FINAL REPORT

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A POLICY RESEARCH REPORT ON

Strengthening the Adoption of Cold Storage among Smallholder Farmers in Nepal

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ABSTRACT

Cold storage has been prioritized in the agricultural policy of Nepal for over a decade. Post-harvest losses and price volatility for perishable produce persist despite significant public investment. This study examines why cold storage infrastructure has failed to translate into broad farmer access and effective utilization. The study has drawn a national inventory of 445 cold storage and cold room facilities and used a mixed-methods field study across 13 districts in Gandaki, Bagmati, Lumbini, and Karnali provinces. The study combined descriptive and spatial analysis of national facility data and semi-structured interviews with 25 operators, 10 farmers, and 5 government officials. Nationally, only 46% of registered facilities were operational, with pronounced provincial disparities: Bagmati and Gandaki combined strong facility counts with comparatively high operational shares, while Lumbini had only 4 operational facilities against 56 non-operational ones. Thematic analysis identified nine interlocking constraints, converging on three structural gaps: a planning gap, in which facilities are sited without feasibility or commodity surveys, producing chronic underutilization; an operating-cost gap, in which subsidy policy has emphasized one-off capital grants over recurring electricity, maintenance, and technical-manpower costs; and a connectivity gap, in which cold storage remains disconnected from refrigerated transport, market information, and farmer aggregation mechanisms. The study concludes that Nepal's cold-chain constraint is institutional and operational rather than a shortage of capital investment, and proposes a sequenced package of feasibility-linked siting rules, rebalanced subsidy design, value-chain connectivity measures, and a National Cold Chain Strategy to close these gaps and improve farmer-level access.

Keywords: *cold storage, cold chain, post-harvest losses, smallholder farmers, Nepal, agricultural policy*

INTRODUCTION

1.1 Background

Food is a basic human right, and food security is significant for the overall human security (Hossain et al., 2018). Each year, approximately 1.3 billion tons of edible food are lost or wasted worldwide, contributing to about 3.3 billion tons of greenhouse gas emissions (Decker et al., 2026). Post-harvest losses are highest in perishable horticultural crops, where inadequate storage and temperature-controlled infrastructure lead to waste of land, water, energy, labor, and capital (Liu et al., 2022). Such losses directly hinder progress toward Sustainable Development Goal 2 (Zero Hunger) and increase food insecurity in developing economies (Sporchia et al., 2024).

In developed economies, investment in cold handling and storage systems has long been recognized as a cost-effective strategy to reduce losses of perishable foods, often proving more efficient than continually expanding production to meet rising demand. The adoption of cold chain technologies in agricultural supply chains for meat, dairy, fish, and horticultural products in the United States and European Union began in the early 1950s. However, despite their demonstrated effectiveness, cold chain systems remain underdeveloped and limited in scope across most developing countries (Kitinoja, 2014). Table 1 highlights how limited cold chain capacity in developing countries contributes to higher food losses, undermining food security and economic development, while developed countries benefit from robust refrigeration infrastructure.

Table 1. The cold chain, food security and economic development

Variable	Global	Developed countries	Developing countries
Population in 2009 (in billions of inhabitants)	6.83	1.23	5.60
Population in 2050 (forecast, in billions of inhabitants	9.15	1.28	7.87
Refrigerated storage capacity (m3/1000 inhabitants)	52	200	19
Food losses % (all products)	25	10	28
Losses of fruits and vegetables (%)	36	15	40
Losses of perishable foods due to lack of refrigeration (%)	20	9	23

Source: Kitinoja (2014)

Studies from Kenya and Nigeria show that smallholder farmers using solar-powered cold storage reduced their post-harvest losses by over 80% and increased their earnings by at least 20% (Takeshima et al., 2026). At a global scale, researchers estimate that developing countries could save 144 million tonnes of food annually if they achieved the same level of cold chain infrastructure as developed nations (Food and Agriculture Organization [FAO], 2022). Cold storage also raises the prices received by farmers and market agents by enabling off-season sales and reducing distress selling (Werner & Kaini, 1997). These benefits translate into strengthened local economies, job creation, and expanded access to export markets (Takeshima et al., 2026).

In Nepal, the horticulture sector has been expanding, with vegetable production in Lumbini Province alone reaching 702,430 tons (Ministry of Agriculture and Livestock Development [MoALD], 2025). However, the severity of post-harvest losses has also been increasing. The post-harvest losses of fruits and vegetables in Nepal range from 12 to 35% of crop yields due to poor handling, packaging, transportation, and storage (Gautam et al., 2019). The potato farmers in Dolakha found that 10.26% of harvested potatoes were lost due to poor post-harvest handling practices and the absence of adequate cold storage only 3% of farmers had access to a cold storage facility (Adhikari & G.C., 2021).

Vegetable prices in Nepal have higher fluctuation in different seasons. Prices for summer cucumber peak in March, reaching up to NPR 200 per kg, and then fall steadily to below NPR 30 per kg as seasonal supply increases. Overall vegetable prices have been reported to surge over 200 percent during supply shortages (Upreti, 2023). These extreme price fluctuations hurt both farmers, who are forced to sell at depressed prices during peak seasons, and consumers, who face inflated costs during lean periods (Werner & Kaini, 1997). Cold storage infrastructure offers a proven solution by enabling farmers to store produce during peak harvest and release it gradually to the market, thereby stabilizing prices, reducing distress sales, and ensuring more consistent food availability throughout the year (Upreti, 2023).

Recognizing these challenges, Nepal's government has articulated clear policy priorities for cold storage development. The Ministry of Agriculture, Forest, and Environment (MoAFE) has been working in the expansion of cold-storage facilities and strategic investment in value chains to secure profitable market access for producers (MoAFE, 2026). The Commercial Policy Implementation Action Plan 2025 envisions establishing and upgrading warehouses, cold stores, and high-tech quality testing laboratories at major border points to strengthen export capacity (MoALD, 2025). Cold storage infrastructure is financed and implemented across all three tiers of government under Nepal's federal structure through the Cold Storage House Establishment Program of the National Agriculture Modernization Project (NAMP), and provincial and local initiatives (Constitution of Nepal [CoN], 2015; MoAFE, 2026). The agriculture and livestock development budget for FY 2082/83 exceeds NPR 57.48 billion, with market infrastructure including cold storage explicitly prioritized for funding (Ministry of Finance [MoF], 2025).

Despite policy commitments outlined in the Agriculture Development Strategy and successive national periodic plans, a substantial gap persists between the stated aspirations for cold storage development and the realities observed on the ground. Investigative reporting has documented that numerous cold storage facilities across Khotang, Parbat, Morang, Sunsari, Kavre, Ilam, and Rolpa remain idle, abandoned, or never became operational despite having received government subsidies (MoALD, 2025). In Morang, half a dozen cold stores have been built, but not even half of them are functioning properly (MoALD, 2025). A facility in Diktel, Khotang, constructed with an investment of Rs 9 million, is lying useless due to a lack of three-phase electricity, poor feasibility studies, construction by inexperienced contractors, and a failure to link facilities with actual agricultural production zones (MoALD, 2025). The fundamental problem is not a lack of policy or investment but a persistent gap between

infrastructure development and actual farmer access, coupled with operational and sustainability challenges that prevent existing facilities from delivering their intended benefits (MoAFE, 2026).

This study addresses the critical problem of why cold storage infrastructure in Nepal, despite being a policy priority with significant budgetary allocation (MoF, 2025), has failed to translate into broad farmer access and effective utilization (Adhikari & G.C., 2021; MoALD, 2025). Specifically, the research examines the operational, institutional, and socioeconomic factors that constrain the accessibility, functionality, and sustainability of cold storage facilities for smallholder farmers. By investigating the barriers to effective cold chain strengthening ranging from governance and financing mechanisms to farmer awareness and infrastructure maintenance, this study aims to generate evidence-based recommendations for bridging the policy-implementation gap (MoAFE, 2026). The findings will inform policymakers, development partners, and agricultural stakeholders on how to design and deploy cold storage interventions that actually reach and benefit Nepal's farming communities, thereby reducing post-harvest losses, stabilizing farm incomes, and advancing national food security objectives (Hossain et al., 2018; Upreti, 2023).

1.2 Statement of problem

Higher post-harvest losses, price volatility, and marketing problems still exist in Nepal despite increased investment in cold storage infrastructure. The anticipated benefits from the investments have not been fully realized, and farmers are facing weak bargaining power and limited access to functioning facilities. Government agencies responsible for implementing cold storage support programs have also struggled to translate policy commitments into effective on-the-ground outcomes. This implementation gap reflects a broader challenge in public support for micro and small enterprises, whose diverse needs, limited scale, and context-specific constraints often reduce the effectiveness of standardized government interventions (Albaz et al., 2020).

Although Nepal has expanded its cold storage infrastructure through various policies, guidelines, and subsidy schemes, significant disparities remain in working conditions, utilization, management capacity, and farmers' access. The distribution of cold facilities in Nepal is presented in Figure 1.

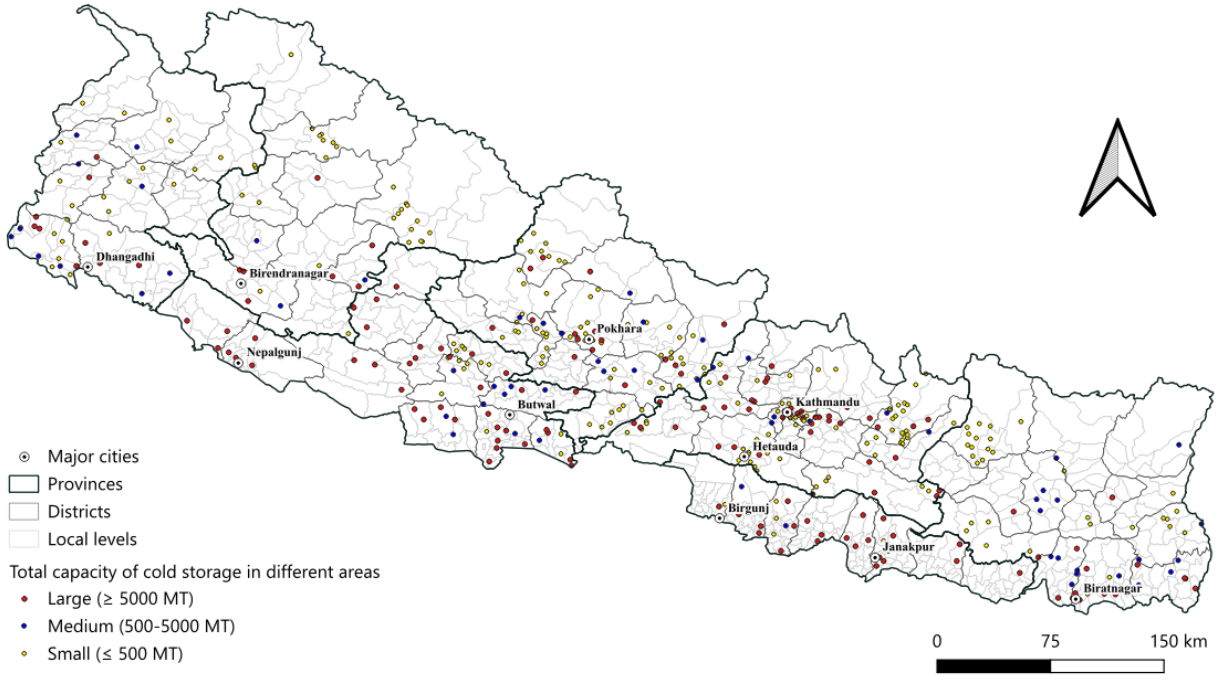


Figure 1. Map of Nepal showing the distribution of cold facilities

Planning and implementation are constrained by fragmented institutional arrangements, inconsistent investment approaches across tiers of government, weak monitoring mechanisms, and limited integration with production zones and agricultural markets. Despite the proliferation of policy instruments, no systematic evaluation has been undertaken to assess whether the current policy framework adequately addresses investment planning, governance, and sustainable operation. Consequently, in the context of ongoing efforts to expand cold storage capacity, the absence of evidence on policy effectiveness prevents the government from prioritizing investments and maximizing benefits for farm income, food security, and trade competitiveness.

1.3 Rationale of study

This study aimed to create empirical evidence that would inform the decision-making processes concerning the design of policies and investments in cold chain development in Nepal. In contrast to efforts to build new infrastructure, the research had questioned whether current policies, institutions, funding, and implementation strategies had the capacity to achieve their objectives. The results would give policymakers a better insight into the policy weaknesses, problems with implementation, and governance matters that need urgent action.

This research work also aimed to provide a practical tool to the Government of Nepal through recommendations that could assist in improving their planning, institutions, subsidy policies, monitoring, and investment priorities for effective implementation. These

recommendations would help to create an efficient and effective cold storage system, that can increase the accessibility of the farmers, improve post-harvest practices, increase the benefits from public spending, and also make the Nepalese agriculture industry commercial and competitive in the long run.

1.4 Research questions

i. How effective are the existing policies, public investments, and institutional arrangements in supporting cold storage development in Nepal?
ii. What are the major policy, institutional, financial, and operational constraints affecting the utilization, management, and sustainability of cold storage facilities?
iii. What policy, regulatory, and institutional reforms are required to improve the planning, governance, investment efficiency, and utilization of cold storage facilities in Nepal?

1.5 Objectives of the study

General objective:
The general objective of the study is to assess the performance and systemic constraints of Nepal's cold chain infrastructure in supporting smallholder farmers.

Specific objectives:

1. To assess the effectiveness of existing policies, public investments, and institutional arrangements for cold storage development,

2. To identify the major policy, institutional, financial, and operational constraints affecting the utilization and sustainability of cold storage facilities, and

3. To recommend and design capacity-building strategies and policy interventions to expand functional, farmer-accessible cold storage.

1.6 Scope and limitations of the study

Scope of the study

This study encompasses rural farmers, agro-enterprises, and cold storage operators in selected districts of Nepal. It has investigated both local and regional market access opportunities that were facilitated through cold storage systems. This study has also highlighted the role of various stakeholders in strengthening agricultural value chains. Particular emphasis is placed on capacity-building strategies and policy design aimed at improving the functionality, efficiency, and competitiveness of cold storage infrastructure. The findings of this study are intended to provide actionable insights for policymakers, development agencies, and cooperatives, enabling them to reinforce rural cold chain networks and enhance market systems in ways that contribute to sustainable agricultural development and farmer welfare.

Limitations of the study

This study is concentrated on local and regional market access opportunities rather than international export markets or cross-border cold chain logistics. While national-level infrastructure and policy constraints are acknowledged, they are not examined in depth, as the research is grounded in selected districts that may not fully represent the diversity of Nepal's agricultural landscape. Time and resource limitations restrict the possibility of conducting a comprehensive longitudinal assessment of cold storage sector.

LITERATURE REVIEW

2.1 National fruit and vegetable production base

The national production statistics presented in Table 2 show a dynamic trajectory of the horticultural and cash crop sector in Nepal. Nepal has been experiencing notable expansion in fruits, vegetables, and potato production, while ginger and garlic production has been in a state of decline (MoALD, 2025). Fruits cultivated in 139,246 ha have reached 1.5 million MT with a 20.7% growth in the past five years. Vegetables have the largest area occupancy of 311,885 ha and have production of 4.44 million MT, though their growth rate is comparatively modest at 12.1%. Potato remains a staple crop, covering 211,505 ha and yielding 3.52 million MT, with a steady 12.5% increase. The production of ginger and garlic is declining, with ginger producing in 22,430 ha and production of 289,330 MT, and garlic producing in 9,558 ha and production of 72,359 MT recorded negative growth rates of -3.2% and -2.0%, respectively. Seasonal fruits have increased in both area and production. Citrus fruits have shown production expansion by 16.3%, winter fruits by 26.7%, and summer fruits by 21.3%. Shrestha et al. (2023) emphasized that fruit and vegetable production has become central to household nutrition and rural income generation, while Paudel and Devkota (2022) state that ginger and garlic face persistent challenges from disease outbreaks and fluctuating export demand. Moreover, citrus and winter fruits are increasingly promoted in mid-hill regions as climate-resilient crops (Khanal et al., 2024).

Table 2. National production, cash crops and horticulture status

Category	Area (ha)	Production (MT)	Production in last 5 years
Fruits	139,246	1,508,701	20.70%
Vegetables	311,885	4,440,116	12.10%
Potato	211,505	3,521,794	12.50%
Ginger	22,430	289,330	-3.2%
Garlic	9,558	72,359	-2.0%
Citrus fruits	48,329	318,939	16.30%
Winter fruits	32,276	147,938	26.70%
Summer fruits	100,736	1,041,824	21.30%

Source: MoALD (2025)

2.1 Causes of food waste in the agri-food supply chain

Several studies identify the multiple causes of food waste across the supply chain. Guarnieri et al. (2021) found that improved logistics, stronger management control, and greater consumer awareness reduce food waste in fruit and vegetable supply chains. Similarly, Bisht (2024) reported that poor scientific harvesting practices and excessive intermediaries contribute significantly to food losses in India. Costa et al. (2022) further demonstrated that effective leadership, knowledge management, communication, collaboration, innovation, and resilient

supply chain design reduce food waste. Strotmann et al. (2017) recommended integrating employees into continuous improvement systems using the Plan-Do-Check-Act (PDCA) cycle to minimize waste. Likewise, Stangherlin and de Barcellos (2018) identified behavioral, personal, and societal factors as major determinants influencing food waste reduction. Göbel et al. (2015) argued that improved communication among supply chain actors is necessary to establish sustainable food systems, while Bilska et al. (2016) recommended coordinated action among all stakeholders involved in food distribution.

2.2 Post-harvest losses and the role of cold storage

By maintaining appropriate storage temperatures, cold storage allows farmers to delay sales until market conditions become more favorable, thereby reducing distress sales immediately after harvest and stabilizing market supply (Singh, 2026). Various empirical studies have consistently shown that limited access to cold storage facilities increases post-harvest loss rates in Nepal. The study further emphasized that improper grading and packaging have significantly increased produce loss. Various controlled storage experiments conducted by Khanal and Bhattarai (2020) indicated that during 60 days of storage, total potato loss was 4 to 5% when it came to the usage of cold storage facilities in comparison to other forms of storage (in-basket and in-house storage), where the 13.04% post-harvest loss was estimated.

2.3 Cold storage and cold chain

The cold chain is an integrated temperature-controlled logistics system designed to preserve the quality, safety, and shelf life for fruits, vegetables, dairy, and other perishables in a supply chian (Edo et al., 2026). It comprises multiple interconnected components, including pre-cooling, cold storage, refrigerated transportation, distribution, retail, and household refrigeration, all of which must operate without interruption to maintain product quality (Behdani, 2018). Among these components, cold storage serves as the central infrastructure, providing temporary preservation that reduces spoilage, stabilizes market supply, and allows producers to market products more strategically.

The literature consistently identifies post-harvest losses as one of the major challenges confronting agricultural supply chains, particularly in developing countries. Globally, approximately one-third of food produced for human consumption is either lost or wasted, representing around 1.3 billion tonnes annually (FAO, 2011). Besides threatening food security, these losses generate high environmental costs, including approximately 3.3 billion tonnes of carbon dioxide equivalent emissions and substantial wastage of water and agricultural land (FAO, 2013). Consequently, strengthening cold storage and cold chain systems has become an important strategy for improving food security while promoting sustainable resource utilization.

China is an important example of how deficiencies in cold chain infrastructure contribute to post-harvest losses. Despite being the world's largest producer of fruits and vegetables, inadequate cold storage facilities and fragmented cold chain logistics continue to result in substantial losses throughout the supply chain. Studies in China estimate storage losses of

15-20% for vegetables and 10-15% for fruits, while additional losses of 5-10% occur during distribution (Liu, 2014). These losses are largely attributed to inadequate storage infrastructure, limited refrigerated transportation, insufficient post-harvest handling technologies, and the dominance of smallholder production systems with limited access to modern cold chain facilities (Liu et al., 2013; Zhao and Huang, 2011). The resulting wastage also places considerable pressure on natural resources, with fruit and vegetable losses accounting for billions of cubic metres of water and millions of hectares of agricultural land annually (Liu et al., 2013).

2.4 Status and distribution of cold storage infrastructure

The list of cold storages facilities has been recorded in the central registry of Ministry of Agriculture, Environment, and Finance. Estimates by industry sources show that the total number of cold storages operating in the country is around 35, while the average capacity per cold storage facility is close to 3,000 metric tons, yet only 23 of these cold storages belong to the Association of Cold Storage of Nepal. Reporting on cold storage facilities indicates differences in their capacity, which varies from large privately run facilities like Kohinoor Cold Storage (capacity reported as 18,000 metric tons) to small government-supported cooperative facilities with a few hundred metric tons of capacity. The organization of PMAMP 2,776 pockets, 336 blocks, around 106 zones, and 14-16 super-zones in different stages of its execution (MoALD, 2025) might be considered one of the ways of assessing whether investment in cold storage follows the production zones.

Geographic evidence is not consistent as there are facilities located in distinct production regions such as Rampur, Chitwan for vegetables and bananas; also Rasuwa and Sindhupalchok in Bagmati province. However, many other facilities especially large private warehouses are located close to urban markets like Kathmandu and Biratnagar (MoALD, 2025).

2.5 Financing, subsidies, and cost of capital

Subsidies to invest in cold storage in Nepal are provided in multiple ways: through subsidies of 50% of electricity charges; through grants of money paid out via Cold Storage House Establishment Program of MoAFE and NAMP, mostly on a sharing scheme between federal/provincial/local governments and through the Interest Subsidy on Commercial Agricultural Loan Guideline by Nepal Rastra Bank, where the borrowing interest is capped at the base rate plus certain premium, with a higher credit ceiling applied for cold storage development (Nepal Rastra Bank [NRB], 2017).

It is unclear though if such a system of subsidies meets the actual cost of capital of investors. The results of analysis done by the Daayitwa show that agricultural loans under this program were occasionally diverted for purposes other than productive investments, such as paying off debts, covering costs related to foreign labor migration, or purchasing land, and that the loans reached primarily the richer or well-connected farmers (Daayitwa, 2022).

2.6 Federalism and multi-tier government roles

The Constitution of Nepal (2015) assigns authority related to agriculture and markets infrastructure among the three levels through Schedule 5 federal powers, Schedule 6 exclusive provincial powers (including agricultural policy of provinces), Schedule 7 concurrent powers of federal and provincial government, Schedule 8 exclusive local powers (including management of markets in the locality), and Schedule 9 concurrent powers among the three levels (CoN, 2015). Such sharing of powers is designed with an intention to facilitate joint investment and, at times, results in successful co-investment and coordination failure (MoALD, 2025) The conflicts between the exclusive and concurrent powers, especially in agriculture, are unsolved at national level and not peculiar to cold storage facilities.

METHODOLOGY

3.1 Conceptual framework

The conceptual framework in Figure 2 proposes that the effectiveness of cold storage facilities in Nepal is influenced by policy and investment interventions, including national policies, financial support programs, and institutional and legal frameworks. These interventions affect cold storage performance through a set of core determinants comprising technical, economic, institutional, and market-related factors. Technical factors include storage capacity, facility design, and temperature management systems, while economic factors relate to investment requirements, operating costs, and financial viability. Institutional factors encompass management and governance capacity, whereas market-related factors include market linkages, transportation networks, and access to information. The framework further recognizes the influence of contextual factors, such as agro-ecological conditions, infrastructure availability, seasonality, and climate-related risks, which may moderate the relationship between policy interventions and performance determinants. Improved performance across these determinants is expected to enhance operational efficiency and policy effectiveness, ultimately contributing to reduced post-harvest losses, improved market access, and increased farmer income and welfare.

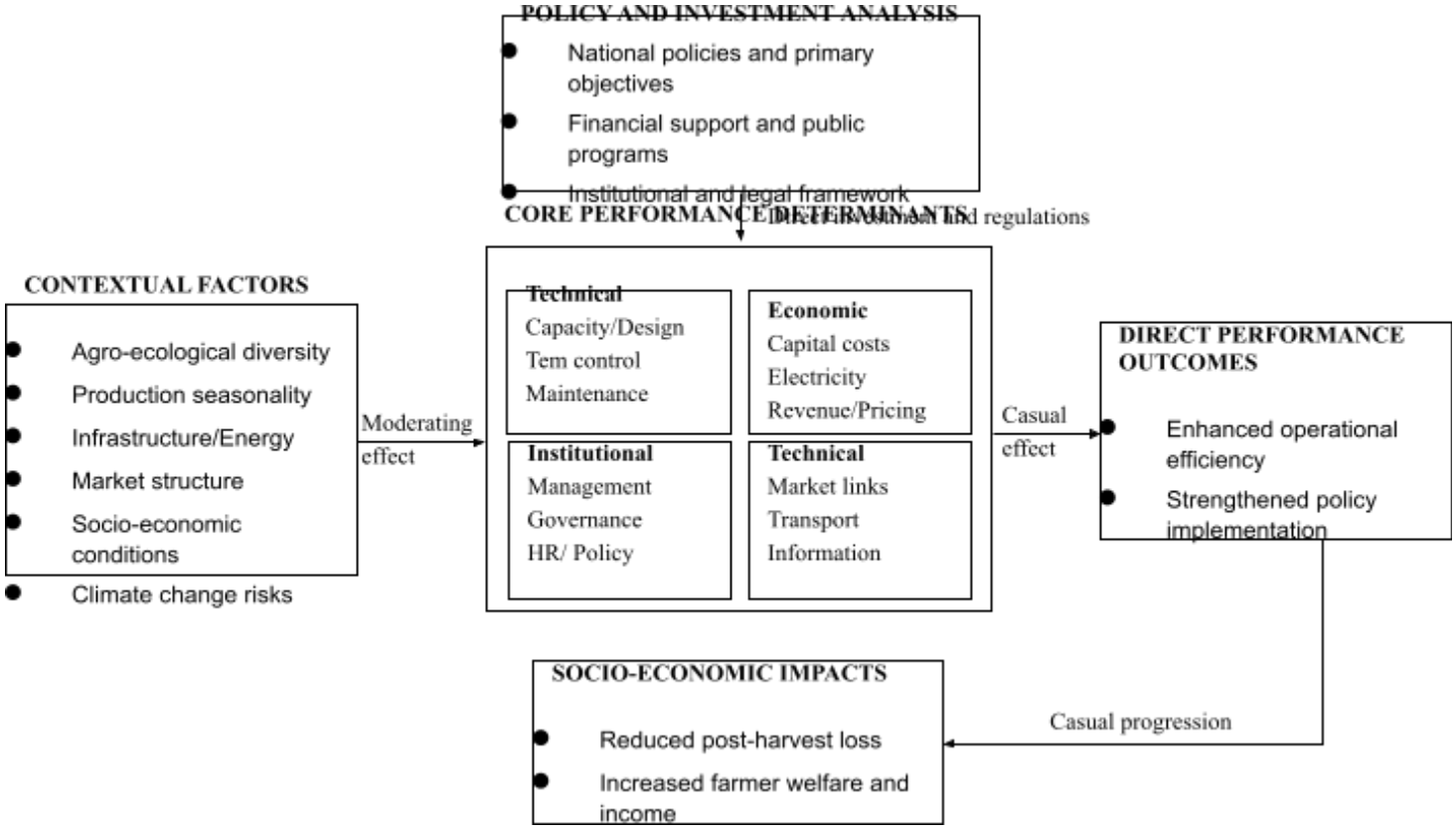


Figure 2. Conceptual framework of the study for strengthening the cold facilities in Nepal

3.2 Study area

The study was conducted in 13 districts of Nepal. The names of these districts include: Kaski, Parbat, Tanahu, and Nawalparasi east from Gandaki province, Chitawan, Dhading, Kathmandu, Bhaktapur, Lalitpur, and Ramechhap from Bagmati province, Kapilbastu and Rupandehi from Lumbini province and Dailekh from Karnali province. These districts were purposively selected to deliberately select respondents with specific characteristics or experiences most relevant to the research objectives, ensuring rich and contextually meaningful data. The geographical location of the study is shown in Figure 3.

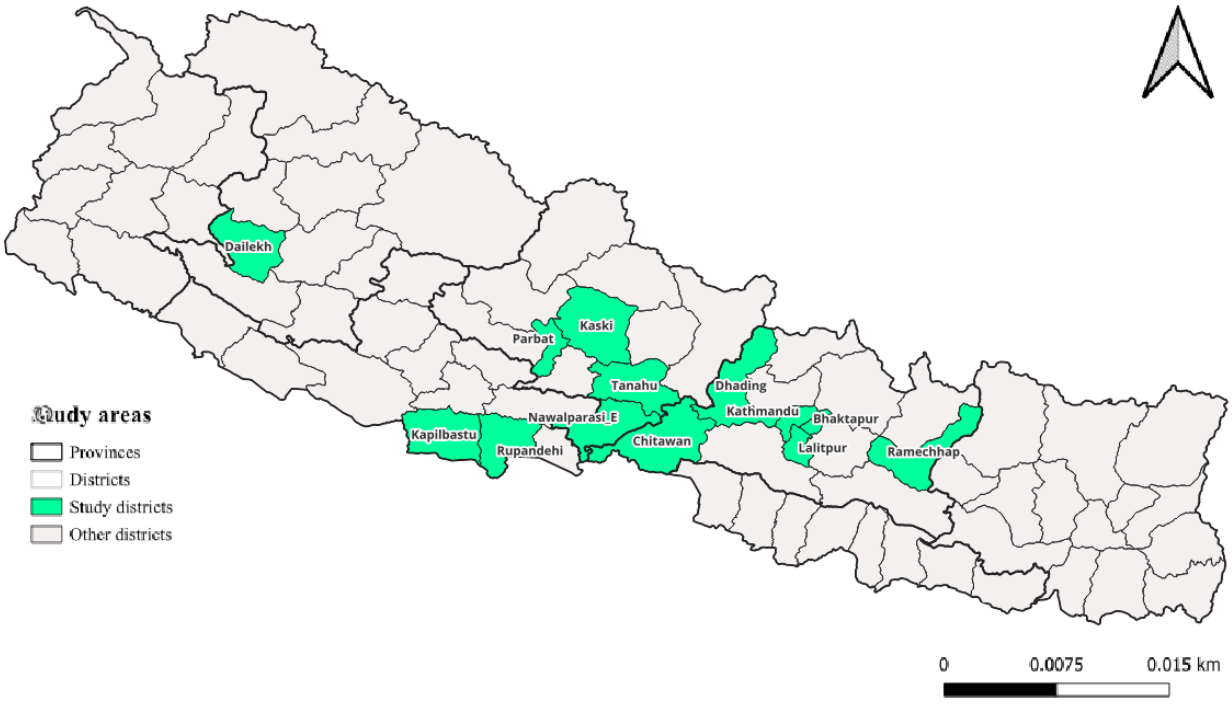


Figure 3. Map of Nepal showing the study areas

Source: QGIS (2026)

3.3 Research design

This study adopted a mixed-methods design combining descriptive and spatial mapping of cold storage infrastructure, policy and document analysis, and comparative qualitative studies of operating facilities. The design was sequenced to move from a national-level inventory toward facility-level case studies that generate the financial, governance, and operational evidence needed before synthesizing findings into gap analysis and recommendations.

3.4 Data collection methods

The study utilized both primary and secondary data sources to assess the effectiveness of Nepal's cold storage policies, institutional arrangements, public investments, and operational practices. The combination of multiple data sources was used for data triangulation to improve the validity of findings and strengthen the credibility of policy recommendations.

3.4.1 Primary data collection

1. **Interview schedule:** Farmers who have used the cold storage facilities and cold facilities operators were surveyed using a semi-structured questionnaire. Purposive sampling was performed to select the respondents who are knowledgeable and actively involved in cold storage usage, cold storage operation, or market delivery of produce. Individuals who lacked direct involvement in cold storage-related activities were excluded, as their experiences did not align with the study objectives. The composition of the sample taken for the study is presented in Table 1.

2. **Key informant interviews (KIIs):** Semi-structured interviews were conducted with agricultural experts, extension officers, and university professors to gain deeper insights into the dynamics of multi-layer farming systems and local challenges.

Table 3. Composition of the qualitative sample by stakeholder group, district, and response mode

Stakeholder group	**Number interviewed**	**Districts represented**	**Response mode**
Cold storage operators	25	Dhading, Tanahun, Kapilvastu, Kaski, Ramechhap, Parbat (Jaljala), Chitwan, Rupandehi, Nawalparasi (Bardaghat Susta West)	Semi-structured interview schedule
Government officials (KIIs)	5	Chitwan (NAMP), Dailekh (Agriculture Development Office), Kaski (MoAFE)	Key informant interview
Farmers	10	Kaski, Chitwan, Tanahu	Semi-structured interview schedule

Among the 25 operators surveyed, 60% (15) run units of 50 MT or more, while 40% (10) operate smaller cold rooms under 50 MT, showing a sample leaning toward larger-capacity facilities as in Table 4.

Table 4. Sample distribution of cold storage operators by storage capacity (n=25)

Category	Frequency	Percent (%)
Cold rooms (capacity < 50 MT)	10	40
Commercial cold storage (capacity ≥ 50 MT)	15	60

3.4.2 Secondary data collection

Secondary data were obtained through an extensive review of relevant publications and policy documents from the Ministry of Agriculture, Forest, and Environment (MoAFE), the Department of Agriculture (DoA), the Central Bureau of Statistics (CBS), and provincial ministries of agriculture and land management. Reports, published books, peer-reviewed journals, and conference proceedings were also consulted to understand cold storage capacity, post-harvest loss trends, and value chain challenges in Nepal.

3.5 Data analysis techniques

The data obtained from the field survey was initially coded and then input into MS Excel and SPSS. For quantitative data, analysis involved calculating percentages, frequencies, as well as determining the minimum, maximum, mean, and standard deviation. The data collected from key informant interviews and focus group discussions were used to verify the information collected through the survey. The information underwent processing and analysis using STATA version 17. The analysis involved employing both descriptive and analytical techniques.

The study has analyzed cold storage use and vegetable marketing practices, adoption challenges, and opportunities using thematic, content, and narrative analysis. Thematic analysis identifies key themes, while content analysis quantifies recurring concepts like policy awareness and cold storage access. Narrative analysis captures farmers' lived experiences, highlighting their perceptions and coping strategies.

Interview transcripts and field notes are subjected to open coding, where recurring words, ideas, and local expressions are identified line by line. Initial codes were grouped into broader categories and are refined iteratively into core themes. Extracts from Key Informant Interviews are systematically compared with government policy documents, budget allocations, and field-level observations to validate or challenge emerging interpretations, grounding the findings in both community experience and documentary review.

3.5.1 Descriptive and analytical analysis

It represents descriptive analysis of the study area, farmers, cold storage operators, and marketing systems. Descriptive statistics such as means, frequencies, standard deviations, percentiles, and standard errors were used to analyze the data.

3.5.2 Mathematical models and empirical analysis

This section presents the mathematical models and formulas used to analyze the capacity utilization, investment structure, operating costs, revenue, and financial performance of the surveyed cold storage facilities. To assess the physical performance and financial viability of cold storage facilities, a set of standard capacity utilization, cost-benefit, and financial ratio formulas were applied to the primary data collected from cold rooms and cold storage facilities.

3.5.2.1 Capacity Utilization Rate

$Capacity\ Utilization\ (\%) = \frac{Annual\ Volume\ Handled}{Designed\ Storage\ Capacity} \times 100$ (Heizer & Render, 2014)

The formula was calculated separately for peak-season and off-season occupancy to capture seasonal variation in facility use (Table 9).

3.5.2.2 Total Capital Investment (TCI)

Total capital investment was calculated using the sum of cost incurred in land, construction, refrigerated equipment, other machinery, electrical installation, vehicle, furniture and other capital investment.

$TCI = Land\ Cost + Construction\ Cost + Refrigeration\ Equipment + Other\ Machinery + Elec$ (Gittinger, 1982)

The share of the investment by different cost components were analyzed using the formula;

$Component\ Share\ (\%) = \frac{Component\ Investment}{TCI} \times 100$

(Gittinger, 1982)

3.5.2.3 Total Annual Operating Cost (TOC)

Total annual operating cost was calculated by summing the wages, electricity, diesel, repair and maintenance, administrative expenses, insurance, and other operating expenses.

$TOC = Salary\ and\ Wages + Electricity + Diesel + Repair\ and\ Maintenance + Administrativ$ (Gittinger, 1982)

While, Total Annual Revenue (TR) was calculated using the formula below;

$TR = Storage\ Service\ Income + Rental\ Income + Other\ Income$ (Gittinger, 1982)

Operating profit (OP) was calculated by reducing the Total Operating Cost from the Total Revenue as given by (Pandey, 2015) and calculated as:

$OP = TR - TOC$

3.5.2.4 Return on Investment (ROI)

The percentage of return on investment was calculated to find how much percentage of revenue was generated from the Total Capital Investment and was calculated using the formula;

$ROI\ (\%) = \frac{OP}{TCI} \times 100$ (Pandey, 2015)

The Revenue-Investment Ratio (RIR) was then calculated using the formula;

$RIR = \frac{TR}{TCI}$ (Gittinger, 1982)

3.5.2.5 Capacity-Normalized Indicators

This study used different indicators to precisely study the investment in the cold storage sector. The formula used were given below;

$Revenue\ per\ MT = \frac{TR}{Designed\ Capacity}$

$$Profit\ per\ MT\ =\ \frac{OP}{Designed\ Capacity}$$

$$Investment\ per\ MT\ =\ \frac{TCI}{Designed\ Capacity}$$

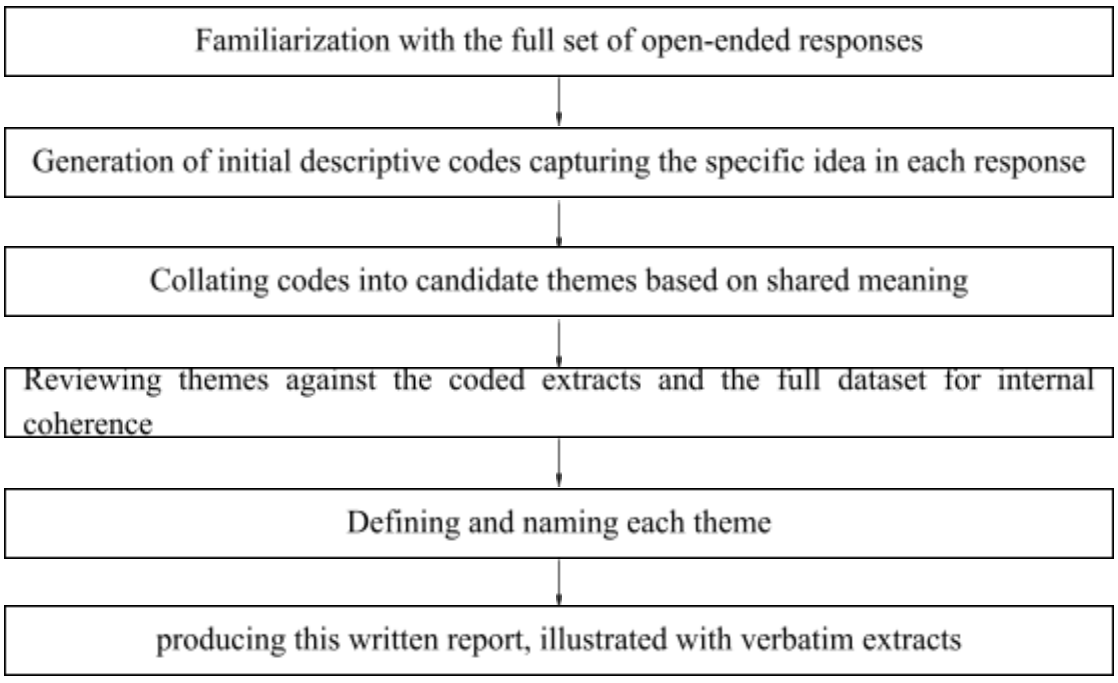
$$Electricity\ Cost\ per\ MT\ =\ \frac{Electricity\ Expense}{Designed\ Capacity}$$ (Reddy et al., 2004)

Mean values of each indicator are reported with their corresponding standard deviations in parentheses (Table 11), enabling comparison of profitability, cost structure, and capital intensity between cold rooms and larger cold storage facilities.

3.5.2 Analytical approach

The analysis follows Braun and Clarke (2019) six-phase approach to reflexive thematic analysis as in Figure 4: (1) familiarization with the full set of open-ended responses; (2) generation of initial descriptive codes capturing the specific idea in each response; (3) collating codes into candidate themes based on shared meaning; (4) reviewing themes against the coded extracts and the full dataset for internal coherence; (5) defining and naming each theme; and (6) producing this written report, illustrated with verbatim extracts. Coding began with a small set of sensitizing concepts drawn from the interview guide (Section 3.3.2), but was otherwise inductive (data-driven): no fixed codebook was applied, and the descriptive codes and nine final themes reported in Chapter 4 emerged from and in several cases diverged from these initial categories.

Because responses came from three distinct stakeholder groups answering partially different question sets, cross-group triangulation was used. A theme was considered stronger where operators, government officials and/or farmers independently raised related concerns, even when using different language. This is noted explicitly within each theme below.



Source: Braun and Clarke (2019)

Figure 4. Reflexive thematic analysis provided by Braun and Clarke (2019)

Table 5. Codebook: themes, constituent codes, and number of coded references

Theme	Representative codes	References
Structural and technical design deficiencies	Missing pre-cooling/cold-chain linkage; civil-heavy design with weak mechanical investment; single-chamber facilities; poor grading/sorting; improper packaging/handling; mechanical damage; storage beyond recommended duration; multi-commodity mismatch	39
Governance, coordination and policy gaps	"No policy" / policy vacuum; weak legal formulation; weak inter-agency and inter-governmental coordination; no feasibility/commodity survey before construction; need for a single coordinating body; national cold-chain strategy/guidelines	34
Underutilization, siting and market aggregation	Off-season idle capacity; construction not linked to production clusters; smallholder scale too small to fill facilities; cooperative aggregation as solution; digital booking/matching platforms	33
Energy cost and power reliability	High electricity/energy cost; calls for tariff concessions; power interruption causing spoilage; solar/renewable energy adoption	31
Value chain integration, standards and market linkage	Commodity-specific storage standards; value addition (grading, packaging, processing); market-price information and forecasting; middleman/intermediary regulation; market linkage between farmers and buyers	31
Subsidy design and financial sustainability	Reliance on capital subsidy; delayed/undisbursed promised funds; hidden costs not covered by subsidy (loading/unloading); calls for operating-cost (vs. capital-only) subsidy; access to credit	30
Human and technical capacity constraints	Shortage of domestic technical manpower; reliance on external expertise; need for training/certification programs; farmer-level post-harvest knowledge gaps	30

Farmer-level access barriers and lived experience	Physical distance to facility; absence of nearby facility; lack of transport; positive outcome (satisfaction, better price) when access achieved	26
Emergent: environmental sustainability and inclusion	Unsustainable waste disposal (fish-waste dumping); interest in composting/biogas alternatives; renewable energy interest; near-absence of spontaneous equity/inclusion comments	23

3.6 Connectivity of nine themes to the cold storage sector

The Figure 5. illustrates the interconnected challenges weakening Nepal's cold storage policy-implementation. At the center lies the overarching structural weakness, surrounded by nine themes that radiate outward: governance and coordination gaps, structural and technical design deficiencies, farmer-level access barriers, human and technical capacity constraints, subsidy design and financial sustainability, value chain and market linkage gaps, energy cost and power reliability, and underutilization with siting mismatch. Together, these themes highlight how institutional, technical, financial, and farmer-level constraints converge to undermine effective cold storage development.

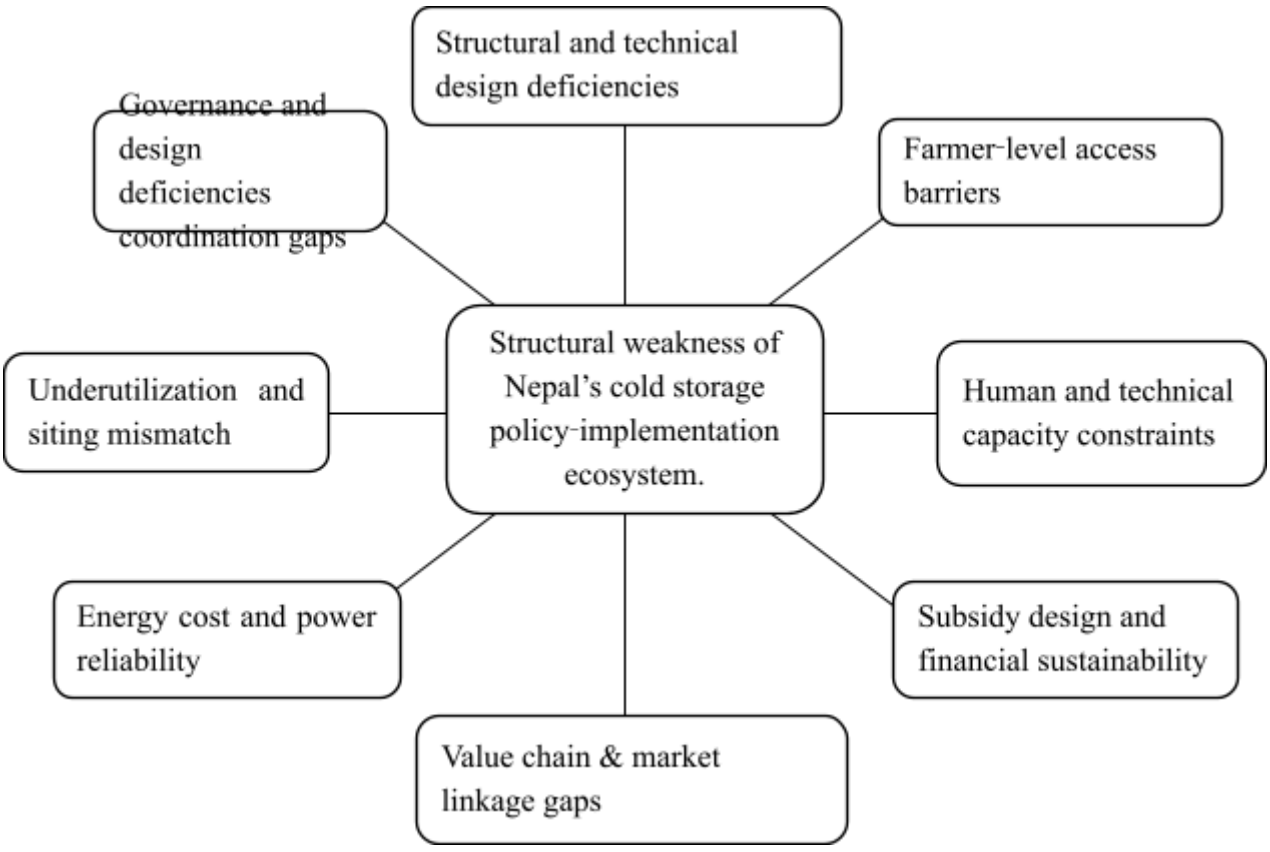


Figure 5. Thematic map linking the nine themes to the central storyline

3.7 Ethical considerations

Informed consent was provided to all participants, ensuring confidentiality and anonymity, and safeguarding personal information. The research adheres to ethical standards by remaining sensitive to cultural norms and practices during data collection. Participants are informed about the study's purpose, ensuring voluntary participation, and efforts are made to avoid any form of harm or discomfort. All data is handled responsibly to maintain trust and integrity.

RESULTS

4.1 National overview of cold storage and cold room facilities in Nepal

Table 6 categorizes 445 cold storage facilities by their storage capacity. The data shows a strong skew toward very small units: 58.65% (261 facilities) are cold rooms under 50 MT, making them the dominant category. Small commercial units (50-500 MT) account for 18.20%, while large commercial facilities (≥1000 MT) make up 16.18%. Medium commercial units (500-1000 MT) are the least common, representing only 6.97% of the total.

Table 6. Distribution of cold storage facilities by storage capacity (MT)

Category	Frequency	Percent (%)
Cold rooms (capacity < 50 MT)	261	58.65
Small commercial cold storage (50 ≤ capacity < 500 MT)	81	18.20
Medium commercial cold storage (500 ≤ capacity < 1000 MT)	31	6.97
Large commercial cold storage (capacity ≥ 1000 MT)	72	16.18

4.2 Distribution of cold rooms and cold storage across different provinces in Nepal

In Nepal, there were 445 facilities with a combined capacity of 278,516 MT of cold storage and cold rooms. Bagmati Province was the leading hub having the highest number of facilities (113) and the largest storage capacity (92,224 MT). This shows that, Bagmati has the dominance in cold storage infrastructure. Madhesh Province had only 37 facilities but records a remarkably high capacity of 77,866 MT, indicating the presence of large-scale storage rather than numerous smaller ones. Koshi and Lumbini have similar development, each with a capacity of 40,797 MT across 64 and 66 facilities, respectively, indicating mid-range infrastructure. The distribution of cold facilities across Nepal is presented in Figure 6 and Figure 7.

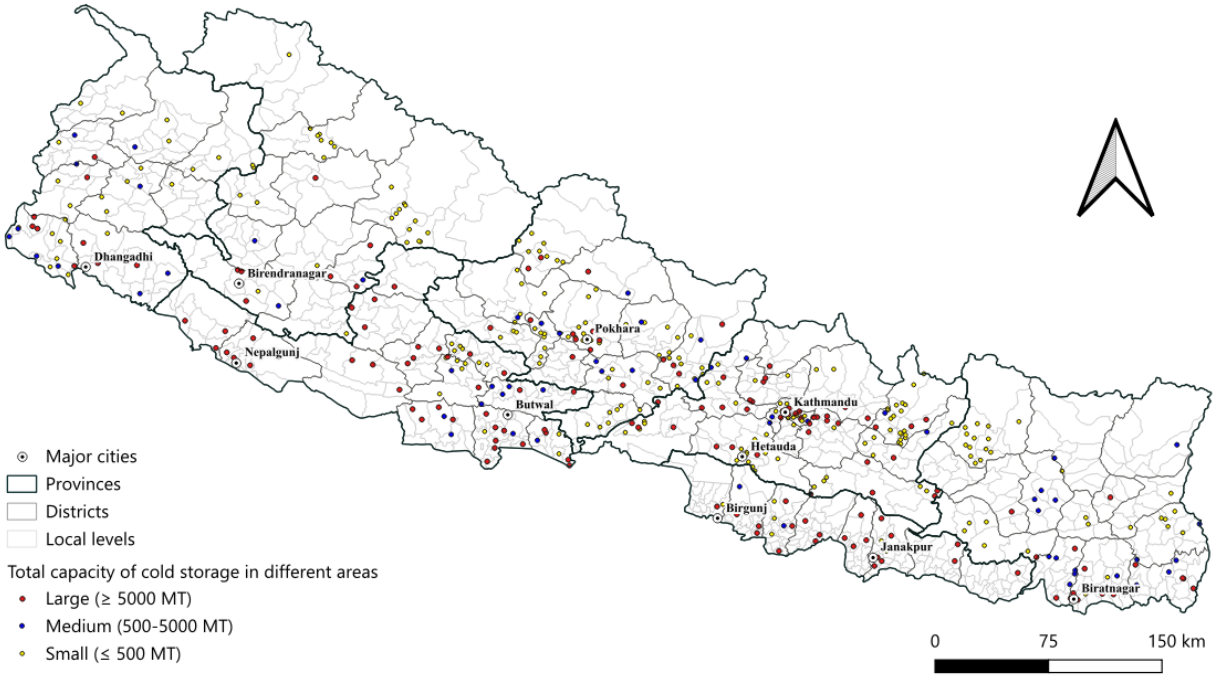


Figure 6. Map of Nepal showing the distribution of cold facilities

Despite having 86 facilities in Gandaki Province, there is a low capacity of 9,683 MT, due to small-scale storage. Karnali remains the least developed, with just 35 facilities and a capacity of 3,924 MT, while Far Western Province has 44 facilities totaling 13,225 MT, representing modest development in this sector. Cold storage distribution shows significant regional disparities, with Bagmati and Madhesh leading in capacity and scale, while Gandaki, Karnali, and Far Western lag behind, underscoring uneven cold storage infrastructure across the country.

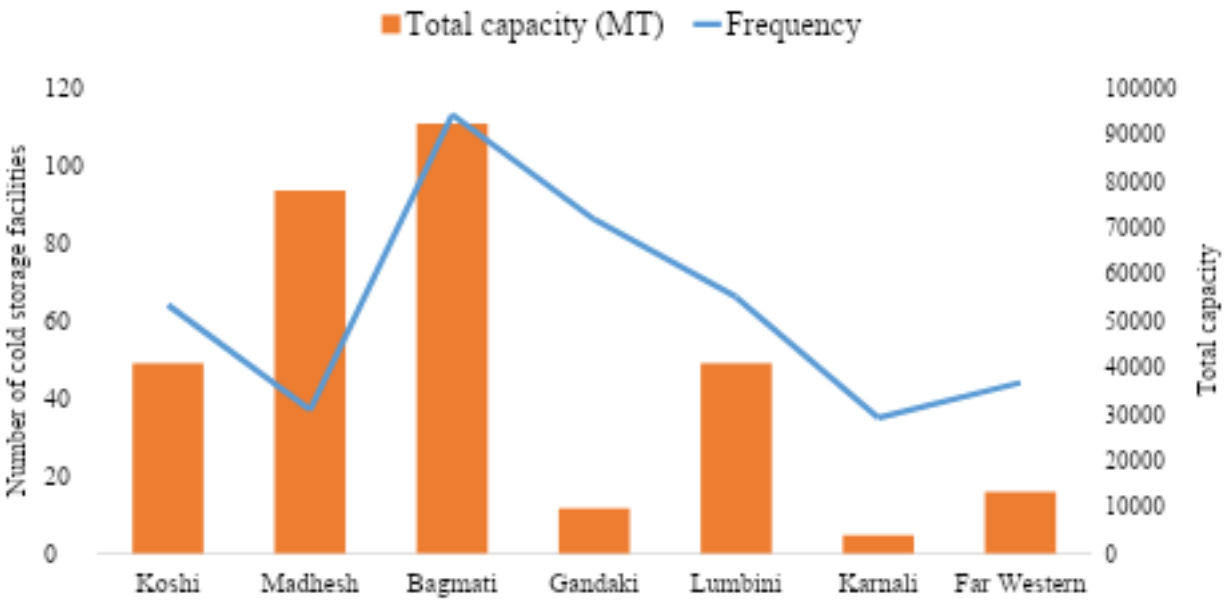


Figure 7. Distribution of cold facilities across different provinces in Nepal

4.3 Operational status of cold storage facilities across different provinces in Nepal

Out of 445 cold storages, 205 were operational, 88 under construction, and 152 were not operational. The operational status of cold storage facilities across different provinces in Nepal is shown in Figure 8. Bagmati Province leads with 56 operational facilities where 36 were under construction, and 21 cold storages were non-operational. This reflects both strong infrastructure and ongoing expansion in Bagmati province. Gandaki shows a similar pattern, with 57 operational units but a relatively high 22 non-operational, suggesting uneven utilization. Madhesh and Koshi demonstrate moderate development, with 22 and 39 operational facilities respectively. These provinces also had smaller shares under construction and non-operational. The result shows that, Lumbini had only 4 operational facilities compared to a 56 non-operational facilities that shows the severe underutilization and infrastructure challenges. Karnali had 15 operational units but 20 non-operational, highlighting limited effectiveness in this region. Far Western Province shows mixed progress, with 12 operational, 14 under construction, and 18 non-operational. Far Western Province had also shown ongoing expansion but weak current utilization. The data reveals that Bagmati and Gandaki are relatively strong in operational cold storage but the Lumbini, Karnali, and Far Western province face significant gaps, underscoring regional disparities in cold chain functionality.

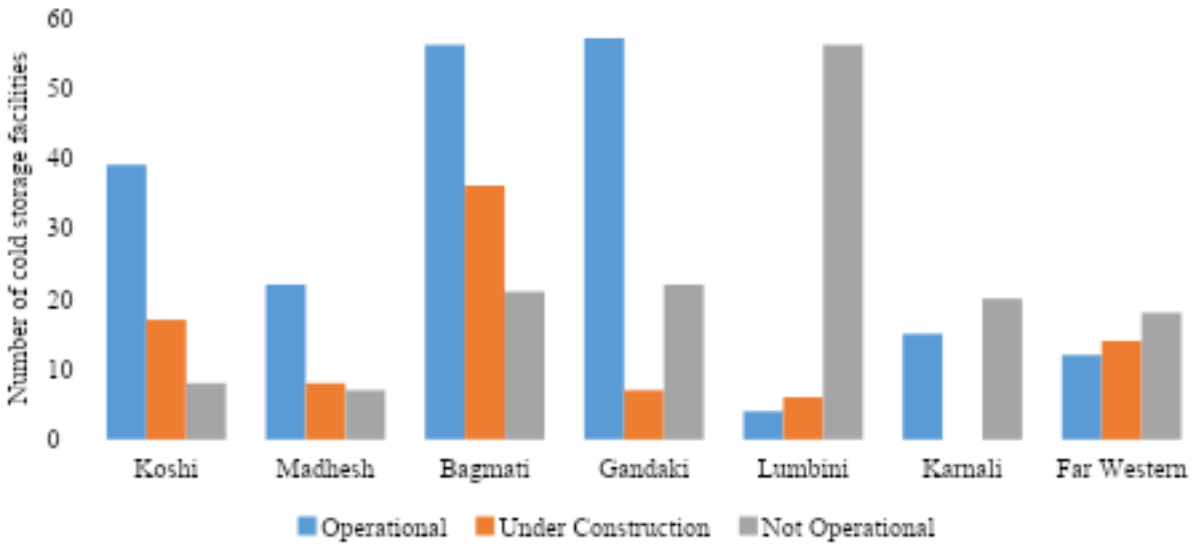


Figure 8. Operational status of cold storage facilities across different provinces in Nepal

4.4 Provincial distribution of cold storage facilities by size classification

Out of different provinces, Bagmati province had 43 large and 63 small storages, reflecting both scale and diversity as shown in Figure 9. Lumbini province followed with a strong presence of 40 large units, though fewer small ones (15), indicating a concentration of bigger facilities. Madhesh province has shown dominance in large-scale storages (28 out of 37 total), indicating reliance on fewer but high-capacity units. Koshi and Gandaki show more balanced distributions, with Koshi having 15 large, 18 mediums, and 31 small storages, while Gandaki has 16 large, 10 medium, and 60 small facilities. Karnali and Far Western provinces are comparatively weaker, with Karnali hosting only 7 large units and a majority of small ones (25), while Far Western has 10 large, 10 medium, and 24 small. Overall, the data reveals that while Bagmati, Lumbini, and Madhesh are strong in large-scale cold storage, Gandaki, Karnali, and Far Western rely heavily on smaller facilities, underscoring regional disparities in storage capacity and scale.

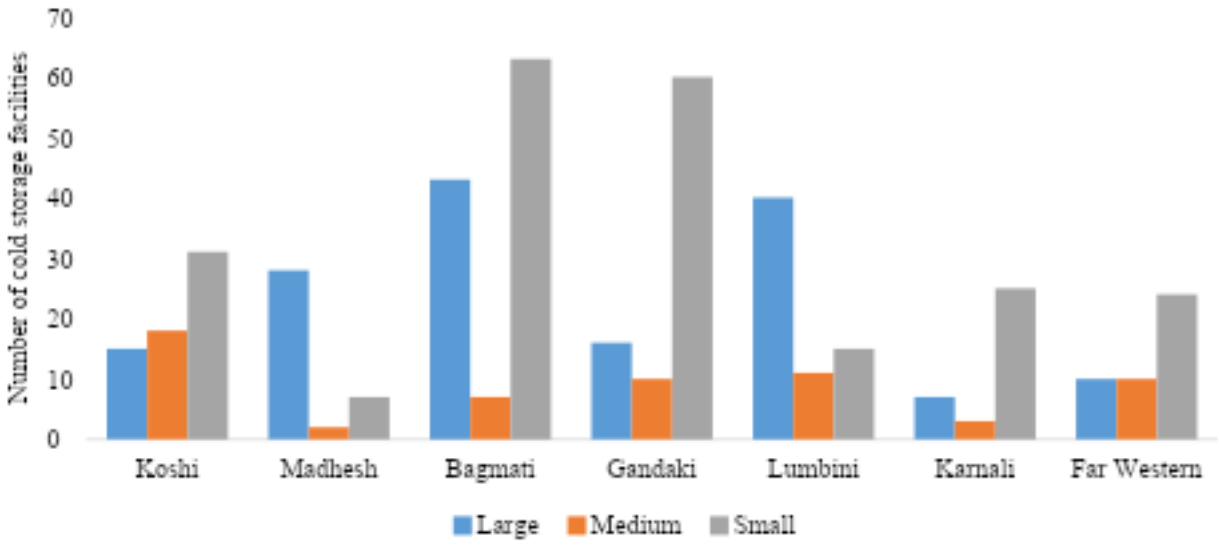


Figure 9. Provincial distribution of cold storage facilities by size classification

4.5 Descriptive statistics of cold storage facilities

Among 25 surveyed operators, most are private companies (84%), use multi-commodity storage (56%) or conventional technology (36%), and all rely entirely on grid electricity (100%). A majority report being profitable (76%), as shown in Table 7.

Table 7. Characteristics of cold storage operators by ownership, technology, power source, and profitability

Variables (n=25)	Category	Frequency	Percent
Ownership	Cooperative-owned facility	3	12
	Government-owned facility	1	4
	Private company	21	84
Storage technology	Conventional	9	36
	Frozen	2	8
	Multi-commodity	14	56
Primary Power Source	Grid electricity	25	100
Facility Currently Profitable	Yes	19	76
	No	6	24

Table 8. presents that mean current utilization rates were comparable across both categories (63.30% for cold rooms and 68.87% for cold storage. Cold rooms recorded notably higher peak-season occupancy (93.00%) relative to larger units (77.67%), whereas larger units demonstrated moderately higher off-season occupancy (39.67% and 24.50%), suggesting

divergent seasonal utilization patterns. Substantial standard deviations, particularly for capacity and throughput in the larger stratum, indicate considerable intra-group heterogeneity.

Table 8. Descriptive statistics of cold storage operational indicators by facility capacity stratum

Variable	Cold rooms (< 50 MT)		Cold storage (≥ 50 MT)	
	Mean	Standard Deviation (SD)	Mean	Standard Deviation (SD)
Designed storage capacity	11.45	5.67	3288.27	4289.24
Current utilization (%)	63.30	17.73	68.87	16.19
Annual volume handled	21.75	31.34	2623.47	3198.56
Peak season occupancy (%)	93.00	7.89	77.67	31.90
Off-season occupancy	24.50	30.86	39.67	25.10

The mean capital expenditure across major investment components for two facility size categories is shown in Table 9. Total investment for larger units (≥50 MT) was substantially higher, amounting to NPR 99.7 million, compared to NPR 2.15 million for cold rooms (<50 MT). Refrigeration equipment constituted the largest cost component for cold rooms (49.8% of total), whereas construction costs dominated the investment structure for larger facilities (51.3%). All individual cost categories exhibited marked absolute disparities between strata, reflecting the economies of scale and infrastructure intensiveness associated with larger cold storage operations.

Table 9. Capital investment composition of cold storage facilities by facility category

Investment components (per facility)	Cold Rooms (NPR)	Cold Storage (NPR)
Land cost	51,000	539,667
Construction cost	602,800	51,100,000
Refrigeration equipment	1,072,000	25,100,000
Other machinery	179,000	10,600,000
Electrical installation	114,500	5,228,667
Vehicle investment	30,000	2,853,332
Furniture and office equipment	26,000	1,006,667
Other capital investment	79,400	3,248,000
Total investment	2,154,700	99,700,000

Table 10. shows mean annual operating costs disaggregated by major expense categories for sampled cold storage operators, stratified by facility capacity. Total annual operating expenditure for larger facilities (≥50 MT) was approximately NPR 16.38 million, markedly exceeding that of cold rooms (<50 MT) at NPR 0.41 million. Electricity emerged as the dominant cost component for larger units, representing 36.9% of total expenditure, whereas salary and wages constituted

the foremost expense for cold rooms at 45.7%. All cost categories exhibited substantial absolute disparities between strata, with relative proportions remaining broadly consistent for maintenance, administrative, and insurance outlays. Notably, the higher absolute and proportional allocation to "other operating expenses" among larger facilities suggests amplified operational complexity and ancillary cost burdens associated with large-scale cold storage enterprises.

Table 10. Average annual operating expenditures of cold storage facilities by facility category

Expense Category	Cold Rooms (NPR)	Cold Storage (NPR)
Salary and wages	186,000	4,656,667
Electricity	132,500	6,043,446
Diesel	8,000	933,667
Repair and maintenance	33,600	1,717,356
Administrative expenses	18,200	897,000
Insurance	8,000	440,339
Other operating expenses	20,500	1,689,011

4.6 Economic and operational efficiency of cold storage facilities

The economic and operational efficiency of cold storage facilities is shown in Table 11. Small cold rooms (<50 MT) achieved higher ROI (17.77%), revenue efficiency, and profit per metric ton, while larger facilities (≥50 MT) generated greater total profits and benefited from lower investment and electricity costs per metric ton. This indicates that small facilities are more capital-efficient, whereas larger facilities benefit from economies of scale.

Table 11. Economic performance indicators of surveyed cold storage by facility category

Indicator	Cold Rooms	Cold Storage
Operating profit (NPR/year)	354,200 (455,175)	5,141,610 (20,200,000)
Return on investment (%)	17.77 (27.13)	-0.30 (12.61)
Revenue-investment ratio	0.37 (0.33)	0.18 (0.11)
Revenue per MT capacity (NPR/MT)	66,421.43 (33,797.87)	9,266.42 (13,842.59)
Operating profit per MT capacity (NPR/MT)	33,183.57 (29,208.04)	824.27 (6,125.40)
Investment per MT capacity (NPR/MT)	223,356.40 (109,463.10)	49,644.48 (46,085.92)
Electricity cost per MT capacity (NPR/MT)	14,084.73 (12,555.96)	3,721.26 (4,290.77)

Note: Figures in the parentheses are SD.

Table 12. reports mean annual revenue across primary income sources for surveyed cold storage operators, disaggregated by facility size. Total annual revenue for larger units (≥50 MT) was approximately NPR 21.50 million, substantially exceeding that of cold rooms (<50 MT) at NPR 0.76 million. Storage service income constituted the predominant revenue stream for both facility types, accounting for the largest share (approximately 74.6% for cold rooms and 72.6% for larger units relative to their reported total revenue). Rental income contributed 21.5% and 18.9%, respectively, while other income accounted for 3.8% among cold rooms and 13.6% among larger facilities, indicating relatively greater income diversification within the larger storage stratum.

Table 12. Average annual revenue structure of cold storage facilities by facility category

Revenue Category	Cold Rooms (NPR)	Cold Storage (NPR)
Storage service income	568,000	15,600,000
Rental income	164,000	4,061,333
Other income	29,000	2,934,293
Total annual revenue	761,000	21,500,000

The percentage composition of annual operating costs among sampled cold storage operators by facility size is shown in Table 13. Electricity and labor emerged as the predominant cost centers across both strata, collectively comprising approximately 77% and 71% of total operating expenditures for cold rooms and larger units, respectively. Larger facilities (≥50 MT) demonstrated moderately higher proportional allocations for diesel, insurance, and other miscellaneous expenses, whereas cold rooms exhibited marginally elevated shares for electricity and labor. Maintenance and administrative cost proportions remained broadly comparable across both groups, suggesting a relatively stable cost structure for these components irrespective of facility scale.

Table 13. Composition of annual operating costs by facility category (% of total operating cost)

Cost Component	Cold Rooms	Cold Storage
Electricity	41.56	37.03
Labor	35.65	33.93
Diesel	0.86	3.88
Maintenance	9.41	9.14
Administration	6.17	5.19
Insurance	1.37	2.28
Other	4.98	8.55

Note: Values represent percentage share of total operating costs

The proportional distribution of capital expenditure across major investment components for surveyed cold storage operators, disaggregated by facility size is shown in Table 14. Construction and refrigeration equipment emerged as the predominant cost centers within both strata, collectively comprising approximately 77% of total capital costs for cold rooms and 80% for larger facilities. Notably, the relative dominance of these components was inverted by facility type: refrigeration equipment accounted for the largest share among cold rooms (49.08%), whereas construction constituted the primary expenditure for larger units (52.82%). All remaining components, including other machinery, electrical installation, and furniture exhibited broadly comparable proportional allocations across both groups, suggesting relatively consistent investment patterns for auxiliary capital items irrespective of facility scale.

Table 14. Composition of capital investment by facility category (% of total investment)

Investment Component	Cold Rooms	Cold Storage
Construction	27.79	52.82
Refrigeration equipment	49.08	27.13
Other machinery	7.81	7.55
Electrical installation	5.12	4.56
Vehicle investment	0.75	2.29
Furniture and office equipment	1.09	1.11
Other capital investment	5.41	3.42

The proportional distribution of capital financing sources among surveyed cold storage operators is shown in Table 15. Cold rooms (<50 MT) relied predominantly on subsidies (44.36%), followed by own investment (28.10%) and loans (27.53%). In contrast, larger facilities (≥50 MT) derived the majority of capital from own investment (47.14%), with loans contributing 32.09% and subsidies accounting for a notably lower share (20.77%). This inverse financing pattern suggests smaller operations exhibit greater subsidy dependency, whereas larger enterprises demonstrate stronger private capital mobilization.

Table 15. Sources of financing for cold storage investments by facility category (% of total investment)

Financing Source	Cold Rooms (<50 MT)	Cold Storage (≥50 MT)
Own investment	28.10	47.14
Loan financing	27.53	32.09
Subsidy financing	44.36	20.77

4.7 Thematic findings

This section presents each theme in descending order of salience, with sub-themes, interpretive narrative, and illustrative verbatim quotations. Quotations are attributed by respondent type and district (operators/farmers) or by district and designation (government officials); facility or office names are given where they add context.

4.7.1 Theme 1: Structural and technical design deficiencies

The study found that structural and technical design deficiencies were the most heavily coded theme in the dataset. This pattern concerns weaknesses in the physical design, construction, and operation of cold storage facilities. This theme cuts across both facility operators (describing what goes wrong inside their own facilities) and government officials (describing systemic design failures they observe across the sector).

An agri-engineer from the NAMP office offered the most detailed critique, describing a pattern where structural (civil) investment crowds out mechanical investment, and where core cold-chain elements are simply missing:

"The mechanical component is missing. Excessive expenditure has been allocated to the civil/structural component. There are electricity-related issues. The facility consists of only a single storage chamber. The cold storage was constructed without surveying the targeted commodities. The cold chain is incomplete, as there is no pre-cooling chamber. There is no real-time data monitoring system, making it difficult to detect machinery faults or product spoilage."

- Agricultural Engineer, NAMP

The critique was also supported at the facility level. Only four cold storage operator had reported owning refrigerated trucks or a digital inventory system, and only three of 25 had a backup generator. The absence of pre-cooling was independently flagged as a direct cause of storage loss by 23 operators:

"Improper grading before storage. Produce entering storage without pre-cooling. Power interruptions and temperature fluctuations are the main reasons that causes the post-harvest lost in this cold storage."

- Cold storage operator, Dhading

"The major causes of the post-harvest loss in this farm includes, inadequate pre-cooling of produce before storage. Poor grading and sorting, with damaged or diseased produce entering storage. Limited technical knowledge among farmers regarding post-harvest management."

- Cold storage operator, Dhading

"Poor packaging and handling. Delayed transportation from farms. Improper grading and sorting before storage."

- Cold storage operator, Tanahun

-

18 cold storage operators had explicitly called for mandatory commodity-specific storage guidelines and for the design of partitioned chambers to address the mismatch between generic single-chamber facilities and the diverse commodities being stored in them. Their recommendations were directly linked to this design theme and the value-chain theme discussed in Section 4.6.5.

4.7.2 Theme 2: Governance, coordination and policy gaps

This theme captures a striking convergence between operators and government officials where both groups, independently, described the current policy and coordination environment as inadequate. Most notably, a NAMP official and an official from the provincial ministry of Agricilture responding to "what are the weaknesses of current policy?" answered simply:

"No policy"

- Government official, NAMP Chitwan
- Government official, Ministry of Agriculture, Gandaki

This statement is reinforced by a provincial official who identified "strong legal formulation" as a missing issue in current policy, and by another who stated the current framework needs to "cover many aspects like technical manpower." Together these suggest that, from within government itself, the current cold storage policy framework is seen as incomplete rather than imperfectly implemented.

Coordination failures were raised at every level. The coordination between ministries, between tiers of government, and between government and facility operators were very poor and that are needed to be strengthen.

"Coordination meeting needed."

- Government official, Agriculture Development Office, Dailekh

"Government coordination, electricity subsidy, bank loan, minimum support price and price ceilings are needed to be strengthen. Repairs and maintenance of the machinery cannot be done within Nepal. We have to go to India for this purpose, so multiple machines had to be kept as backup, which increases our capital investment. We have three additional machines for the same purpose, which increases our cost."

- Cold storage operator, Chitwan

Fifteen operators' had complaint further, alleging that promised 50% electricity subsidy from the central government had not materialized:

"Several cold storage operators have submitted requests for financial support; however, the Ministry of Finance has yet to disburse the funds."

- Cold storage operator, Kaski

Both operators and officials independently linked weak governance to poor siting decisions. Facilities constructed without first verifying local production volumes or commodity needs, discussed further under Theme 3. Three separate operators from Ramechhap, Parbat and Tanahun called, in near-identical language, for cold storage to be "prioritized in production clusters" and built "only after demonstrating sufficient production volume," which they frame as a governance/planning failure rather than a purely technical one.

All five government officials who addressed the question affirmed that Nepal should adopt a National Cold Chain Strategy, seeing it as the mechanism to resolve this fragmentation:

"Yes, cold storage needs to develop near the production zone which helps to circulate production and enables storage whenever and wherever required for the future use."

- Government official, Agriculture Development Office, Dailekh

4.7.3 Theme 3: Underutilization, siting and market aggregation

This theme addresses why so much installed cold storage capacity are idle for much of the year. This pattern is also visible quantitatively where average off-season occupancy was 13% while peak season occupancy was 89%). Respondents attributed this primarily to a mismatch between facility location and scale. The volume of production nearby had also influence the utilization capacity that was compounded by individual smallholder farmers' inability to generate enough throughput.

"Smallholder farmers often produce insufficient quantities to fully utilize cold storage facilities. The government should encourage cooperatives and farmer groups to aggregate produce. I can see that it can enable efficient utilization of storage capacity, reducing unit storage costs, and improving bargaining power in the market."

- Cold storage operator, Ramechhap

"Government needs to prioritize investments in production clusters instead of administrative boundaries. Cold storage should be established only where sufficient production volumes exist or where commodity aggregation through cooperatives can ensure minimum utilization throughout the year."

- Cold storage operator, Jaljala, Parbat

A government official made the same point from the demand side, describing underutilization as arising from “subsistence agriculture”, that farmers in some catchments do not yet produce a marketable surplus large enough to justify nearby cold storage. One operator proposed a technology-enabled fix: a “national digital cold storage information system showing available storage capacity, commodity prices, and facility locations,” and “digital booking platforms” connecting underutilized facilities with nearby farmers and traders. He emphasized reframing underutilization as a part of an information/matching problem rather than solely a production-volume problem.

4.7.4 Theme 4: Energy cost and power reliability

Energy was featured heavily in operators' recommendations, consistent with its position as the most frequently cited operational constraint (80%) in the structured survey. Two distinct sub-concerns emerged in the context of electricity: the cost of electricity, and the reliability of supply.

“50% electricity subsidy to the cold storage should be continue to sustain the cold storage facilities”

- Cold storage operator, Kaski

“Government should reduce electricity tariff for agricultural cold storage. Also, provincial government can fund for cold-chain infrastructure.”

- Cold storage operator, Tanahun

Beyond tariff relief, several operators have also shown interest in renewable energy specifically in solar power. They emphasized it can be the way to reduce exposure to grid cost and unreliability altogether. They also said having the solar infrastructure, no request is needed for a larger subsidy on the existing grid connection:

“The government can promote to install solar power to reduce electricity costs, and strengthen digital inventory and cold-chain management systems. If the government started to enhance the solar energy in the cold storage, we are ready to adopt the solar power in our facility and support the initiative.”

- Cold storage operator, Nawalparasi (Bardaghat Susta West)

“Power interruptions and temperature fluctuations was the most cause of storage loss”

- Cold storage operator, Dhading

4.7.5 Theme 5: Value chain integration, standards and market linkage

This theme tries to connect cold storage more tightly to the broader agricultural value chain. It uses different standards, value-addition, price information, and regulation of intermediaries rather than treating storage as an isolated piece of infrastructure.

"Research in commodity-specific storage guidelines should be performed and that guidelines must be mandatory for all cold storage facilities to store the products. Policies should focus on connecting nearby farmers, cooperatives, and traders with underutilized cold storage facilities through digital booking platforms, collection centers, and contract farming arrangements to maximize infrastructure use."

- Cold storage operator, Kapilvastu

"Support value addition near cold storage facilities, including grading, sorting, packaging, and processing units, to increase farmers' returns."

- Cold storage operator, Dhading

Government officials raised a related but distinct concern about the role of middlemen in the marketing chain. Two officials identified "Middleman" as a key issue when asked how private-sector participation could be improved, although they provided no further elaboration. While brief, this response signals that the role and regulation of intermediaries remain an unresolved issue in the current policy framework.

Farmers should also have access to "real-time market price information and seasonal price forecasts," one operator argued, so that the decision to store or sell immediately can be made on better information.

4.7.6 Theme 6: Subsidy design and financial sustainability

While the quantitative data shows subsidy is the dominant source of initial investment, the qualitative data reveals operators are less concerned with the existence of subsidy than with how it is designed and delivered. Three specific gaps recurred:

"Despite a nominal capacity of 2,500 MT, the effective storage capacity is only 2,300 MT. Furthermore, although a 50% subsidy was provided, the costs associated with loading and unloading operations raised the overall investment burden."

- Cold storage operator, Chitwan

Sub-theme 6b: A preference for operating-cost support over one-off capital subsidy

"Future subsidy schemes should prioritize operational support, market development, business incubation, and supply chain strengthening."

- Cold storage operator, Rupandehi

Sub-theme 6c: Disbursement delay and broken commitments

As already quoted under Theme 2, one operator directly accused the Ministry of Finance of failing to release promised payments, which is a trust or credibility issue that likely compounds the operational-cost pressures documented in Theme 4.

4.7.7 Theme 7: Human and technical capacity constraints

A recurring concern, raised independently by operators and officials, is the shortage of domestically available technical expertise for refrigeration and cold-chain systems. In some cases, there were shortages severe enough to require sourcing expertise from abroad:

"There is no one to carry out the technical work within Nepal. One must go to Delhi, so we had to keep multiple machines as backup."

- Cold storage operator, Chitwan

"Cold storage operations face several challenges: (i) inadequate technical manpower, (ii) damage to stored products, (iii) non-operational facilities, and (iv) elevated operational costs."

- Government official, Ministry of Agriculture, Kaski

At the other end of the value chain, several operators pointed to a parallel capacity gap among farmers themselves. They have stated that farmers have limited knowledge of grading, pre-cooling, and post-harvest handling practices, which links this theme back to the storage-loss sub-theme under Theme 1. Recommendations converged on structured training and certification programs, most explicitly from the Rupandehi fish-storage operator, who called for "specialized training and certification programs in fish cold storage operation, refrigeration systems, blast freezing, food safety, and equipment maintenance."

4.7.8 Theme 8: Farmer-level access barriers and lived experience

The data obtained from the farmers are critically valuable because they describe cold storage policy from the demand side. This type of perspectives is largely absent from the operator and government-dominated sample. The two accounts diverge sharply on access, which itself is informative: distance and transport, not awareness or willingness, appear to be the deciding factor.

"far location"

- Farmer, Kaski (reason for not using cold storage)

"Too far. No facility. Lack of transport."

- Farmer, Kaski (constraints to regular use)

By contrast, the farmer who did have practical access to cold storage reported a positive experience rating her overall satisfaction as "Satisfied" and confirming that cold storage helped

her to obtain a better selling price. Taken together, these accounts support the same conclusion reached independently by operators and government officials in Theme 3: proximity and physical and logistical access, rather than the intrinsic value of cold storage itself, appear to be the binding constraints on farmer-level uptake.

4.7.9 Emergent theme: environmental sustainability and inclusion

This theme was not directly applied by the survey instrument but emerged spontaneously in a small number of responses, and is reported here because of its potential policy relevance. The Rupandehi fish-storage cooperative operator was the clearest voice on this theme, describing current waste-disposal practice candidly and proposing alternatives:

"Current waste disposal practices (dumping or feeding pigs) should be replaced with environmentally sustainable approaches such as fish waste composting, fish meal production, organic fertilizer, or biogas generation."

- Cold storage operator, Rupandehi

Interest in solar power (Theme 4) can also be read as an emergent environmental sub-current within the energy-cost theme, motivated primarily by cost rather than sustainability. Notably, despite the quantitative finding that a minority of facilities are woman- or marginalized-community-owned, none of the respondent operators, officials, or farmers raised gender or social inclusion spontaneously in any open-ended response suggesting this remains an externally-observed data point rather than a stakeholder-articulated priority in its current form.

4.8 Cross-cutting synthesis

Reading the nine themes together, a clear storyline emerges. In the districts surveyed, Nepal's cold storage sector has succeeded in building infrastructure largely through capital subsidies. The surrounding ecosystem needed had to be built to make that infrastructure work sustainably. Three interlocking gaps recur across almost every theme:

- A planning gap: Facilities are sited and scaled without systematic feasibility or commodity surveys (Themes 1 and 2), leading directly to the severe underutilization documented in Theme 3.
- An operating-cost gap: Subsidy policy has focused on one-off capital support, while the recurring costs that determine day-to-day viability including electricity, (Theme 4), technical manpower (Theme 7), and uncovered installation costs (Theme 6) remained comparatively unaddressed.
- A connectivity gap: Cold storage is treated as a standalone facility rather than a node in a value chain. There is a missing links to refrigerated transport, market information, farmer aggregation, and quality/commodity standards (Themes 3 and 5) to the farmers who most need it (Theme 8).

The strong, largely unprompted convergence between cold storage operators (who experience these gaps operationally) and government officials (who acknowledge them from a policy vantage point, in one case as “no policy”) is itself a significant finding. The finding suggests, these are not perception gaps between stakeholders who disagree about the state of the sector, but a shared, cross-validated diagnosis of where current policy falls short. And it might show the necessity for the integrated National Cold Chain Strategy that all government respondents endorsed.

CONCLUSION

This chapter concludes the overall findings from the study. On effectiveness: national-level data show that Nepal has built substantial cold storage capacity, but more than one-third of the cold storages were only operational and almost one-fourth of the cold storage facilities are under construction at the time of the study. This gap between capacity built and capacity functioning is uneven across provinces where, Bagmati and Gandaki combine strong facility counts with comparatively high operational shares, while Lumbini Province have just few operational facilities despite of documented capital investment. This pattern is consistent with the core policy problem being not a shortage of infrastructure investment but a shortfall in the institutional, financial, and technical conditions required to keep that infrastructure running.

On the constraints side, the nine themes generated through thematic analysis of operator, official, and farmer interviews converge on three interlocking gaps that were also identified in the cross-cutting synthesis. A planning gap has arised because facilities were frequently sited and scaled without systematic feasibility or commodity surveys, which produces chronic underutilization. An operating-cost gap arises because subsidy policy has concentrated almost entirely on one-off capital support, while the recurring costs of electricity, technical manpower, and uncovered installation expenses remain largely unaddressed. A connectivity gap arises because cold storage is treated as a stand-alone facility rather than as one node within a wider value chain, disconnected from refrigerated transport, market-price information, farmer aggregation mechanisms, and commodity-specific quality standards. At the farmer level, the binding constraint is physical and logistical access, distance and lack of transport rather than lack of awareness or willingness, consistent with the operator- and government officials.

On the institutional arrangements: the study finds that Nepal's three-tier federal structure that has been designed to enable joint investment in cold storage, lack coordination in co-investment and causes alleged fund misappropriation. The strong call among the government officials interviewed for a National Cold Chain Strategy, together with the notable convergence between operators' and officials' independent suggests that these are not merely perception gaps between stakeholders but the findings point to a shared and mutually reinforcing diagnosis of the areas in which the current policy framework falls short.

Taken together, these findings support a central conclusion: Nepal's cold-storage system suffers less from a scarcity of public investment than from weaknesses in the institutional architecture needed to convert that investment into functioning, farmer-accessible infrastructure. These weaknesses include inadequate feasibility-driven planning, limited recurring operating support, insufficient technical capacity, weak market connectivity, and inadequate monitoring of implementation and performance. These institutional and operational gaps must be improved rather than simply expanding capital subsidy volumes. So, this must be a primary policy priority for reducing post-harvest losses, strengthening farmers' bargaining power, and building a resilient, farmer-centered cold chain for Nepal's agricultural sector.

POLICY RECOMMENDATIONS

This study proposes a set of policy and institutional recommendations for the effective operation and successful implementation of a cold-chain network in Nepal. Following policy and institutional recommendations, four interconnected cross-cutting gaps have been developed: planning, operational costs, and connectivity, as well as an additional cross-cutting gap relating to governance and monitoring.

1. **Close the planning gap: feasibility-linked, production-zone siting**
   - Make a commodity type and production-volume feasibility survey as a mandatory precondition for approving any federal, provincial, or local subsidy for new cold storage construction. This will allow facilities to be sited only where sufficient, sustained production volume exists or can realistically be aggregated.
   - Align cold storage siting decisions with MoAFEs existing NAMP pocket, block, zone, and super-zone classification, so that public investment follows the geography of commercial production rather than administrative boundaries and urban proximity.
   - Require partitioned, multi-chamber facility designs where a feasibility survey identifies multiple target commodities, to address the mismatch between generic single-chamber facilities and diverse local produce documented in Theme 1.

2. **Close the operating-cost gap: rebalance subsidy design**
   - Shift a portion of subsidy allocation from one-off capital grants toward recurring operating-cost support, covering electricity, routine maintenance, and loading/unloading costs that operators report as currently uncovered.
   - Sustain and reliably disburse the existing 50 % electricity tariff subsidy, and establish a transparent, published disbursement timeline so that operators can plan cash flow rather than absorb delayed government commitments.
   - Expand access to affordable domestic technical maintenance and spare-parts servicing, so operators are not forced to maintain costly redundant backup machinery because repairs currently require sourcing expertise from India.
   - Pair capital subsidy approval with a mandatory operating-cost and revenue-sustainability plan submitted by the facility owner or cooperative, to reduce the risk of facilities becoming financially unviable after construction.

3. **Close the connectivity gap: link cold storage to the value chain**
   - Develop and enforce commodity-specific cold storage design and handling standards, covering pre-cooling, grading, and packaging, to reduce the storage losses linked in Theme 1 to poor handling practice rather than cold-chain gaps alone.
   - Support a national digital cold storage information system that lists available capacity, commodity prices, and facility locations, and enables booking, to connect underutilized facilities with nearby farmers and traders as proposed by operators in Theme 3.
   - Promote farmer and cooperative aggregation mechanisms, including contract farming and collection centers, so that individually small smallholder volumes can be pooled to reach the throughput needed for facilities to operate efficiently.

- Invest in last-mile rural transport and road connectivity in cold storage catchment areas, since distance and lack of transport, not awareness, were the binding constraint on farmer-level access reported in Theme 8.
- Introduce regulatory attention to the role of market intermediaries, and expand farmer access to real-time market price information, so that the decision to store or sell can be made on better information.

4. **Strengthen governance, coordination, and accountability**
   - Adopt a National Cold Chain Strategy, as endorsed by government officials interviewed in this study, to serve as the single coordinating framework across MoAFE, NAMP, provincial ministries, and local governments, clarifying overlapping roles under Schedules 6, 7, 8, and 9 of the Constitution of Nepal.
   - Establish a single coordinating body or clearly designated lead agency for cold storage subsidy design, siting approval, and inter-governmental communication, to reduce the fragmentation described by both operators and officials in Theme 2.
   - Introduce mandatory monitoring and public reporting on subsidy disbursement, facility construction status, and operational status by province, closing the transparency and accountability gaps identified in Theme 6 and consistent with the non-operational facilities documented in Lumbini Province and elsewhere.
   - Invest in structured technical training and certification programs for both facility operators (refrigeration systems, maintenance) and farmers (grading, pre-cooling, post-harvest handling), targeting the human and technical capacity constraints identified in Theme 7.
   - Incorporate environmentally sustainable waste-disposal and renewable-energy options, such as solar power for cold storage operation and composting or biogas alternatives for organic waste, building on interest expressed by operators in Theme 4 and the emergent theme in Section 4.6.9.

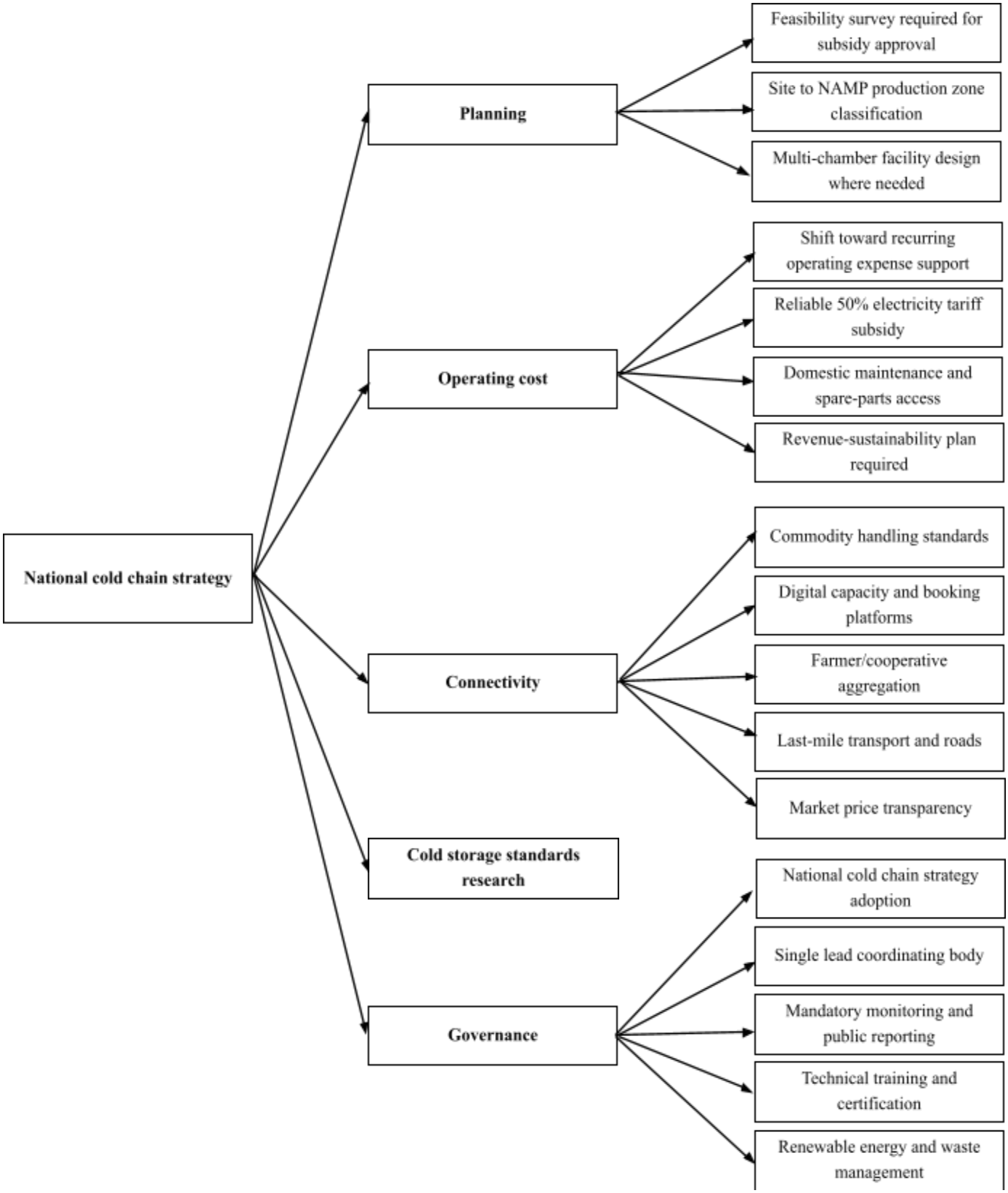


Figure 10. Policy recommendation for developing the national cold chain strategy in Nepal

5. Sequencing of policy recommendations

These recommendations are not equally urgent. In the short term (0-1 year), the priority is disbursement transparency and clearing the backlog of promised but undelivered electricity and capital subsidies, since this directly affects the financial viability of already-built facilities. In the medium term (1-3 years), the priority is adopting feasibility-linked siting rules and the National Cold Chain Strategy, so that new public investment does not repeat the underutilization pattern documented in this study. In the longer term (3-5 years), the priority is building out the connectivity layer, digital matching platforms, transport infrastructure, and commodity standards, that allow existing and new cold storage capacity to function as part of an integrated value chain rather than as isolated facilities.

Table 16. Sequencing of the policy recommendations for the cold chain development

Horizon	Priority
Short term (0-1 year)	Cold storage standards research, disbursement transparency and clearing the backlog of promised but undelivered electricity and capital subsidies, since this directly affects the financial viability of already-built facilities.
Medium term (1-3 years)	Adopting feasibility-linked siting rules and the National Cold Chain Strategy, so new public investment does not repeat the underutilization pattern documented in this study.
Longer term (3-5 years)	Building out the connectivity layer, digital matching platforms, transport infrastructure, and commodity standards, so existing and new cold storage capacity functions as part of an integrated value chain rather than isolated facilities.

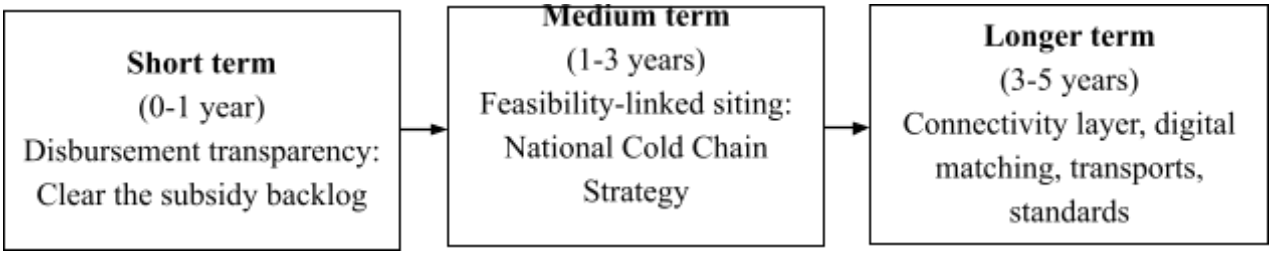


Figure 11. Sequencing of the policy recommendations for the cold chain development

ANNEX

Master plan for the development of cold chain in Nepal

Selection of district production hotspots (fruit and mountain horticulture)

The success of cold chain development is only possible with the proper selection of the production hotspot and building the infrastructure based on the production area. This study has used the yearbook districts table of MoAFE for a full-production cluster map. Table 5. Shows the highest-value anchor districts identified from the same publication and cross-referenced against known horticultural belts, useful for prioritizing the first tranche of Level 1/2 facilities:

Table 17. Selection of district production hotspots for the various region in Nepal

Agro-ecological zone of Nepal	Districts	Products
High mountain	Mustang, Jumla, Humla, Dolpa, Mugu, Manang	Apple, apricot, high-value off-season vegetables
Mid-hill fruit belt	Kavre, Sindhuli, Lamjung, Syangja, Palpa, Baglung, Ilam	Citrus, potato, vegetables, off-season vegetables
Eastern hills (citrus/cardamom)	Ilam, Panchthar, Terhathum, Dhankuta	Citrus (mandarin), ginger
Terai vegetable belt	Jhapa, Morang, Sunsari, Rupandehi, Kapilbastu, Banke, Bardiya, Kailali	Tomato, cauliflower, cabbage, off-season vegetables, mango, banana, litchi
Kathmandu Valley	Kavre, Nuwakot, Dhading, Makwanpur, Chitwan	Vegetables, potato; highest-value proximity to largest urban market

Three-tier cold storage hierarchy

The proposed cold-chain development plan for Nepal uses a three-tier system designed to manage agricultural products from production areas to national and international markets. At the local level, collection cold rooms with capacities of 50–200 metric tons would be established in production municipalities and managed by cooperatives, producer organizations, or communities to support collection, sorting, grading, and pre-cooling. Regional cold-storage facilities, located at district headquarters and market centers, would provide 500–2,000 metric tons of storage for product consolidation, distribution, and market access through private or public–private partnerships. At the national level, strategic hubs with capacities of 5,000–20,000 metric tons would be developed at major logistics centers, supported by government and operated by private entities, to enable long-term storage, national redistribution, and export preparation as shown in Table 7.

Table 18. Proposed three-tier cold-chain infrastructure development plan for Nepal

Tier	Location	Capacity (MT)	Ownership	Function
Local collection cold room	Production municipalities	50-200	Cooperative/producer organization/community	Collection, sorting, grading, pre-cooling
Regional cold storage	District headquarters and market centers	500-2,000	Private / PPP	Storage, consolidation, distribution
Strategic national hub	Major logistics centers	5,000-20,000	PPP / government anchor + private operation	Long-term storage, national redistribution, export prep

Strategic cold chain development plan for Nepal: Infrastructure sizing and capacity allocation (2035 target)

The proposed cold chain infrastructure plan for Nepal targets the integration of approximately 20% of national fruit and vegetable production, which is equivalent to 1.2 million metric tons annually, into a tiered cold chain network by 2035. The proposed plan can be a strategic middle ground between the country's current penetration rate of less than 5% and the 25–35% benchmarks observed in nations with mature horticultural export sectors. The network architecture comprises five distinct tiers. The local-level infrastructure can be built where 350-450 storage rooms can be distributed across production-cluster municipalities with combined capacity of 55,000-70,000 MT. So, local-level infrastructure will represent 6% of total network capacity. For the regional facilities, 55-65 installations with 65,000-90,000 MT capacity can be built, possessing an 8% share in the total network capacity. Seven strategic facilities with 55,000-120,000 MT capacity contributing 11% share can be built as a national distribution hub. Upgrading of existing 35-44 infrastructure contributing to 80,000-90,000 MT and 9% share and import/border-linked installations of 8-10 facilities with 30,000-50,000 MT capacity having 4% share of network can be built. These preliminary sizing estimates is derived through application of a 15-25% cold chain penetration target to provincial production volumes and standardized facility capacity benchmarks.

Table 19. Proposed cold chain infrastructure network by tire, facility distribution, capacity allocation, and network share (2035 target)

Tier	Indicative of facilities	Total capacity (MT)	Share of network
Local	350-450 rooms nationally (1-2 per production-cluster municipality)	55,000-70,000	6%
Regional	55–65 facilities	65,000-90,000	8%
National hub	7 hubs	55,000-120,000	11%

Tier	Indicative of facilities	Total capacity (MT)	Share of network
Existing stock (retained/upgraded)	35-44 facilities	80,000-90,000	9%
Import/border-linked cold chain	8-10 facilities	30,000-50,000	4%

Seven National Strategic Hubs: Logistical Rationale and Infrastructure Sizing

We have identified seven strategic hubs distributed across major logistical and production corridors of Nepal. These strategic hubs are collectively designed to anchor the country's horticultural value chain modernization. The Kathmandu Valley hub can serve as the primary national node with an indicative capacity of 15,000-20,000 MT. The infrastructure can leverage the dominance of Kalimati in wholesale trade and the existing 32.7-acre Chobhar Inland Container Depot (ICD) operated under a public-private partnership framework for import integration. Bharatpur/Chitwan can have 8,000-12,000 MT, and Pokhara can have 8,000-12,000 MT function as the central Terai and Gandaki gateways, respectively. Chitwan is positioned at the intersection of the east-west highway and Prithvi highway and is a robust vegetable production land. Pokhara connects high-altitude fruit zones from Mustang to lowland markets and the one of the point for the mid-hills highway. Further, Pokhara has international airport for high-value air cargo operations of the national products. Butwal/Bhairahawa can built 6,000-10,000 MT capacity that anchors the Lumbini logistics corridor with dual connectivity through the operational Bhairahawa ICD (established 1999) and Gautam Buddha International Airport. Nepalgunj can built 5,000-8,000 MT capacity as it provides the only viable lowland cold chain access point for Karnali Province through its dry port infrastructure. The eastern and far-western extremities can be served by Biratnagar with 6,000-10,000 MT capacity, which processes 300-400 trucks daily through its Inland Clearance Post (ICP) linking Koshi's potato and vegetable production base to Indian markets. Dhangadhi can built 5,000-8,000 MT, which consolidates Kailali/Kanchanpur output and facilitates hill and mountain horticultural connectivity of Far-western Province.

Table 20. Geographic distribution and functional rationale of seven national cold chain hubs

Hub	Rationale	Indicative capacity range (MT)
Kathmandu Valley	Largest urban market (Kalimati handles the bulk of national wholesale trade); existing Chobhar ICD (32.7-acre dry port, PPP-operated) for import linkage	15,000-20,000
Chitwan	Central Terai junction; East-West Highway and prithvi highway; strong vegetable production land	8,000-12,000
Pokhara	Connect Mustang, mid-hill highway,mountain fruit belt and downhill; Pokhara International Airport for high-value air cargo	8,000-12,000

Hub	Rationale	Indicative capacity range (MT)
Butwal / Bhairahawa	Lumbini logistics junction; Bhairahawa ICD (dry port, operational since 1999) and Gautam Buddha International Airport	6,000-10,000
Nepalgunj	Mid-west gateway; Karnali's only practical lowland cold-chain link; Nepalgunj Dry Port	5,000-8,000
Biratnagar	Eastern hub; Biratnagar ICP (300–400 trucks/day) links Koshi's largest potato/vegetable base to India	6,000-10,000
Dhangadhi	Far-west gateway; Terai production connecting the hills and mountains	5,000-8,000

Vehicle categories and sizing method

Class	Capacity (MT)	Typical use
Small reefer	1-3	Level 1 → Level 2 collection runs, hill/mountain roads
Medium reefer	5-10	Level 2 → Level 3 consolidation, district-to-hub
Large reefer	15-25	Level 3 → Level 3 / Level 3 → wholesale market, highway corridors, cross-border

Fleet sizing method: for a corridor carrying V metric tons/year of cold-chain volume, average trip distance D km, and an average of 220 operating days/year with a round-trip cycle time proportional to distance, required vehicles ≈ (V × round-trip-days) / (capacity × 220). Applying this to the §4.2 capacity targets and the corridor volumes implied by the provincial production data in §1.2 gives the following indicative national fleet, dominated by medium reefers because most flow is district-to-hub consolidation rather than long-haul:

Class	Indicative national fleet, 2035
Small reefer (1–3 MT)	100 vehicles
Medium reefer (5–10 MT)	20 vehicles
Large reefer (15–25 MT)	7 vehicles
Total	127 vehicles

National Cold Chain Corridors

Seven corridors structure the network, following existing highway alignments and the mountain-to-market production geography identified in Section 1.

Corridor	Route	Anchor commodities
Eastern Corridor	Taplejung → Ilam → Dharan → Biratnagar	Citrus (mandarin), cardamom, tea-belt vegetables
Central Corridor	Sindhuli → Dhulikhel → Kathmandu	Vegetables, off-season vegetables, potato

Corridor	Route	Anchor commodities
Gandaki Corridor	Mustang → Beni → Pokhara	Apple (Mustang), potato, mountain horticulture
Western Corridor	Baglung → Pokhara → Butwal	Citrus, vegetables, potato
Mid-West Corridor	Jumla → Surkhet → Nepalgunj	Apple (Jumla), potato — Nepal's most storage-deprived corridor given road access constraints
Far-West Corridor	Baitadi → Dhangadhi	Vegetables, citrus, mountain produce
Terai Belt Corridor	Jhapa → Biratnagar → Janakpur → Birgunj → Chitwan → Butwal → Nepalgunj → Dhangadhi	The trunk corridor: highest volume, links all Level 3 hubs, carries both domestic Terai production and cross-border import/export flow

The Terai Belt Corridor is the backbone: it is the only alignment that touches all seven national hubs and every major India border crossing, and should be prioritized for the first tranche of Level 3 hub investment and the majority of the large-reefer fleet.

Mountain-Hill-Terai Vertical Integration

Nepal's production geography is fundamentally vertical - from Himalayan apple and mountain vegetable belts through mid-hill citrus and off-season vegetable zones down to Terai bulk vegetable and fruit production - and the cold chain must be built as a set of vertical links, not just horizontal corridors.

Belt	Districts	Cold chain role
Mountain	Mustang, Jumla, Humla, Dolpa, Mugu, Solukhumbu	Source zone for premium apple and off-season vegetables; needs Level 1 pre-cooling rooms and reliable seasonal road/air links given near-zero existing cold storage
Hill	Kavre, Sindhuli, Lamjung, Syangja, Palpa	Consolidation zone; largest concentration of viable Level 2 sites given production density and road access
Terai	Jhapa, Morang, Sunsari, Bara, Parsa, Chitwan, Rupandehi, Banke, Kailali	Bulk production and the interface with the highway network, dry ports, and India border trade

For mountain districts without year-round road access (parts of Humla, Dolpa, Mugu), the practical cold-chain link is seasonal - small Level 1 rooms sized to the road-open season, feeding into Level 2 hubs downhill once trucks can move, supplemented by air cargo through Pokhara or Nepalgunj for the highest-value, lowest-volume crops (premium apple, off-season vegetable seed stock) where the economics justify it.

Imported Produce Network

The scale of import dependence

Nepal's fruit import bill reached roughly NPR 21 billion in the first ten months of FY 2025/26, up 20.3% year-on-year, following NPR 21.17 billion for the full FY 2024/25 and NPR 19.57 billion in FY 2023/24 (DoC, 2025). In FY 2023/24 alone, recorded vegetable imports through the eastern border (Kakarbhitta) included 51,113 MT of tomato (NPR 1.02 billion), 28,869 MT of bitter gourd, 15,029 MT of okra, 14,787 MT of green chili, and smaller volumes of onion, pumpkin, and gourds - commodities Nepal also grows domestically, indicating the gap is seasonal and storage-driven rather than purely comparative-advantage driven.

A 2023/24 fruit breakdown shows 63,714 MT of banana (NPR 2.65 billion) and 16,725 MT of orange (NPR 1.15 billion) among the largest single import lines - both crops Nepal also produces domestically in the Terai (banana) and hills (citrus).

Border and gateway infrastructure

Point	Country	Infrastructure	Trade share (import value, FY 2022/23)
Birgunj	India	ICP + ICD at Sirsiya (38 ha, only rail-linked dry port, connects to Kolkata/ Vishakhapatnam seaports, >20,000 TEU/yr)	~33% of import value; largest gateway
Bhairahawa	India	ICD (operational since 1999, 250-truck parking) + Gautam Buddha International Airport	~15%
Biratnagar	India	ICP (300–400 trucks/day, inaugurated 2020)	~12%
Kakarbhitta	India	ICD / "Mechi Nagar Dry Port" (200 containers/trucks per day); main eastern vegetable-trade point	Included in eastern-region trade share
Nepalgunj	India	ICP under construction / dry port developing	Mid-west gateway
Rasuwagadhi	China	ICD under construction at Timure	Small but strategic; northern alternative route
Tatopani	China	ICD at Larcha	Small; periodically disrupted by border closures/earthquake damage
Kathmandu (Chobhar)	(inland)	ICD, 32.7 acres, PPP-operated, operational April 2022	Distribution hub, not a border point, but functions as the Valley's import gateway

Source: DoC (2025)

Import cold chain flow

Border Cold Storage → Transit Cold Storage → Regional Hub → Wholesale Market → Retail Distribution. In practice, Birgunj and Bhairahawa should carry the first purpose-built border cold-storage/pre-cooling facilities (sized at roughly 2,000–4,000 MT each, reflecting their import share), since they already have functioning customs, quarantine, and rail/road transshipment infrastructure- the missing link is cold storage and reefer capacity at the transshipment point itself, not the border-crossing process.

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