of animals, due to ill health and increased mortality if progeny of crossbreeding are not able to withstand potentially harsher climates.

3. Potential for increase in socio-economic well-being with expansion of modern animal breeding facilities

It is difficult to quantify the potential for improvement in socio-economic well-being. Benefits include improved yields, leading to higher income, and improved hardiness, resulting in reduced health costs. Costs include higher inputs of feed and care to amplify genetic improvement.

4. Drivers and barriers related to setting up modern AI facilities

The government policy is to expand establishment of AI centres and services. The barriers to setting up of AI centres include:

- Expense of setting up AI centres, though partial support is provided by the central and state governments
- Supply of liquid nitrogen to remote areas and villages

- The perception about semen provided through government channels is that chances of conception are less and that the semen is not of the desired breeds
- Bulls are locally available
- Lack of uptake and demand from farmers, though AI is free, because of farmers' perceptions about the higher level of care and inputs needed for crossbred animals, or non-acceptance of AI.

In conjunction with the need for expansion of AI facilities, the future strategy of breeding needs discussion. So far, the aim of breed improvement programmes has been to increase milk yield. With the need for adaptation to climate change, breed improvement programmes need to additionally focus on heat stress tolerance and disease resistance. For strengthening and/ or accelerating breed improvement to enhance resilience, the following may need to be done:

- Deliberations with breeders, herders, animal husbandry depts, researchers, and extension workers about the need for and nature of breed improvement in the context of climate change
- Selection of breeds and associated management practices
- Development of a programme of outreach and participatory research, including factoring in the risks associated with
- Development of adapted cross-bred animals, through traditional and modern methods including AI and the associated management practices and wider resource management arrangements

Opportunities for new market connectivity and enhanced incomes

Currently, the major preferred markets for sale of agriculture produce in this region are Pune, Satara, Pimpode, Wai, Wathar and Bhuinj. Sugarcane, cultivated by about 13 farming households from the Satara study cluster, is sold to two sugar factories in or near Wai and Bhuinj. For small amount of agriculture production, farmers usually prefer local markets such as Wai, Pimpode and Wathar. Around 68 percent households prefer local markets as transportation is unaffordable for them. Pune and Satara are considered distant markets, though Pune is a preferred market as demand is high and there are less chances of produce not getting sold. Around 10 percent of the farmers from the Satara cluster sell their produce in Satara city market while 29 per cent farmers prefer the Pune market. Farmers from this cluster do not sell to hotels or organized retail companies. Some farmers were engaged in contract farming earlier but stopped it now as it is was not remunerative. The cases of Sahyadri Farms and Savitribai Phule women's farmer producer company in Nashik are inspiring examples of farmers' collectives creating a diverse range of produce and processed products, and exploring new markets. In both cases, cooling and processing facilities have played an important role, as has a certain scale of operation and diverse and unique products.

Box 10 - Sahyadri Farms, Nashik

Sahyadri Farms has successfully aggregated 8,000 small and marginal farmers who grow a variety of crops in the district of Nashik, Maharashtra. The organisation has created market linkages between farmers and local as well as international markets. Investment in infrastructure has been made across the value chain from logistics, storage to marketing. Farmers are a part of a crop-specific FPC to aggregate their produce and sell to Sahyadri Farms. Grapes are one of the main crops growing in Nashik along with other crops such as tomatoes, guavas, bananas, etc. Produce is taken from farmers and aggregated for sorting, grading and packaging in their facilities. The premises are located close to the farms, reducing transport time, cost and optimises produce quality. Cold storage with a capacity of 2000 metric ton has been constructed to store crops. Such facilities allow market linkages with distant areas and exporting[3].

Due to a range of agri-input facilities such as storage capacity, food processing and assured transport facilities, farmers have noted a reduction in risks associated with market volatility. Some farmers associated with Sahyadri Farms have noted greater incomes as compared to farmers outside of the organisation. During surplus supplies or low market prices, crops such as tomatoes are processed and stored to be sold as puree or sauces.

The organisation is structured as a parent company, Sahyadri Farmers Producer Company Limited (SFPCL) with 650 members with individual shareholding (Patankar et al., 2020) SFPCL is responsible for post-harvest management and distribution of produce. Under the parent company, crop-wise farmer producer companies such as Grape FPC are formed to aggregate produce from small holder farmers. A subsidiary retail marketing company known as Sahyadri Agro Retails Ltd is responsible for sales, marketing, processing and consumer networking (*Sahyadri Farms: India's Largest Farmer Producer Company*, 2020). The business model adopts robust governance, aggregation and marketing. The structure allows clear decision-making through defined roles and responsibility for each stakeholder involved in the value chain from farm to fork.

[3] Presentation given by Sahyadri Farms during visit.

Thermal comfort for living, learning, working and connectivity

Although human populations are adapted according to their local climates, the mortality risk increases due to extreme heat (Kovats & Hajat, 2008; World Health Organization, 2014). In the past 50 years, heat waves killing more than 100 people have become twice as likely to occur during hot summers, and over 88 million people in rural areas, aged 65 years or over, (Census 2011) may be most at risk of heat-related mortality.

In order to reduce mortalities from high heat exposure, various studies have recommended passive cooling such as ventilation, roof insulation/reflection, increasing green spaces, painting roofs white to increase reflection as well as heat warning systems (Rogot et al., 1992; Silva et al., 2010). In rural areas, cooling with electrical appliances for air circulation and space cooling account for most of the electricity used (Smart Power India, 2019). Fan penetration in the rural market was approximately 65% in 2017 and is expected to reach up to 76-78% by 2019-20 (India Brand Equity Foundation, 2019). The building sector consumes around 57% of the entire cooling energy demand (Kumar et al., 2018). The SEforAll report in 2018 highlights key barriers in adopting energy efficient technologies include lack of financial support, imperfect communication with consumers on energy savings' benefits, and a lack of product availability especially in rural markets (SEforAll, 2018). Affordability remains a key issue in the penetration of cooling appliances such as air coolers and air conditioners.

India has more than 3000 cooling degree days, one of the highest in the world. A cooling degree day is a measurement quantifying demand of energy needed to cool a building. It is the number of degrees that a day's average temperature is above a reference temperature, which is the temperature above which buildings need to be cooled (Lalit & Kalanki, 2019). The Bureau of Energy Efficiency has notified in October 2019 that the default setting on air conditioners should be 24°C (Bureau of Energy Efficiency (Particulars and Manner of Their Display on Labels of Room Air Conditioners) Regulations, 2017, 2017), from January 2020. Prayas Energy Group suggests that while a reference temperature may be set for ACs, it is more appropriate to estimate 'trigger temperatures' for fans, coolers and ACs, that may vary for different income groups. The trigger temperature is the point at which a cooling appliance is turned on, considering the operating expenses. This may be 25°C, 26°C or 28°C for fans and coolers, and may even be 30°C or 32°C for ACs for different income banks (A. Sreenivas, personal communication, 16 November 2020). While this appears reasonable, studies on 'trigger temperatures' would be useful, especially in different climatic zones and humidity levels. The projected increase in cooling hours would push up this demand.

1. Managing the Heat – current practices

The Satara region usually experiences one or more heat waves between March to June that may last from 2 to 30 days. A number of measures are adopted to cope with the summer heat, such as working on the farms early in the mornings or later in the evenings when it is cooler, using shaded areas, using umbrellas or a scarf, dietary with more fluids like sugarcane juice or buttermilk, etc.

Table 38 – Cooling measures adopted in hot weather (apart from electrical appliances)

Cooling Measures	Karanjkhop		Randullabad		Yeola cluster	
	HH number	Percent	HH number	Percent	Number	Percent
Shade	165	35.56	180	72.58	230	
Use an umbrella or scarf	164	35.34	172	69.35	199	
Change in work timings	162	34.91	177	71.37	210	
Diet changes	134	28.88	155	62.50	27	

2. **Passive Cooling in Buildings**

Construction techniques, building materials, opening sizes in relation to room sizes, location of openings, building orientation of the building etc. are important in comfort in building interiors.
Passive cooling techniques often found in the traditional building structures include:

- Traditional pitched roofs
- Techniques to help dissipate warm air and take in cool air, such as addition of a mezzanine floor with wooden flooring, incorporation of ventilators, chimney shafts, and internal courtyards
- Use of building materials that keep the interior relatively cooler, such as Mangalore tiles and RCC slabs for roofs, stone, brickwork with mud plaster for walls, and stone for flooring
- Orientation of the building with respect to the sun path to avoid heating
- Appropriate window sizes for ventilation.

3. **Changes in housing structures**

Housing stock in Karanjkhop and Randullabad has undergone a substantial change in the last ten recent years with 38% of the houses in Karanjkhop and 72% percent in Randullabad reconstructed.

Table 39 - Age of residential structures in Satara cluster

Age of structure	Karanjkhop		Randullabad	
	Number	Percent	Number	Percent
0-10 years	175	38	181	71.8
10-25 years	156	34	44	17.7
25-50 years	84	18.3	17	6.9
50-100 years	40	8.7	9	3.6
More than 100 years	5	1	0	0

Roofing

Roofing materials commonly used in this cluster are cement sheet, Mangalore tiles, simple roofing tiles, asbestos and tin sheets. Thirty one houses in the cluster use mixed roofing or more than one roofing material. Tin sheet is the most common roofing material. Old houses usually have simple or Mangalore tiles. Even though they cause thermal discomfort during summer and create noise during monsoon season, tin sheets are preferred because they are sturdy, safe and secure, cause no water leakage, are cheap and easily available in the market. In order to avoid discomfort caused during summer and monsoon, people grow big trees around houses. On the other hand, simple and Mangalore tiled roofing require regular maintenance. Tiled roofs get damaged by monkeys and hail storms and are not easily repairable as skilled manpower for maintenance of these roof is not easily available. Cement slabs are expensive and only the affluent can afford this kind of house.

About 60% of the houses appear to be using roofing materials that are likely to make the interiors uncomfortably hot during the summers. Shifting to cooler materials may be expensive and/ or tedious, but simple modifications could help reduce heat and noise, such as a coat of reflective paint or adding a thatch for insulation and avoiding noise due to rain.

Figure 10 - Different types of household structures in Karanjkhop, Satara

Table 40 - Roofing materials of earlier residential structures, reported in Satara cluster				
Old house roof	Karanjkhop		Randullabad	
	Number	Percent	Number	Percent
Thatched	14	8.86	38	27.34
Simple tiles	58	36.71	71	51.08
Mangalore tiles	25	15.82	13	9.35
Tin sheet	55	34.81	13	9.35
Cement sheet	2	1.27	3	2.16
Asbestos sheet	0	0.00	0	0.00
Cement slab	4	2.53	1	0.72

Table 41 - Roofing materials in current residential structures								
Type of roofing	Karanjkhop		Randullabad		Cluster		Patoda	Dhulgaon
	Number	Percent	Number	Percent	Number	Percent	number	number
Tin sheet	258	62.32	127	51.42	385	58.25	87	57
Cement slab	80	19.32	17	6.88	97	14.67	31	14
Mangalore tiles	41	9.90	27	10.93	68	10.29	3	1
Simple tiles	17	4.11	33	13.36	50	7.56	4	0
Thatched	8	1.93	39	15.79	47	7.11	0	2
Asbestos sheet	6	1.45	2	0.81	8	1.21	0	0
Cement sheet	4	0.97	2	0.81	6	0.91	35	6

Walls

Most houses in the cluster have brick and cement walls, followed by houses with clay and stone walls. The more sophisticated walls of bricks, cemented and plastered, constitute 17.63 percent houses in the cluster. Twenty percent households in Randullabad have clay and thatch walls. 25 houses in Karanjkhop and 9 in Randullabad have more than two types of walls.

Table 42 - Walling materials of earlier residential structures, reported in Satara cluster

Previous house wall type	Karanjkhop		Randullabad	
	Number	Percent	Number	Percent
Clay and thatched	35	23.03	49	34.75
Clay and stone	100	65.79	80	56.74
Stone and cemented	3	1.97	5	3.55
Bricks and cement	10	6.58	7	4.96
Bricks, cement and plastered	4	2.63	0	0.00

Table 43 - Changes in wall materials, Yeola cluster

Wall material	Patoda		Dhulgaon	
	Earlier	Current	Earlier	Current
Clay and thatched	4	1	1	1
Clay and stone	15	2	2	13
Stone and cemented	1	37	1	14
Bricks and cement	4	111	1	50
Bricks, cement and plastered	-	4	-	1

Flooring

Even though walls and roofs are of modern construction materials, around 32 percent houses in Karanjkhop and 35 percent in Randullabad have floors with cow dung coating. Other preferred flooring materials are tiles, kota or marble stone floors. Cow dung coated floors provide excellent thermal comfort, but the task of maintaining such floors falls to women, adding to their drudgery.

Table 44 - Flooring materials of earlier structures, reported in Satara cluster

Material	Karanjkhop		Randullabad	
	Number	Percent	Number	Percent
Cow dung	63	78.75	126	86.90
Stone	2	2.5	0	0
Kota	3	3.75	5	3.45
Marble	6	7.5	1	0.69
Mosaic	0	0	0	0
Cement	3	3.75	11	7.59
Tiles	3	3.75	2	1.38

Table 45 - Flooring materials in current residential structures

Material	Karanjkhop		Randullabad		Cluster		Patoda	Dhulgaon
	Number	Percent	Number	Percent	Number	Percent	Number	Number
Cow dung	146	31.81	84	34.57	230	32.76	12	7
Stone	14	3.05	1	0.41	15	2.14	34	22
Kota	87	18.95	47	19.34	134	19.09	1	2
Marble	95	20.70	2	0.82	97	13.82	55	39
Mosaic	19	4.14	11	4.53	30	4.27	1	0
Cement	17	3.70	10	4.12	27	3.85	3	1
Tiles	81	17.65	88	36.21	169	24.07	53	9

4. **Shifts towards more energy intensive materials and increasing cooling demand**

The usage of traditional materials and designs is declining. The household survey revealed that during summer months, houses with roofs of cement slab and Mangalore tiles were least affected by heat, whereas roofs with asbestos sheet, tin sheet and simple tiles were most affected by heat. However, comparing the roofing materials in 2011 and 2019, the use of Mangalore Tiles and GI sheets has gone down, while Asbestos and RCC usage has increased. There is a shift away from relatively traditional to relatively modern materials in rural building structures, even though the use of materials like asbestos for roofing causes interiors to heat up. The patterns and reasons for these shifts elicited through discussions with residents and other stakeholders, showed that:

- People who have modest but stable incomes have preferred to continue using the traditional material of Mangalore Tiles.
- Residents with higher incomes have chosen to demolish their old residences and convert them to structures with modern construction techniques and materials such as RCC slab and aluminium sliding windows.
- Asbestos Cement sheets and GI sheets that are relatively cheaper but also durable, are preferred by residents facing economic hardships.

The number of houses in the village has increased by 5.4 percent, in the main *gaothan* area selected for mapping. Houses in the old Gaothan area of the village have continued to use traditional materials (Mangalore Tiles), but when repairs or modification are done, then Asbestos Cement or Galvanised Iron sheets replace the traditional materials. Residents who have constructed new houses or redeveloped old houses have preferred to go for RCC Slabs.

5. **Drivers of change in building materials and designs**

The reasons for choice of building material or construction technology, as elicited from the study are:

- Cost of material/ construction technique
- Availability of construction material
- Ease of maintenance
- Durability
- Thermal comfort

Roof material	Cost	Maintenance effort	Thermal comfort	Usage
Mangalore tiles	High	High	High	Decreasing
GI sheets	Low	Low	Low	Decreasing?
Asbestos sheets	Low	Low	Low	Increasing
RCC	High	Low	High	Increasing

The trend of change in building materials is likely to increase the demand for active cooling.

India’s Housing for All programme, the Pradhan Mantri Awas Yojana – Gramin (PMAY-G) presents an opportunity to strengthen climate responsive architecture and usage of appropriate building materials for thermal comfort. Financial assistance is provided for the rural poor for construction of houses. A few households in both villages have used the scheme (5.4 percent households in Karanjkhop and 2.4 percent in Randullabad).

The Ministry of Rural Development and the UNDP have developed *Pahal: Prakriti Hunar Lokvidya - A Compendium of Rural Housing Typologies*, with designs for appropriate and affordable designs for different regions in India. The Public Works Department, Govt of Maharashtra has recently included bamboo in the State Schedule of Rates 2020-21. Newer materials with high durability, ease of maintenance, lower costs, better thermal performance, locally sourced, and lower embedded energy may be explored.

"The Regional House Typology study has been done for Maharashtra by UNDP. This is a detailed and very useful, practice oriented study available for use. What is needed further is to develop guidelines for PMAY based on this study, and also mechanisms to get feedback from users and beneficiaries". Shri Bharat Shendge, Ex-Director, PMAY, Maharashtra

The uptake of PMAY-G has been limited in the project villages. However, as the major government-led programme for rural housing in the country, PMAY-G could become a key driver for energy efficient and climate responsive rural housing. Further work to develop the ecosystem for this sector and enhancing awareness about the benefits of such designs and materials, the possibility of priority support for energy efficient housing proposals under PMAY-G is essential and it could help in slowing down the trend of increasing cooling demand.

6. Vegetation and Greening

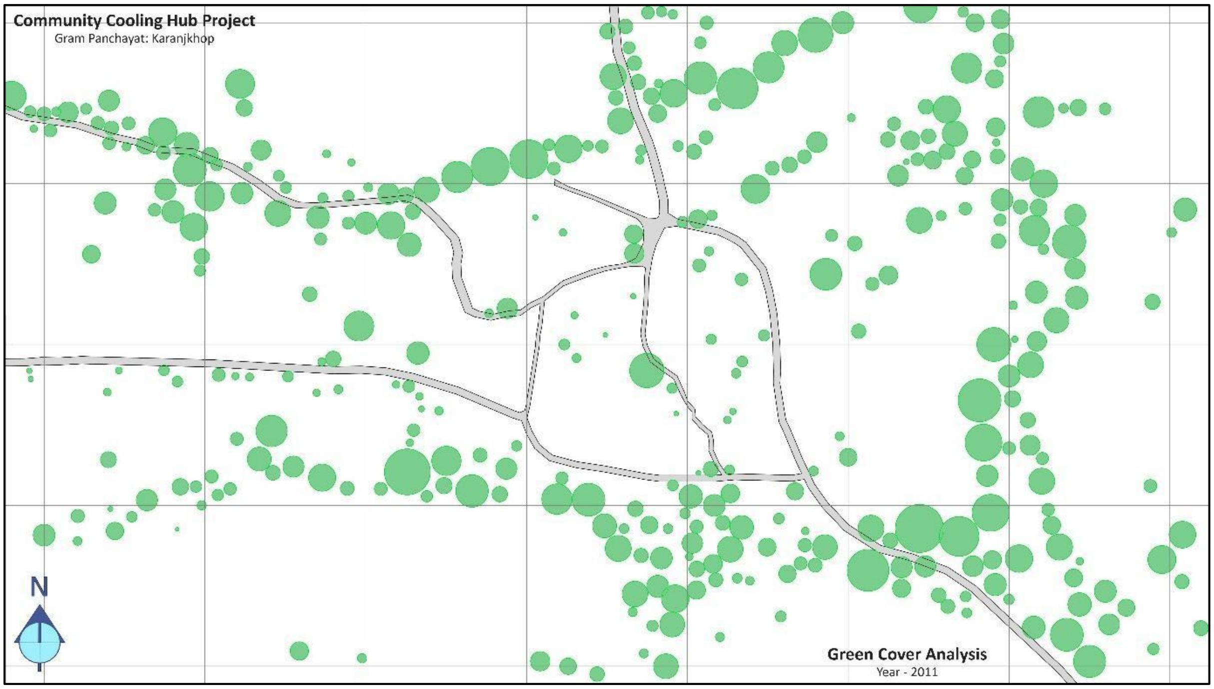
Big trees around the house play a very important role in providing respite from summer heat. They also protect the house from cyclonic winds and reduce the noise created by raindrops and hailstorms. In recent times, due to increase in population and new construction activities, the villages are becoming crowded and old trees are being cut down. In Karanjkhop, only about 28 percent households in Karanjkhop have trees around their houses. Comparatively, in Randullabad around 49 percent households have big trees near their houses. With limited room to construct spacious houses in the main village area, and security and safety no longer such a concern as they were decades ago, there is now a trend to construct new houses at farmlands, for those who can afford it. At the farm lands, there is usually enough space to plant trees around the house which helps in providing protection from extreme weather.

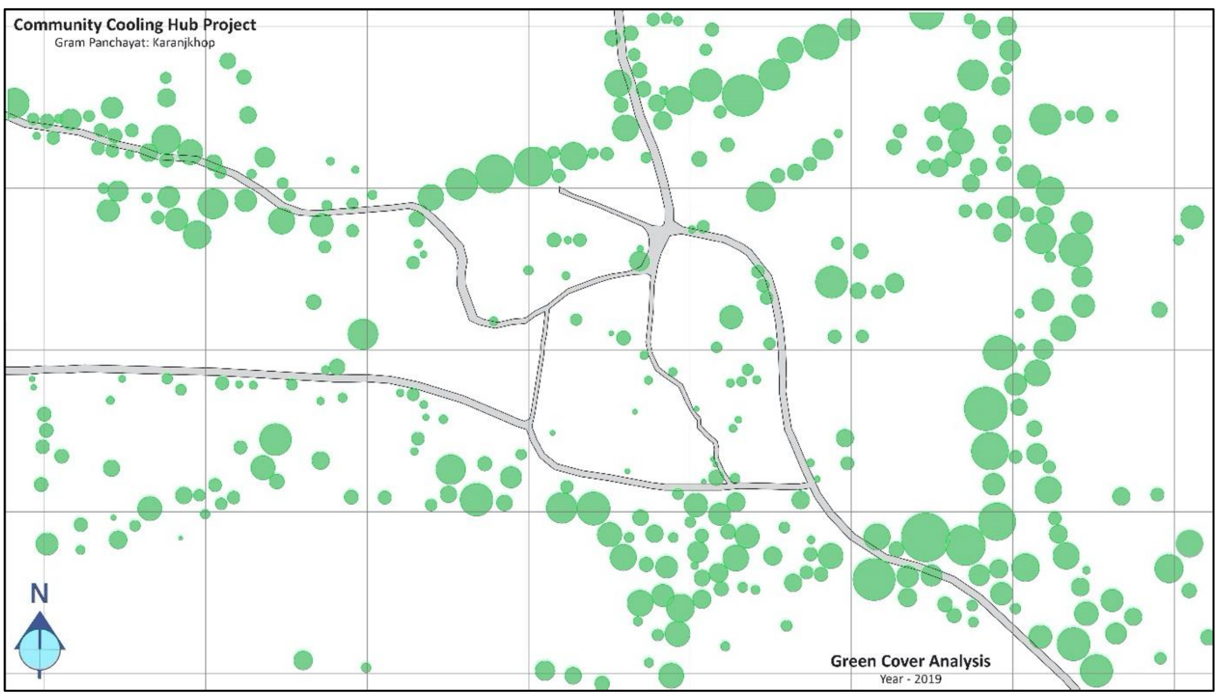
Table 46 - Green cover around houses

Trees around house	Karanjkhop		Randullabad		Patoda		Dhulgaon	
	Number	Percent	Number	Percent	Number		Number	
Yes	129	27.80	122	49.19	111		74	
No	335	72.20	126	50.81	50		6	

A physical count of trees using the satellite image shows that the total number of fully grown trees in the village in 2011 was 343. As of 2019, the total number of trees was 351. Even though there is a small increase in the number of total trees, it has been observed that in 2011 older larger trees were in significant numbers. New trees have been planted in the village recently. The tree canopy comparison using the satellite images shows that total green cover has reduced by 5.5 percent.

Figure 11 - Green Cover in Karanjkhop, 2011 & 2019





7. **Access to space cooling**

Fans and table fans are most prevalent, yet much below the national and state averages. Only a few houses have coolers, though about 25 percent respondents were interested to buy a cooler and 16 percent wanted to buy fans. 129 households in the cluster have refrigerators. Most households have started buying refrigerators in the last 4 years. More than half the respondents felt that their present cooling equipment is adequate and do not wish to buy more equipment. Very few households are interested in buying air conditioners (1.5%).

Table 47 - Households with cooling appliances in Satara cluster

Appliances	Households in Karanjkhop		Households in Randullabad	
	Number	Percentage	Number	Percentage
Fan	87	18.8	90	36.3
Table fan	65	14	81	32.7
Cooler	6	1.3	1	0.4
Refrigerator	59	12.7	68	27.4

Table 48 - Usage of different cooling appliances in Satara cluster

Equipment		Karanjkhop	Randullabad	Cluster
Fan	Average age	6.38	4.09	5.24
	Number	132	103	235
	Number of households	87	90	177
	Average price (Rs.)	1854	2239	1212
	Average use per day	7.26	8.33	7.80
Table fan	Average age (yrs)	3.17	3.05	3.11
	Number	70	81	151
	Number of households	65	81	146
	Average price (Rs.)	1392	1986	1689
	Average use per day	7.54	9.91	8.73
Cooler	Average age	0.19	1.4	0.80
	Number	6	5	11
	Number of households	6	5	11
	Average price (Rs.)	5900	3300	4600
	Average use per day (summers only)	4	3	3.5

Table 49 - Usage of cooling appliances in Yeola cluster

Equipment	Parameter	Value
Fan	Average age years	3.86
	Number per household	1.11
	Average price	1400
	Average use per day	4.71
Table fan	Average age	4.8
	Number per household	1.05
	Average price	2000
	Average use per day	6
Cooler	Average age	2.71
	Number per household	1
	Average price	-
	Average use per day	4

Table 50 - Desire to purchase household cooling equipment				
	Karanjkhop		Randullabad	
	Number of HH	Percent	Number of HH	Percent
Fan (Ceiling and table)	107	23.06	9	3.63
Cooler	60	12.93	120	48.39
AC	6	1.29	9	3.63
Additional space cooling not required	287	61.85	110	41.94
Refrigerator	147	31.68	73	29.44
Refrigerator not required	317	68.32	173	69.75

8. Awareness about health impacts of heat

Though respondents were able to direct relation of heat with exhaustion and heat stroke, they were largely unaware of the relation between heat stress and ailments related to the heart, kidney, lungs, brain and diabetes. The awareness is slightly higher in Randullabad as compared to Karanjkhop where on an average 1.85 percent people think that there is any relation between extreme heat and these illnesses. Except diabetes almost 17.74 percent people think that there is a relation between extreme heat and these illnesses. Surprisingly about 80 percent of the patients at the Rural hospital have weakness, joint pain etc. due to working long hours under the sun in farms.

Table 51 - Awareness about heat related illnesses							
Related disease	Karanjkhop (percent)			Randullabad (percent)		Yeola cluster (percent)	
	Yes	No	Don't Know	Yes	No	**Yes**	**No**
Heart	2.16	88.36	9.48	22.98	77.02	53.11	46.89
Kidney	1.51	89.01	9.48	16.53	83.47	46.47	53.53
Lungs	2.80	85.13	12.07	14.52	85.48	3.11	6.89
Brain	0.86	88.15	10.99	16.94	83.06	39.00	61.00
Diabetes	1.94	87.72	10.34	2.02	97.98	14.94	85.06

9. Socio-economic and environmental implications

The availability of active cooling services and products may lead to an increase in energy consumption, which unless powered by renewable sources may increase the carbon footprint. The consideration of high energy bills in part may keep the usage of cooling devices down to when necessary.

Promotion of traditional practices including changes on diets, clothing, work schedules and lifestyles for summer months, passive cooling and making it accessible in terms of materials, costs and trained human resources should accompany expansion of active cooling for thermal comfort.

"My husband is a daily wager and I take up tailoring jobs at home to support the family. In the summer it becomes really difficult to work, stay and sleep in tin shed houses. Also as we can't afford refrigerator and the temperature in tin shed house is high, the leftover food and milk always get spoiled"

Chitra Dagale, Bhatwadi, Sinnar

An approach that combines behaviour changes, physiological acclimatization, and passive and active cooling would help in lowering the adverse impact of extreme heat on personal health, and of cooling service provision on the environment.

Human Health Services

The cooling needs in the rural health sector include cooling for vaccine storage, storage of medicines at the sub-centres/ primary health centre (PHC)/ Rural Hospital (RH), blood storage and thermal comfort in health care setups. Health care services are provided by both public and private health care facilities.
India's Universal Immunization Programme (UIP) targets about 26.7 million infants and 29 million pregnant women every year. The Ministry of Health and Family Welfare, Govt of India has set a goal of 90% Fully Immunized Children. The proportion of immunized children was about 62% in 2015-16. Since then, through Mission Indradhanush and Intensified Mission Indradhanush, the Ministry has sought to accelerate vaccination coverage in coordination with multiple ministries and government bodies. To address existing gaps and meet the additional requirement due to new vaccines being added to the UIP, over 28,340 cold chain equipment were purchased and distributed to various states/ districts.

The Electronic Vaccine Intelligence Network (eVIN) is a digital information system on the vaccine supply chain, stocks and storage temperatures. Through an initiative supported by GAVI-the Vaccine Alliance, and UNDP, eVIN is being set up at all 27,000 vaccine storage centres across all districts in the country. This system facilitates real-time monitoring of storage temperatures by installation of nearly 50,000 temperature loggers. Cold chain managers are being deployed in every district for supervision.

1. **Current Practices**

   In the Satara cluster, two private clinics in Karanjkhop and one in Randullabad provide outpatient care for minor health problems. People usually access these facilities even if they have to pay for services because they are highly accessible. The nearest Public Health Sub-centre in this cluster is in Karanjkhop. The sub-centre building is under renovation at the moment hence it is not operational. The Rural Hospital in Pimpode is at distance of 7.5 Km from Karanjkhop. The Primary Health Centre is situated in Wathar at a distance of 12.8 Km. Satara Civil Hospital is at a distance of 48 Km.

   The interviews of health care staff indicated that usually vaccines are supplied as per demand, every month.. Vaccination days for vaccines of which open vials can't be kept are planned carefully. Usually, there is no vaccine loss at the PHC.

   Currently the labour room at the PHC in the Satara cluster does not have an air conditioner. The nearest blood bank is at Satara, 60 km away. The Rural Hospital and Primary Health Centre procure blood in advance from Satara and preserves that in the medical supplies refrigerator. The ambulance is not air conditioned.

2. **Reach of national vaccine programmes**

   As per the National Family Health Survey 2015-2016 (NFHS 4), Nashik had 79% while Satara had 59% Fully Immunized Children. However, healthcare staff at the Primary Health Centres of these clusters have stated that the coverage is now 100%, with the efforts under Mission Indradhanush. The results of the latest survey, NFHS 5, are not yet published due to the disruptions caused by Covid 19.

3. **Cooling needs in health care facilities**

   Space cooling is needed for the care of patients, in labour rooms, operation theatre, delivery ward as well as for the work efficiency of the staff. The Labour Room Quality Improvement Initiative (LAQSHYA) guidelines, 2017 by the Government of India recommend that labour complexes should have split ACs with required tonnage (tonnage=Square root of area) / 10) and one ceiling fan per labour table. Currently, the Primary Health Centre in Wathar station and Rural Hospital in Pimpode do not have air conditioning.

The adequacy of current health services, and consequently the (latent) cooling demand, is related in part, to the proximity and accessibility of health services.

Table 52 - Cooling demand related to health services				
Sub-sector	**Commodity**	Temp range	Relative humidity	**Capacity**
Vaccine storage (RH & PHC)	Vaccine and Ice pack Freezer	-15 to -25	NA	0.091 m^3
	Ice-lined Refrigerator	2 to 8	NA	0.095 m^3
	Insulated Ice box	2 to 8	NA	0.27 m^3
	Vaccine carriers	2 to 8	NA	0.0054 m^3
Medicine storage (RH & PHC)	Operation theatre	2 to 8	NA	0.44 m^3 (170 lit)
	Labour room	2 to 8	NA	0.44 m^3 (170 lit)
	Pharmacy	2 to 8	NA	0.44 m^3 (170 lit)
Blood storage (RH & PHC)	Blood bags	2 to 6	NA	0.30 m^3
Building Space cooling (1.60 $m^{3)}$	Labour room	26 to 28	NA	1 Ton split AC & 1 ceiling fan
	Operation theatre	26 to 28	NA	1 Ton
	Delivery ward	26 to 2	NA	3 Ton AC & 3 Fans
	Staff room	26 to 28	NA	1 Ton AC

4. Future needs for cooling facilities in healthcare centres

Along with active cooling solutions, some passive methods of thermal cooling such as changes in building structure, materials could be suggested so that health facilities have thermal comfort for patients.

The last active cooling points are the Rural Hospital and Primary Health Centres. The time or distance the vaccine has to travel in passive cooling should not be more than 8 hours. Wastage of vaccines, and the time spent in travel could be reduced by setting up active cooling points closer to the villages. Vaccine carriers are designed for ambient temperature of 43 ^{0}C. With future temperature projections, some design changes in vaccine carriers, or practice changes may be needed to avoid temperature breaches.

Cooling Needs Quantification

1. Total agricultural production and volumetric cooling requirements

Satara Cluster: The analysis is done based on annual agricultural production of the survey sampled population.. The analysis also covers other major areas of cooling needs such as health, animal husbandry and transport. Table 53 consolidates the volume of agriculture production and cold storage requirements such as temperature, relative humidity for each agriculture commodity grown in studied sites.

Sinnar Cluster: Most of the crop is harvested in March and hence, the cooling demand would be higher during this month with load up to 8000 kg. This is due to an addition of 6300 kg onion crop production solely in March. October has the second highest production as carrot production rises to about 2300 kg. Tomato production sharply increases in August by 3100 kg.

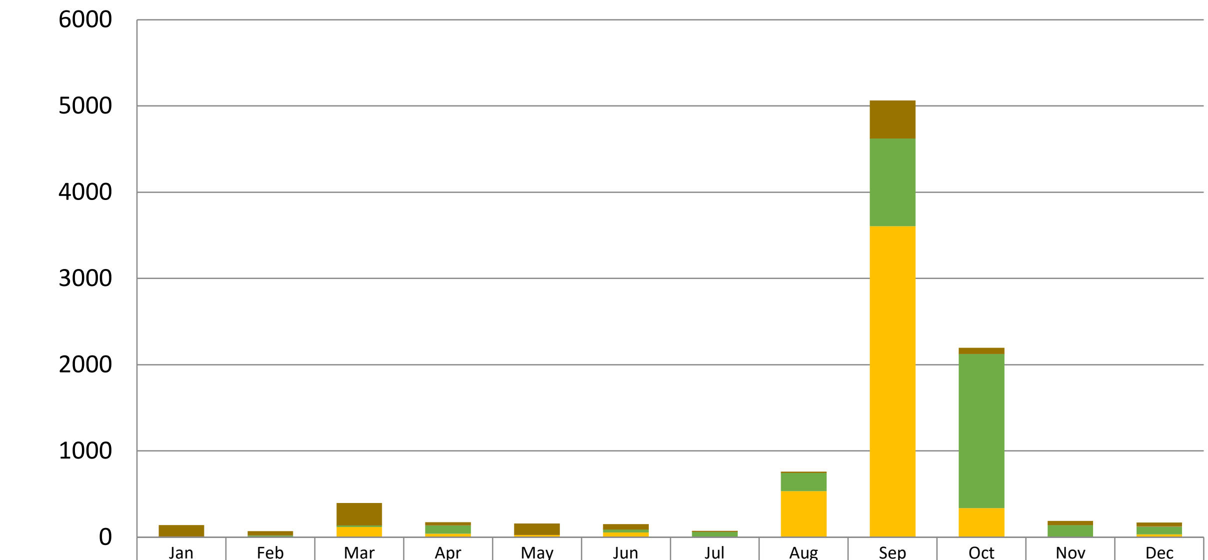
Yeola Cluster: Most of the crop is harvested in March, like at Sinnar. Total annual production reached 24683 kg in March with the addition of 16596 kg/m^3 onion crop production and 7600 kg grapes. Maize production increased sharply by 2904 kg/ in November. During the summer months, there is no perishable produce in Yeola cluster.

Table 53 - Sector-wise agriculture production and volumes of cooling requirements for Satara cluster

Sub-sector	Commodity	Temperature range	Relative humidity	Annual quantity Kg & (m^3)	Application
Seed storage	Potato	12 °C	90-95	43920 Kg (418 m^3)	@800 Kg per acre (54.9 acre)

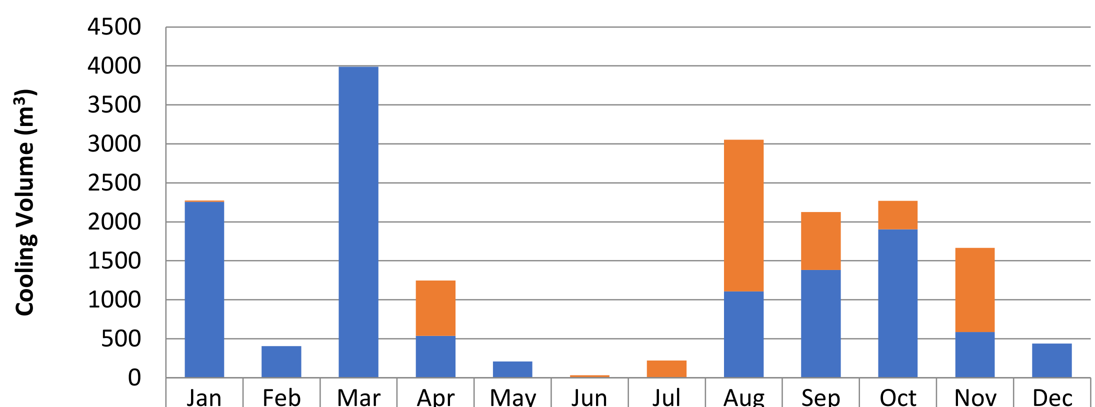
Sub-sector	Commodity	Temperature range	Relative humidity	Annual Volume (Kg & m^3)	Density
Produce cooling	Banana	12 to 15°C	85 to 95	50000Kg (52.58 m^3)	950.93 Kg/ m^3
	Chilly	10 to 15°C	85 to 95	80 (1.41 m^3)	56.74 Kg/ m^3
	Common Bean	5 to 6°C	90 to 95	223575Kg (2129.28 m^3)	105 Kg/ m^3
	Drumstick	14°C	65 to 70	5000Kg (119.22 m^3)	42 Kg/ m^3
	Garlic	0°C	65 to 70	3115Kg (35.65 m^3)	87.38 Kg/ m^3
	Ginger	10 to 12°C	90	29700Kg (283.27 m^3)	104.85 Kg/ m^3
	Green pea	0 to 2°C	90 to 95	208482 Kg (3561.36 m^3)	58.54 Kg/ m^3
	Lima Bean	3 to 5°C	90 to 95	4660Kg (88.88 m^3)	52.43 Kg/ m^3
	Maize	0°C	95 to 98	1000Kg (9.54 m^3)	104.82 Kg/ m^3
	Onion	0°C	65 to 70	22390Kg (256.27 m^3)	87.37 Kg/ m^3
	Pomegranate	0°C	90 to 95	4000Kg (20.25 m^3)	197.53 Kg/ m^3
	Potato	4 to 8°C	95	217750Kg (2076.98 m^3)	104.84 Kg/ m^3
	Pumpkin	10 to 13°C	50 to 70	27000Kg (54.77 m^3)	492.98 Kg/ m^3
	Tomato	13 to 21°C	90 to 95	104740Kg (482.04 m^3)	217.28 Kg/ m^3
	Turmeric	3 to 5°C	65 to 75	18700Kg (176.36 m^3)	106.03 Kg/ m^3
Total				937112Kg (9757.24 m^3)	

Figure 12 - Cooling needs by temperature and volume in Satara cluster



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
10 to 21 C	127.23	46.23	258.52	33.92	132.03	63.87	8.73	14.2	438.89	69.69	46.6	46.97
5 C	1.48	1.15	1.15	1.15	1.15	1.47	1.47	1.47	1.47	1.48	1.48	1.48
2 to 8 C	6.51	17.29	18.24	98.83	2.5	32.1	59.8	209.48	1014.87	1786.17	138.47	88.34
Below 2 C	3.42	5.72	117.47	38.34	23.75	54.45	1.71	534.24	3606.44	337.53	0	34.33
-17.8 to 4.4 C	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34

Figure 13 - Cooling needs by temperature and volume in Sinnar cluster



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
10 to 21 C	18	0	0	708	0	25	211	1947	743	365	1077	0
2 to 8 C	2255	405	3987	539	211	9	9	1108	1384	1906	588	439

Figure 14 - Month-wise crop production volume, Sinnar cluster

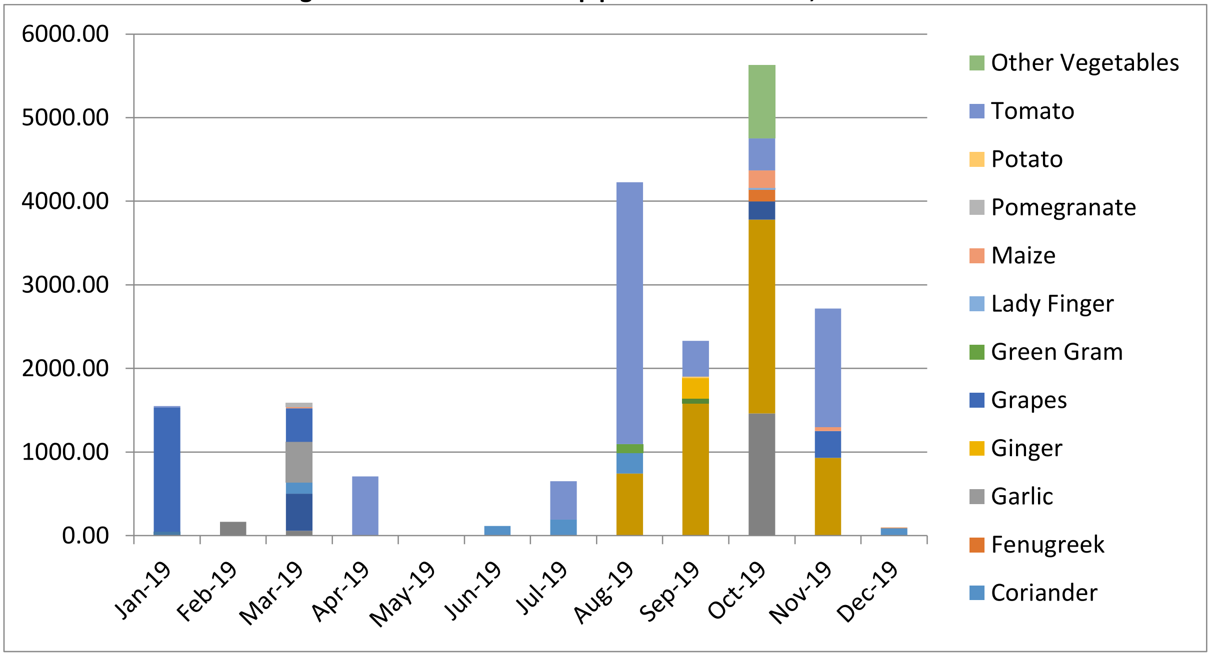
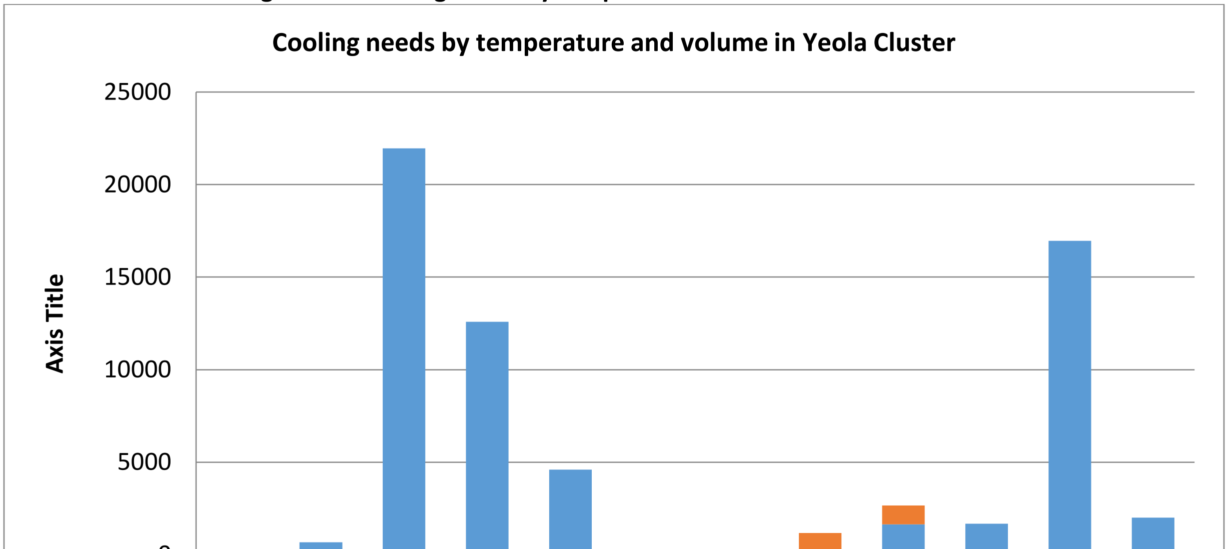
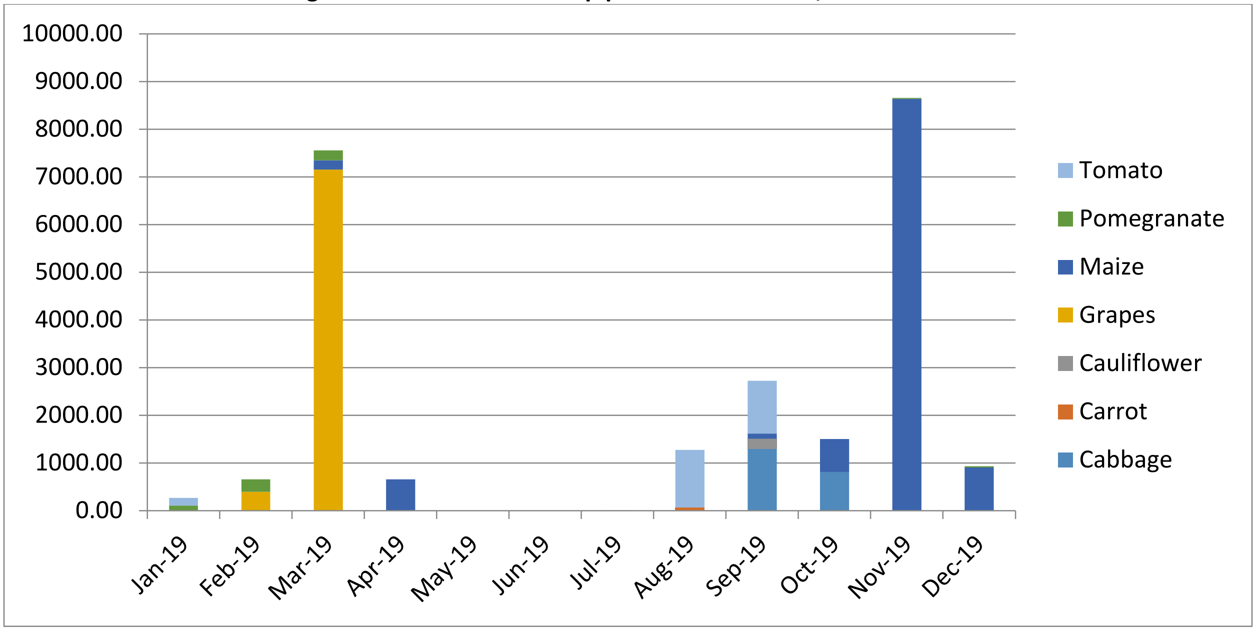


Figure 15 - Cooling needs by temperature and volume in Yeola Cluster



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
10 to 21 C	147	0	0	0	0	0	3	1112	1019	0	0	0
2 to 8 C	114	674	21970	12592	4590	0	0	64	1639	1665	16958	1996

Figure 16 - Month-wise crop production volume, Yeola Custer



Passenger transport cooling needs

Motorbikes and public bus services (state transport or ST buses) are the most preferred primary mode of transport for trips outside the villages in the Satara and Yeola clusters. About 62 percent and 38 percent commuters in Karanjkhop and Randullabad respectively stated the public bus service as their primary preference. In Yeola too, motorbikes are the most used primary mode of transport and the public bus is the most important secondary mode. Shared vehicles is the most preferred secondary mode in Satara cluster. This is the case in Yeola cluster too, but the proportion is lesser.

Personal motorized two-wheelers are used for trips to the nearest markets. Trips to Satara and Wai to sell agriculture produce, buy vegetables and other provisions and to access tertiary health care are typically by bus or share-autos. Hired shared jeeps and public bus services are preferred for trips to Pune and other distant cities and destinations. A similar pattern is observed in Yeola cluster.

Table 54 - Mode of travel

Satara cluster modes	Karanjkhop		Randullabad	
	Primary (%)	Secondary (%)	Primary (%)	Secondary (%)
Two-wheeler	33.62	1.94	50.80	9.68
Four-wheeler	1.29	2.16	6.45	13.31
State transport bus	61.64	34.27	38.30	40.73
Share auto, jeeps, vans	3.02	59.91	2.82	22.98
Railway	0	0	0	2.02
Yeola cluster modes	Dhulgaon		Patoda	
	Primary	Secondary	Primary	Secondary
Two wheeler	90.00	0.00	77.64	1.24
Four wheeler	1.25	6.33	0.00	5.59
State transport bus	6.25	83.54	21.74	68.32
Share auto, jeeps, vans	2.5	10.13	0.6	18.63
Railway	0.00	0.00	0.00	0.00

The public bus services that run between villages and from block/ district level to village do not have air conditioning. As the frequency of the public bus services is very low, share taxis are used, but as they tend to overload passengers they are not the most preferred option.

Except in Karanjkhop (42 percent), more than half the respondents in the other villages expressed the need of air conditioning in passenger transport.

Table 55 - Preference for air conditioning in passenger transport

	Karanjkhop	Randullabad	Patoda	Dhulgaon
Percentage responding 'yes'	42	59	73	58

The basic public transport services need strengthening, including both public bus services as well as shared rickshaw or other intermediate public transport modes.

Public interest in cooling solutions

One of the questions asked in the household survey was whether any discussions have been taking place in the village community on the need for cooling in any of the sectors. Responses showed that there have been multiple discussions in the study villages around topics such as measures to be taken to prevent loss of agriculture produce, milk and milk products, thermal comfort in schools and anganwadis, tree plantation, environment preservation, up-gradation of health centres. The major issues of concern in both the villages are spoilage of agriculture produce, milk and milk products, tree plantation and equip sub-centers to provide quality health services. The farmers are keen to prevent loss of agriculture produce such as common beans, green peas, potato and potato seeds.

In Randullabad gram panchayat, all these issues have been discussed at least once. The satellite imagery analysis of Karanjkhop showed that new trees have been planted in this region. The sub centre in the village is being newly constructed and villagers hoped to have a well-resourced sub-centre. The anganwadis in Randullabad do not have an electricity connection causing thermal discomfort to children and anganwadi workers. The school building has tin sheet roofing making it uncomfortably hot. The teachers have planted trees around the school which provide some respite during the summer. In Randullabad, villagers have taken an initiative to construct a check dam near the village and have prepared a water budget of the village.

Box 11 - Cooling related discussion topics raised in the gram sabha

- Spoilage of agricultural produce, milk and milk products
- School building repairs & comfort of students in all seasons (e.g. install fans, roofing work)
- Tree plantation
- Environmental degradation and measures to prevent it
- Install fan and preservation unit for vaccines in the sub-centre

Community participation in the gram sabha is higher in Randullabad (65.32%) as compare to Karanjkhop (38.36%). Randullabad is a smaller village and BAIF has been working in this village for the last twelve years and a number of projects have been taken up with the community's participation. The two milk dairies in the village operate on cooperative basis. These factors have contributed towards community mobilization and organization in Randullabad. In the last one year, four gram sabhas have been conducted in Randullabad while in Karanjkhop, five gram sabhas have been conducted. The women organizations in both the villages are also very active. Four mahila gram sabhas have been conducted in both the villages in the last one year.

This indicates that there is considerable public interest and likelihood of active participation in developing community cooling solutions.

5. Designing Community Cooling Hubs

1. **Framework or Principles for 'fit-to-purpose' CCH facility**
   The ambition for CCHs is that cooling would help enhance the well-being of the community, for which the SDG targets provide a broad reference framework. The following are suggested as a minimum framework to guide the development of 'fit to purpose' localized solutions:
   1. Improve well-being of all, especially in outcomes of nutrition, health, incomes, and clean energy
   2. Prioritize benefits to the poorest and more marginalized individuals and households, and help reduce inequities and inequalities
   3. Improve the participation of women and marginalized individuals and groups in decision-making
   4. Improve understanding about climate change and environmental management Improve the resilience and productivity of the natural resource base (or at least 'do no harm')
   5. Reduce losses and wastes of resources
   6. Mitigate GHG emissions/ be carbon neutral and not use ozone depleting substances

2. **Governance and Business Models**
   Appropriate governance and business models will be needed to apply the above principles into the functioning of the entity and enable efficient, decentralized, democratic functioning and just redistribution of benefits to community members. Further deliberation is needed on certain aspects that would influence how true to the principles would the CCH organization remain over time:
   - Equitable distribution of economic benefits depends upon the larger social context and systems. The governance model for CCH would need to carefully consider the local context and bring in affirmative action within reasonable limits of economic sustainability. The experience with cooperatives and FPOs shows that the egalitarian objectives of such institutions may get compromised with political interference and control.
   - Financing models available/ accessed for development of CCH. What kind of mix may help in balancing between political stakes and economic and social sustainability is a question for deliberation.
   - Adequacy of the current policy frameworks and whether they are conducive enough to promote sustainable models of renewable energy, and what competition a CCH facility using renewables may face from cheaper, conventional electricity and fossil fuel based options.

   While it is anticipated that the main economic activity and revenue source will be agriculture and dairy, certain services and associated charges may need to be developed through institutional partnerships with government entities, such as the Education Dept, Health Dept, and Women and Child Development Dept.

   The entity that manages the CCH will need an organizational structure and processes with functional capabilities that could include the following, depending on the services offered:
   - Clarity of vision and purpose of the cooling hub and cooling solution
   - Systems to monitor and evaluate the extent to which the purpose is served
   - Continued inventorying of cooling needs and methods of service provision
   - Management and maintenance of cooling infrastructure and services
   - Product labelling, traceability, reporting protocols for sensitive products like vaccines
   - Policy on costing and pricing of different cooling facilities and services
   - Commercial negotiation practices with different types of customers

● Marketing of fruits, vegetables and other produce
● Post-harvest handling of produce
● Education and outreach related to the range of services, e.g. for nutrition, human and animal health, space cooling including passive cooling, resilience of the resource base, etc.
● Facilitating training and skilling for use of cooling facilities, e.g. in mushroom cultivation

The governing institution can additionally take responsibility of setting up market linkages, promoting modern farming practices, extension services, deciding crops and promote collaborative farming.
The governing structure of the CCH may include a Chairperson, a Board of Directors and a general body of members. The executive staff of the CCH may be appointed separately and may include:
● Chief Executive Officer
● CCH facility manager
● Administration in charge
● Marketing and sales manager
● Accountant
● Loading unloading staff
● Reefer vehicle driver

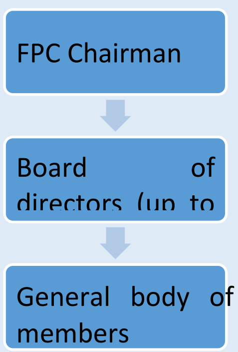
Multiple options of business models to run CCHs are presented in Table 56. Developing cluster-specific business models will enable integrated planning for cold chain infrastructure.

Table 56 - Business Model options to manage community cooling hubs

Elements	FPO	Cooperative	Private entity	Government
Ownership of Infrastructure	FPO	Cooperative	Private entity	Government
Management	Board of Directors of FPO/ hired staff	Cooperative Board/ hired staff	By a private entity/ employee	By a government department / staff
Services	• Members have access to a fixed quantum of cooling space with additional space available on rent • Individual, institutional non-members hire space against user charges		Facility is leased to individual and institutional users against user charges	
	Public health services to be paid for by the related government agencies, e.g. storage of vaccines under the UIP, cooling services for anganwadi space, cooling of mid-day meal provisions			
Farm supplies	Inputs can be bought in wholesale and sold to members		Bulk procurement against orders	Subsidised inputs
Sources of Finance	Grants, loans	Grants, loans	Owners' investment, loans	Subsidies, schemes
Revenue Sources	Multiple cooling services	Multiple cooling services	Multiple cooling services	Agriculture production, user fees
Profit-sharing	Farmers as FPO shareholders	Cooperative members	Proprietors	No 'profits' are made
Procurement - Manpower, insurance	Trained professional body	Labourers as manpower, collective Insurance	Company employed manpower, Private insurance schemes	Government-led insurance schemes
Market access	Contracts, commercial centres	Nearby markets	Contracts, service agreements, marketing channels	Mandis, APMC

Box 12 - FPO as the Manager

Farmer Producer Organisations (FPOs) have been an efficient and cost-effective way to benefit small and marginal farmers. Currently, one of the key issues faced by FPOs is the lack of access to infrastructure such as warehousing and cold chain facilities. In most commercial agriculture models, primary producers are missing. By aggregating resources and produce, FPOs can manage production and post-harvest handling. Due to the economy of scale, FPO model can manage agri-supply chain along with post-harvest processes to connect with multiple consumer sets. See Figure 17.



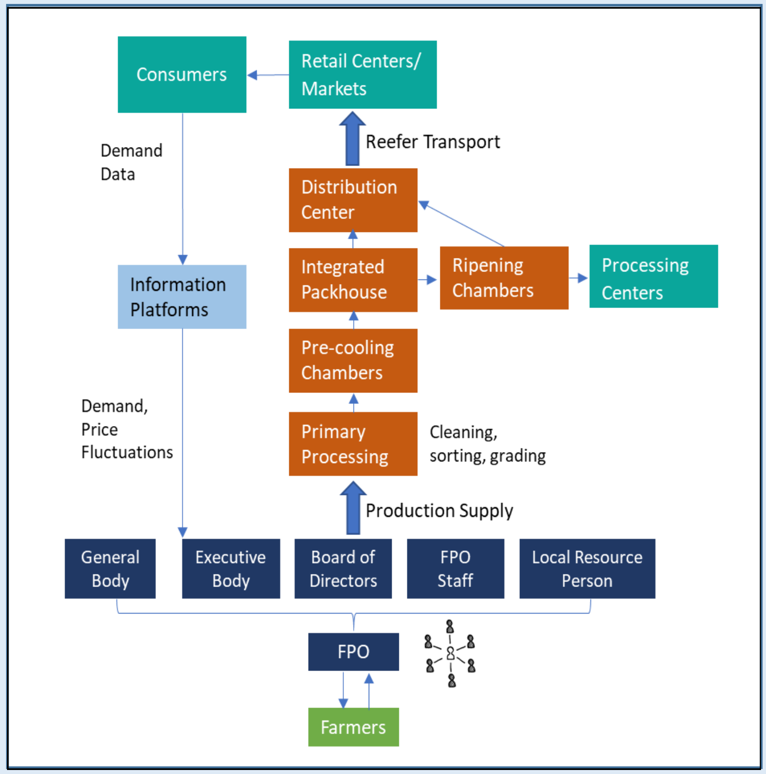


Figure 17 - Farmer Producer Organisation Model

<table>
<tr><th colspan="3">Table 57 - NGO partners ' preferences for governance and business model for CCH</th></tr>
<tr><th>Entity</th><th>Advantages</th><th>Disadvantages</th></tr>
<tr><td rowspan="2">FPCs</td><td>BAIF
• This is the best governance option as the members are already accustomed to governance and are generally better equipped for running business model.
• If good business plan is given, FPOs can run CCH efficiently
• Capital required can be partially raised through shares.</td><td>• If business plan fails, FPOs won't be able to govern.
• Large number of members can be disadvantageous.
• FPOs are centralized, profit will not be redistributed.</td></tr>
<tr><td>Yuva Mitra
• Yuva Mitra can bring in private investors, which is the model adopted by Krushak Mitra
• A not-for-profit company can be registered (Section 8), with farmers as shareholders
• YM has brought together 1000-2000 farmers as FPO.
• FPO can manage on a macro-level.
• It will be easy to seek funds from government
• It has social investment in the form of shares</td><td>As number of members are high, at times it is difficult to arrive at the consensus.</td></tr>
<tr><td rowspan="2">Cooperative</td><td>BAIF
Milk cooperatives can take over the storage of milk</td><td>Cooperatives supply milk to different dairies, integration may be challenging</td></tr>
<tr><td>Yuva Mitra</td><td>Politicization is a hurdle</td></tr>
<tr><td rowspan="2">SHG</td><td>BAIF
• SHG help can be taken for some sectors
• SHGs are very active
• There is one organization of SHGs: Sanyukta Mahila Samiti</td><td></td></tr>
<tr><td>Yuva Mitra
SHG is informal version of FPOs. SHG can manage operations on micro-level for bringing together groups within areas itself.</td><td></td></tr>
<tr><td rowspan="2">Youth Association</td><td>BAIF - Youth associations are there. But potential is unknown</td><td></td></tr>
<tr><td>Yuva Mitra - Not considered</td><td></td></tr>
<tr><td rowspan="2">Gram Panchayat</td><td>BAIF
Overall management can be taken care of by Gram Panchayat. They need to involve as they can address community level issue effectively</td><td></td></tr>
<tr><td>Yuva Mitra
-</td><td>Yuva Mitra
Politicization is a hurdle. A 50 MT cooling plus 50MT precooling was set up near Sinnar. Due to political conflict, it has not been opened yet for use of farmers</td></tr>
<tr><td>Village watershed committee</td><td>BAIF
• Small number of members, can take quick decisions and work efficiently.
• BAIF implements all its projects though these committees.</td><td></td></tr>
</table>

3. Business Potential and Sales Forecast

Table 58 - Immediate sales potential of Community Cooling Hub		
Sectors	Annual fee	Comment
1. Agriculture Produce	854904	@Rs1 per Kg per 15 days
2. Seed storage	600000	@Rs1 per Kg per season
3. Cow, buffalo milk, milk products	50000	Rs 10000 per month, equivalent to monthly operational cost of dairy
4. Goat milk and milk products	54000	Considering goat milk production of about 2000 litres, daily 500 lites cheese plant processes 500 litres milk per day. Cooling cost @Rs1 per litre per day. Assuming same scheme implemented in Koregaon
5. Animal vaccine	5200	@Rs 1 per dose
Total yearly collection	1564104	

Table 59 - Rural cooling service business potential

Likelihood	Cold storage and cooling services		Potential customers / partners
High	Mid-day meal	Fruits, vegetables, milk, eggs storage	Anganwadi, School
High	Retail and home food	Fruits, vegetables, milk, eggs, chocolates	Shop owner/ shop keeper/ households
High		Chilled water, cold drinks,	
High		Meat, ice-cream	
High	Seed storage	Long duration storage of seeds	Individual farmers/ FPO
Needs further discussion	Coolhouse	Cool space to grow mushrooms etc	Individual farmers
High	Packhouse	Table and shelving space hire for sorting, grading, packing of fruits, vegetables	Individual farmers / FPO
High	Fruit & vegetable store	Day, week and month wise storage	Individual farmers
Medium	Food processing	Processing, storage	FPO/ SHG/ entrepreneurs
High	Dairy	Bulk milk cooler	Dairy Cooperative
High		Dairy processing plant	
High	Eggs	Storage	Individual poultry farmers
Medium	Meat	Slaughterhouse, packaging	Animal keepers cooperative
Medium		Storage	
Needs further discussion	Artificial insemination	AI straws storage	BAIF
High	Vaccine & medical supply store	Animal vaccine storage	Pharmacist
Needs further discussion		Human vaccine, blood, medical supplies	PHC/ Dept of Health
High	Vaccine icepacks	Icepacks for animal vaccine carriers	Pharmacist
Needs further discussion		Icepacks for human vaccine carriers	Health Dept
Needs further discussion	District cooling	Health facility cooling	Health Dept
Needs further discussion		Community space cooling	Gram Panchayat
Medium		Anganwadi space cooling	Gram Panchayat / ICDS Dept
Needs further discussion		Homes and workspaces (e.g. banks)	Individual homes & entities
Needs further discussion	Vehicle cooling	Private transport cooling	Individual users
Needs further discussion		Public transport cooling	MSRTC, operators
Needs further discussion		Para-transit cooling	Operators
Needs further discussion	Emergency supplies	Storage of rations, medical supplies	Gram Panchayat

Likelihood: High (green) | Medium (yellow) | Needs further discussion (grey)

4. Start-up Expenditure

The start-up expenditure would include:

- Rent/ purchase land
- Cost for obtaining licenses and permits
- CCH design, manufacture and commissioning
- Reefer vehicle purchase
- Market promotion
- Operational cost for 3 months

Multiple components are needed to form an integrated system. The financial expenditure needed is given in Table 60.

Table 60 - Cost of Components for Integrated cold chain infrastructure

Component	Price in INR
Post-harvest unit (Primary processing)	INR 31.5 million
Plastic crates 20kg capacity	INR 250 per crate
Pre-cooling unit	INR 2.5 million per unit of 6MT
Cold storage (for multiple temperature and product use)	INR 10,000 per MT (Max 5000 MT Capacity)
Racking system bins, Pallets	INR 3500 per MT
Reefer vans	Cost per van: 4MT: INR 1.16 million 9MT: INR 2.6 million 15MT: INR 3.0 million
Solar energy system	INR 3.5 million
Ripening chambers	INR 0.1 million per MT
Others costs such as for land, doors, generator, etc.	

5. Funding Support

Financial support for formation and strengthening of FPCs, available from the sources listed below, could be utilized for start-up expenditure of setting up a CCH. The sources include:

- NABARD has set up a ‘Produce Fund’ for INR 200 crores, to nurture new FPCs, support business policy development and help them establish market linkages
- Small Farmer’s Agriculture Consortium (SFAC) set up under the Ministry of Agriculture to form, and strengthen FPCs, train FPO leadership and member farmers on business plan formulation & execution, compliances, administration and basic accounting; infrastructural support etc.
- Maharashtra Agriculture Competitiveness Project
- Gat Sheti (Group Farming) Project (200 Cr)
- 50% discount on storage charges of agri-produce in facilities of the Maharashtra State Warehousing Corporation
- Subsidies on interstate transportation for agri produce trade, by the Maharashtra State Agricultural Marketing Board (MSAMB).
- World Bank projects, CSR, Funding organizations

6. Information Systems to support Community Cooling Hubs and farm produce marketing

There is a growing recognition for a need to innovate technologies that help enhance yield, lower risk or help farmers be better prepared for adverse conditions, link producers to post-harvest processes and create market linkages for fresh and processed produce. Currently, farmers are highly dependent on traders for market prices, though television is also an important source for price information, as well as for weather advisories. The usage of apps for price information is still quite low. The dependence on traders for market information, and farmers' reasons for not accessing other sources needs to be explored further in order to intervene in this sector.

Table 61 - Farmers' sources of information

Aspect	Sources	Karanjkhop (% of respondents)	Randullabad (% of respondents)
Crop prices	Mobile applications	10 (2.16)	19 (7.66)
	Newspaper	19 (4.09)	31 (12.5)
	Television	54 (11.64)	162 (65.32)
	Trader	301 (64.87)	114 (45.97)
	Radio	0 (0.00)	7 (2.82)
Weather advisory	Mobile application	39 (8.41)	60 (24.19)
	Newspaper	19 (4.09)	2 (0.80)
	Television	386 (83.19)	185 (74.60)
	Radio	12 (2.59)	1 (0.40)
Extension services	Agrostar	13 (2.80)	22 (8.87)
	BharatAgro	4 (0.86)	1 (0.40)
	KVKS	0 (0.00)	6 (2.42)
	M-Kisan	1 (0.22)	12 (4.84

In parallel to the village level surveys, a consultation with different app and service providers in this space was organized in December 2019, to share the concept of the community cooling hub and information needs, and to understand the state of the art of IT based agri-tech business models. Desk reviews of different apps and services and interviews of entrepreneurs were also done.

Digital penetration and funding are expected to support the growth of agri-tech start-ups adopting innovative business models to support farmers, under the farm to fork supply chain. Farm to fork refers to the flow of food from the original farm to the aggregator, wholesaler, retailer and lastly consumer's fork. With relevant solutions addressing multiple challenges tackled by single platforms, emerging agri-businesses are becoming robust and disrupting norms. A recent report by NASSCOM indicates that approximately USD 200 million has been funded to agri-tech start-ups in 2019 in the country.

Normally, agriculture follows a cobweb model (Alagh, 2011). During shortage of supplies of a crop, price increases. Following season, more farmers grow the same crop resulting in price crash. Forecasts for price-sensitive crops for example onions and other horticulture crops will help farmers take informed decisions on growing different crops. They will reduce shocks and sudden pricing hikes. Farmers can benefit from knowing the price fluctuations in the forecasts to determine the optimum crop and its quantity. Without market data, farmers take surplus/ insufficient produce, thus affecting overall profitability. Most of the produce harvested in a given location is transported from crop clusters to the marketplace at the same time, creating a surplus and depreciating produce prices, which is exacerbated in areas of crop clustering. The agri-tech space is evolving to use IT in providing solutions for such challenges.

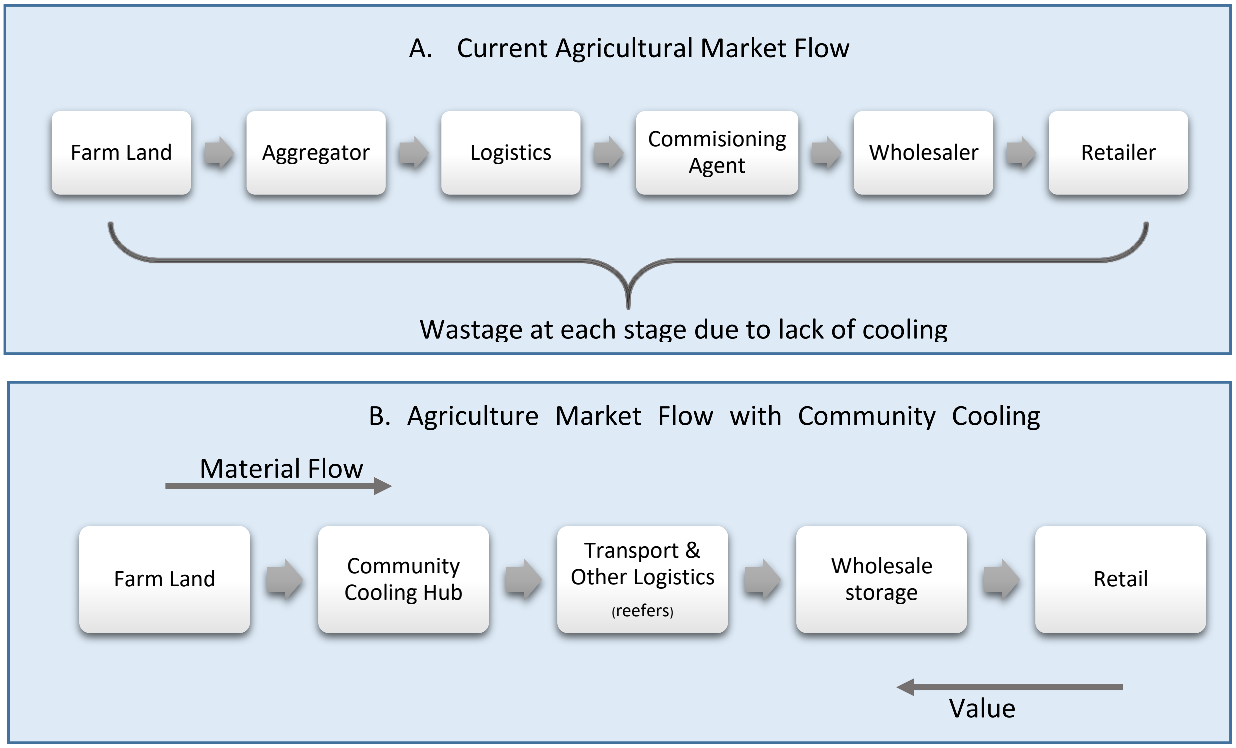


Figure 18 - 'Farm to Fork' and 'Fork to Farm' flows

Under the current market flow (Figure A), food losses account for up to 40% food wastage (MP Ensystems, 2019). Through advancement in technology and emergence of robust clean cold chain (Figure B), food losses can be avoidable. Such key elements have the potential in meeting India's doubling farming income by 2022 through reduction in costs, wastage and optimizing supply chain. There are a number of benefits of managing harvest and logistics.

'Fork to Farm' refers to the flow of key information from wholesaler, retailer or consumer to producer, helping farmers to manage demand, choice of crop, timing of plantation and harvesting. By knowing market knowledge base, farmers would be able to calculate on how much they need to invest into the storage in cold facilities in order to maximise their profits. Information and services under post-harvest play a key role in building an ecosystem for cold chain. Farmers will be able to access timely information on market demand and pricing; they could instead stagger harvesting and release produce to the market at stabilized/assured pricing. Information system using data analytics, artificial intelligence provides an opportunity to understand and solve the market conundrum.

To facilitate Community Cooling Hub (Figure B; MP Ensystems, 2019), we are looking for the following features in an application:

1. Crop-wise price forecasting (weekly, monthly)
2. Crop-wise demand forecasting (weekly, monthly)

3. Consumer demand requests (e.g. a particular variety of mushroom)

Along with a few government interventions promoting technology for farmers, there is an active participation of private players providing app-based information systems and platforms within farmer networks. Multiple platforms have emerged to provide information and services to agricultural production, through private sector investment and entrepreneurial participation.

Services provided include:
1. Weather advisories
2. Input advisories
3. Purchase offers
4. Market prices and forecasts
5. Information on packhouses and warehouses

Flow of information from wholesaler, retailer or consumer to producer i.e. fork to farm helps harvesting of crops at a strategic time and helps to decide on which crop to grow. Such crucial information will drive viable business models to support cold chain as an integral part of the ecosystem. Seeing the value, a few forms of communication targeted for farmers have emerged, such as e-NAM and e-Choupal.

Consumer information such as demand on particular crops, new trends in products can enhance profitability. Fork to farm information flow is also taking place through consumer groups, consumer supported agriculture (CSA), etc.

However, reliable crop price forecasting is yet to fully penetrate into all farms. The accuracy in forecasts would depend on how enterprises utilize artificial intelligence, data analytics and algorithms. There is still a large gap in the implementation of received information from fork to field. A clear mechanism is needed to provide farmers with information on consumer preferences, latest trends and precise demands for farmers to easily respond to. The government can develop a single common platform to disseminate key information for fork to field and vice versa.

Based on the telephonic conversations, meetings with app developers and secondary sources, it is clear that there will be significant growth in the agri-technology space. Recommendations on further activities to incorporate information systems with the community cooling hubs:

1. Understand the penetration of e-Nam and e-Choupal in the partner sites to check the possibility to extend services under a single platform rather than introducing multiple platforms.
2. Continue to assess the utility of apps to farmers, including in interface design and in physical and logistics support to back up sale/ purchase agreements
3. Website to present information on the research outcomes.
4. Collaborate with app developers like Fasal, CropIn and KrishiHub who have already developed in-house software to forecast crop prices and to provide fork to farm information such as consumer requests for particular produce.
5. Recognising key parameters like direct market linkages between farmers and consumers to enable selling produce and simultaneously place demands for produce.

7. Physical design principles for Community Cooling Hubs

Principles

The cooling solutions of a community cooling hub would

1. Use climate-friendly cooling technologies
2. Have a merit-order of energy sources, with waste heat, renewable energy, and grid assisted systems
3. Be efficient in energy use using a 'thermal ladder' for differential cooling of different chambers, for the range of cooling services anticipated
4. Provide cooling services for multiple commodities, including agri-produce, retail, water, vaccine and medical supplies, cold packs for general use packaging/ mobile needs, etc

Standards and Guidelines

The technical standards and guidelines to be followed for cold storage facilities include

1. Standards developed by the Department of Agriculture & Cooperation, Ministry of Agriculture in year 2009, for multi-commodity cold storages for short term and long term storage of fresh horticulture products.
2. Vaccine storage standards by Good Distribution/Storage practices for pharmaceutical products, 2018 by Central Drugs Standard Control Organization (CDSCO), Ministry of Health & Family Welfare, Govt of India.

The database of critical storage conditions for different types of produce in terms of temperature, humidity, CO_2 level, loading rate, air circulation, and ventilation requirement is not available for Indian conditions due to lack of research. Standards mentioned in World Food Logistic Organization may be followed.

The major design factors in simple cooling solutions are provision of precooling, adequate refrigeration, air circulation and provision for stacking and storage. For a facility that is expected to store different commodities, design needs include multiple chambers with different temperature and relative humidity requirements, protection from odour, CO_2 concentration, frequency of entry and exits, sensitivity of commodities to ethylene requirements. The facility may also require separation of access for different purposes and exterior design requirements. Ancillary spaces or units may be needed such as for grading and sorting of farm produce, pre-cooling, ice-pack conditioning for vaccine carriers, etc. If an anganwadi, community hall and public workspaces are to be attached in some way to the cooling facility, the architecture of these would have designs appropriate to their function, which may be quite distinct from the design of the core facility. Further, in the rural context, the quantity of commodities required to be stored vary over the seasons, the compartments should be modular to change capacities as per demand.

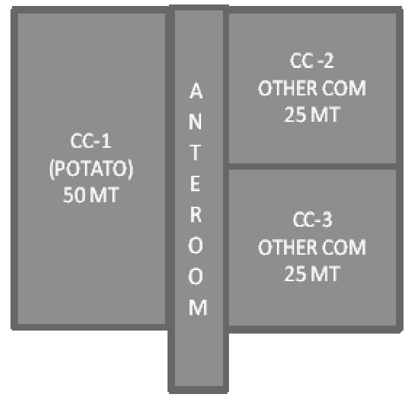
Agri produce storage facility for Satara cluster
Potato, green peas and common beans are identified as the major farm produce in this area that need post-harvest storage facilities. For a multi-chamber cold storage facility, it is proposed to provide a separate chamber for potato and other chambers for rest of the commodities. Necessary care must be

taken while deciding upon storage commodities in terms of odour and ethylene production. A tentative proposed layout with capacities is indicated in Figure 19 - Proposed layout for agri-produce cooling facility

The refrigeration system shall be Air cooled DX split units with environment-friendly refrigerant. The chambers should be designed to operate at temperatures and relative humidity based on the nature of the stored commodities. An mini storage for animal husbandry may be added on as a separate chamber.

The area required for a 100 MT unit with 3 storage chambers is about 4000 sq feet and the electrical load 30 KW. A grid connected solar PV system is proposed for lighting load of the facility.

Figure 19 - Proposed layout for agri-produce cooling facility for Satara cluster

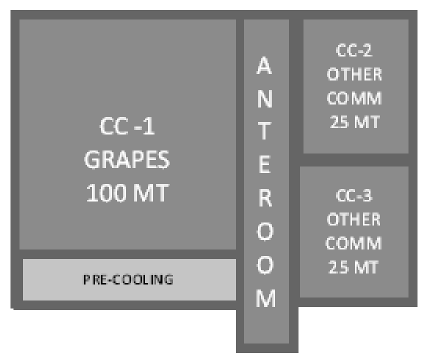


Agri produce storage facility for Yeola cluster

Major agricultural produce in this region for which a post-harvest storage facility is required are grapes, cabbage and cauliflower. Grapes and pomegranate are the major proportion of the produce. In the proposed facility, a separate chamber with pre-cooling facility is proposed for grapes. Generally pre-cooling would be used for export quality grapes. Necessary care must be taken while deciding upon storage commodities in terms of odour and ethylene production

Tentative proposed layout with capacities is indicated in Figure 20.

Figure 20 - Proposed layout for agri-produce cooling facility for Yeola cluster



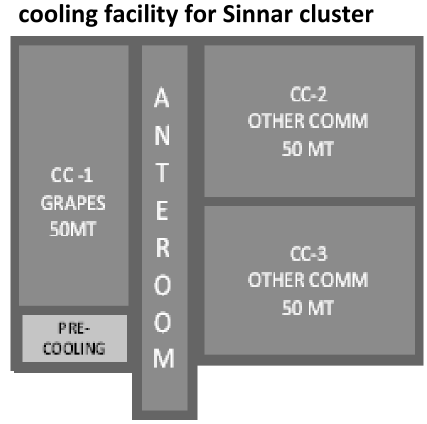
The refrigeration system shall be Air cooled DX split units with environment friendly refrigerant.
Stacking and storage arrangements should be firmed up with detailed engineering for effective air movement. The area required for the facility is 5000 sq feet and electrical load 50 KW.

Agri produce storage facility for Sinnar cluster

Major agricultural products in this region are identified as grapes, carrot, cabbage and cauliflower. In the proposed facility, separate chamber with pre-cooling facility is proposed for grapes. Generally pre-cooling would be used for export quality grapes. Other 2 chambers are proposed for rest of the commodities. Necessary care must be taken while deciding upon storage commodities in terms of odour and ethylene production.

Tentative proposed layout with capacities is indicated in Figure 21. The refrigeration system shall be Air cooled DX split units with environment friendly refrigerant. The respective chambers shall operate at desired temperatures and relative humidity based on the

Figure 21 - Proposed layout for agri-produce cooling facility for Sinnar cluster



requirement of the stored commodities. Necessary controls shall be provided for the same. Stacking and storage arrangements shall be firmed up in detailed engineering for effective air movement. The area required for the facility shall be @ 5000 sq feet and Electrical load shall be @ 50 KW.

Other sectoral cooling needs

In order to combine cooling for other sectors in the community cooling hub, multiple factors need to be considered. Fruits and vegetables need to be kept separate from other commodities like meat, domestic items (milk, yoghurt) to prevent damage. If refrigerated lockers were to be given to the communities for domestic purposes, an evaluation and monitoring is needed to understand its acceptance and day-to-day use. Health sectoral equipment requires a separate system of operation as the protocol follows stringent guidelines set by the government. A community hall with a separate Air conditioning system can be proposed for extreme heat conditions.

8. Siting options for community cooling facilities and services

This section presents different options of site locations for setting up cooling facilities after various consultations with the villages government officials and partner organisations' staff. Moreband Figure 22 is a village situated close to the studied villages.

Figure 22 - Site Scenario 1 – Moreband

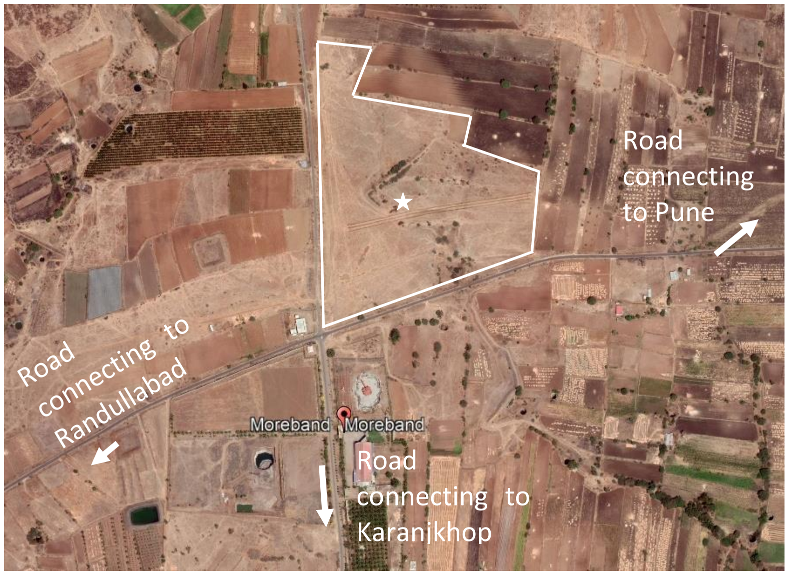


Figure 23 - Site Scenario 1- suggested site for CCH

Locational advantages: The marked location (Figure 23) is situated 1.5 km from both the studied villages and hence is in close proximity. The area has good road conditions suitable for trucks and vans. There is strong connectivity to Pune highway. The total area is around 5-6 acres of private land. The land owner has multiple locations of owned land. Due to the limited availability of water in this particular space, the owner has decided to do agriculture at other locations. The soil type is arable. Moreband is also close to nearby villages called Solashi, Nandwal (marked in Figure 24) as well as Pimpode, Sonke, etc. The community cooling hub can also be used by nearby villages for their produce and other cooling needs.

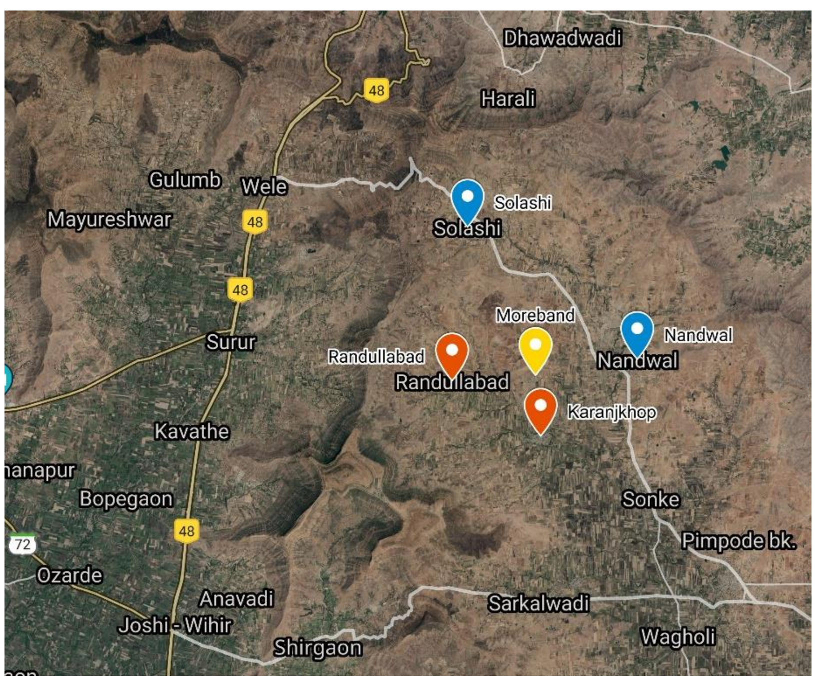


Figure 24 - Site Scenario 1 - Villages in proximity to Moreband (Shiloshi, Nandwal, Sonke, Pimpode)

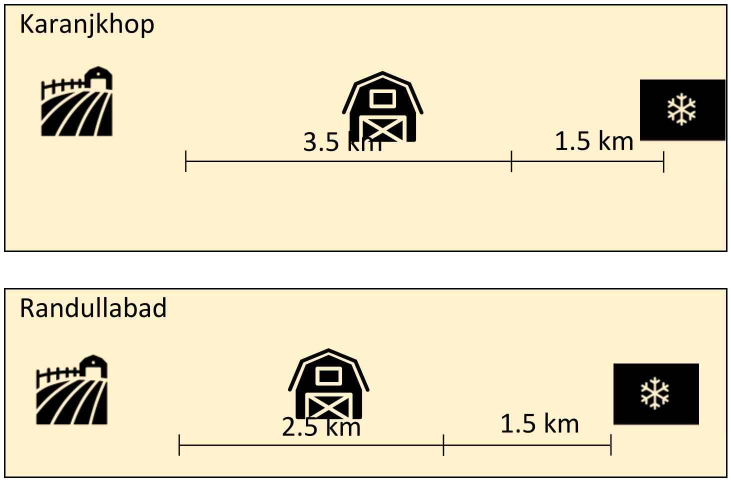


Figure 25 - Approximate distance between farthest farm land, the centre of the village and CCH

Locational Disadvantages: As shown in Figure 25, produce loading and unloading using tempos/ trucks will take place in a maximum distance of 5 km between farmland and cooling hub.

Comparative Analysis: If the hub was located within the village, the distance between hub and farm could have been reduced. However, adequate public land is unavailable. Loading vehicles will be needed to reach to the Moreband sites. During the transport from farm to hub, produce can be pre-cooled in the reefer tempo/ truck itself.

Siting locations for community spaces

In Randullabad, there is a community hall owned by Gram Panchayat and an Anganwadi identified in Figure 26 as a possible location for community cooling space during extreme heat conditions. It is important to note that all Anganwadi services are designed for children, therefore, the area is quite small. Proximity between the community hall and Anganwadi can cater to a larger group of people. This area is located close to the centre of the village where most of the people gather together.

Figure 26 - Community Hall (A) and Anganwadi (B) in Randullabad

In Karanjkhop, there are 4 Anganwadi spaces as the village is bigger. The larger sized Anganvadi space has been identified as a possible location for the community cooling space. See Figure 27.

Figure 27 - Anganwadi in Karanjkhop

6. Conclusions and Future Work

The rural cooling needs assessment attempted a multi-dimensional study using a mixed methods approach. Through site studies in three village clusters in Satara and Nashik, using household surveys, interviews, focus groups, mapping and other tools, a wide range of development needs were explored using the lens of cooling. The aim was to understand how rural communities are meeting their nutrition, livelihood, health, living space and mobility requirements with special reference to the role of cooling. The objective was to assess how cooling could enhance well-being. Rich narratives and datasets have been gathered that provide some insights into the many different ways by which the natural resource base could be enhanced, while improving the comfort and resilience of communities, with a range of cooling technologies. The information gathered also has pointers to the fragility of the social-ecological complex, especially in the face of climate change and impending increases in temperatures and extreme events. These provide an impetus to go further with the studies initiated over the last few months.

A few next steps are placed in this concluding section, which may be taken in the immediate months as well as over the longer term. The Covid 19 pandemic and lockdown situations have left the study team with a sense of incompletion. Though the formal project time lines are over, we hope there are opportunities to take these explorations to the next logical levels. Ideally, a longer-term participatory action research initiative with the village clusters, the NGO partners and research team, should be formulated.

The next steps and future areas of work include:

1. Presentation of the findings of the studies to the local communities, FPOs and sectoral government and other actors to ideate on whether the range of cooling needs identified seem relevant, the extent to which they are seen as important to address, and the priorities among them

2. Deliberations on the status of each rural development sector connected with cooling, the need for improvement of the basic service (e.g. in public transport, electricity access and reliability), and how the provision of cooling solutions may affect demand and supply.

3. Deliberations on local interest and commitment to take up the multidimensional enterprise of community cooling solutions

4. Collection of data related to the following, in order to evolve the design of solutions:
    - Shareholding in local farmer producer companies and investment capacity
    - Local energy mix potential with costing
    - Projections over a period of 10 or more years/ life of equipment in terms of need/ demand and rate of return/ recovery would be desirable for different situations

5. Development of the detailed design and testing of community cooling solutions for the range of needs

6. Discussions on skill sets and human resource needed as well as exploring the readiness to acquire new skills and assume leadership and entrepreneurship roles

7. Development of improved methods to forecast future needs

8. Discussions on the ecosystems of each cooling domain – cooling solutions must be part of a holistic effort to improve well-being; local and other actors need to consciously consider the range of actions that should accompany active cooling solutions for different needs and develop simultaneous initiatives

9. Evolving an appropriate governance structure for cooling solutions that retains a focus on inclusive well-being, and methods to assess this

10. Certain key aspects require policy dialogue, which has not been possible due to the pandemic situation, but which need to be taken up as next steps:
    - Climate responsive rural building construction, retrofits and repairs, especially under the PMAY - Rural
    - Storage of vaccines and medical supplies at the village cluster level
    - Human resource and cold chain enhancement for animal healthcare

11. Develop and demonstrate how community cooling can help in disaster and disruption preparedness, which is already included in the CCH concept, and the need for which has been indicated by current pandemic

12. Identify financial support for participatory study and action, dialogues, pilots, and infrastructure and skills development to initiate and sustain community owned and managed rural cooling solutions, potentially in the form of Community Cooling Hubs.

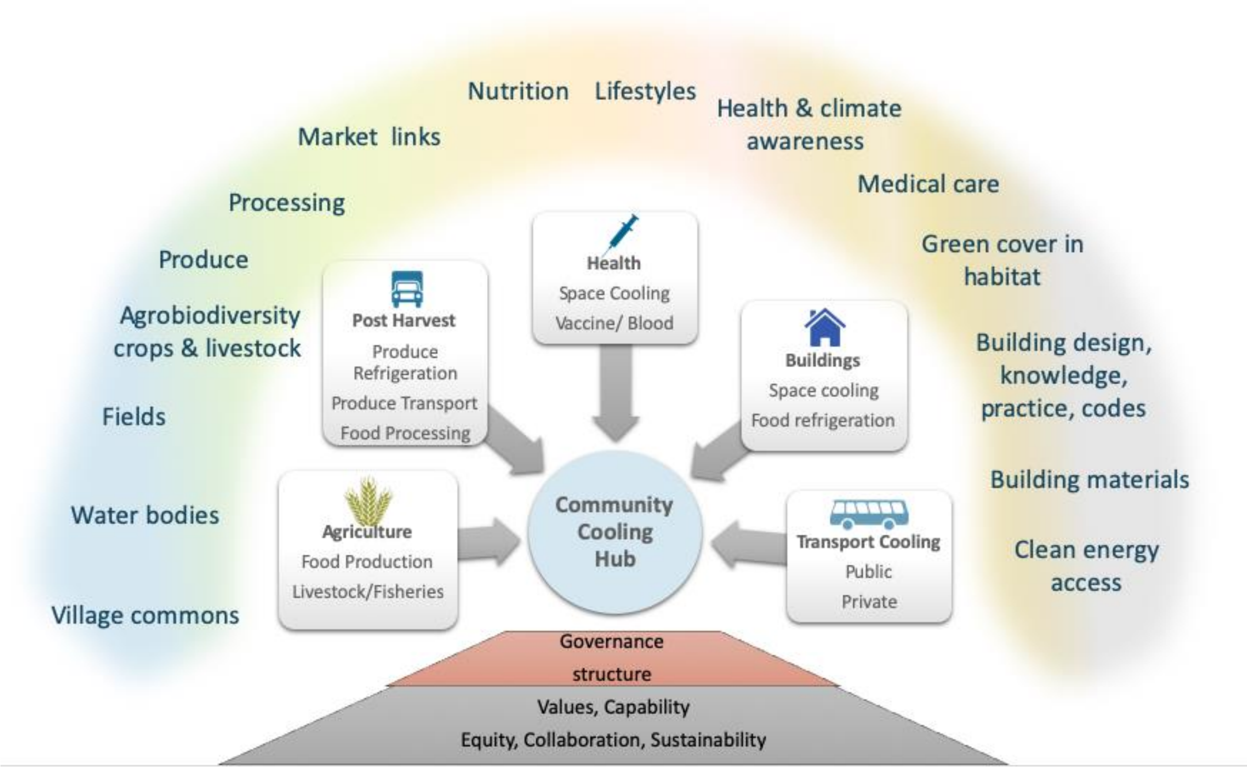


Figure 28 - Cooling solutions must be embedded within ecosystem integrity and human well-being

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