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Cold chain investment opportunities in horticulture in Egypt

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COLD CHAIN INVESTMENT OPPORTUNITIES IN HORTICULTURE IN EGYPT

NL هولندا
Chemonics Egypt Consultants
WAGENINGEN UNIVERSITY & RESEARCH

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Executive Summary

Agriculture contributes to approximately 11% of the Egyptian Gross Domestic Production (GDP) demonstrating a real growth rate of about 3%, employing about 20% of the total workforce in Egypt[1], the largest share compared to other sectors. Agriculture also contributes to about 18% of commodity export earnings[2]. Additionally, the sector is a major source of wages and self-employment for women, especially in rural areas. Egypt's agri-food system as a whole, considering both agriculture, food processing as well as related input and trade systems, contributes 24.5% to Egypt's GDP[3]. Egypt's growing arable land and its fertile soils as well as government initiatives promoting agricultural productivity, food safety, export readiness, and foreign direct investment, the launch of the National Silo project, the establishment of the National Food Safety Authority (NFSA) as well as incentives towards water saving such as water treatment and desalination, drip irrigation, and canal lining.

However, Post-Harvest Loss (PHL), which refers to food lost from crop harvesting to the consumer due to spoilage, quality, nutritional, or other types of losses, contributes to up to 55% of the overall food loss and waste in Egypt[4], creating a bottleneck that poses challenges to the advancement of agricultural, food security, environmental, and socio-economic development in the nation. PHL is partially attributed to the absence of effective and sustainable post-harvest-to-consumer cold chains in Egypt. The term "cold chain" refers to controlling the temperature of perishable goods from the point of origin to the point of consumption to ensure quality and safety, avoiding texture degradation, coloration, bruising, and microbiological growth[5].

Improving access to cold chains is a priority for Egypt's food security and food systems sustainability. It can effectively contribute to diminishing PHL and hence decrease waste, help close Egypt's food gap, as well as preserve scarce water and energy resources used in food production. Improved cold chains would also mean increased income for farmers due to decreased losses and maximization of crop value. Finally, Egypt's significant export potential can be further developed with effective cold chains.

In this context, **the Netherlands Agricultural Network in Egypt, Chemonics Egypt Consultants, and Wageningen University and Research, partnered to develop an investment map exploring cold chain opportunities in Egypt.**

The goal of the study is to facilitate the **reduction of food losses, enhance export potential, and improve value chain productivity, and smallholder farmer competitiveness** by stimulating new business opportunities and investments in cold value chain technologies and services in Egypt. **It also aims to increase the visibility** of the most promising and needed cold chain business opportunities and **reduce the market entry barriers** for investors to initiate future investment engagements in cold chain value chain technologies and services, based on **Egyptian-Dutch co-innovation and co-investment[6].**

1 Central Agency for Public Mobilization and Statistics (2021)
2 Egyptian State information service
3 UNIDO and Embassy of Switzerland in Egypt (2020)
4 FAO in Egypt
5 Singh, Santosh, et al. "Assessment of the Cold Chain Market in Kenya" (2023)
6 Agrologistics Sector Study Netherlands, Wageningen (2022)

- **Twenty-eight business opportunities serving horticulture value chains in Egypt were identified**
- **Ten most promising cold chain business opportunities** prioritized, using multi-dimensional criteria including economic, social, and environmental indicators, and 10 fact sheets developed.
- **Sixteen renewable energy and energy efficiency solutions**
- **Five business models that can support the adoption and upscaling of cold chain solutions in Egypt were identified**

Using the "Business Opportunity Mapping" (BOM) methodology developed by Chemonics Egypt Consultants with the United National Industrial Development Organization (UNIDO) in 2014. **Twenty-eight business opportunities serving horticulture value chains in Egypt** were identified based on secondary research as well as with inputs from 20+ market and technical experts and **then prioritized according to multi-dimensional criteria to map the ten most promising cold chain business opportunities serving horticulture value chains.** The study also includes important sustainability measures, including **fourteen renewable energy and energy efficiency solutions**, that could be integrated with existing or new cold chains to enhance climate resilience and profitability while also providing guidelines linking technology classes to crop types. Additionally, **fact sheets were developed for the top ten business opportunities** to highlight key elements regarding the market, process, forward and backward linkages, and financial features as well as important considerations and impact potential. In addition, the study suggests **five business models** that can be implemented in Egypt in the short term to drive the uptake of cold chain investments.

The twenty-eight identified business opportunities presented in the annex section of the report **are diverse in terms of the targeted value chain components, investment size, and origin of the technology needed to realize the business opportunity.** In summary:

1. **Targeted value chain components:**
    a. 30% of the business opportunities relate to pre-cooling solutions, 25% relate to packhouses and industrial facilities, 15% relate to temperature-controlled transportation, 15% relate to centralized cold storage for the local market, and 15% relate to ripening chamber opportunities.

2. **Investment size:**
    a. 25% of the business opportunities can be classified as small-size investments (up to a Capex of U.S Dollars 30,000), whereas 75% of the business opportunities can be classified as large-size investments (minimum Capex of U.S Dollars 150,000), whereas

3. **Origin of technology:**
    a. 45 % of the business opportunities are available through local manufacturing in Egypt, whereas 55% of the business opportunities rely on technologies that are available through imports.

The top ten business opportunities deduced as per the multi-dimensional criteria are:

1. Centralized collection centres for farmers and food aggregators
2. Natural or mechanical ventilation systems for potatoes in dry areas
3. Multi-crop Packhouses for food aggregators
4. Small multi-purpose packhouses for rural markets
5. Small-scale reefer trucks for small-scale produce transportation
6. Reefer trucks for large holder farmers, food processors, exporters
7. Hydro-cooling units near production sites for large-holder farmers

8. Evaporative pre-cooling units near production sites for large-holder farmers
9. Cold storage units near consumption centers for wholesalers
10. Forced air mobile cooler for small holders (portable)

The top 10 identified business opportunities are diverse in terms of targeted value chain components, end-users served, investment size, and linkages with clients and suppliers. In summary:

1. **Targeted value chain components and end-users served:**
   a. Five of the business opportunities relate to pre-cooling and refrigerated storage, three relate to packhousing and collection, and two relate to temperature-controlled transportation.

2. **Investment size:**
   a. Four of the business opportunities are classed as small-size investments (up to a Capex of U.S. Dollars 30,000), whereas six of the business opportunities are large-size investments (minimum Capex of U.S. Dollars 150,000).

3. **Origin of technology:**
   a. Two of the business opportunities utilize technologies that are dominated by local manufacturing in Egypt, whereas the remaining eight business opportunities make use of technologies that are dominated by imports from other markets.

4. **Forward and backward linkages with clients and suppliers:**
   a. Six of the top 10 business opportunities have strong forward linkages with the clients, whereas two of the top 10 business opportunities have moderate forward linkages with the clients, and two business opportunities have weak forward linkages with the clients.
   b. Four of the top 10 business opportunities have strong backward linkages with the suppliers, whereas two of the top 10 business opportunities have moderate backward linkages with the suppliers, and four of the top 10 business opportunities have weak backward linkages with the suppliers

The study hopes to inspire dialogue and concrete action towards developing and scaling cold chain solutions in Egypt as well as to advice farmers, investors, and financiers on business opportunities with high chances of success in Egypt.

The remaining structure of the report is as follows:

- **Section 2** provides context to the Egypt-focused cold chain study as well as describes the methodology used in the study and key considerations.
- **Section 3** covers the status and drivers of cold chain investments in Egypt.
- **Section 4** provides an overview of cold chain applications and technologies for Egypt as well as presents the identified business opportunities.
- **Section 5** Proposed business models highly relevant to the context of Egypt.
- **Section 6** presents the conclusion and recommendations for the way forward.

About the Netherlands Agricultural Network: By positioning the Netherlands as the international cooperation partner, the Netherlands Agricultural Network (LAN) strengthens the earning capacity of the Netherlands and contributes to the realization of the Sustainable Development Goals. Agricultural attachés are located at the economic department of 60 Netherlands embassies and consulates worldwide and attend 80 countries. Together with their teams they provide assistance to Dutch entrepreneurs, companies and knowledge institutions. They also represent the Netherlands at international organizations, such as FAO/WFP/IFAD in Rome, EU in Brussels and OECD in Paris.

About Chemonics Egypt Consultants: Chemonics Egypt Consultants (CE), an Egyptian Engineering and Management Consulting firm based in Cairo, was founded in 1992 as a franchise to Chemonics International (CI), a Washington D.C. based international development consulting firm. The firm has 450+ projects in 15+ countries in the Middle East and North Africa (MENA) with the public and private sectors as well as Non-Governmental Organizations (NGOs), international development agencies and donors. Its sectors of focus include elements of green economy such as: water and wastewater; waste management and recycling; sustainable agriculture and food production, and sustainable energy and energy efficiency. Services include direct advisory to start-ups and MSMEs, green credit facility design, financial and economic studies, and investment promotion.

About Wageningen University and Research: Wageningen University & Research is the cooperative framework of Wageningen University and the Wageningen Research Foundation, which comprises nine independent research institutes. The domain of Wageningen University & Research consists of three related core areas: Food, feed & biobased production, Natural resources & living environment as well as Society & well-being. The organization's research themes focus on climate change, circular & biobased economy, nutrition & health, "from hunger to food security", and biodiversity. The work of Wageningen University & Research comprises three components: education, independent research, and value creation.

SECTION 1

INTRODUCTION & BACKGROUND

By 2050, the global population is expected to be ten billion, necessitating a 56 percent increase in food production[7]. In addition to the increasing pressure on the food supply, the world loses or wastes about 30% of the food produced for human consumption. This equates to more than one billion metric tons each year, equivalent to one trillion U.S. Dollars[8]. According to a different estimate, more than 300 million metric tons of avoidable consumer food waste globally caused around four Exajoules (EJ) of energy inefficiencies, equivalent to the combined electricity consumption of Germany and France, with a water footprint of 82 billion cubic meters, equal to Mexico's yearly water use[9]. Moreover, one of the main causes of food insecurity for millions of global citizens is Post-harvest Food Loss (PHL)[10].

The significance of addressing post-harvest losses is reflected in The United Nation's Sustainable Development Goal 12.3, which addresses food security by calling to cut in half per capita global food waste at the retail and consumer levels and reduce food losses along production and supply chains, including post-harvest losses, by 2030[1].

In the Near East and North Africa (NENA), Food Loss and Waste (FLW) in food value chains amount to 250 kilograms (kg) per person costing governments and citizens more than 60 billion U.S. Dollars annually[11]. For a region that has a growing food gap, and is facing rising food inflation rates as well as a shortage of water and arable land with limited productivity, the social, economic, and environmental effects are severe. **In Egypt the loss of fruits and vegetables loss is estimated to reach up to 55 percent of production annually[12] only from farm production to mid-stream activities, before reaching food processors and/or consumers;** with United Nations Environment Programme (UNEP) indicating about 50kg per capita per year[13].

Agriculture crop loss and waste in Egypt are prompted by various technological, environmental, operational, market, as well as legislative and regulatory factors, including a weak cold chain infrastructure. Insufficient producer knowledge of high-quality inputs, limited awareness of Good Agricultural Practices (GAP), mismanaged pest and disease infestations, as well as damaging climatic and weather conditions, are some examples of technological and environmental factors. Inadequate handling of the products on the farm and wholesale or retail levels, limited forward-backward integration between end users and farmers, and weak logistics infrastructure for perishable agricultural products, including cold chain, are prominent examples of operational, market, as well as legislative and regulatory factors[14]. Food Loss and Waste (FLW)[15] in Egypt is also exacerbated due to the significant segmentation and fragmentation of agricultural land ownership. Around four percent of Egypt's land area is classified as agricultural land, translating to approximately ten million feddans (acres)[16]. However, nearly 90% of agricultural producers in Egypt are smallholder farmers with land holdings of less than three feddans (acres)[17].

7 World Resources Institute
8 WFP (World Food Programme)
9 Coudard et al., “Global water and energy losses from consumer avoidable food waste” (2021)
10 Post-Harvest Loss Reduction | WFP Innovation
11 CA1060EN.pdf (fao.org)
12 Food Loss and Waste | FAO in Egypt | Food and Agriculture Organization of the United Nations
13 TZH 28 - Tackling food loss and waste Egypt | FAO | Food and Agriculture Organization of the United Nations
14 Analysis of determinants to mitigate food losses and waste in the developing countries: empirical evidence from Egypt | SpringerLink
15 FLW is defined as a decrease, at all stages of the food supply chain from harvest to consumption, in mass, of food that was originally intended for human consumption, regardless of the cause
16 World Bank Data
17 International Food Policy Research Institute - Market-Oriented Agriculture Targeting Small-Scale Farmers

In addition to increasing the stress on food security, FLW results in significant economic loss. Egypt is a net importing country with agricultural commodities representing more than a quarter of the total imports (WTO, 2020)[18]. Egypt imports about 40% of the food it needs every year (FAO, 2021)[19]. However, Egypt's exports are growing, and the country has ambitious growth targets. Yet the country could realize greater export potential by investing in reducing PHL. As an example, FLW is significant in some of Egypt's top producing and exporting crops. At least one-fifth of the crops produced are lost or wasted. Between 20 to 22% of the potatoes production in Egypt was wasted across the supply chain between 2014 and 2018 as well as 43% of tomatoes and 28% of grapes in 2013[20] with a study reporting up to 50% of tomatoes and 45% of grapes in pre-consumer stages of the value chain in later years[21]. For illustrative purposes, assuming the volume of the three crops wasted were exported instead, with a selling price of 50 U.S. Dollars per metric ton, the lost revenue is at least 50 million U.S. Dollars annually. The lack of packaging, pre-cooling, and cold storage facilities was identified by a group of exporters as causing major trade obstacles for export markets that require certain quality standards (Elansari and Yahia, 2012)[22].

FLW leads to significant farmer income loss as well as water, energy, and land use inefficiencies. FLW in Egypt has a significant energy and water footprint. The agriculture sector in Egypt uses about 80% of its water withdrawal[23]. In 2010, Egypt had 500 cubic meters of renewable water resources per capita annually[24]. Yet, according to the Food and Agriculture Organization (FAO), "90 m3 of water per capita is lost each year due to the production and distribution of food that ends up lost or wasted"[25]. Moreover, one estimate noted that two acres per capita annually "is used to produce food that goes to waste"[26]. Such losses also lead to energy inefficiencies. Moreover, reducing food waste across the value chain is likely to result in additional income gains for smallholder farmers assuming an increase in the volumes sold and fair market transactions. For instance, farmers with limited access to cooling suffer direct financial losses and weaker negotiating power due to the need to sell their produce quickly after harvest, often at a lower price, to prevent loss from decay. FLW-reducing solutions like cold chain could also support enhancing the quality of the crops and their shelf lives as well as allow for smallholder farmers to control their sales cycles, allowing them to store their crops for longer periods and to sell at a wider range of prices.

A missed opportunity for climate action, natural resource conservation, and public health. FLW in Egypt also has a significant carbon emissions footprint. It results in almost 500 kg per capita of CO2 equivalent emissions per year contributing to climate change[27]. This excludes the Greenhouse Gas emissions from the energy infrastructure food value chains in Egypt and hydrofluorocarbon (HFC) emissions from the existing cold chain. Moreover, as of 2010, about 56% of the municipal solid waste composition in Egypt consisted of organics, including but not limited to food waste, of which more than 80% are disposed of in opened dump sites, waterways, and drains, which could cause the contamination of water supplies and negatively impact the health and welfare of

18 World Trade Organization. (2020). Egypt and the WTO
19 FAOSTAT Food and agriculture data (2021)
20 Food Loss and Waste Database | Technical Platform on the Measurement and Reduction of Food Loss and Waste | Food and Agriculture Organization of the United Nations (fao.org)
21 Food and Agriculture Organization of the United Nations
22 Analysis of determinants to mitigate food losses and waste in the developing countries: empirical evidence from Egypt | SpringerLink
23 Food and Agriculture Policy Review: Egypt (fao.org)
24 https://www.fao.org/in-action/water-efficiency-nena/countries/egypt/en/
25 Food and Agriculture Organization of the United Nations
26 Food and Agriculture Organization of the United Nations
27 Food and Agriculture Organization of the United Nations

citizens[28]. The food waste in landfills also contributes to significant GHG emissions. Moreover, poor PHL could also lead to the rise of food-borne diseases.

Cold chain solutions should be considered as a key solution to minimize Post-Harvest Loss (PHL), one of the main drivers of Food Loss and Waste (FLW) in Egypt. In 2022, the Food and Agriculture Organization (FAO) indicated that half of all fruit and vegetables in Egypt are wasted, along with 40% of fish and 30% of both milk and wheat[29]. For this reason, the study focused on assessing cold chain investment opportunities in horticulture value chains, albeit the significant opportunity in other value chains as well. The term "cold chain" refers to controlling the temperature of perishable goods from the point of origin to the point of consumption to ensure quality and safety, avoiding textual degradation, coloration, bruising, and microbiological growth[30]. Cold chain solutions are necessary to reduce horticulture losses by extending the shelf-life and retaining the quality of crops. Moreover, sustainably designed cold chain solutions can effectively enable market reach beyond hyper-local opportunities, increasing the revenues of farmers, processors, distributors, and retailers. This will in turn support significant environmental and socio-economic gains.

It is important to note that cold chain solutions come with diverse technologies that vary in their capital cost, technical complexity, applications, and energy requirements. Hence, there is no silver bullet and there is a need for tailored solutions and business models to serve various market sizes and segments. **Given the relatively high capital cost compared to other types of agri-food equipment, business model innovation is critical for the penetration of cold chain solutions in Egypt.**

The study accounts for diverse cold chain applications and technologies across horticulture value chains in Egypt and sheds light on various types of investment sizes, technology origins and complexities, and end-user types.

With a joint belief in the potential for inclusive and sustainable growth in Egypt's agro-logistics activities, the Embassy of the Netherlands, Chemonics Egypt Consultants, and Wageningen University and Research (WUR) partnered to develop an investment map and present business model options for cold chain opportunities in Egypt. The study aims to provide visibility and awareness of the most promising and needed cold chain opportunities in Egypt to mobilize investments in relevant technologies and services. Given the need to elevate most elements of the agri-food value chain in Egypt, from farm to fork, the study considered upstream technologies (farm-level), mid-stream technologies (logistics, processing, and packaging), and downstream technologies (retailers, wholesalers, consumers) for various crop groups. It also addresses high-potential renewable energy and energy efficiency applications across the value chain to be integrated into existing or new infrastructure for enhanced cost-effectiveness and climate sustainability. Cold chain opportunities, and supplementary processes, are present at almost every stage across the agricultural value chain, thus creating a broad and attractive investment landscape.

Finally, the study hopes to **inspire dialogue and concrete action** towards **developing and scaling cold chain solutions in Egypt** as well as to advise **farmers, investors, and financiers** on business opportunities with high chances of success in Egypt. **We aspire that the study serves as a launching pad for further market research and analysis as well as Egyptian-Dutch co-innovation and co-investment.**

Methodology. The study employed a methodology called "Business Opportunity Mapping" (BOM), a systematic process of surveying the market and identifying top business opportunities based on specific investment and

28 Composition (left) and performance (right) of MSW in Egypt as reported... | Download Scientific Diagram (researchgate.net)
29 A new partnership between FAO and the Egyptian Food Bank to reduce food waste | FAO in Egypt | Food and Agriculture Organization of the United Nations
30 Singh, Santosh, et al. "Assessment of the Cold Chain Market in Kenya" (2023)

impact priorities. The BOM methodology was developed by Chemonics Egypt Consultants with The United Nations Industrial Development Organization (UNIDO) Egypt in 2014. Its main output is general investment profiles and a presentation of key market information which could serve as input to feasibility studies and other financing or policy-making activities. Since 2014, it has supported the mapping and assessment of 300+ green and circular economy business opportunities for the private sector, entrepreneurs, development institutions, financial institutions, policy makers, and civil society. Over the years, it has succeeded in reducing investment risks as well as directing and mobilizing financing toward more financially viable opportunities with high economic and environmental returns. The methodology was implemented in 30+ projects spanning three countries, and used by a diverse spectrum of 100+ stakeholders. Given the difficulty in obtaining certain types of data in many emerging economies, the methodology builds on secondary research and the Delphi method, a systematic and interactive forecasting and decision-making method which relies on diverse expert inputs[31]. This study leveraged secondary research, expert consultations, and insights from a focus group with key practitioners and industry leaders.

31 https://www.investopedia.com/terms/d/delphi-method.asp

SECTION 2

STATUS AND DRIVERS OF COLD CHAIN INVESTMENTS IN EGYPT

Intending to identify cold chain gaps and potential business opportunities, this section presents an overview of the current situation of cold chain applications in Egypt as well as key demand drivers.

Limited penetration of cold chain solutions in Egypt. The refrigerated warehouse capacity in Egypt was 0.085 m^3 per urban resident in 2018 reducing to less than 0.005 m3 per capita in 2020 while the worldwide average in 2020 was 0.15 cubic meters per urban resident. Moreover, the average size of refrigerated warehouses in Egypt is 6,200 cubic meters in 2020, representing only six percent of the capacity in the Netherlands and seven percent of the capacity in Peru and Mexico. This may also indicate limited consolidation, in addition to per capita capacity, as compared to markets where the average size of refrigerated warehouses is greater than 100 thousand cubic meters[32]. Land-side cold chain solutions in horticulture in Egypt mainly include pre-cooling, bulk cold storage, perishable terminal, reefer vehicles as well as industrial, commercial, and household refrigerators. Packhouses and cold storage are largely privately owned and mainly accessible to large aggregators and multinational companies. The majority of farmers in Egypt, small-holder farmers, cannot access cold chain solutions mainly due to the high cost of the solutions. The small-holder farmers' agricultural production is limited. Therefore, the revenues generated are insufficient to purchase and access cold storage solutions. Few facilities are affordable and accessible for small and medium-holder farmers, like the Horticultural Export Improvement Association (HEIA) Luxor Cold Storage House in Upper Egypt[33] and the Esna Packhouse[34]. As of June 2023, 85 packhouses in Egypt are certified by Egypt's NFSA.[35] Moreover, most cold chain and food processing activity in Egypt is in Lower Egypt, the region which represents more than 70% of food processing gross output. Even though Upper Egypt plays a key role in primary agriculture, contributing about 30% to gross agricultural output (IFPRI, 2018)[36], it faces large unmet potential for both cold chain and food processing.

Despite the low and uneven penetration of cold chain solutions in Egypt, technical capacities and technologies are accessible. For example, more than 90% of the air conditioning systems in Egypt are assembled nationally and refrigeration equipment manufacturers in the country produce display cabinets, chest freezers and refrigerators, and fan coils[37]. Moreover, several government bodies, including the Agriculture Exporting Council, Food Export Council, and National Food Safety Authority have initiatives to qualify and enhance the capacities of the human resources required in key cold chain-related roles.

Growing domestic demand and export potential. Despite having an extensive and growing dairy, meat, fish, and pharmaceutical market in Egypt, which would increase the demand for various cold chain solutions, the study focused on identifying business opportunities within horticulture value chains. Between 2020 and 2021, Egypt produced 13.2 and 21.2 million metric tons of Fresh Fruits and Vegetables (FFV), respectively with an estimated market size of 3.8 Billion U.S. Dollars[38]. Being a lower middle-income[39] country, the domestic demand for cold chains in FFV is often driven by the upcoming middle class having more disposable money to spend in supermarkets and retail outlets. As a result, the demand for cold chains is expected to further grow, hence suitable

32 GCC (2020)
33 Horticultural Export Improvement Association
34 USAID
35 Arab Republic of Egypt National Food Safety Authority, 2023
36 IFPRI Egypt
37 Cool Up Programme (2022)
38 CAPMAS – Annual Bulletin for Crop Production in Egypt
39 World Bank Data, 2021

solutions should be made available and accessible. This poses attractive investment opportunities for investors willing to mobilize investments in the agricultural cold chain space in Egypt. The Egyptian FFVs market is expected to register a compound annual growth rate (CAGR) of 4.3% during the forecasted period 2022-2027[40] largely driven by the population growth of 1.7 % annually[41]. Moreover, Egyptian exports occupied a significant share of 40% of the local production in 2021. In the same year, the export of FFVs from Egypt to the EU only totaled approximately U.S. Dollars 1.4 Billion[42]. The large and growing FFV market in Egypt paired with the urgency to close the food gap nationally and internationally, provides a vast market opportunity for cold chain investments to strengthen and develop the cold chain infrastructure in Egypt[43].

Supported agricultural national projects and progammes in Egypt. Food security is a top priority as per Egypt's 2030 vision, therefore Egypt is undergoing the reclamation and restoration of land areas to increase its cultivated area from 9.7 million feddans in 2023 to more than 15 million feddans by 2030. This is expected to be achieved through the implementation of a number of projects such as the "One-and-a-Half Million Feddans Project", "New Delta Project", and "Toshka Project"[44]. The implementation of such projects will lead to a surge in the market supply which will require significant upscaling of cold chain solutions to meet the increase in the local production of fruits and vegetables. Therefore, an attractive investment landscape is created for investors interested in investing in the agricultural cold chain space. Moreover, such projects use scarce water, often from non-renewable groundwater or at rates outstripping the rate of renewal. The newly reclaimed land is often in less densely populated areas, meaning farm produce may be transported for longer distances to their destination. The locations and long distances pave the way for the implementation of cold chain solutions as well as present an opportunity to strengthen existing cold chain infrastructure to ensure minimal PHL along the value chain. In view of water scarcity, reducing PHL equates to reducing the loss of virtual water. The underserved and growing demand for cold chain solutions across horticulture value chains presents a significant opportunity for investors for the deployment of a variety of solutions serving different market segments and geographies.

40 Mordor Intelligence - Egypt Fruits & Vegetables Market Size & Share Analysis - Industry Research Report - Growth Trends
41 World Bank Data
42 Capmas – Foreign Trade Annual Bulletin
43 World Bank Data
44 (El Nour, Agricultural and Food-Policies in Egypt between 2014 and 2021 What Changed and What Didn't 2023)

SECTION 3

COLD CHAIN APPLICATIONS IN THE AGRICULTURAL VALUE CHAINS IN EGYPT

This section delves into cold chain gaps and solutions across key stages of the horticulture value chain in Egypt. It also covers the business opportunities identified and possible business models for deployment in Egypt as well as addresses high-potential renewable energy and energy efficiency applications across the value chain to optimize costs and promote climate sustainability.

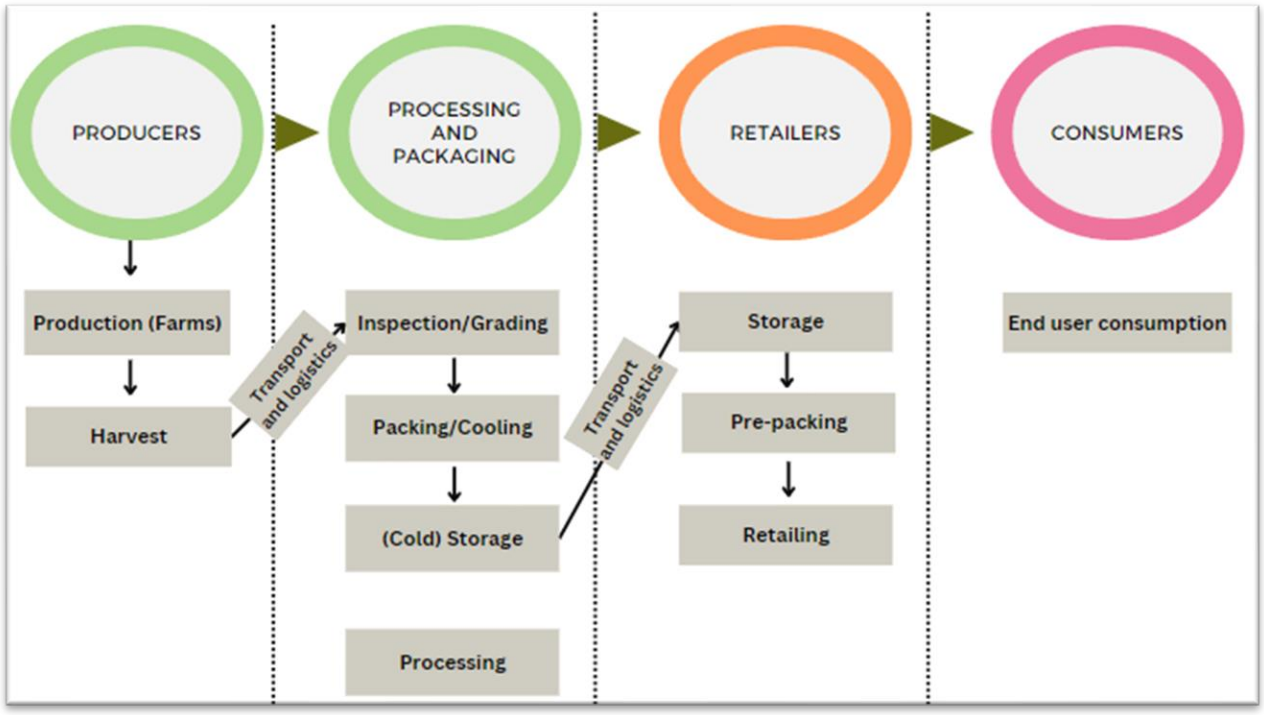
Cold Chain Gaps

Currently, the extent of integration of cold chain solutions in Egypt has been limited and not given the deserved recognition. Cold chain solutions are most effective when implemented across the whole value chain, from production to end-user consumption. Fragmented cold chain solutions can result in product quality deterioration due to ambient temperature fluctuation. This section presents an overview of the horticulture value chain in Egypt and focuses on identifying key gaps. As illustrated in Figure 1, the horticulture value chain is comprised of four main stages: production, processing and packaging, retailing, and consumption, with each stage made up of one or more sub-components. Cold chain demand exists at every stage. Energy-efficient and sustainable cooling in the residential sector is promising and has significant market potential in Egypt. However, the study did not assess business opportunities in this value chain stage. Solutions in this final stage of the value chain would be more effective once the cold chain infrastructure has been developed along the value chain.

This section briefly presents cold chain gaps from agricultural producers to consumers.

Pre-cooling in the production stage, the rapid removal of field heat shortly after the harvest of a crop is often a

Figure 1 Horticulture Value Chain. Source: Adapted from FAO and IRENA Renewable energy for agri-food systems – Towards the Sustainable Development Goals and the Paris Agreement.



necessary measure yet is often neglected. In the farm production phase, which includes growing and harvesting,

crops should be pre-cooled immediately after harvest to remove the field heat and cool the produce to optimal temperature before transportation to a cold storage warehouse or market. In Egypt, most farmers do not pre-cool their produce but rather transport it directly to packhouses and wholesale markets. The absence of pre-cooling can be attributed to the low awareness associated with the benefits and the high upfront cost required to purchase pre-cooling systems, given that most landowners are smallholder farmers. A range of technologies and systems can be utilized to address the lack of pre-cooling activities in Egypt.

Cold chain solutions in the processing and packaging stage of the value chain are limited to large-holder farmers and aggregators. Once harvested, the crops are transported to packhouse facilities where inspection, grading, packing, cooling, and temperature-controlled storage occur. Depending on the product, processing may also occur in manufacturing facilities. Processing and packing usually take place either at the farm, privately, or in private centralized packhouses operated by third-party service providers. In Egypt, large-holder farmers and agriculture aggregators are better equipped financially and operationally, compared to small and medium-holder farmers, to build the necessary infrastructure and systems to process and package their crops on their farms and usually own and operate pre-sorting, packaging, and cold storage facilities for example, Belco, Farm Frites, PICO, and Daltex. Centralized packhouses exist but their utilization is limited in rural areas due to various reasons including long distances from the farms and the farmers' lack of awareness of the business case. In addition, many farmers are unaware of the added value that the packhouses provide their crops and therewith the opportunity to negotiate a higher selling price. As a result, the handling, storage, and sales of perishable food items frequently occur entirely outside of temperature-controlled facilities when there is insufficient cold storage, especially in rural locations.

While the penetration of refrigerators in retail markets is considerable, cold chain in wholesale markets lags. Directly from the farm or following the processing and packaging stage, fresh or treated produce is transported from packhouses to wholesale, retail, and consumer markets. In Egypt, wholesale markets are a central last-mile logistic hub for fresh fruits and vegetables; supermarkets, HORECA (hotels, restaurants, and catering) individual consumers fulfill their needs via wholesale markets, like Obour market which is a hub for wholesales in the Greater Cairo region. However, wholesale markets in Egypt are not equipped to accommodate produce in a temperature-controlled environment which presents an important opportunity to invest in upgrading and equipping wholesale markets with cold chain solutions. For instance, the lack of necessary infrastructure and awareness regarding the benefits of temperature-controlled storage contribute to the absence of cold chain solutions in Egypt. Cold chain solutions in this stage can also include energy-efficient and enhanced refrigerated supermarket displays. There is room for enhanced adoption of cold chain solutions among wholesalers and retailers to extend the shelf-life of products and reduce food loss and waste.

Transportation and logistics services mainly serve end-users with large production and distribution capacities. Transportation, as a cross-cutting value chain component, simultaneously happens across the value chain to transport the products from one point to another. Currently, only large-scale refrigerated transportation is available in Egypt and is utilized by large-scale farms that target international food processors or the export market. On the other hand, smallholder farmers suffer from a competitive disadvantage due to their inability to utilize refrigerated transportation due to its absence on a small scale.

Cold Chain Technologies

Following the assessment of the main gaps in horticulture value chains in Egypt as well as the key crop classes affected, this section investigates applicable technologies. Although the concept of temperature-controlled storage is present worldwide, **technological sophistication varies from one country to another.** For instance, less developed nations frequently keep food in primitive rooms, rooms equipped with simple and non-latest technologies, rather than advanced cold storage facilities or warehouses during the distribution and retail stages of the agri-food chain.

The study maps the different technologies that are most suitable to be deployed in Egypt across the horticulture value chain, such as evaporative cooling, hydro-cooling, vapour compression, forced air cooling, and sorption. Every technology consists of five fundamental elements: power source, energy storage, refrigeration technology, transmission of heat, and insulation. These technologies are different from one another concerning key specifications and operational characteristics such as output temperature range, energy efficiency, areas, and crops of application.

In Egypt, refrigeration and cooling technologies are considered technically mature and widely available. However, it is essential to note that refrigeration technologies are more common within residential, commercial, and industrial sectors rather than the agricultural sector. Therefore, adopting and introducing these technologies to the agricultural sector presents massive investment and business opportunities.

Table 1 highlights the **technologies that can be utilized to mobilize cold chain investments within the agricultural value chain.** The technologies are presented from a functional point of view. Moreover, the opportunities and challenges associated with each technology are presented to determine the advantages and risks of deployment. Furthermore, the technologies are reviewed with respect to typical cooling times, product moisture loss, water contact with produce, energy efficiency, CapEx, and examples of relevant crops that can be cooled via each technology (

Cooling Technology	Specifications and Characteristics					
	Typical cooling time (hours)	Product moisture loss (% range)	Water contact with produce	Energy efficiency	Capital expenditure intensity (CapEx)	Examples of relevant crops
Evaporative cooling	5 – 10	0	No	Medium	Low	Tomatoes, Mangoes, Bananas, Green pepper and leafy vegetables.
Hydro-cooling	0.1 – 1.0	0 – 0.5	Yes	High	Medium	

						Apples, pears, watermelons.
Vapor compression	20 – 100	0.1 – 2.0	No	Low	Medium	Tomatoes, Mangoes, Bananas, Green pepper and leafy vegetables.
Forced air cooling	1 – 10	0.1 – 0.2	No	Medium	Medium	Applicable to all fruits and vegetables.
Sorption	20 – 100	0.1 – 0.2	No	Medium	High	Bananas, Citrus, Mango and "High value produce".

). These characteristics were chosen to compare the technologies because they provide an indicative overview of their key differences. In addition, the chosen technology attributes were classified as the most asked and enquired about by stakeholders during the study's focus group.

Table 1 Overview of cooling and refrigeration technologies that can be utilized to mobilize investments in cold chain solutions in horticulture value chains

Technology	Description
Evaporative cooling	**Design:** Evaporative cooling makes use of the cooling effect caused by water evaporation. Water is applied to a porous surface (e.g., pads, sand, or charcoal). Water absorbs energy in the form of heat from the surrounding air as it evaporates by changing phases from a liquid to a gas, causing the porous surface to cool-down. This straightforward cooling technique simply needs water

	freely flowing over a porous surface to act as a coolant; it uses no additional energy because it is powered by ambient heat. However, using fan-assisted systems will accelerate the cooling process. **Opportunities/Advantages** • Suitable for hot and dry areas. • Cheaper compared to other cooling technologies. • Relies on water as a refrigerant, which does not negatively impact the environment. **Challenges** • Difficult to accurately determine the output temperature range. • Its effectivity depends on the ambient humidity. • Minimal heat extraction from the produce, typically ranging between 7 to 10°C
Hydro-cooling	**Design:** Hydro-cooling provides a cooling effect to harvested fruits and vegetables through contact with chilled water. This reduces the temperature of the produce rapidly. Cool water can be supplied through showers or water beds where the produce is immersed in the water bath. **Opportunities/Advantages** • Simultaneously cools large amounts of produce. **Challenges** • Only applicable to certain Fresh Fruits and Vegetables (FFV) depending on shell and size, for example, watermelons and pears. • High requirements on water cleanliness to avoid product damage and contamination.
Vapour compression	**Design:** Vapour compression refrigeration cycle is the most popular cooling technology used in Egypt. Vapour compression cooling uses an electricity-powered mechanical compressor to circulate a refrigerant between high and low pressures. Thus, it is sometimes referred to as mechanical refrigeration. The refrigerant evaporates while absorbing heat from a cooling chamber in a low-pressure atmosphere, producing a cooling effect. The gaseous refrigerant is subsequently compressed, condensed, and therefore returned to its liquid form while rejecting the heat, that it had previously absorbed, outside the cooling chamber. **Opportunities/Advantages** • Mature technology in the Egyptian market. • Available after-sales services. **Challenges** • Periodic maintenance of the mechanical equipment is needed.
Forced air cooling	**Design:** The cooling system operates through forced convection of cooled air over the warmer produce. The produce is stacked in pellets in a special arrangement in a sealed refrigerated room to create a difference in pressure. A fan is used to move the refrigerated air through the pellets

	to cool down the produce. The convective contact of high-speed refrigerated air with warm produce creates rapid, uniform, predictable cooling. **Opportunities/Advantages** • High-speed process which reduces the time taken to cool down the produce, therefore, allowing for more efficient use of the facility/system. • The proper set-up of the system and fans ensure rapid and uniform cooling which enables the user to predict the cooling time. **Challenges** • Proper ordering and packing procedures must be followed to ensure uniform cooling of all produce.
Sorption	**Design:** The physical/chemical attraction between a working pair of substances, a refrigerant and an ab-/adsorbent, is the basis for the thermally powered refrigeration process with no need for mechanically-moving parts. At room temperature, the refrigerant will evaporate in a low-pressure atmosphere absorbing heat from the cooling chamber. The gaseous refrigerant is, then, ab-/adsorbed by the ab-/adsorbent absorbing even more heat from the chamber. This also results in a reduction in the evaporator's pressure, allowing for the evaporation of additional refrigerant. To return to the initial conditions, the refrigerant is evaporated from the ad-/adsorbent using thermal energy. **Opportunities/Advantages** • Systems rely on natural, sustainable refrigerants, such as water and ammonia. • Absence of mechanically-moving parts reduce noise and maintenance. • Flexible energy sources can be used including, electricity, solar heat or combustion. **Challenges** • Higher system complexity than vapor compression systems. • Limited applicability for FFV due to high relative cost.

Cooling Technology	Specifications and Characteristics

	Typical cooling time (hours)	Product moisture loss (% range)	Water contact with produce	Energy efficiency	Capital expenditure intensity (CapEx)	Examples of relevant crops
Evaporative cooling	5 – 10	0	No	Medium	Low	Tomatoes, Mangoes, Bananas, Green pepper and leafy vegetables.
Hydro-cooling	0.1 – 1.0	0 – 0.5	Yes	High	Medium	Apples, pears, watermelons.
Vapor compression	20 – 100	0.1 – 2.0	No	Low	Medium	Tomatoes, Mangoes, Bananas, Green pepper and leafy vegetables.
Forced air cooling	1 – 10	0.1 – 0.2	No	Medium	Medium	Applicable to all fruits and vegetables.
Sorption	20 – 100	0.1 – 0.2	No	Medium	High	Bananas, Citrus, Mango and "High value produce".

below highlights the key characteristics of each cooling technology to present an overview of the key differences between the technologies. The following characteristics were chosen to point out the differences between the cooling technologies: Typical cooling time, Product moisture loss, Water contact with produce, Energy efficiency, Capital expenditure intensity, and Examples of relevant crops.

Typical cooling time indicates the average time required for the produce to reach its optimal cooled temperature. This is important to consider the cooling time to arrange the required logistics needed for the crops.

Product moisture loss indicates the percentage of water lost from the produce during storage. Moisture loss is an important factor to consider to ensure that the crops being cooled and stored are not losing excess water that can ultimately deteriorate the quality and cause shriveling.

Water contact with the produce indicates whether there is direct contact between the produce and the water. This is important not only to ensure the availability of a continuous and clean water supply but also to ensure

that special packing and stacking requirements are fulfilled to avoid product damage from infections and microbial growth.

Additionally, **capital expenditure intensity** refers to the required initial investment to realize the business opportunity and is used to compare the required initial investment for each technology.

Finally, **examples of relevant crops** are included to indicate the most suitable crops that can be used with each technology in Egypt.

Table 2 Cooling and refrigeration technology overview with key specifications and characteristics for investment decision-making highlighted

Cooling Technology	Specifications and Characteristics					
	Typical cooling time (hours)	Product moisture loss (% range)	Water contact with produce[45]	Energy efficiency	Capital expenditure intensity (CapEx)	Examples of relevant crops
Evaporative cooling	5 – 10	0	No	Medium	Low	Tomatoes, Mangoes, Bananas, Green pepper and leafy vegetables.
Hydro-cooling	0.1 – 1.0	0 – 0.5	Yes	High	Medium	Apples, pears, watermelons.
Vapor compression	20 – 100	0.1 – 2.0	No	Low	Medium	Tomatoes, Mangoes, Bananas, Green pepper and leafy vegetables.
Forced air cooling	1 – 10	0.1 – 0.2	No	Medium	Medium	Applicable to all fruits and vegetables.
Sorption	20 – 100	0.1 – 0.2	No	Medium	High	Bananas, Citrus,

45 (Makule et al., 2022)

						Mango and "High value produce".

SECTION 4

BUSINESS OPPORTUNITIES

The study identified 28 business opportunities that were assessed and prioritized to conclude the top 10 business opportunities with the highest chances for success. Given the need to elevate most elements of the agri-food value chain, from farm to fork, our approach was to map cold chain solutions in the horticulture value chain with a wide range of applications, rather than ones that are highly crop specific. Therefore, we considered upstream technologies (farm-level), mid-stream technologies (logistics, processing, and packaging), and downstream technologies (retailers, wholesalers, consumers) for various crop groups. The identified business opportunities were assessed and compared using multiple criteria. The framework was particularly developed to compare diverse business opportunities and reflect both the economic and commercial side of the opportunities in addition to social and environmental objectives of creating employment, reducing emissions as well as supporting unskilled labor and women. This framework also considers forward[46] and backward[47] business linkages assessing the existence of connections between suppliers and buyers and their proximity. The assessment framework consisted of the following criteria:

1. **Market**

- *Forward-linkage potential:* Describes the existence and proximity of linkages to clients in existing economic activities and value chains, such as distributors and other clients.
- *Backward-linkage potential:* Describes the existence and proximity of linkages to suppliers in existing economic activities and value chains.
- *Existence of demand:* Describes the availability of demand on the outcome of the business opportunity under assessment.

2. **Economic**

- *Capital intensity:* Describes the initial investment needed to realize the business opportunity
- *Operating cost:* Describes the operating cost needed to operate the project

3. **Technology**

- *Availability of technology:* Describes the availability of the technology in Egypt in the business opportunity under assessment.
- *The adaptability of technology:* Suitability of the technology to the ambient conditions of Egypt

4. **Barriers to market entry**

- *The simplicity of technology:* Describes the level of sophistication involved in the technology used in the business opportunity under assessment.
- *Availability of service providers in Egypt:* This is primarily to assess the after-sales services that can be provided in Egypt such as the availability of maintenance and spare parts

46 The forward linkage potential was assessed based on geographical proximity to the client/market
47 The backward linkage potential was assessed based on geographical proximity to the suppliers/inputs

- *The intensity of competing products:* Describes the intensity of competition in the market about to be entered.
- *Access to knowledge and expertise:* Describes the ease of attaining the necessary knowledge and expertise to understand, build, operate, and innovate the technology involved in the business opportunity under assessment.
- *Bargaining power of suppliers:* Describes how much bargaining power suppliers have. For example, if only one supplier exists but has multiple buyers, the supplier will be at a strong advantage. Key elements to consider in this criteria are supplier concentration, difficulty switching from one supplier to another, etc.
- *Bargaining power of buyers:* Describes how much bargaining power customers have. For example, if there is only one buyer but multiple suppliers, the buyer will have a strong advantage. Key elements to consider in these criteria include customer concentration, price sensitivity, information availability, etc.

5. **Social and Environmental**

- *Favorability to the unskilled/semi-skilled:* Describes the ability to create jobs for those who are unskilled and struggling to find jobs.
- *Job creation potential:* Describes the ability to create jobs for those unemployed and struggling to find jobs.
- *Job favorability for women:* Describes the ability to create jobs for women. The most favorable business opportunities tend to be at the farm level as well as at the packhouses.
- *Potential to reduce GHG emissions:* Describes the potential reduction of GHGs accompanied by the implementation of the business opportunity under assessment primarily from the source of energy.
- *Potential to improve crop export readiness:* Potential to enhance the quality of the crops exported to the EU such as grapes, potatoes, citrus, and strawberries since this was a strategic objective of the project

Top Ten Business Opportunities

Error! Reference source not found. presents the top 10 business opportunities that were derived from the scoring against the multidimensional criteria described above. The business opportunities are presented in the demand-technology-supply format. The demand highlights the target market that each business opportunity serves, the supply highlights the required inputs to realize the business opportunity, whereas the medium that satisfies the demand via the supply is highlighted under the technology.

Table 3 Ranking of the top 10 business opportunities

Serial Number	Business Opportunity Title	Demand	Technology	Supply
1	Centralized collection centres for farmers and food aggregators	Farmers and food aggregators	Sensors and other automated technologies/ processes	Production line, processing and packaging lines, cold storage units
2	Natural or mechanical ventilation systems for potatoes in dry areas	Farmers	Ventilation systems	Air inlet, air filtering, fans, ducts, dehumidifier
3	Multi-crop Packhouses for food aggregators	Aggregators	sensors and other automated technologies/processes	Fully automated production line packhouses (including IQF, automated sorting, conveyors, packaging, and cold storage units)
4	Small multi-purpose packhouses for rural markets	Small holder farmers and traders	Sensors and other automated technologies/processes	Automated production line packhouses (including IQF, automated sorting, conveyors, packaging, and cold storage units)
5	Small-scale reefer trucks for small-scale produce transportation	Refrigerated transport of small produce capacity (12 pellets approx.) over short distances	Traditional vapour compression, Coolbot sensor, insulation, ventilation	Reefer trucks/ engine components for assembly Conventional window style air conditioner, insulation, Coolbot sensor
6	Reefer trucks for large holder farmers, food processors, exporters	Large-holder farmers and/or food processors (Refrigerated transport of produce for large-holder farmers, and exporters	Powered by the engine - Liquid air cryogenic engine	Reefer trucks/ engine components for assembly

Serial Number	Business Opportunity Title	Demand	Technology	Supply
7	Hydro-cooling units near production sites for large-holder farmers	Large holder farmers	Hydro-cooling	Hydro pre-cooling systems, cooling towers, crops
8	Evaporative pre-cooling units near production sites for large-holder farmers	Large holder farmers	Evaporative Cooling	Evaporative pre-cooling systems, cooling towers, evaporative pads, fans, water tanks, crops
9	Cold storage units near consumption centers for wholesalers	Wholesale traders (Cold stored produce for wholesale markets)	Traditional Vapour compression refrigeration, (refrigerant can be R717)	Vapour compression system, refrigerant
10	Forced air mobile cooler for small holders (portable)	Smallholder farmers	Forced air cooling	Electronic, electric components, fans, and material (metals and insulations)

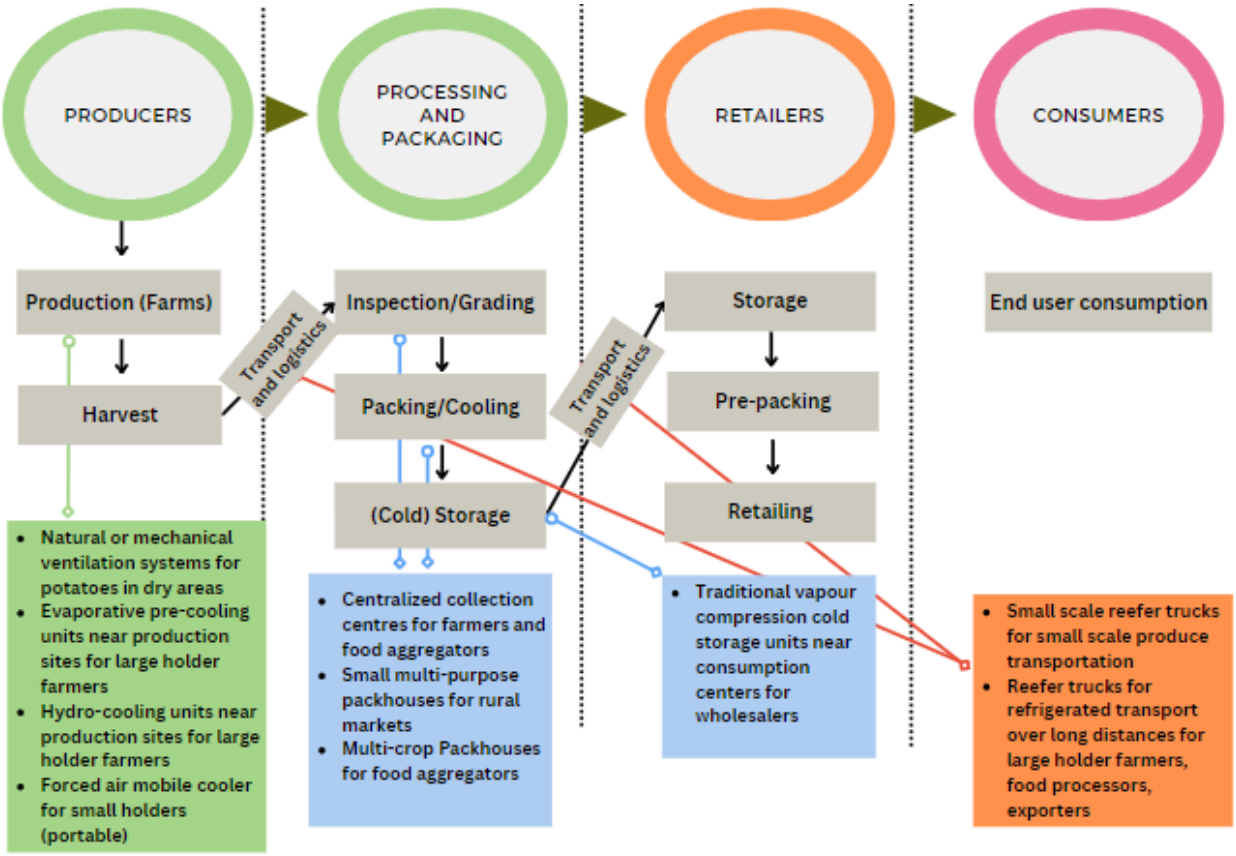
Table 4 Heatmap and business opportunity scoring[48]

48 The heatmap serves as a visual presentation, via colour codes, of the scores of the top 10 business opportunities against the prioritization criteria. The highest and lowest achievable scores for each criteria are 10 and 1 respectively. The descending scale of scores is denoted by the green, yellow, and red colours presented in the heatmap. High scores are presented via the green colours, the medium scores via yellow colours, and low scores via red colours.

Table 5 Classification of the top 10 business opportunities with respect to Capex, end-user, and origin of technology

Business Opportunity	Capex	End-User			Origin of Technology	
		Upstream (Farmers)	Midstream	Downstream (Retailers)	Readily Available	Imported
Centralized collection centres for farmers and food aggregators	High	✓	✓	✓		
Natural or mechanical ventilation systems for potatoes in dry areas	Low	✓	✓	✓	✓	
Multi-crop Packhouses for food aggregators	High	✓	✓	✓	✓	
Small multi-purpose packhouses for rural markets	High	✓			✓	
Small-scale reefer trucks for small-scale produce transportation	Medium		✓		✓	
Reefer trucks for large holder farmers, food processors, exporters	High		✓			✓
Hydro-cooling units near production sites for large-holder farmers	Low	✓				✓
Evaporative pre-cooling units near production sites for large-holder farmers	Medium	✓				
Cold storage units near consumption centers for wholesalers	Medium			✓	✓	
Forced air mobile cooler for small holders (portable)	Medium	✓				✓

Figure 2 Mapping of the top ten business opportunities from producers to retailers in the horticulture value chain



The top ten business opportunities (BOs) are described below with further details presented in the factsheets provided in the ANNEX.

Centralized collection and distribution center for farmers and food aggregators. This opportunity services the cold chain industry. It consists of sorting and grading lines as well as processing and packaging lines. The technology has low complexity as it relies on mature mechanical processes such as sorting, grading, and packing. The opportunity benefits from high forward and backward linkages given the availability and proximity of suppliers and buyers nationally. It also benefits from low OpEx. It is a solution with high CapEx driven by the cost of the processing and packing lines that are mainly imported. The main revenue streams are the sales and maintenance of turnkey centers as well as the provision of collection and aggregation services to clients. Investors relying only on the sales and maintenance of such systems in Egypt may face a challenge in growing sales since the replacement rate is low and the options to upgrade are limited.

Natural or mechanical ventilation systems for potatoes in dry areas for different types of farmers and aggregators. This business opportunity can significantly prolong the storage of potatoes in the fall and winter seasons and reduce loss and waste at storage. This closed environment mainly relies on readily available ventilation systems including air inlets, air filtering, fans, ducts, and control systems (typically imported), with a dehumidifier as an add-on for enhanced performance. The technology has low complexity as it is based on mechanical heat and mass transfer, yet it provides high-value add and is highly resilient. There is

medium competition in this space. The opportunity benefits from high forward and backward linkages given the proximity of suppliers and buyers nationally. It also benefits from low CapEx and OpEx compared to other cold chain solutions. A key advantage for end-users is that the technology is very durable, it has a long lifespan and limited maintenance needs. Its failure rates are also typically low. Albeit the significant market demand and size, this may pose a disadvantage to investors relying only on the sales and maintenance of such systems in Egypt since the replacement rate is low and the options to upgrade are limited.

Multi-crop packhouses for food aggregators. Serving diverse types of crops and all year long serving farmers and aggregators in rural areas in Egypt. Key processes include receiving the produce, sorting, grading, cleaning, treatments, packaging, cooling, and storage. The technology has low complexity as it relies on mature mechanical processes such as sorting, grading, packing, and cooling. The opportunity benefits from high forward and backward linkages given the availability and proximity of suppliers and buyers nationally. It is a solution with high CapEx driven by the cost of the processing and packing lines that are mainly imported. There is also a need to maintain the required operational conditions for different crop types to avoid quality deterioration and damage. The main revenue streams are the sales and maintenance of turnkey packhouses as well as the provision of packing and/or storage services to clients. Being multi-crop enables the packhouses to operate at different seasons, thus ensuring the continuous operation of the packhouse, resulting in reduced operational expenses. Being multi-crop serves a wider and larger target audience which can potentially increase revenues. Multi-crop packhouses can serve a wide range of F&Vs that require handling and cold storage, which can ultimately prolong the shelf life and reduce postharvest losses associated with such F&Vs. One of the key crops that can benefit from this business opportunity is onions. For instance, when onions are not correctly stored in a temperature-controlled environment with the necessary ventilation and dehumidification procedures, there is an opposed risk of the formation of microbial infections that can damage and infect the stored onions. Moreover, multi-crop packhouses can serve as a hub to store the crops intended for export. Doing so can ensure that the crops channeled to export routes meet the required export standards; therefore potentially increasing the volume of exported crops.

Small multi-purpose packhouses for rural markets. It consists of sorting and grading lines, processing and packaging lines, and cold storage units. The technology has low complexity as it relies on mature mechanical processes such as sorting, grading, and packing. The opportunity benefits from high forward and backward linkages given the availability and proximity of suppliers and buyers nationally. It is a solution with high CapEx driven by the cost of the processing and packing lines that are mainly imported. The main revenue streams are the sales and maintenance of turnkey centers as well as the provision of packing and/or storage services to clients. Being multi-purpose enables the packhouses to carry out numerous processing activities, thus ensuring the continuous operation of the packhouse, resulting in maximized revenues. Moreover, being multi-purpose serves a wider and larger target audience which can potentially increase revenues.

Small-scale reefer trucks for small-scale produce transportation. Refrigerated trucking, commonly known as "reefer," is a form of freight shipping that focuses on moving goods that need to be transported in a temperature-controlled environment. The goods are typically transported in a caravan that has a built-in

refrigeration system[49]. Small-scale reefer trucks are roughly larger than refrigerated vans and smaller than the large reefer trucks typically used in Egypt. They can typically hold about 12 pellets. They target small and medium-holder farmers who represent most landowners in Egypt. In addition to the potential to serve a large market size, this opportunity faces low competition in the Egyptian market, giving it high market growth potential. The technology has medium complexity, using vapor compression cooling with equipment including conventional window-style air conditioners, Coolbot sensors, insulation, and inverters. The opportunity benefits from high forward and backward linkages as well as medium CapEx and OpEx. Key revenue streams include the sales and maintenance of reefer trucks or their rental. The rental fees can be based on either quantity or distance covered. Small-scale reefers are mostly suitable for shorter distances (<100 Km) since the minimum achievable cooling temperature is 1°C.

Reefer trucks for largeholder farmers, food processors, and exporters. This opportunity also benefits from technology with medium complexity, relying on a mechanical process. The main equipment includes condensers, compressors, evaporators, insulation, sensors, and heavy trucks. Reefers could also be equipped with fleet monitoring systems. The opportunity realizes high forward- yet low backward linkages since many components are imported. It faces high CapEx and medium OpEx. It also faces competition from existing logistics providers and refrigerated transportation trucks and services. Key revenue streams include the sales and maintenance of units as well as their rental. The rental fees can be based on either quantity or distance covered. Growth potential can be to include online real-time monitoring and presentation of transported produce to clients. A key disadvantage of this opportunity is that the loading of the goods has to happen systematically to ensure cooling effectivity. Moreover, If the components need to be maintained or replaced, then the truck will not be functional until then.

Hydro-cooling units near production sites for largeholder farmers. After harvest, fruits and vegetables are subjected to hydro-cooling, which involves submerging them in ice or cold water to stop the ripening process. Compared to other cooling methods, such as vapor compression cooling, hydro-cooling rapidly cools the produce as long as the water is kept at close to freezing temperatures[50]. The technology is quite simple and relies on a mechanical process (heat transfer). Equipment includes hydro-cooling systems, cooling towers, water outlets, crops, and possibly water treatment units depending on the quality of the water source. It is typically applicable to large-size harvests. This opportunity benefits from low competition, low to medium CapEx and OpEx, and, high forward linkages yet the technologies are not readily available in Egypt resulting in low backward linkages. Key revenue streams include the sales and maintenance of hydro-cooling units. A key benefit of the technology in this opportunity is that it lowers the required workload of a cold storage facility since optimum storage temperature is reached more quickly. This also helps decrease CO_2 emissions compared to mechanical cooling. A key disadvantage is its restricted applicability to hard fruits and vegetables such as apples, pears, and watermelons. Moreover, water sanitation is a critical factor to prevent contamination and decay of fruits and vegetables. A special arrangement for fruits and vegetables is necessary to avoid the trap of water.

49 https://www.freightquote.com/define/what-is-refrigerated-trucking/
50 https://coldlogic.com.au/hydro-cooling/

Evaporative pre-cooling units near production sites for largeholder farmers. Evaporative cooling is an effective and affordable method of lowering the temperature and raising the relative humidity in an enclosure. Soon after harvest, the evaporative cooler has potential utility for short-term vegetable and fruit preservation. In addition to lowering the storage temperature, it also raises the relative humidity, which is crucial for preserving the freshness of the produce[51]. Therefore, this opportunity is most suitable in areas with low humidity. The technology has medium complexity with the main equipment being fans, evaporative pads, water tank and pump, piping system, and humidifiers. The business opportunity benefits from high forward and backward linkages as well as low competition nationally. Evaporative cooling also has lower energy consumption than mechanical cooling. Even though the CapEx is relatively high and the OpEx is moderate, the payback of this relatively less energy-intensive alternative solution may decrease due to the increase in electricity prices and other fuel sources. Key revenue streams include the sales and maintenance of evaporative pre-cooling systems to largeholder farmers. A proposed value proposition can be to provide online monitoring and data analytics (turnkey solutions) to farmers that can be based on a subscription model. The long lifespan of the system and components decreases the rate of recurring clients; therefore, it is important to consider the Internet of Things (IoT) and turnkey solutions.

Cold storage units near consumption centers for wholesalers. The main customer segment for this opportunity is wholesale markets in Egypt. The technology has moderate complexity and relies on mechanical cooling. The main equipment are compressors, condensers, expansion valves, evaporators, refrigerants, and insulation. Competition is moderate and the opportunity benefits from high forward and backward linkages. The technology is reliable and widespread therefore knowledge and expertise regarding the operation and maintenance of the system and components is accessible. There is also a high possibility and compatibility to integrate solar systems. Key revenue streams include the sales and maintenance of cold storage units as well as the rental of storage space to wholesale markets. The rental model can be based on quantity or time. The key disadvantage of this business opportunity is the high CapEx and OpEx, particularly for small businesses and other types of agriculture aggregators which limited financial capabilities such as agricultural NGOs.

Forced air mobile cooler for smallholders (portable). This opportunity is designed for rapid cooling of the product straight from the field mainly targeting small holder farmers. It allows for cooling for up to 10 hours. The technology is very flexible and applicable to all fruits and vegetables. On-site cooling eliminates the transportation costs to cooling facilities. The technology is moderately complex and relies on vapour compression cooling with a dedicated fan setup. The opportunity has moderate CapEx and OpEx yet it benefits from low competition as well as high forward linkages and low backward linkages. Key revenue streams include the sales of cooling units to individual small holder farmers, the sales of cooling units to a cluster of neighboring farmers, and the rental of units to different small holder farmers. The rental model can be based on time or quantity. The main disadvantage is that portable forced air cooling systems are not widely spread in Egypt and the cost of customer acquisition may be higher due to the high investment in awareness creation and marketing.

51 https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3602570/

Energy efficiency Solutions and Integration of Renewable Energy

Cooling calls for significant energy consumption, posing a problem and an opportunity. The cold chain, which includes commercial and residential refrigeration, contributes five percent of the total Greenhouse Gas (GHG) emissions from the global food system. The rise in GHG emissions that would result if future cold storage capacity were to come from fossil fuel-based systems would exacerbate climate change. Yet, developments in effective and renewable cooling technologies offer a chance to increase cold storage capacity in a way that is both accessible and environmentally responsible, especially in rural locations[1].

The study presents **fourteen high-potential renewable energy and energy efficiency applications across the value chain** for existing or new infrastructure to be cleaner as well as more efficient and climate resilient.

1. Scanners for produce for large-scale aggregators, food processors, and exporters to achieve high-quality produce. The technology includes three-dimensional scanning using high-quality scanners.
2. Eco-friendly refrigerants for retailers. The technology is based on heat transfer principles and refrigeration using environmentally friendly compression and refrigeration systems.
3. Online monitoring transported produce for logistic services using sensors e.g. to measure temperature, humidity, and PH.
4. Radio Frequency Identification (RFID) systems for food processors for the continuous and efficient monitoring and tracing of transported produce. The technology includes radio frequency identification using a user interface and data chips.
5. Radio Frequency Identification (RFID) systems for retailers enable the continuous and efficient monitoring and tracing of transported produce. The technology includes radio frequency identification using a user interface and data chips.
6. Variable Speed Drives (VSD) with compressed air units and chillers are applicable for various types of cooling equipment with motors. The technology includes VSD and automation components.
7. Data logging systems for logistic services in transportation to support the quality monitoring of transported produce. The technology includes data logging / computer-based systems as well as temperature and humidity sensors.
8. Gel packs for small holder farmers to facilitate transportation. The packs will serve to reduce the heat gain of produce for small-size local shipments. The technology is heat transfer via phase change packaging (Gel packs).
9. Smart packaging stickers for packhouses and industrial facilities for quality monitoring, shelf-life extension, and temperature control. To the best of the author's knowledge, such stickers are not produced in Egypt and will require to be imported.
10. Smart control systems for cold storage facilities for packhouses and industrial facilities. The technology includes various sensors (including temperature and humidity sensors) as well as tracking systems.

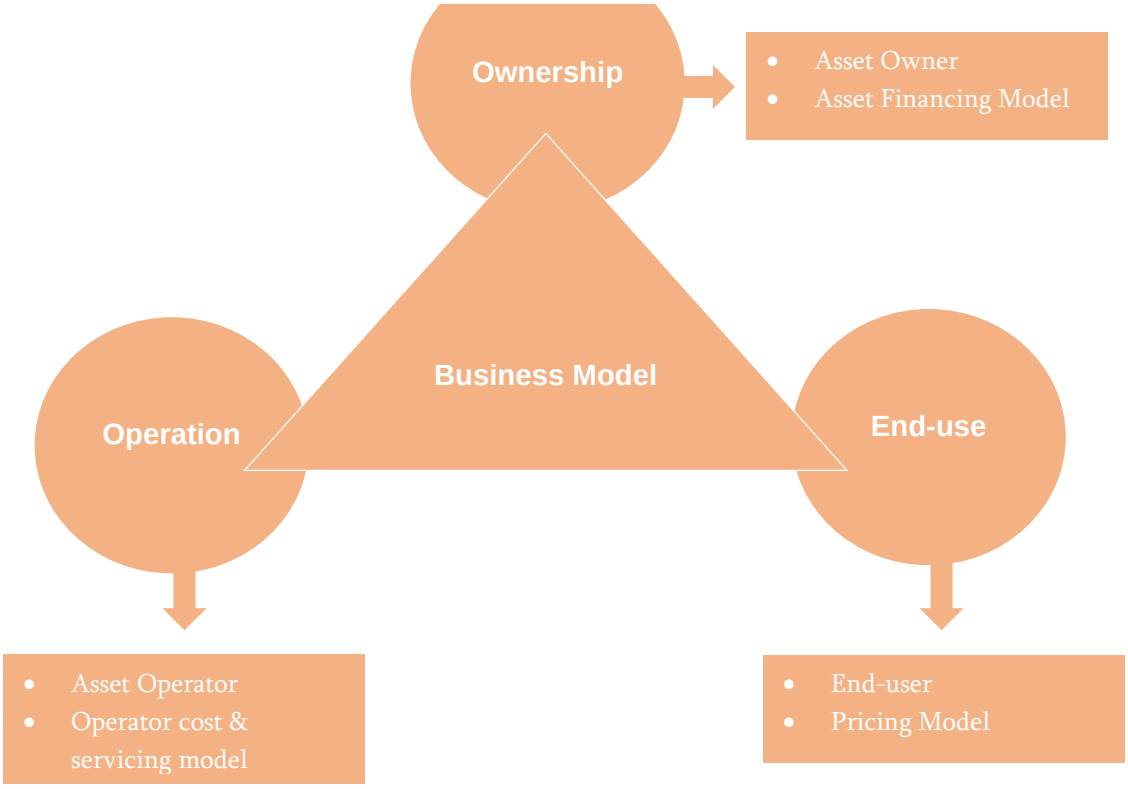
11. Devices for rapid test analysis of produce for packhouses to control the quality of the produce. The technology includes rapid test devices and total soluble solids (TSS).
12. Building Management Systems (BMS) for packhouses for the efficient monitoring and control of operating conditions in packhouses. The technology includes Building management system software and sensors.
13. Lithium batteries for appliances (forklifts) at cold storage facilities for optimized energy storage.
14. Solar Powered Energy for packhouses (on/off-grid) with technologies including solar PV panels, inverters, and energy storage
15. Sandwich panels at Packhouses for thermal insulation. The panels can aid in minimizing heat transfer and thus retaining the desired temperature.
16. Water treatment units to ensure that water quality is as required. Water treatment units can be implemented at Packhouses that require a clean supply of water or at hydro-cooling stations.

SECTION 5

BUSINESS

International and national experience shows that the penetration of cold chain solutions is highly dependent on the availability of highly locally tuned business models. While large-holder farmers and agri-food aggregators tend to own and operate their private infrastructure, innovative business models are needed to increase cold chain penetration, particularly for small-holder farmers and Small and Medium Enterprises (SMEs). The emergence of business models such as Cooling-as-a-Service (CaaS), rental, and lease-to-own models contributed to making cold chain solutions commercially available and affordable to smaller-sized beneficiaries in many emerging markets, especially for small holder farmers in the first mile. Accordingly, in this section, we present key business models that could enable cold chain solutions in Egypt, for various types of end-users. The business models are explained through three points of view: who owns the solution, who operates it, and who the end-user is in addition to the types of financial transactions at every level.

Figure 3 Main Pillars of the Business Model



The first fundamental pillar of the business model, ownership, comprises the asset owner and the financing model used to acquire the asset, which can be either direct capital investment or financed assets. The operation, the second business model pillar, consists of the asset operator and the operating financial model adopted to run the asset, such as rental. End-users are the beneficiaries expending their money to utilize cold chain solutions and services. Several pricing mechanisms and strategies can be used to offer cold chain solutions to the end-users, such as rentals per storage weight or duration. The presence of different stakeholder groups, pricing, and operational strategies have led to innovative and flexible business models

that can be used to drive the uptake of cold chain solutions. The business models presented are derived from the possible combinations that can result from the different options of the ownership, operation, and end-use points of view. The following are the business models, in no particular order of rating or favourability, that can be adopted in Egypt within the horticultural cold storage value chain with the highest success potential:

1. Upfront Purchase
    a. Capital investment
    b. Asset Financing
2. Lease-to-own
3. Rental
    a. Traditional rental
    b. CaaS (Cooling-as-a-Service)
4. 3PLs (3rd Party Logistics)
5. ESCOs (Energy Savings Companies) Model

Upfront purchase

Target clients are clients able to purchase cold chain solutions upfront, such as Large scale private farms – Large-scale scale food processors – Governments – NGOs, and Charity Associations.

Owner and operator of the cold chain solution: Purchaser of the cold storage solution

Dynamics: Upfront purchasing requires the customers to acquire the asset by paying the total cost via a one-time transaction. The upfront purchase can be made via direct capital investment or financed assets. When clients purchase upfront through their money/capital, direct capital investments are considered. On the other hand, asset financing is when a financial institution finances the asset's purchase on behalf of the client, and clients repay the total amount borrowed with interest to the financial institution. The investment scheme dictates how the business and financial calculations will be accounted for. For instance, the cold chain solution will be considered an asset in the supplier's financial statements, unlike other business models such as leasing/rental. The asset purchaser can then operate the cold chain asset/facility for their business activities or provide cooling services to other parties, such as smaller-scale food processors and traders.

Benefits

- **Reduced risk of default and delayed payments** since the asset is purchased upfront which reduces the financial risk for the seller from default and late payments. As a result, this positively impacts the seller's cash flow management cycle and eliminates any perceived financial risks.

Challenges

- **Smaller customer segment:** The business model targets end-users who have the financial capacity to purchase cold chain solutions via capital investment, such as large-scale private farms, food processors, traders, governments, charity associations, and cooperatives. However, the agricultural sector in Egypt is primarily comprised of smallholder farmers. For instance, 47% of Egypt's field crop production is from farms of less than three acres. Therefore, the business model only focuses on a smaller segment which can limit the sales of the cold chain solutions.

Lease-to-own

Target clients are clients that do not have the financial capability to purchase cold chain solutions through upfront purchase at the moment, such as cooperatives, large-scale farmers and food processors, and aggregators.

Ownership of the cold storage solution: The ownership belongs to the solution provider during the leasing period and is transferred to the client once the leasing period is concluded

Operation of the cold chain solution: The client

Dynamics. In lease-to-own, clients are required to pay a small upfront payment of the total cost of the cold storage solution, with the remaining cost split over a fixed term ranging from 20 – 60 months. Once the payment cycle is concluded, the ownership of the asset/solution is transferred to the client. Leasing constructions are quite common practice for cold chain development, and this is true for both high-income and middle-income countries. A recent example: "Kenyan-based company has recently applied to Rentco (EA) Ltd for a strait leasing deal (100%) for a 500 multi-commodity potato storage facility including all technology and equipment. This application concerns a (€ 74.500) lease, repayable in 5 years every quarter at an interest rate of 14,5% and a grace period of 3 to 6 months." Similar business models are observed in developing countries in Latin America and Asia[52].

Benefits

- **Full ownership of the asset:** Ownership of the asset remains with the lessor, who has the right to regain ownership if the lessee falls behind on payments. As a result, the lessor reduces the risk perceived in case of default payments.

- **Quick and high profits:** The lessor receives periodic lease payments from the lessee, which can cover the cost of the asset and generate future profits. The lease-to-own model is considered to be quick with respect to other business models. However, the upfront purchase model is considered to be quicker than the lease-to-own model.

Challenges

- **Unable to change the lease term agreements:** Lease terms are often fixed at the start of the lease period, which prevents the lessor from amending the lease terms. For instance, if the market price changes, the lessor cannot amend the lease price. In addition, if the price of the assets increases due to inflation, then the lessor is not benefiting from the increase in asset price.
- **High risk associated with default or incomplete payments:** Deferred, incomplete, or late payments can pose a significant risk to the business owner as the projected revenues are not achieved, whilst the asset is still being operated by the client. Such scenarios can lead to incurred revenue losses which can pose a financial risk for the business owner.

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Rental

Target clients are clients who are not able or willing to purchase cold storage solutions, such as smallholder farmers, food processors, and traders.

Owner and operator of the cold storage solution: The cold storage solution provider

Dynamics. Rental models require the user to pay a flat rental fee per annum or month. The traditional rental model dictates that the user pays a fixed fee per month or annum to rent the cold storage space or solution. On the other hand, CaaS is a service-based model where the clients can benefit from the cold storage facilities and solutions by paying a fixed rate for using the cold chain facility/solution for a particular weight and time duration. For instance, the service pricing can be set according to the quantity of stored produce in Kg, the number of crates or area required, and the required storage duration per month or year. Therefore, the cooling as a service model improves the smallholder farmers', processors', and traders' access to cold storage by providing suitable payment options.

Benefits

- **Larger market size/Bigger client pipeline:** Smallholder farmers represent the majority of farmers in Egypt. Therefore, adopting a business model targeting this segment can increase the supplier's revenues, supporting business growth, expansion, and positioning within the Egyptian market.

Challenges

- **Operational challenges:** Implementing the CaaS model at a large scale can make enforcing a large number of CaaS contracts challenging for suppliers, especially if the supplier is enforcing the contracts themselves rather than through a third party.

- **Responsibility of the facility and produce:** In the CaaS model, the facility's owner is also the operator. For instance, the owner is responsible for providing and maintaining the required storage conditions for the produce. To achieve this, the owner has to be aware of the ideal storage requirements and conditions to avoid the damage and deterioration of the stored produce. In addition to this, the owner is responsible for the maintenance of the cold storage equipment which requires financial, technical, and time commitments.

Third-Party Logistics (3PLs)

Target clients are clients that wish to outsource the logistics (storage and transportation) of their produce, such as large-scale farmers and private-sector food processors, traders, and aggregators targeting the local and export markets.

Owner and operator of the cold chain solution: The 3PL company

Dynamics. This model has been recognized as a fundamental growth driver in any country's scaling up of cold chain solutions[1]. In this model, a 3rd party logistics company owns and manages the cold chain assets (storage and transportation) and offers its services to clients in the market. Contractual agreements between the supplier and the client determine the costs associated with using the facilities. In this model, the logistics company does not gain ownership of the produce and is merely responsible for storing and handling the

produce. There are several 3rd party logistics companies in Egypt such as Logistica Egypt and The Arab Company for Food Industries and Cooling.

Benefits

- **Competitive pricing:** 3rd party logistic companies work with many client companies, enabling them to utilize their economy of scale. As a result, the 3PL company can provide their clients with attractive rates, ultimately expanding the client pipeline and corresponding to increased potential revenues.

- **Increased profit margins:** Having a large number of clients, the 3PL company can minimize its operational expenses because the operations are common for a large number of clients. Reducing operational expenses enables the 3PL company to comfortably determine its profit margins.

Challenges

- **Limited trust in the model:** Farmers and traders lose the sense of control over their stored produce being transported when they use 3PL providers. They have to trust that the logistics company can meet their desired level of satisfaction.

- **The large investment required:** Setting up a 3PL company is a large-scale investment that requires large capital investment to establish and operate the company. Therefore, evaluating the market of interest against different factors such as the market landscape, entry points, and competitiveness is important before establishing the 3PL company.

Energy Service Company (ESCO) or Profit-sharing from Savings Model

Target clients: Existing or to-be-established food processors, traders, 3PL companies, and cold chain solution owners that are interested in optimizing and conserving their energy consumption

Owner of the energy efficiency system: The ESCO

Operator of the energy efficiency system: The client

Dynamics: The ESCO (Energy Service Company) model shares profits from a savings model that allows the client to benefit from energy efficiency services through a contractual agreement. In this model, the ESCO retrofits and installs energy efficiency systems and components that aid clients in minimizing their energy consumption. The ownership of the energy efficiency systems is reserved for the supplier, whereas the operation and management of the systems is the property management office's responsibility. The business model dictates that the client pays a fixed percentage of the savings incurred from the energy efficiency systems installed to the system supplier.

Benefits

- **Attractive market in Egypt:** Egypt's resource and energy efficiency market is currently experiencing growth due to the increase in energy prices, which urges cold chain owners and operators to find

and implement energy-saving solutions. The urge to shift to energy-efficient solutions plays a key role in the ESCO model uptake in Egypt's cold chain solutions.

- **Attractive and accessible model to a large market segment:** The business model not only allows clients to enjoy reduced expenditure on energy but also provides them with extra cash that can be deployed in other business activities. In addition, clients enjoy the benefits without having to purchase energy-efficiency solutions and systems, making the ESCO model an attractive approach to clients. The ESCO model's benefits allow a large target audience, clients that cannot purchase the energy efficiency solutions, to opt for the model to implement energy efficiency solutions.

Challenges

- **Hard to measure and verify savings:** Measuring and verifying the energy savings in a facility is the core activity of implementing the ESCO model. Egypt has no general technical specifications for facility energy conservation measurement and verification. A number of factors will influence the amount of energy savings, such as the user's energy conservation awareness and management capabilities. As a result, it is difficult for the ESCO and the client to reach a consensus on the amount of energy savings and therefore determine the benefit sharing.
- **High required capital investment:** Setting up an ESCO is a large-scale investment that requires the founding party (investor) to thoroughly investigate the market of interest against several factors, such as the market landscape, entry, and competitiveness, before purchasing energy efficiency solutions. A large number of systems is required to expand and generate profits, which comes at a significant cost.
- **Ownership and operation rights:** In this model, the energy efficiency system supplier is the system owner, whereas the client is the operator. The distinction between ownership and operation hinders the exploitation of the ESCO model. For instance, the energy efficiency system operator might not have the required awareness and/or technical skills to manage and conserve energy consumption which might lead to reduced energy savings. Therefore, the client's awareness and skills, among many other factors, are critical factors that determine the business' profits.

SECTION 6

CONCLUSION

With significant growth potential on both the demand and supply sides, largely driven by increasing domestic demand for agricultural produce and exports as well as the expansion of arable land area, Egypt has a significant opportunity to demonstrate sustainable agri-food growth.

The Egyptian market has a high potential for Dutch investors willing to mobilize investments in the agricultural cold chain space, given the current significant market demand, and potentially growing, in Egypt. **The resultant business opportunities target a range of different value chain components as well as different investment sizes**. The variety of business opportunity characteristics provides an attractive investment guide to investors who are keen on investing in different value chain components across a wide spectrum of investment sizes. **Moreover, investors of different market backgrounds and investment sizes' appetites are expected to find appealing business opportunities that can serve as an entry point to a growing and rich market.**

However, Post-harvest Loss (PHL) contributes to up to 55% of the overall food loss and waste in Egypt presenting a missed opportunity for the nation to enhance its agricultural productivity, food security as well as other socio-economic and environmental aspects. **Enabling innovative business models and equitable access to cold chain solutions across horticulture value chains are key to diminishing PHL and to achieving food systems sustainability.** Cold chain solutions can effectively contribute to decreasing food waste which in turn could help preserve the scarce water and energy resources used in food production. Improved cold chains could also increase income for farmers and enhance export readiness. **However, there is limited penetration of cold chain solutions in Egypt, despite the availability and accessibility of many of the needed technical capacities and technologies.** For example, pre-cooling in the production stage is often neglected or underserved while cold chain solutions in processing, packaging, transportation, and logistics activities are mainly deployed and accessible to large private entities such as large holder farmers, agri-food aggregators, and exporters. Moreover, while the penetration of various types of refrigeration technologies for retail markets is considerable, cold chain in wholesale markets lags.

Given the need to elevate most elements of horticulture value chains, from farm to fork, the study mapped cold chain solutions in horticulture with a wide range of applications and for various crop groups. The twenty-eight identified business opportunities were derived from secondary research via an extensive literature review. Moreover, the secondary research results were validated via a validation focus group arranged with +20 top Egyptian market players. **The twenty-eight business opportunities were then assessed and compared by +5 local and international experts** via multiple criteria to consider commercial, social, and environmental aspects in **prioritizing the top ten for small to large-scale investments.**

The top ten opportunities are:

1. Centralized collection centres for farmers and food aggregators
2. Natural or mechanical ventilation systems for potatoes in dry areas
3. Multi-crop Packhouses for food aggregators
4. Small multi-purpose packhouses for rural markets

5. Small-scale reefer trucks for small-scale produce transportation
6. Reefer trucks for large holder farmers, food processors, exporters
7. Hydro-cooling units near production sites for large-holder farmers
8. Evaporative pre-cooling units near production sites for large-holder farmers
9. Cold storage units near consumption centers for wholesalers
10. Forced air mobile cooler for smallholders (portable)

The study also identified sixteen high-potential renewable energy and energy efficiency applications across the value chain for existing or new infrastructure to be cleaner as well as more efficient and climate resilient. Moreover, since cold chain solutions come with diverse technologies that vary in their capital cost, technical complexity, and applications, the diversity of business models to serve various market sizes and segments is critical for the penetration of cold chain solutions in Egypt. The business models with high chances of success in Egypt are upfront purchase, lease-to-own, traditional rental and Cooling-as-a-service (CaaS), Third Party Logistics (3PLs), and Energy Service Company (ESCO) or Profit-sharing from Savings Model. Finally, the study hopes to inspire further dialogue and concrete action towards developing and scaling cold chain solutions in Egypt as well as to advise farmers, investors, and financiers on business opportunities with high chances of success in Egypt.

SECTION 7

ANNEX

The Identified Twenty-Eight Business Opportunities

#	BO	Demand	Technology	Supply
Pre-Cooling BOs				
1	Evaporative pre-cooling units near production sites for large holder farmers	Large holder farmers	Hydro-cooling	Hydro pre-cooling systems, cooling towers, crops
2	Evaporative pre-cooling units near production sites for large holder farmers	Large holder farmers	Evaporative Cooling	Evaporative pre-cooling systems, cooling towers, crops
3	Sorption pre-cooling units near production sites for farmers	Large holder farmers	Solar thermal sorption cooling	Sorption cooling units, solar thermal system, solar energy
4	Sorption pre-cooling units near production sites for large holder farmers	Large holder farmers	Biomass sorption cooling, biomass combustion	Sorption cooling units, biomass units, biomass pellets
5	Traditional vapor compression pre-cooling units near production sites for farmers	large holder farmers (to serve Pre-cooled harvested produce)	Biogas powered vapor compression system, anaerobic digestion	Vapor compression cooling units, biomass units, animal manure
6	Forced air mobile cooler for small holders (portable)	Small holders 10 hours cooling	Forced air cooling	Electronic, electric components and material (metals and insulations)
7	Forced air solar powered small cooler for small holders	Small holders 10 hours cooling	Forced air cooling solar powered	Electronic, electric components and material (metals and insulations)
8	Natural or mechanical ventilation systems for potatoes in dry areas	Farmers	Ventilation systems	Air inlet, air filtering, fans, ducts
Pack Housing and Industrial Facilities				

#	BO	Demand	Technology	Supply
9	Automated bulk packhouses for large holder farmers	large holder farmers (Effective storage, handling and grading of produce)	sensors and other automated technologies/processes	Fully automated production line packhouses (including IQF, automated sorting, conveyors, packaging, cold storage units)
10	IQF or batch freezing units for processors and exporters	Processors and exporters (Frozen produce for exporting and local markets)	Blast freezing or Batch freezing	Liquid air or nitrogen
11	Small multi-purpose packhouses for rural markets	Small holder farmers and traders	Sensors and other automated technologies/processes	automated production line packhouses (including IQF, automated sorting, conveyors, packaging, cold storage units)
12	Centralized collection centres for farmers and food aggregators	Farmers and food aggregators	Sensors and other automated technologies/processes	Production line, processing and packaging lines, cold storage units
13	Multi-crop Packhouses for food aggregators	Aggregators	sensors and other automated technologies/processes	Fully automated production line packhouses (including IQF, automated sorting, conveyors, packaging, cold storage units)
14	Water treatment for Packhouses	Packhouse owners and operators	Washing or spraying	Antimicrobial compounds, sprinklers, rinse tanks, water supply
16	Sandwich panels for packhouses and cold storage units	Packhouses	Sandwich panels	Insulation material
Refrigerated Transportation				

#	BO	Demand	Technology	Supply
17	Reefer trucks for refrigerated transport over long distances for large holder farmers, food processors, exporters	large holder farmers and/or food processors (Refrigerated transport of produce for large holder farmers, and exporters	Powered by engine - Liquid air cryogenic engine	Reefer trucks/ engine components for assembly
18	Small scale reefer trucks for small scale produce transportation	Refrigerated transport of small produce capacity (12 pellets approx.) over short distances	Traditional vapour compression, Coolbot sensor, insulation, ventilation	Reefer trucks/ engine components for assembly Conventional window style air conditioner
19	Traceability systems for farmers	Farmers	Traceability systems	Online platform, barcodes
20	Traceability systems for food aggregators	Food aggregators	Traceability systems	Online platform, barcodes
Hub Cold Storage- centralized cold storage for local market				
21	Sorption cold storage units near consumption centers for wholesale traders	Wholesale traders (Cold stored produce for wholesale markets)	Sorption refrigeration	Sorption refrigeration system
22	Solar thermal sorption cold storage units near consumption centers for wholesale traders	Wholesale traders (Cold stored produce for wholesale markets)	Solar thermal sorption refrigeration	Sorption refrigeration system, solar thermal system, solar energy
23	Biomass/biogas sorption cold storage units near consumption sites for wholesale markets	Wholesale traders (Cold stored produce for wholesale markets)	Biomass sorption refrigeration, biomass combustion – biogas unit/manure	Sorption refrigeration units, biomass units, biomass pellets – biogas unit/manure
24	Cold storage units near consumption centers for wholesalers	Wholesale traders (Cold stored produce for wholesale markets)	Traditional Vapour compression refrigeration, (refrigerant can be R717)	Vapour compression system, refrigerant

#	BO	Demand	Technology	Supply
Ripening chambers/units Business Opportunities				
25	Ripening specific storage equipment for small scale ripening of climacteric fruits for small sized farmers	small scale farmers	Airtight/sealed and locked containers or bags	Ripening bags
26	(Semi-automatic/ automatic) ripening chambers near production sites for climacteric fruits (Sales of ripening units) for medium to large capacities	(medium to large sized local and export suppliers)	Ethylene, forced air ripening units (motorized dampers) ventilation system	Ripening chambers
27	Ripening chambers near production sites for climacteric fruits for medium to large capacities	(medium to large sized local and export suppliers)	Ethylene, smoke chambers, ventilation system	Ripening units
28	Mobile ripening units for climacteric fruits for large capacities	large farmers, aggregators and exporters	Ethylene, mobile ripening units and ventilation system	Mobile ripening units

Business Opportunity Factsheets

Having identified the top ten business opportunities, a factsheet for each BO is developed to present key data and information. Below is a sample business opportunity (BO) factsheet. Each factsheet provides the necessary information pertaining to each opportunity, and the base for developing the entrepreneurs' business model, team, and action plan. The factsheets cover the following six main aspects of the business opportunity:

1. Market
2. Process
3. Business linkages
4. Economic features
5. Considerations
6. General impact

The factsheets provide an overview of the main pillars that shape an investment decision. If a business opportunity is deemed of interest, then the information presented in the factsheet can be used to assess the feasibility of the opportunity. A description of the factsheet and the factsheets for the top 10 BOs are presented below.

BO FACTSHEET #: Title of business opportunity	
Market	
Final Products	Provides a general description of the final product.
Required Inputs	Required supply (feedstock, raw material), equipment, etc. to realize the BO.
Intensity of Competing Products	Description of the level of existing competition (low – medium – high)
Process	
Complexity - Type of Process	The level of complexity of the typical operational processes (simple-moderate – high). Also, illustrates the categorical type of the production process.
Technology	Mentions what is perceived to be the most appropriate technology
Equipment & Material	The main required equipment and material (not exhaustive).
Human Resources	Presents the key operational human resources needed
Business Linkage	
Forward Linkage	Types of markets/clients.
Backward Linkage	Types of suppliers.
Economic features	
Key Revenue Stream(s)	Refers to main revenue streams (not exhaustive).
CapEx	Describes the CapEx (High – medium – Low)
OpEx	Describes the OpEx (High – medium – Low)
Considerations	
Key Challenge(s)	Key challenges which the business model must tackle.

Advantages	The advantages of the opportunity compared to others in the markets and given the project objectives.
General Impact	
Environmental	Environmental impact in its wider context of resource preservation or energy efficiency
Social	Direct social impact – all opportunities have a positive social impact.

BO FACTSHEET 1: Centralized collection centres for farmers and food aggregators	
Market	
Final Products	Centralized collection centres
Required Inputs	Crops and system components
Intensity of Competing Products	Low – albeit there being individual and dispersed collection centres, centralized collection centres are not widely available
Process	
Complexity - Type Of Process	Low complexity –mechanical processes
Technology	Mechanical processes such as sorting, grading, and packing
Equipment & Material	Sorting and grading lines, processing and packing lines
Human Resources	Systems engineers, maintenance engineers, marketing and sales specialists
Business Linkage	
Forward Linkage (Clients)	Farmers and aggregators in Egypt
Backward Linkage (suppliers)	System suppliers
Economic features	
Key revenue stream(s)	Sales and maintenance of collection centres Providing collection and aggregation services to clients
CAPEX	High – driven by the cost of the processing lines that are mainly imported
OPEX	Low – driven by the need of unskilled labour and low tech and robust processes
Considerations	
Key Challenge(s)	• Investors relying only on the sales and maintenance of such systems in Egypt may face a challenge in growing sales since the replacement rate is low and the options to upgrade are limited • Marketing and reaching out to clients in rural areas
Advantages	• Being centralized provides the opportunity to have clients in different geographical areas and clusters • High available demand
General Impact	
Environmental	Being centralized cuts the resultant emissions from unnecessary transportation
Social	Creates job potential to the unskilled labour and women

BO FACTSHEET 2: Natural or mechanical ventilation systems for potatoes in dry areas	
Market	
Final Products	Natural or mechanical ventilation systems
Required Inputs	Potatoes and system components as mentioned below
Intensity of Competing Products	Medium – albeit there being limited suppliers providing such systems for agriculture purposes, existing HVAC providers could expand to providing such systems due to their low complexity
Process	
Complexity - Type Of Process	Low complexity; mechanical heat and mass transfer
Technology	Mechanical ventilation
Equipment & Material	Air inlets, air filtering, fans, ducts, control system, optional dehumidifier
Human Resources	Systems and maintenance engineers
Business Linkage	
Forward Linkage (Clients)	Farmers
Backward Linkage (suppliers)	System suppliers
Economic features	
Key revenue streams	Sales and maintenance of ventilation systems
CAPEX	Low – will increase if dehumidifier is added
OPEX	Low – will increase if dehumidifier is added
Considerations	
Key Challenge(s)	• Mainly viable in areas with low humidity • Investors relying only on the sales and maintenance of such systems in Egypt may face a challenge in growing sales since the replacement rate is low and the options to upgrade are limited • Low barrier to entry for competition
Advantages	• High demand • High potential to improve crop export readiness • Simple technology • Available technology, knowledge, and expertise as well as after sales services in Egypt market • Low CapEx and OpEx • High system/product durability with long lifespan and low failure rates
Impact	

Environmental	• Prolongs the storage of potatoes in fall and winter seasons, reduces potato loss and waste at storage • Energy efficient
Social	Improved farmer equity due to prolonged and effective storage, creates job potential for skilled workers.

BO FACTSHEET 3: Multi-crop Packhouses for food aggregators	
Market	
Final Products	Multi-crop Packhouses
Required Inputs	Crops and packhouse components
Intensity of Competing Products	Low – albeit there being individual and dispersed packhouses, there is a lack of multi-crop packhouses in Egypt
Process	
Complexity - Type Of Process	Low complexity –mechanical processes
Technology	Mechanical processes such as sorting, grading, packing and cooling
Equipment & Material	Sorting and grading lines, processing and packaging lines, cold storage units
Human Resources	Systems engineers, maintenance engineers, marketing and sales specialists
Business Linkage	
Forward Linkage (Clients)	Farmers and aggregators in rural areas in Egypt
Backward Linkage (suppliers)	System and component suppliers (the processing lines and machinery are imported)
Economic features	
Key revenue stream(s)	Sales and maintenance of multi-crop packhouses Providing packing and/or storage services to clients
CAPEX	High – driven by the cost of the processing lines that are mainly imported
OPEX	Low – driven by the need of unskilled labour and continuous operation of the packhouse
Considerations	
Key Challenge(s)	• Investors relying only on the sales and maintenance of such systems in Egypt may face a challenge in growing sales since the replacement rate is low and the options to upgrade are limited • Marketing and reaching out to clients in rural areas • Need to maintain required operational conditions for different crop types to avoid quality deterioration and damage • Highly dependent on imported processing lines

Advantages	• Being multi-crop enables the packhouses to operate at different seasons, thus ensuring the continuous operation of the packhouse, resulting in reduced operational expenses • Being multi-crop serves a wider and larger target audience which can potentially result in the increase in revenues • High available demand
General Impact	
Environmental	Being centralized cuts the resultant emissions from unnecessary transportation
Social	Creates job potential to the unskilled labour and women

BO FACTSHEET 4: Small multi-purpose packhouses for rural markets	
Market	
Final Products	Small multi-purpose packhouses
Required Inputs	Crops and packhouse components
Intensity of Competing Products	Low – albeit there being individual and dispersed packhouses, there is a lack of multi-purpose packhouses in Egypt, especially in rural areas
Process	
Complexity - Type Of Process	Low complexity – mechanical processes
Technology	Mechanical processes such as sorting, grading, packing and cooling
Equipment & Material	Sorting and grading lines, processing and packaging lines, cold storage units
Human Resources	Systems engineers, maintenance engineers, marketing and sales specialists
Business Linkage	
Forward Linkage (Clients)	Small scale farmers and aggregators in rural areas in Egypt
Backward Linkage (suppliers)	System and component suppliers (the processing lines and machinery are imported)
Economic features	
Key revenue stream(s)	Sales and maintenance of multi-purpose packhouses Providing packing and/or storage services to clients
CAPEX	High – driven by the cost of the processing lines that are mainly imported
OPEX	Low – driven by the need of unskilled labour and continuous operation of the packhouse
Considerations	
Key Challenge(s)	• Marketing and reaching out to clients in rural areas • Need to maintain required operational conditions for different crop types to avoid quality deterioration and damage

	• Highly dependent on imported processing lines
Advantages	• Being multi-purpose enables the Packhouses to carry out numerous processing activities, thus ensuring the continuous operation of the packhouse, resulting in maximized revenues • Being multi-purpose serves a wider and larger target audience which can potentially result in the increase in revenues • High available demand
General Impact	
Environmental	Being centralized cuts the resultant emissions from unnecessary transportation
Social	Creates job potential to the unskilled labour and women

BO FACTSHEET 5: Small scale reefer trucks for small scale produce transportation	
Market	
Final Products	Small scale reefer trucks
Required Inputs	Harvested produce and system components
Intensity of Competition	Medium to high competition – limited number of providers focusing on small scale applications yet there is some competition from traditional logistics providers and the informal sector
Process	
Complexity - Type Of Process	Medium – Mechanical cooling
Technology	Vapour compression cooling
Equipment & Material	Conventional window style air conditioner, Coolbot sensor, insulation, Inverter, pick-up truck
Human Resources	Mechanical engineers, maintenance engineers, marketing specialist, and drivers
Business Linkage	
Forward Linkage	Small holder farmers in Egypt
Backward Linkage	System suppliers (available nationally yet some components such as Coolbot sensors are imported)
Economic features	
Key revenue streams	• Sales and maintenance of reefer trucks • Rental of reefer trucks. The rental fees can be based on either quantity or distance covered • SaaS fleet management solutions
CAPEX	Medium – driven by high cost of most system components
OPEX	Medium – fuel and maintenance costs
Considerations	

Key Challenge(s)	• Only suitable for shorter distances (<100 Km), the minimum achievable cooling temperature is 1oC • Marketing and reaching to small holder farmers; low farmer awareness regarding the added returned value resulting from the expenditure on refrigerated transportation • Limited capacity (12 pellets) • Lack of awareness regarding proper loading and operational procedures- requires human resources to be trained and certified in loading and driving, etc. • Inflexible applications; if the components need to be maintained or replaced, the truck cannot be used for other purposes.
Advantages	• Targets small holder farmers that represent the majority of landowners in Egypt • High demand • High potential to improve crop export readiness • Available technology, knowledge, and expertise as well as after sales services in Egypt market • Applicable to all fruits and vegetables for short distances
General Impact	
Environmental	• Reduces food loss and waste during transportation • Increases shelf life of products
Social	Increased return on agricultural activities and creates job opportunities for moderately skilled and unskilled labour

BO FACTSHEET 6: Reefer trucks for large holder farmers, food processors, exporters	
Market	
Final Products	Reefer trucks for large holder farmers, food processors, and exporters
Required Inputs	Harvested produce and system components
Intensity of Competition	Low to Medium – existence of various types of refrigerated transportation trucks and services in Egypt serving different markets
Process	
Complexity - Type Of Process	Medium complexity – mechanical process
Technology	Vapour compression cooling
Equipment & Material	Condenser, compressor, evaporator, insulation, sensors, heavy trucks (optional: fleet monitoring systems)
Human Resources	Mechanical engineers, maintenance engineers, marketing specialist, and drivers
Business Linkage	

Forward Linkage	Large holder farmers, food processors and exporters
Backward Linkage	Component and system suppliers mainly international
Economic features	
Key revenue stream(s)	• Sales and maintenance of units • Rental of reefer trucks to clients. The rental fees can be based on either quantity or distance covered • SaaS fleet management solutions
CAPEX	High – cost of system components including trucks
OPEX	Medium – cost of fuel and maintenance
Considerations	
Key Challenge(s)	• Lack of awareness regarding proper loading and operational procedures- requires human resources to be trained and certified in loading and driving, etc. • Inflexible applications; if the components need to be maintained or replaced, the truck cannot be used for other purposes • Moisture loss need to be controlled over long-distance trips
Advantages	• High demand • High potential to improve crop export readiness • Available technology, knowledge, and expertise as well as after sales services in Egypt market • Applicable to all fruits and vegetables if moisture loss is properly controlled
General Impact	
Environmental	Protection of perishable crops during transportation decreasing food waste during transportation
Social	• Increase return on agricultural activity for farmers by providing an opportunity for geographical expansion of revenue channels. • High job creation potential and favorability to unskilled labour

BO FACTSHEET 7: Hydro-cooling units near production sites for large holder farmers	
Market	
Final Products	Hydro-cooling units for large holder farmers
Required Inputs	Harvested produce and system components
Intensity of Competition	Low – relatively new technology in Egypt
Process	
Complexity - Type of Process	Low – Mechanical (Heat transfer)
Technology	Hydro-cooling (Using water in direct contact with crops to reduce its temperature)

Equipment & Material	Hydro cooling systems, cooling towers, water outlets, crops, water treatment units (optional)
Human Resources	Systems engineers, maintenance engineers
Business Linkage	
Forward Linkage	Large holder farmers
Geographical Proximity	High
Local/Regional/Nationwide	Local
Backward Linkage	System suppliers
Local/Regional/Nationwide	international
Geographical Proximity	Low
Economic features	
Key Revenue Stream(s)	Sales and maintenance of hydro-cooling units
CAPEX	Low – if access to clean water is available. CapEx would increase if large water treatment systems are needed
OPEX	Low – relatively more expensive maintenance and need for continuous sanitation of water and could increase if large water treatment systems are needed
Considerations	
Key Challenge(s)	• Applicability is restricted to hard fruits and vegetables such as apples, pears, and watermelons • Water sanitation is a critical factor to prevent contamination and decay of fruits and vegetables • A special arrangement for the fruits and vegetables is necessary to avoid trapping of water which causes contamination • Less known and available technology in Egypt compared to mechanical, evaporative, and forced air. Limited expertise and aftersales service albeit the technology being simple. • Market entry and penetration of the product or service
Advantages	• Simple technology • Can simultaneously cool large amounts of produce • Rapid cooling - shorter required cooling time than vapour compression cooling • High demand • High potential to improve crop export readiness
General Impact	
Environmental	• Lower carbon footprint compared to mechanical cooling, since water is cooled passively in a cooling tower • Reduce loss and waste due to product quality deterioration and increased product shelf-life • Lowers the required workload of a cold storage facility since optimum storage temperature is reached more quickly

Social	• Increase return on agricultural activity for farmers by providing an opportunity for geographical expansion of revenue channels. • High job creation potential and favorability to unskilled labour

BO FACTSHEET 8: Evaporative pre-cooling units near production sites for large holder farmers	
Market	
Final Products	Evaporative pre-cooling units for large holder farmers
Required Inputs	Harvested produce and system components
Intensity of Competition	Medium – limited suppliers in Egypt targeting the agriculture sector, limited local manufacturing, more complex technology
Process	
Complexity - Type of Process	Medium complexity – Evaporative cooling
Technology	Evaporative cooling
Equipment & Material	Fans, evaporative pads, water tank and pump, piping system, humidifiers
Human Resources	Systems engineers, maintenance engineers, and marketing specialist
Business Linkage	
Forward Linkage	Large holder farmers in Egypt
Backward Linkage	System and component suppliers (mostly available nationally)
Economic features	
Key revenue stream(s)	• Sales and maintenance of evaporative pre-cooling systems • Software-as-a-service (SaaS) for online monitoring and data analytics
CAPEX	Medium – driven by high cost of most system components
OPEX	Medium – limited maintenance needs to Medium – skilled labour
Considerations	
Key Challenge(s)	• Most suitable in areas with low humidity • Key components rely on imports (e.g. evaporative pads) • Investors relying only on the sales and maintenance of such systems in Egypt may face a challenge in growing sales since the replacement rate is low and the options to upgrade are limited • Technology not commonly used in Egypt
Advantages	• Lower energy consumption than mechanical cooling • High demand • High potential to improve crop export readiness • Available technology, knowledge, and expertise as well as after sales services in Egypt market • High system/product durability with long lifespan and low failure rates

	• Can be easily integrated with greenhouses • Applicable to all fruits and vegetables due to the reduced moisture loss
General Impact	
Environmental	• Sustains the quality of harvested produce and thus reduces food waste • Lower energy consumption than mechanical cooling • Reduces the energy required to cold store the crops at later stages
Social	Job creation potential for both skilled, like HVAC engineers, and unskilled labour.

BO FACTSHEET 9: Cold storage units near consumption centers for wholesalers	
Market	
Final Products	Cold storage units for wholesale markets
Required Inputs	Produce and system components
Intensity of Competition	High – any type of refrigeration technologies
Process	
Complexity - Type Of Process	Medium – Mechanical cooling
Technology	Vapour compression
Equipment & Material	Compressor, condenser, expansion valve, evaporator, refrigerant, and insulation
Human Resources	Manual labour, HVAC engineer, maintenance engineer, and marketing specialist
Business Linkage	
Forward Linkage	Wholesale markets in Egypt
Backward Linkage	System suppliers (nationally available)
Economic features	
Key Revenue Stream(s)	• Sales and maintenance of cold storage units • Rental of storage space to wholesale markets. The rental model can be based on quantity or time.
CAPEX	Medium – driven by system components
OPEX	High – high energy consumption and maintenance needs
Considerations	
Key Challenge(s)	• High risk for moisture loss from the crops • High energy consumption and maintenance needs
Advantages	• High demand • Simple, mature, and widespread cooling technology in Egypt therefore the knowledge regarding the operation and maintenance of the system and components is accessible • Vapour compression systems can be easily integrated with solar PV compared to other cooling technologies • Applicable to all fruits and vegetables if moisture loss is properly controlled
General Impact	
Environmental	• Reduce loss and waste due to product quality deterioration • Increased product shelf-life
Social	High job creation potential and favorability to unskilled labour

BO FACTSHEET 10: Forced air mobile cooler for small holders (portable)	
Market	
Final Products	Portable forced air cooler for small holder farmers
Required Inputs	Harvested produce and system components
Intensity of Competition	Low – relatively new technology in Egypt
Process	
Complexity - Type Of Process	Medium- Mechanical cooling process
Technology	Vapour compression cooling with dedicated fan set up
Equipment & Material	Compressor, evaporator, expansion valve, electronic, electric components, fans and material (metals and insulations), and portable mount
Human Resources	HVAC engineer, maintenance engineer, marketing specialist, and drivers
Business Linkage	
Forward Linkage	Small holder farmers in Egypt
Backward Linkage	System suppliers (international)
Economic features	
Key Revenue Stream(s)	• Sales of cooling units to individual small holder farmers • Sales of cooling units to a cluster of neighboring farmers • Rental of units to different small holder farmers. The rental model can be based on quantity
CAPEX	Medium – higher than vapour compression due to the need for special fan arrangement
OPEX	High – energy intensity and maintenance needs
Considerations	
Key Challenge(s)	• Less known and available technology in Egypt compared to mechanical and evaporative. Limited expertise and aftersales service albeit the technology having medium complexity. • Market entry and penetration of the product or service • Moisture loss and levels need to be controlled during operation
Advantages	• Large market - Small holder farmers represent the majority of agricultural land owners in Egypt and the technology is applicable to all fruits and vegetables • On-site cooling eliminates the transportation costs to cooling facilities • Independency of the availability of cooling centres • Applicable to all fruits and vegetables if moisture loss is properly controlled • High available demands
General Impact	
Environmental	• Reduce loss and waste due to product quality deterioration • Increased product shelf-life
Social	Creates potential for unskilled labour and women

SECTION 8

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