Agriculture *for* Development

Special Issue on the clean cold chain in agriculture in developing countries

Tropical Agriculture Association

No. 36, Spring 2019

Guidelines for Authors
Agriculture for Development

The editors welcome the submission of articles for publication that are directly related to the aims and objectives of the Association. These may be short communications relating to recent developments and other newsworthy items, letters to the editor, especially those relating to previous publications in the journal, and longer papers. It is also our policy to publish papers, or summaries, of the talks given at our meetings.

Only papers written in English are accepted. They must not have been submitted or accepted for publication elsewhere. Where there is more than one author, each author must have approved the final version of the submitted manuscript. Authors must have permission from colleagues to include their work as a personal communication.

Papers should be written in a concise, direct style and should not normally exceed 3,000 words. Please use Times New Roman font, 12-point size for the text body, with lines single spaced and justified, and pages numbered. Tables, graphs and photographs may take a further 1 page plus, but we try to keep the total length of each paper to 3-4 pages of the journal. Good-quality photographs are particularly welcomed, as they add considerably to the appearance of the contents of the journal. We prefer high-resolution digital images (*ie* separate from the Word file).

Format

- An informative title not exceeding 10 words.
- Authors listed, usually with first name and surname.
- A short biographical note about each author is included, preferably with a photograph. If still working, indicate your position and email address. If retired, your previous job (eg formerly Professor of Agriculture, ABC University).
- For papers longer than 1,500 words, a short abstract (summary) of 150-200 words.
- A short introductory paragraph is useful describing, succinctly, the current state of work in the relevant field.
- Système International (SI) units should be used. Others units should be related to SI units at the first mention.
- No full stops should be used with abbreviations such as Dr or Prof, or eg, ie, status quo, viz and inter alia. Acronyms and initialisms such as GFAR, FAO, IFPRI and GDP do not have full stops or spaces between the letters. Acronyms and initialisms should be spelled out in full at their first mention.
- Thousands should be indicated by a comma and no space, eg 12,400.
- Use 's' rather than 'z' (eg fertiliser, organisation, mechanisation).
- Commercial equipment and products referred to should name the product and company, but addresses should be omitted.
- State any statistical methods used, eg analysis of variance (ANOVA), and ensure that the analysis method chosen is appropriate for the data. Data tables presenting, for example, mean values should include the appropriate standard errors (SE) and degrees of freedom (DF).
- Results should be presented in an orderly fashion and make use of tables and figures where necessary.
- Discussion should focus on the work presented and its relationship with other relevant published work.
- Sources of funding should be listed in the acknowledgements.

References

- Please do not use footnotes in the text.
- Key references should be cited, but these should be kept to a minimum.
- Only papers accepted for publication or published may be cited.
- In the text, cite by author's surname and date – (Waller, 2009) or Waller (2009). Use '&' between names of two authors; use 'et al' for three or more authors.
- At the end of the paper, give full details of references in alphabetical order and in the journal style as per the examples below.
- Personal communications in the text should be cited as: initials, name, affiliation and/or location, personal communication.

Journal (article): Bajželj B, Allwood JM, Cullen JM, 2013. Designing climate change mitigation plans that add up. *Environmental Science & Technology*, 47(14), 8062-9.

Journal (online): Osbourne K, Dolman AM, Burgess S, Johns KA, 2011. Disturbance and the dynamics of coral cover on the Great Barrier Reef (1995-2009). *PLoS ONE* http://www.plosone.org/article/info%3Adoi%2F10.1371%2Fjournal.pone.0017516

Book: Brammer H, 2012. *The physical geography of Bangladesh*. Dhaka, Bangladesh: University Press.

Book (edited): Fuglie KO, Sun Ling Wang, Ball E, eds, 2012. *Productivity growth in agriculture: an international perspective*. Wallingford, UK: CAB International.

Book (chapter): Warner K, 1997. Patterns of tree growing by farmers in eastern Africa. In: Arnold JEM, Dewees PA, eds. *Farms, trees & farmers: responses to agricultural intensification*. London: Earthscan Publications, 90-137.

Conference proceedings (published): McIntosh RA, 1992. Catalogues of gene symbols for wheat. In: Miller TE, Koebner RM, eds. *Proceedings of the Seventh International Wheat Genetics Symposium*, 1987. Cambridge, UK: IPSR, 1225-1323.

Agency publication: Grace D, Jones B, eds, 2011. *Zoonoses (Project 1) Wildlife/domestic livestock interactions*. A final report to the Department for International Development, UK.

Dissertation or thesis: Lenné JM, 1978. *Studies of the biology and taxonomy of* Colletotrichum *species*. Melbourne, Australia: University of Melbourne, PhD thesis.

Online material: Lu HJ, Kottke R, Martin J, Bai G, Haley S, Rudd J, 2011. Identification and validation of molecular markers for marker assisted selection of *Wsm2* in wheat. In: Plant and Animal Genomes XIX Conference, abstract W433. [http://www.intl-pag.org/19/abstracts/W68_PAGXIX_433.html]. Accessed 20 April 2012.

Tables

- Self-explanatory with an appropriate legend above the table, without abbreviations.
- Number with Arabic numerals, eg Table 2.
- Refer to tables in the sequence in which they are presented.
- Use superscript lower-case letters, eg a, b and c, for footnotes.

Figures

- Self-explanatory with an appropriate legend below the figure, without abbreviations.
- Number in a separate series from the tables.
- Use Arabic numerals, eg Figure 2.
- Subdivisions within figures should be labelled with lower-case letters, eg a, b and c.
- The author must obtain permission to reproduce illustrations (graphs, tables, images) that have already been published.
- Photo captions must include the photographer's name (and affiliation), and figure captions should include the source (unless original).

Submission

Your paper should be submitted ready for editing and publication.

Accepted text file types: Word (.doc or .docx), rich text format (.rtf) or postscript (.ps) only.

Accepted figure file types: .tif, .eps, .jpg or .pdf.

No lecture notes or PowerPoint presentations, please. If the paper is a presentation from a TAA meeting, please let us have it or as soon as possible afterwards so that there is no last-minute rush in trying to meet the next publication deadline.

Send submissions via email to editor_in_chief@taa.org.uk, preferably in an attached file.

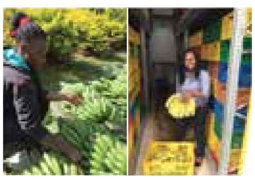
Copyright

Agriculture for Development holds the copyright of all published articles, but the authors retain the right to publish all or part of an article elsewhere, with due acknowledgement.

Cover images

High-quality colour images, suitable for the cover of *Agriculture for Development*, are welcomed and should be sent to the Editor-in-Chief (editor_in_chief@taa.org.uk).

November 2018



Cover photograph: Bananas being collected from rural farmers (left); and, bananas after being ripened for six days in cooling units in Nairobi (Photos: Peyton Fleming).

Contents

The Tropical Agriculture Association (TAA) is a professional association of individuals and corporate bodies concerned with the role of agriculture for development throughout the world. TAA brings together individuals and organisations from both developed and less-developed countries to enable them to contribute to international policies and actions aimed at reducing poverty and improving livelihoods. It grew out of the Imperial College of Tropical Agriculture (ICTA) Association, which was renamed the TAA in 1979. Its mission is to encourage the efficient and sustainable use of local resources and technologies, to arrest and reverse the degradation of the natural resources base on which agriculture depends and, by raising the productivity of both agriculture and related enterprises, to increase family incomes and commercial investment in the rural sector. Particular emphasis is given to rural areas in the tropics and subtropics and to countries with less-developed economies in temperate areas. TAA recognises the interrelated roles of farmers and other stakeholders living in rural areas, scientists (agriculturists, economists, sociologists etc), government and the private sector in achieving a convergent approach to rural development. This includes recognition of the importance of the role of women, the effect of AIDS and other social and cultural issues on the rural economy and livelihoods.

contact:
editor_in_chief@taa.org.uk
editor_ag4dev@taa.org.uk
Tel: 01694 7222897

ISSN 1759-0604 (Print)
ISSN 1759-0612 (Online)

Promoting clean and energy-efficient cold chains in India

Mahesh Patankar and Roshni Yehuda

Mahesh Patankar, PhD, is a resource efficiency specialist with interest in energy, water and livelihood linkages. He leads the efficient and clean cold-chain incubation effort at MP Ensystems. Mahesh is a Senior Advisor with the Regulatory Assistance Project driving energy transitions in India, and also leads a water efficiency project in Maharashtra for the World Bank-hosted 2030 Water Resources Group. mahesh@mpensystems.com

Roshni Udyavar Yehuda, PhD, is an avid proponent of rural and urban transformations with a keen interest in creating market linkages between the water and food sectors, in addition to contributing to the creation of environmentally benign and energy-efficient built spaces. Roshni heads the operations at MP Ensystems. roshni@mpensystems.com

Abstract

This article presents highlights from a new report by MP Ensystems funded by Shakti Sustainable Energy Foundation, and supported by the University of Birmingham. *Promoting clean and energy efficient cold-chain in India* (April 2019) is an assessment of clean cold chain in India. The aim was to bring together policies, finance and technology-innovation attributes of the evolving cold chain in India with an aim to provide strong evidence and recommendations to make technologies affordable, financeable and implementable by small and large implementation partners from warehousing, haulage and bulk-processing/storage options. The project has sought the active support and expertise of various organisations from government agencies, institutions and businesses. For the fieldwork, a team worked in four states in India during the period July-November 2018 to understand the current state of cold chain in India (Haryana, Punjab, Maharashtra and Karnataka; offering regional diversity) and how to ensure the transition to a developed and pan-country cold chain with minimal environmental impact – *ie* curtailing CO_2 emissions and other pollution. The purpose of the study was to explore systems-level thinking on the need for clean cold chain moving from farm to fork as the flow of goods and repurposing value through the cold chain from the fork to the farm, and the development of a broad roadmap for clean cold-chain development in India.

Figure 1. Goals of the study on clean cold chain in India (Source: MP Ensystems Advisory Pvt. Ltd, 2018)

Background to clean cold chain in India

The Prime Minister's Office has set India the target of doubling farmers' incomes by 2022 (NITI Aayog, 2015). Up to 40 percent of food is lost between the farm gate and market (Committee for Doubling Farmers' Income, 2017). This reduces farmers' income, their capacity to invest, and their incentive to grow more food; it also impacts on the cost of food in a rapidly urbanising marketplace. The Government of India has identified investment in cold-chain logistics – to mitigate post-harvest losses and enable fast connectivity with markets – as a vital component in its seven-point farm-income strategy (NITI Aayog, 2015).

As part of its climate change initiatives, India has set ambitious targets to make agriculture and food logistics sustainable. Conventional diesel-powered transport refrigeration units and pack houses, for example, emit not only high levels of CO_2, but also grossly disproportionate amounts of nitrogen oxides (NO_x) and particulate matter (PM).

To double farmers' income by expanding the use of conventional, highly polluting cold-chain technologies would simply mitigate one problem by worsening another. It is vital that any new cold-chain infrastructure should be clean – zero-emission and powered by renewable energy.

What is clean cold chain?

Cold chain is an integrated, seamless and resilient network of refrigerated and temperature-controlled pack houses, cold storage, distribution hubs and vehicles used to maintain the safety, quality and quantity of food produce, while moving it swiftly from point of harvest to point of consumption. It should enhance economic wealth, cash flow and security for farmers, growers and fishers, and improve food quality, safety and value to the consumer; *and achieve this sustainably with minimum environmental and natural resource impact.*

Table 1. Post-harvest infrastructure protocols for selected products and list of products selected (Source: NCCD, 2015)

<table>
<tr><th>Product</th><th>Logistics flow
(in order of component listed)</th><th>Category
(temperature range)</th></tr>
<tr><td colspan="2">Fresh fruit</td><td rowspan="13">Chill (0-10°C)</td></tr>
<tr><td>1. Apple</td><td>CS – PH – T – CH – t – FE</td></tr>
<tr><td>2. Grapes</td><td>PH – T – CH – t – FE</td></tr>
<tr><td>3. Orange</td><td>PH – T – CH – t – FE</td></tr>
<tr><td>4. Strawberry</td><td>PH – T – CH – t – FE</td></tr>
<tr><td>5. Kiwi</td><td>CS – PH – T – CH – t – FE</td></tr>
<tr><td colspan="2">Fresh vegetables</td></tr>
<tr><td>6. Potato</td><td>CS – Ts – FE</td></tr>
<tr><td>7. Tomato</td><td>PH – T – CH – t – FE</td></tr>
<tr><td>8. Cauliflower</td><td>PH – T – CH – t – FE</td></tr>
<tr><td>9. Okra</td><td>PH – T – CH – t – FE</td></tr>
<tr><td>10. Carrot</td><td>CS – PH – T – CH – t – FE</td></tr>
<tr><td>11. Cabbage</td><td>CS – PH – T – CH – t – FE</td></tr>
<tr><td colspan="2">Fresh fruit</td><td rowspan="4">Mild chill (10-20°C)</td></tr>
<tr><td>12. Mango</td><td>PH – T – CH – RC – t – FE</td></tr>
<tr><td>13. Banana</td><td>PH – T – CH – RC – t – FE</td></tr>
<tr><td>14. Papaya</td><td>PH – T – CH – RC – t – FE</td></tr>
<tr><td colspan="2">Other food products</td><td rowspan="4">Frozen (below -18°C)</td></tr>
<tr><td>15. Processed products</td><td>PU – T – CH – t – FE</td></tr>
<tr><td>16. Meat & meat products (livestock, poultry, fish)</td><td>PU – T – CH – t – FE</td></tr>
<tr><td>17. Dairy products (ice cream, butter)</td><td>PU – T – CH – t – FE</td></tr>
<tr><td>18. Onion</td><td>SS – Ts – FE</td><td>Normal (20-30°C)</td></tr>
<tr><td colspan="3">CS – cold storage bulk; CH – cold storage hub; FE – front-end merchandising; PH – pack house; PU – food processing unit or allied; RC – ripening chamber; SS – storage structure; t – last-mile transport; T – long-haul reefer transport; Ts – non-reefer transport</td></tr>
</table>

Table 2. Energy demand throughout a typical vegetable chain (Source: FAO, 2015)

		Diesel/gasoline	**Electricity**	**Natural gas**
	Fertilisers			✓
Production	Irrigation	✓ (pumps)	✓ (pumps)	
	Cultivation on farm	✓ (machinery)	✓ (greenhouse)	✓ (heating greenhouses)
	Harvesting	✓ (machinery)		
Storage	Storage/refrigeration		✓	
Transport	Transport	✓	✓	
Processing	Sanitising/cleaning		✓	✓
	Grading and sorting		✓	
	Peeling/cutting		✓	✓ (steam)
	Blanching	✓ (boiler fuel)	✓ (heat)	✓ (heat)
	Cooling		✓	
	Drying	✓	✓	✓
	Freezing		✓	
Packaging	Can filling		✓	
	Can exhausting	✓ (heat)	✓	✓ (heat)
	Can sealing		✓	
	Heat sterilisation	✓	✓	✓
	Packaging		✓	

The current primary energy impact at various stages of the horticulture produce and processing chain is indicated in Table 2.

Summary of the project

A team comprising experts from MP Ensystems (supported by the University of Birmingham) and Shakti Sustainable Energy Foundation worked in four states in India during the period July-November 2018 to better understand the current state of cold chain in India and how to ensure the transition to a developed and pan-country cold chain with minimal environmental impact – *ie* curtailing CO_2 emissions and other pollution. This exploration was carried out in the states of Haryana, Punjab, Maharashtra and Karnataka, offering regional diversity. The purpose of the study was to explore systems-level thinking on the need for clean cold chain moving from farm to fork as the flow of goods and repurposing value through the cold chain from fork to farm, and the development of a broad roadmap for clean cold-chain development in India. The report benefitted from four case studies from the state of Haryana captured through in-person interviews.

The systems-level thinking includes understanding of:

- farming as a livelihood opportunity for farmers;
- the value chains from the perspective of their energy footprints in particular;
- current failures and barriers to the deployment of cooling technology;
- the role of technologies relevant to the first and the last mile of goods flow alongside cold storage, efficient (low-carbon) and clean (low global-warming potential [GWP] and low ozone-depleting potential) components of cold rooms, pack houses and processing plants;
- projection of energy conservation (in global warming) and greenhouse gases (GHGs, CO_2e), NO_x and PM emission reduction due to adoption of energy-efficient equipment technologies and low GWP refrigerants in cold chain till 2030;
- application of closed-loop systems resulting in maximised productivity per unit of energy;
- interventions to support deployment of low-carbon technology including, but not limited to, finance, policy and training; and
- envisaging cooling as a ‘service’, the role of data connectivity and IT-enabled/mobile technology platforms to inform the decisions on the time and duration of harvesting, improving the holding life and associated value of the products, resulting in wins for both producers and consumers.

As a part of this exploration, the project team interacted with the following stakeholders:

1. government (state and national) officials from agriculture, horticulture, electricity, renewable energy, energy efficiency

and water resources departments (approximately 20 one-on-one interactions and one roundtable);

2. 10 small and large farmer-producer companies;
3. more than 50 farmers dependent on the farming sector (primarily fruits and vegetables), including women;
4. six agri-value-chain start-ups *including those run by women entrepreneurs*;
5. more than 30 Indian and UK technology providers dealing with integrated system designs, refrigeration systems/equipment, natural and low-GWP refrigerants, solar-PV and solar-thermal hot-water/steam-generating units; phase change materials in reefer vans, cool rooms, processing units and retail stores; internet of things/artificial intelligence (AI)/block-chain platform developers with applications developed for the agriculture sector (spread over two roundtables and bilateral meetings); and
6. four leading banks in India that provide credit to farmer-producer companies, farmers, technology providers; and angel- and venture-capital fund managers focussing on agri value chains.

Output

As a result of this process, the group of experts presented this report on the social, technical and economic aspects of the farm-to-fork and fork-to-farm value chain, presenting the importance and opportunities, including cooling-as-a-service and making a business case for a mobile-technology-driven decision tool that could positively impact farmers' income and producer/consumer surplus. The report considers specific interventions and, using farmer-producer organisations, proposes frameworks for end-to-end system-level approaches.

The development impacts of cold chain go beyond food loss to include improved nutrition; increase in farmers' incomes; new jobs for operation and maintenance of cold chains; and deriving co-benefits from access to functioning cold chains (health, economic development, environment), including secondary agriculture and sector-wide community development. The report presents strategies, barriers and innovations for bringing novel cold-chain solutions to market, including partnership with stakeholders, investment/financing options and regulatory policy, and considers ways to introduce such solutions into the development policy of developing-country governments and international financial institutions.

Key findings include the following.

Under-utilisation of newly constructed cold-storage facilities by government agencies due to:

- lack of stakeholder consultation with farming community;
- failure of economics of cold storage;
- operational inefficiencies and high cost of electricity; and
- geographic siting and location of the pack houses and cold-storage facilities.

Role of cold chain in improving nutritional value of food, going beyond the objective of increasing farmers' incomes and reducing food loss. A recent World Business Council for Sustainable Development presentation highlighted the low nutritional value of agricultural output in India.

Availability of technologies is not a key concern. Clean cold-chain technologies are available. What is needed is feasibility and applicability in local contexts and harnessing human resources through skills training for maintenance and operation of cold chain.

Use of the internet of things for market connectivity and quality control. An example is Sahayadri Farm Fresh, a cooperative of more than 6,000 farmers, whose produce is geo-tagged to provide information about its origin, handling, storage temperature, *etc*.

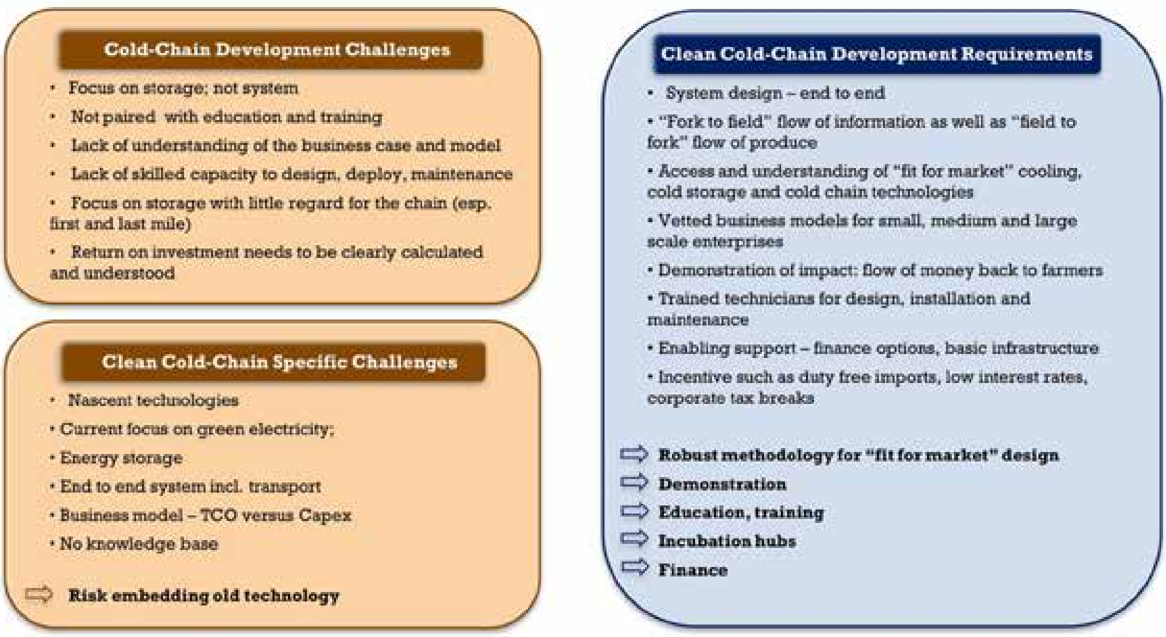


Figure 2. Challenges and routes for clean cold chain, India (Source: MP Ensystems Advisory Pvt. Ltd, 2018).
Capex = capital expense; Opex = operational expenditure; TCO = total cost of ownership.

Dissolving silos in India for better utilisation of thermal resources. India has the largest quantity of thermal storage in the form of cold-storage facilities. These need to be geographically tagged with attributes to improve usability and linked with grids of biomass, biogas, solar, wind, micro-hydroelectricity, *etc*.

Training and capacity-building will be key to setting up clean cold chain – increasing awareness among farmers about the merits of cold-chain infrastructure, their expected level of participation, and ways to use enhanced internet of things-based techniques are important training needs to be fulfilled.

Based on the findings of the study, MP Ensystems Advisory and the University of Birmingham have developed four key recommendations for the next stage of clean cold-chain development in India. The recommendations were guided by the case studies in different states, but mainly from Haryana, interaction with various stakeholders through workshops, and the field visits.

1. **Facilitate hackathons and prepare a framework for IT solutions** for developing clean cold chain in India using the latest block-chain technologies. Participants – stakeholders including representatives from farmer-producer organisations, technology consultants and providers, government representatives, funding agencies, bilateral organisations, consultants and entrepreneurs, or interested individuals and organisations including designers, programmers, coders, developers, recruiters and CEOs – can develop (independently or in groups) possible solutions and software codes for developing a clean cold chain.
2. The development will require **an informed needs assessment process with the farming community**, and identification of the drawbacks, lacunas and requirements of existing systems. Taking into account existing schemes and infrastructure, how can IT enable the enhancement achieved by cold-chain infrastructure and deliver value back to the farm from the fork?

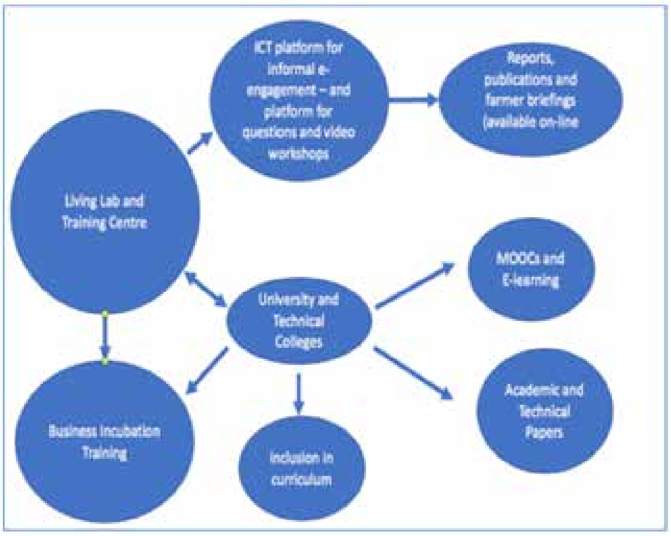


Figure 3. Training and development for clean cold-chain network diagram (Source: MP Ensystems Advisory Pvt. Ltd and University of Birmingham)

3. **Living laboratories** – We propose that national governments collaborate with state governments and farmer-producer organisations in setting up 'Living laboratories' to showcase new clean cold and cooling technologies to be integrated into practice locally. The focus will be to demonstrate a live model of integrated clean cold technologies, to develop economic models in which to fit the framework of new technologies, and to work with the farmer communities. Living laboratories can serve as centres of advocacy, outreach, training and awareness on cold chain, as well as research and development centres to deal with contextual issues.
4. **Business models** – We propose new business propositions such as 'IT-enabled services to manage harvesting and logistics'. There is an opportunity for assessing the added value of fork-to-field information flow and how best to capture that value for the farmers both in immediate decisions and market connectivity and in longer-term development. We propose establishment of 'cold as a service' by integrating food cold chains with other cold-dependent services such as secondary agriculture, vaccines, community health facilities and emergency services, thereby developing strategies and co-benefits to create sustainable community cooling services.
5. **Training –** Development of a roadmap for awareness, training and capacity-building to address the technical, technological and social aspects of providing clean cold-chain infrastructure. This will include business incubation; training in advanced internet of things, AI and block-chain applications; curriculum development for university students and professionals; developing massive open online courses (MOOCs) and e-learning programmes; as well as training in information and communication technologies (ICTs).

Support from government

The state and central governments through the DFI (Doubling Farmers' Income) mission, as well as for agriculture and export promotion, are providing subsidies, grant-in-aid and soft loans to support farmers, farmer-producer organisations and private entrepreneurs.

In the course of numerous interactions with officials from the State Government of Haryana, the Horticulture Department's Crop Cluster Development Program (CCDP) was identified as one of the most progressive and advanced schemes to promote clean and efficient cold-chain infrastructure. The Department of Horticulture along with the Small Farmers' Agri-Business Consortium, Haryana (SFACH) has developed crop clusters, assessing the tonnage of production and growth season for different crops. The Department has an overall budget of 5.1 billion rupees (USD 73 million) for providing up to 70 percent subsidy to farmer-producer organisations for cold-chain infrastructure, including pack houses, ripening chambers, sorting and grading facilities, cold-storage facilities and reefer vehicles.

It has received proposals from 47 farmer-producer organisations and has already shortlisted and issued letters of intent to 21 of them.

Pilot visits were conducted to *mandis* (farmer markets), pack houses, cold-storage facilities and bulk cold-storage facilities in Panchkula, Sonepat and Shahbad in Haryana, and Ropar in Punjab to provide an initial understanding of the functioning, resources, supply chain and operational requirements.

The pack houses commissioned by the Government of Haryana in 2010-2012 at *mandis* located in Shahbad, Panchkula and Kurukshetra are available on lease. The *mandi* at Panchkula operated by a farmer-producer organisation is equipped with a pack house of 5 tonnes capacity. The farmer-producer organisation includes more than 300 marginal farmers who sell varieties of fruits and vegetables sourced from their own fields in the region. Every participating farmer has been given a membership card to occupy and set up a small retail shop in the space provided at the *mandi*. The farmer-producer organisation also manages wholesale trading of other agricultural products. Similarly, individual or groups of farmers and farmer-producer organisations run *mandis* in Shahbad and Kurukshetra. The pack house at Shahbad has one pre-cooling unit of 5 tonnes, storage space for more than 100 tonnes, cold-storage units for 25 tonnes for potato and other vegetables and fruits, and a ripening chamber for 20 tonnes. Cooling technology used in all of these are a Freon-based variable-capacity compression refrigeration system and equipment supplied by Blue Star and Bitzer.

Figure 4. Government-commissioned *mandi* (farmers' market) at Panchkula (Photo: Shirish Deshpande)

The supporting pack houses in Shahbad and Panchkula were under-utilised. The users gave the following reasons for poor utilisation of the facilities:

- lack of appropriate infrastructure to transport produce from farm gate to the pack house;
- limited financial capacity of marginal and small-scale farmers to store the produce at the farm gate – they therefore try to encash the produce as soon as possible; distress sale is a well-known phenomenon; and
- high cost of electricity, coupled with low operational efficiencies.

First- and last-mile considerations in cold chain

Field studies show that most of the wastage occurs at the first (farm gate) and last (handling after retail) miles of cold chain. First-mile transportation is dependent on farm vehicles such as tractors, which are inadequate for maintaining freshness of horticultural produce and lead to losses. Conventional reefer vehicles are financially unaffordable for farmers unless the services are grouped under a farmer-producer organisation or cooperative.

Cold chain needs to be created through bottom-up approaches, as last-mile logistics are also not in place. The larger infrastructure components (middle components in the supply chain, *eg* packhouses and cold-storage facilities) are not utilised because of virtual entry and exit barriers in smooth material flow. The barriers can be attributed to:

- limited infrastructure and technology applications suitable for first- and last-mile business processes;
- high cost of operating at small scale with existing cold-chain facilities;
- inadequate knowledge and skills to carry out the processes efficiently to ensure productivity and financial viability; and
- lack of policy support to facilitate first-mile processes in cold chain.

Only large and established business formats have been able to utilise the cold chain. However, most of the farmers in India have small or medium-sized landholdings (less than 4 ha). Thus, there is a strong need to create support for building capacities at the first and last miles to realise the Government of India's goal of doubling farmers' income.

Market not yet thinking beyond conventional technology mix

Based on interviews with farmers and farmer-producer organisation representatives, technology providers and government officials in Haryana, it is clear that almost all current efforts to double farmers' income are focussed on adding cold-chain infrastructure using conventional cooling technologies.

While an energy efficiency building code exists, it is not applicable to the cold chain, as guidelines pertaining to cold chain focus on maintaining quality of produce and not on energy efficiency or system sustainability.

Critical intervention – new business models

From our research, the conventional ways of dealing with cold chains need substantial changes. The economic and technical feasibility of the cold chains can emerge when the thinking changes from 'farm to fork' to 'fork to farm' (Figure 5). Currently, the entire economics of farm produce is governed in a sub-optimal manner in which harvesting is not necessarily linked to market triggers. With the advent of information technology applications in India, it is opportune to imagine a business structure that links market needs with harvesting and post-harvest storage and haulage.

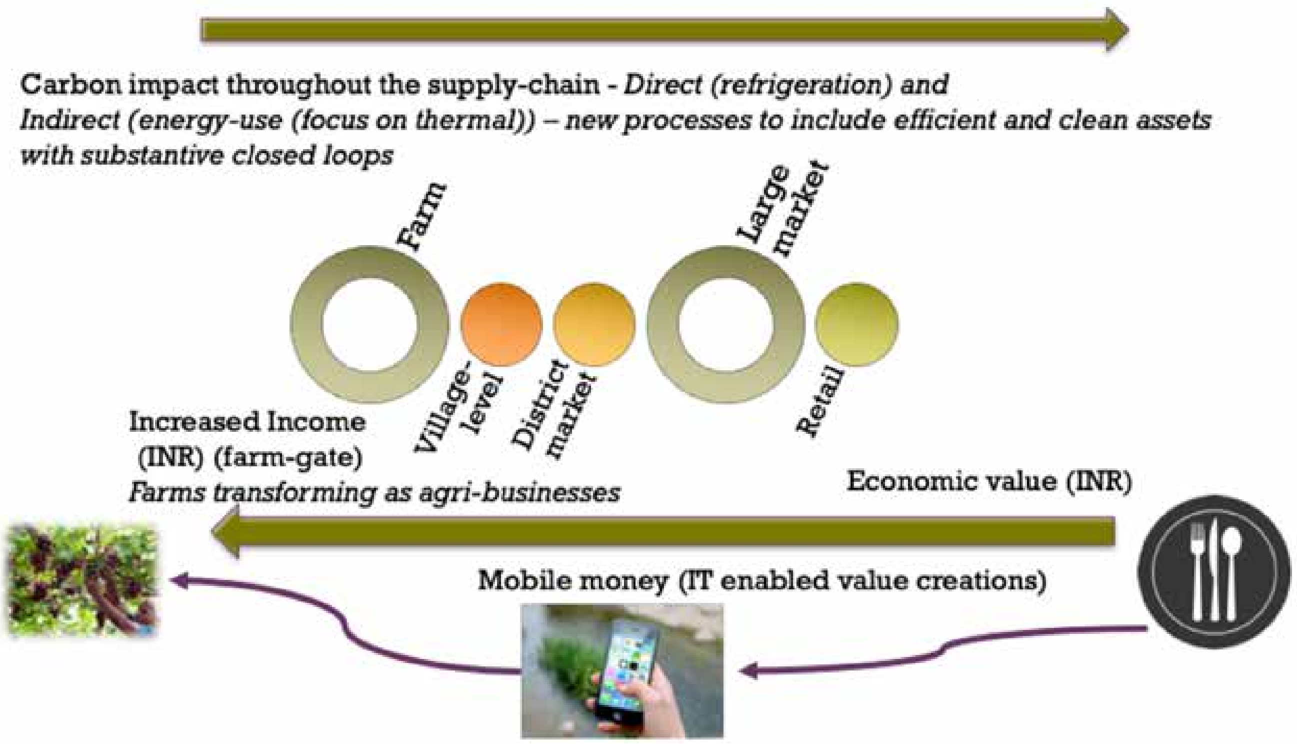


Figure 5. New business propositions (Source: MP Ensystems Advisory Pvt. Ltd, 2018)

We propose two predominant business opportunities that were discussed with prospective and existing entrepreneurs during the course of the project: (1) IT-enabled services to manage harvesting and logistics; and (2) 'Cooling as a service' that provides access, improves market connectivity and maximises efficiency with the lowest carbon footprint.

IT-enabled services to manage harvesting and logistics

Table 3. Business proposition 1: IT-enabled services to manage harvesting and logistics (Source: MP Ensystems Advisory Pvt. Ltd, 2018)

Primary goals:
Linking the market requirements for fruits and vegetables with the time of harvesting
Reducing losses in haulage by accurately linking time of harvesting, storage and market
Prospective businesses:
Farmer-producer organisations created as subsidiary companies or business units
Social entrepreneurs supported through impact investors – start-ups with IT skills
Established Indian and oversees brands
Pre-launch activities:
Market assessments, understanding of holding life of produce in each section of the logistics chain
Understanding of inventory management at the farm gate and at markets (wholesale and retail)
IT platform development considering connectivity in the rural sector, data capture of commodity prices
Cost and revenue model:
Initiation costs to include setting up of IT platforms, development of apps that are compatible with 3G/4G connectivity
Revenue generation through a subscription-based model (an annual fee to be charged to the group of farmers) and create advertising revenues
Other benefits:
Computer literacy at the villages – including adult education
Local youth creativity centres to assist the villagers to reach out to global platforms and associated job creation
Extension of logistics support services to health and educational systems

The Information Technology Bill passed in May 2000 paved the way for India's IT revolution, boosting e-commerce and internet-related business. The 'knowledge revolution', as it is now termed, resulted in cyber cafés in rural areas providing villagers with access to computerised land records. Project Gyandoot, for example, helped farmers get the best prices for their produce from nearby markets (Paradkar, 2000).

Agri App, iffcokissan app, Agri Media Video App, Farm Bee RML Farmer and KisanYojna are some of the popular Android-based apps that provide services such as an online market, answers to agricultural queries, latest technologies for improving agricultural production and latest *mandi* prices (Tat, 2018).

The mKisan portal of the Government of India, under the National e-Governance Plan – Agriculture (NeGP-A), provides a SMS (short messaging service) portal for farmers with low internet penetration in rural areas but mobile connectivity to nearly 89.3 million farm families, enabling state and central government organisations to reach out to farmers through internet, touch-screen kiosks, agri-clinics and Kisan call centres. Portals using services such as USSD (unstructured supplementary service data), IVRS (interactive voice response system) and Pull SMS enable farmers and other stakeholders to receive messages and web-based services on their mobile phones without using the internet (Ministry of Electronics & Information Technology, 2014). A number of free agriculture-related apps are provided by the Ministry of Agriculture.

The envisaged outcomes of business proposition 1 are:

1. to enable and empower farmers by facilitating the flow of knowledge and information;
2. to trace the forward- and reverse-flow value of cold chain from farm to fork and fork to farm – reducing food losses and bringing the value back to the farmers – working in the form of a block-chain technology; and
3. to increase transparency in the supply chain.

Cooling as a service

The standard business model of delivering cooling for both space cooling and cold chain typically involves the sale of equipment. Cooling as a service sees customers paying for the cooling on an as-used basis, with a third party funding the capital, infrastructure and maintenance costs and selling a service. Examples of the cooling-as-a-service model include pay-per-service models, where a technology provider installs and maintains the cooling equipment, and recovers costs through usage payments made by the customer (*eg* ColdHubs, EcoZen).

These payments are fixed-cost-per-unit for the cooling service used (*eg* per tonne of refrigeration, cubic metre of cooled air, or as simple as cost per tray of food in a cold store overnight). The payment is not dependent on the savings (as with an Energy Services Company model), but instead agreed in advance as a function of actual usage. ESCO models are also present in the sector, mostly in relation to commercially owned equipment.

Given the growth in demand for cooling in developing markets (especially cold chain for subsistence farmers), cooling-as-a-service models benefit customers by removing the upfront capital investment. The model also reduces the perceived technology risk for the clients, as they are not required to invest in the technologies directly, and are not exposed to equipment failure. Cooling as a service can give technology providers a stronger incentive to increase their own profits by reducing their products' operating costs through innovation. Cooling as a service can also increase the likelihood that cooling equipment is effectively serviced and maintained (and upgraded), lowering the risk of unplanned breakdowns and creeping inefficiency.

Based on the models discussed here, we have proposed a model cold chain to be implemented by the CCDP scheme: an integrated pack house with automatic sorting, grading and packing of fruits and vegetables for round fruits and vegetables (2 tonnes per hour); additional manual processing line for other vegetables; two pre-cooling units each of 6 tonnes, each handling two batches of pre-cooling per day; and two cold rooms of 125 tonnes each designed for a temperature range of 0-8°C to suit the requirements of a variety of products.

The CCDP has the goal of creating farmers' collectives, especially small-scale producers at various levels across the state, to disseminate technology, improve productivity, empower farmers by improving access to services, and thereby increase income. The scheme focusses on forward and backward integration by creating on-farm infrastructure required for organised marketing of fresh fruits and vegetables by farmer-producer organisations/companies completing the supply chain from production to market. This could be a suitable vehicle to manage a facility and deliver cooling as a service using sustainable technologies to farmers.

Table 4. Business proposition 2: Cooling as a service that provides access, improves market connectivity and maximises efficiency at the lowest carbon footprint (Source: MP Ensystems Advisory Pvt. Ltd, 2018)

Primary goals:
Create access to cold chains – first- and last-mile transportation, cold rooms with energy-efficient and low-ODS (ozone-depleting substances) use systems
Promote waste-to-energy and solar-thermal/solar-PV systems to reduce fossil-fuel-based systems
Create grid-support services through the cold-chain assets
Promote innovative technologies such as phase-change materials and eutectic plates used in construction and transportation networks
Prospective businesses:
Energy service companies, equipment-leasing companies and integrators creating a 'pay-as-you-go' model for the number of hours of operation of cold rooms and miles travelled during the transportation phase
Farmer-producer organisations created as subsidiary companies or their business units or social entrepreneurs carrying out the above-mentioned activities
Pre-launch activities:
Standardised designs for alternative refrigerants, alternative energy technologies
Understanding of operational and maintenance requirements
Development of a business plan to launch one service extended to multiple states
Understanding of energy markets and possible renewable-energy integration/grid-support opportunities
Cost and revenue model:
Project development and implementation costs taking into consideration the central and state government subsidies/ incentives available
Revenue generation through a monthly fixed fee and/or operating expenses benchmarked to the use of cooling as a service
Cross-sale of hot water and secondary cooling to healthcare and rural industries
Other benefits:
Local youth (female and male) involved in operation and maintenance services, creating jobs
Extension of logistics support services in health and rural industries

Conclusions

There is no doubt that successful development and implementation of the clean cold chain could solve many issues related to high food losses in a sustainable way, delivering economic, environmental and societal benefits while reducing resource depletion for future generations. However, many of the outreach methods typically used for engaging growers, traders, storage operators, transporters and marketers do not yet incorporate clean cold-chain development and management. Moreover, successful communication is not just practical information about a single technology.

For accelerated and successful clean cold-chain development, we propose a synergistic collaboration built upon a technology-agnostic 'Living laboratory' programme that would develop appropriate curriculum and training programmes around entrepreneurship and business, as well as demonstrate technology in real-world situations to deliver a robust and verified evidence base. Such a programme should be comprehensive, designed for different sectors, supply-chain actors and service providers, with effective implementation of a portfolio of classroom-based and e-learning-based outreach methods, including training-of-trainers programmes and local post-harvest innovation platforms. It should specifically support the formation and empowerment of women-led businesses in the value chains.

References

Committee for Doubling Farmers' Income, 2017. *Report of the Committee for Doubling Farmers' Income*, vol. 3 *Post-production agri-logistics: maximising gains for farmers*. New Delhi: Department of Agriculture, Cooperation and Farmers' Welfare, Ministry of Agriculture and Farmers' Welfare.

Ministry of Electronics and Information Technology, 2014. *mKisan Portal – mobile based services for farmers*. New Delhi: Ministry of Agriculture, Government of India.

NCCD, 2015. *All India cold-chain infrastructure capacity (assessment of status & gap)*. New Delhi: National Centre for Cold-chain Development. [https://nccd.gov.in/PDF/CCSG_Final%20Report_Web.pdf]. Accessed 21 March 2019.

NITI Aayog, 2015. *Raising agricultural productivity and making farming remunerative for farmers*. An occasional paper. New Delhi: National Institution for Transforming India Aayog, Government of India. [http://www.niti.gov.in/writereaddata/files/document_publication/Raising%20Agricultural%20Productivity%20and%20Making%20Farming%20Remunerative%20for%20Farmers.pdf]. Accessed 15 September 2018.

Paradkar S, 2000. India's computer revolution. *Encyclopaedia Britannica*. [https://www.britannica.com/topic/Indias-Computer-Revolution-716206]. Accessed 25 March 2019.

Sims R, Flammini A, Puri M, Bracco S, 2015. *Opportunities for agri-food chains to become energy-smart*. Rome: Food and Agriculture Organization of the United Nations; Washington, DC: United States Agency for International Development. [http://www.fao.org/3/a-i5125e.pdf]. Accessed 21 March 2019.

Tat J, 2018. Top 5 best android apps for Indian farmers/agriculture – 2018. *MyStory*, 2 August [https://yourstory.com/mystory/e374fa4df7-top-5-best-android-app]. Accessed 25 March 2019.

News from the field

The cold truth about Ethiopia

Addis Ababa, Ethiopia – Professor Yetenayet Bekele Tola cringed as he patrolled the nation's largest fruit and vegetable market recently. Mounds of lettuce and swiss chard laid out on newspapers were wilting in the morning's rising sun in the sprawling capital-city market. Bananas in straw baskets were already bruised and blackened.

There wasn't a refrigerator to be found to keep the crops fresh.

For Dr Yetenayet, who studies food science and technology at Jimma University, the damaged food is a pungent reminder of a fragmented food-distribution system that is a significant contributor to the country's – and Africa's – severe malnutrition problems. Losing fruit and vegetables, along with other key perishables such as milk, is a loss of essential nutrients, vitamins and minerals that would otherwise help sustain millions of Ethiopians.

"There is no cold room storage whatsoever," Dr Yetenayet said. *"The way fruits and vegetables are being handled is not up to standard. It leads to lots of spoilage. The food can't get to people, and it's less nutritious."*

While agricultural production of fruit and vegetables in Africa's second most populous country has surged in recent decades, millions of Ethiopians are still not eating them. Those suffering the most are the rural poor, many of them smallholder farmers living beyond the reach of electricity, refrigeration and viable markets. Most of what they grow on their tiny plots are cereal crops, including *teff* (a local grain), maize and sorghum, for home consumption. Fruit and vegetables are too expensive.

Refrigeration, or cold storage, certainly exists in the massive strawberry farms and flower hothouses that line the dusty roads south of Addis Ababa, the country's capital. But Ethiopia – and Africa – is facing a reckoning in how to create and sustain a network of refrigeration to feed their own.

I recently spent a week travelling across much of Ethiopia chronicling where refrigeration was taking hold. I visited families in rural areas and saw first-hand how food refrigeration and cold storage, while still rare, are beginning to take stronger hold in diverse parts of the country, from commercialised urban areas to a small remote island using solar-powered refrigeration.