TRIBHUVAN UNIVERSITY

INSTITUTE OF ENGINEERING

THAPATHALI CAMPUS

A seminar paper on "Comparison between Cool bot technology and Conventional refrigeration system"

by

Sailesh Sitaula

(27286)

A REPORT

SUBMITTED TO THE DEPARTMENT OF INDUSTRIAL ENGINEERING

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE

DEGREE OF

BACHELOR IN INDUSTRIAL ENGINEERING

DEPARTMENT OF INDUSTRIAL ENGINEERING

KATHMANDU, NEPAL

JUNE 2022

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It is hereby certified that this report, entitled

"A seminar paper on Comparison between Cool bot technology and conventional refrigeration system cold storage"

prepared by Sailesh Sitaula

"Department of Industrial Engineering"

The facts and ideas presented in this paper are an outcome of the student's hard work and dedication to the project, undertaken as a partial fulfillment for requirements for degree of

Bachelor in Industrial Engineering.

The outcome of this project has been highly appriciated.

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ABSTRACT

Many developing countries are still not well equipped with cold chain facilities. Refrigeration has been the principal known method of successful storage of fresh fruits and vegetables to retain their freshness and flavour. When fruits and vegetables are harvested, they are cut off from their source of water and nutrition and soon start to deteriorate. They lose weight, texture, flavour, nutritive value and appeal. Both time and temperature are important factors in post-harvest product deterioration .Cooling the harvested product control the rate of quality loss by slowing the rate of respiration. The warmer the temperature, the faster the deterioration and the shorter the storage life; conversely, the cooler the temperature, the slower the deterioration and the longer the storage life. The more quickly the product is cooled, the longer it will remain marketable.

This paper aims to provide clarity between concept of Cool bot technology based cold storage and Conventional refrigeration system based cold storage. The use of cool bot technology is very popular in developed country in recent times. This paper is to clarify the choice according to different situation. In early pages it consist of. This paper deals with a comparison is made between cool bot based cold storage and conventional refrigeration system cold storage. Then the paper focus on technical analysis and economic analysis of both technology .This not only includes the cost and time but also the aesthetics and energy consumptions.

Keyword: *Cold storage, Conventional Refrigeration System, Cool bot*

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IOE	Institute Of Engineering
MT	Metric Ton

LIST OF SYMBOLS

A	Surface area	[m^2]
Cp	Specific heat capacity	[Kj/Kg^{o}C]
Kw	Kilowatt	[Kw]
Q	Quantity of heat	[Kw/Day]
T_i	Temperature of inside air	[^{o}C]
T_o	Temperature of outside air	[^{o}C]
U	Overall Heat transfer coefficient	[m/s]

CHAPTER ONE
INTRODUCTION

1.1 Background

A cool store or cold store is a large refrigerated room or building designed for storage of goods in an environment below the outdoor temperature. Products needing refrigeration include fruit, vegetables, seafood and meat. Cold storage is a facility that primarily stores food items that are short-lived and highly likely to get spoilt under normal conditions. These may include fruits, vegetables, fish, meat etc. These food items are stored under optimum temperature (primarily low) and humid environment as required for individual items. Almost all cold storage rooms are designed such that these properties are pre-configured based on what is being stored. Some cold rooms are made such that these properties are adjustable.

Vapor Compression refrigeration system

The Vapor Compression Refrigeration Cycle involves four components: compressor, condenser, expansion valve/throttle valve and evaporator. It is a compression process, whose aim is to raise the refrigerant pressure, as it flows from an evaporator. The high-pressure refrigerant flows through a condenser/heat exchanger before attaining the initial low pressure and going back to the evaporator. A more detailed explanation of the steps is as explained below.

1. Compression: The refrigerant enters the compressor at low temperature and low pressure. It is in a gaseous state. Here, compression takes place to raise the temperature and refrigerant pressure. The refrigerant leaves the compressor and enters to the condenser. Since this process requires work, an electric motor may be used. Compressors themselves can be scroll, screw, centrifugal or reciprocating types.

2. Condensation: The condenser is essentially a heat exchanger. Heat is transferred from the refrigerant to a flow of water. This water goes to a cooling tower for cooling in the case of water-cooled condensation. Note that seawater and air-cooling methods may also play this role. As the refrigerant flows through the condenser, it is in a constant pressure. One cannot afford to ignore condenser safety and performance. Specifically, pressure control is paramount for safety and efficiency reasons. There are several pressure-controlling devices to take care of this requirement

3. Throttling and Expansion: When the refrigerant enters the throttling valve, it expands and releases pressure. Consequently, the temperature drops at this stage. Because of these changes, the refrigerant leaves the throttle valve as a liquid vapor mixture, typically in proportions of around 75 % and 25 % respectively. Throttling valves play two crucial roles in the vapor compression cycle. First, they maintain a pressure differential between low- and high-pressure sides. Second, they control the amount of liquid refrigerant entering the evaporator.

4. Evaporation: At this stage of the Vapor Compression Refrigeration Cycle, the refrigerant is at a lower temperature than its surroundings. Therefore, it evaporates and absorbs latent heat of vaporization. Heat extraction from the refrigerant happens at low pressure and temperature. Compressor suction effect helps maintain the low pressure. There are different evaporator versions in the market, but the major classifications are liquid cooling and air cooling, depending whether they cool liquid or air respectively.

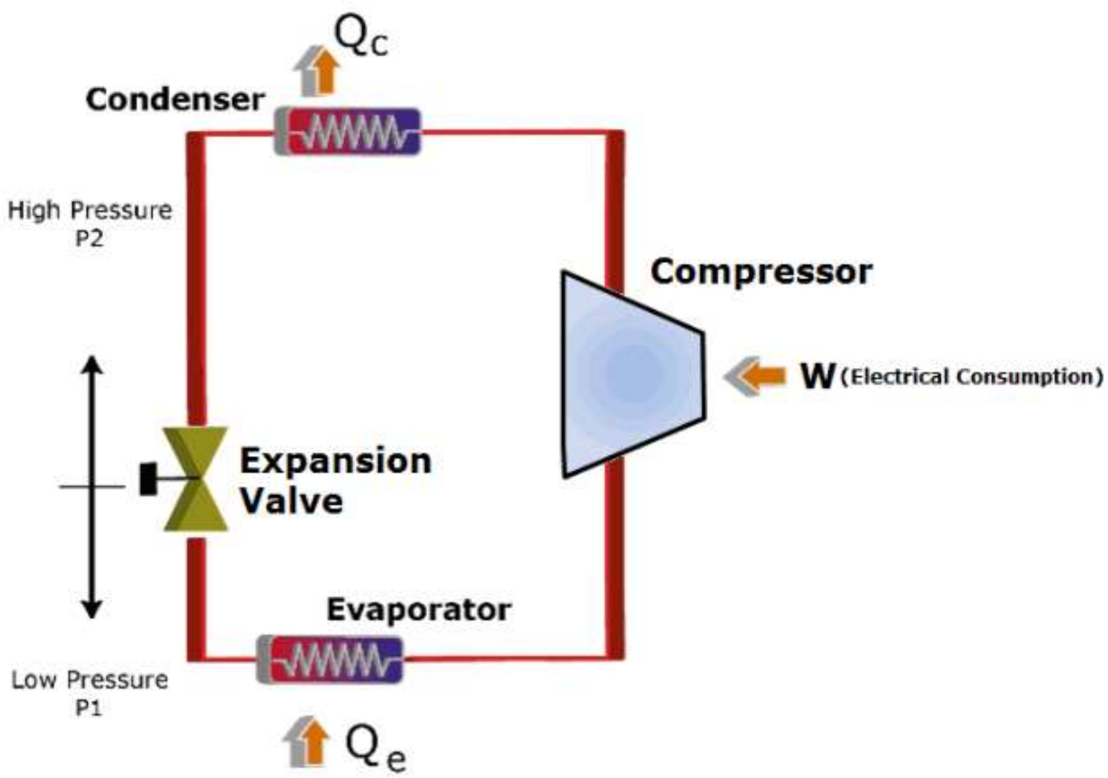

Figure 1.1: Vapour Compression Cycle (Source: www.araner.com)

Conventional Refrigeration system based cold storage

The refrigerant's boiling point is reduced by increasing its temperature and pressure by the compressor. Heat is removed from the refrigerant as it is changed from gaseous to the liquid state by the condenser. Now the refrigerant is transferred to the reservoir for storage. Further, the refrigerant is moved to an expansion valve to reduce the temperature and pressure in the liquid state. The last step takes place in the Evaporator, where the heat from the surroundings is used to change the refrigerant again to a gaseous state, thus causing the cooling effect. The blower circulates this cool air.

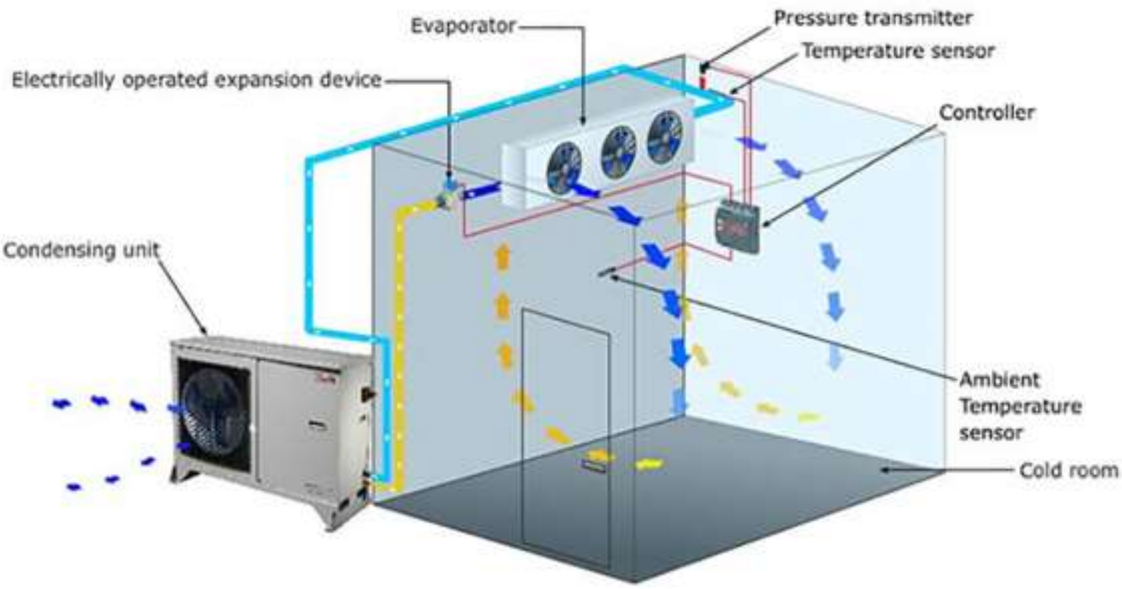

Figure 1.2: layout of Conventional Refrigeration System (Source:www.danfoss.com)

Cool bot based Cold Storage

Cool bot based cold storage is simply a connection between Residential AC and Cool bot where a cool bot acts as a control unit which reduce temperature, defrost AC and save energy by stopping its compressor as soon as it reaches desired temperature. Cool bot helps to reduce the temperature of residential AC which is explained below.

Figure 1.3: Cool bot based Cold storage (Source: www.storeitcold.com)

- **Residential AC:**

Air conditioning, often abbreviated as A/C or AC, is the process of removing heat and controlling the humidity of air in an enclosed space to achieve a more comfortable interior environment by use of powered "air conditioners" or a variety of other methods, including passive cooling and ventilative cooling. Air conditioning is a member of a family of systems and techniques that provide heating, ventilation, and air conditioning (HVAC). Air conditioners, which typically use vapor-compression refrigeration, range in size from small units used within vehicles or single rooms to massive units that can cool large buildings

The heat transfer capacity of an air conditioner can remove enough heat from a house to drop the temperature by 20°F. It can be set to do less, but it can't be made to do more. The compressor and refrigerant that carry out heat exchange are unable to pump out the amount of heat necessary to go any colder.

- Cool Bot:

The CoolBot Walk-in Cooler is a large storage room which has been transformed into a refrigeration room by equipment of CoolBot gadget and a standard air conditioner (AC). The CoolBot controller has been designed to trick the AC into operation at much lower temperature than indoor temperatures. The controller also tracks frost buildup on the coil and periodically stops the AC, allowing time for defrosting. The concept achieves low enough temperatures (0°C) allowing storage of perishable commodities.

Figure 1.4: Cool bot (Source: www.storeitcold.com)

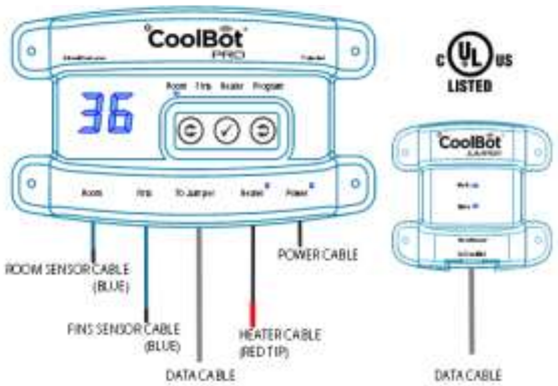

Figure 1.5: Cool bot schematic diagram (Source: www.storeitcold.com)

1.2 Statement of problem

Nepal's economy is largely dependent on agricultural, which accounts for 36% of GDP and absorbs about two-thirds of the labor market. About 30% of Nepal's total land is used for agricultural purposes. But the country's farmers do not get remunerative prices because of a lack of investment in cold storages. For a country where a large part of the population is dependent on agriculture for livelihood, it is essential to invest heavily in storage and warehouse facilities. The cold storage will solve the problem of the marketing aspects as they will be able to store their product when their price is low and sell it when their price is high of and also provide healthy fruits and vegetables to the customers.

Cold storages are key requirements in the post-harvest storage and distribution function of perishable commodities and food products. It facilitates the delivery of perishable agricultural products like fruits, vegetables, meat, fish, poultry, milk and milk-based products from production centers to consumption centers. It keeps your products at a set temperature of your choosing, which keeps them fresh and makes them last longer.

1.3 Objectives

1.3.1 General objectives:

- To compare cold storage technology based ln cool bot and Conventional refrigeration system.

1.3.2 Specific objectives:

- To perform fundamental and economic analysis.
- To calculate initial cost and annual expenses for each Cold storage system.
- To forecast cost for fifteen years its service life
- To determine Payback period.

1.4 Significance of study

According to the Association of Cold Storage of Nepal, about 35 cold storages are running in Nepal, among which 23 are the members of the association. The average size of the cold storages of Nepal is 3,000 metric tons. An investment for cold storage generally takes 47cr. Nepalese rupees to 65cr. Nepalese rupee value to set up cold storage of 5000 MT in Nepal. Even this amount could vary according to the location. Cost is one of the reason Nepal is struggling to make cold storage facility available for farmers at every part of country wile Nepal has so far only used conventional refrigeration system based cold storage this study objective is to find which one is cost efficient and which will be best way to take cold storage facility to every farmers of Nepal.

1.5 Limitations

- The custom rate of different electrical component may vary year by year.
- Since Coolbot is used to bypass AC temperature it can have effect in AC service life.

CHAPTER TWO
LITERATURE REVIEW

The design of cold storage facilities is usually directed to provide for the storage of perishable commodities at selected temperature with consideration being given to a proper balance between initial, operating, maintenance, and depreciation costs. The basic procedures for constructing or implementing the cold store units are should have the following requirements:

- Process Layout

  The most important requirement for any food project using insulated envelopes is to determine the process layout of the operation which is to be housed by the envelope. In the case of a meat plant, this can be a carcass dressing line or a boning room, or for a cold store, the pallet layout and mode of operation must be established. It is simply no good building an envelope and then attempting to place the processing machinery inside it.
- Planning Drawings and Application

  It is only after concluding the process layout that a planning application can be made when the dimensions of the envelope and supporting buildings can be frozen.

- Design Drawings and Specifications

  Once planning approval has been obtained then the preparation of design drawings and specifications can proceed.

2.1 Heat load calculations

The heat load for a cold storage is the total load of (a) heat loss through wall, floor, roof (ceiling), and doors (b) equipment load (lighting etc.), (c) cooling load for preserved material, (d) respiration load, and (e) human occupancy load.

The mathematical modelling for individual load calculation to design a cold storage is given as follows:

$$Q=UA\Delta t$$

Where U is the overall heat transfer coefficient, A is the cross section area of the wall perpendicular to the heat flow and Δt is the temperature difference between ambient (outside) temperature and inner side cold storage temperature. The overall heat transfer coefficient of the wall can be calculated by,

$$U = \frac{1}{\frac{1}{hin} + \frac{l1}{k1} + \frac{l2}{k2} + \frac{1}{hout}}$$

If the steady state flow is considered than, the heat flow is

$$Q = UA\ (To - Ti)\ Kcal / hr$$

Where,

U =Overall heat transfer coefficient (Kcal/m^2hr° C)

A= Surface area through which heat is transferred (m)

To=Temperature of outside air (°C)

Ti =Temperature of inside storage space (° C)

Product Load

Product cooling = (Weight of the fruit) (Specific heat of fruit) (Temperature difference)

Box heat load (Hard wood) = (weight of the box) (sp heat of box) (temp. difference)

Total product load = Box Heat load + Product cooling

Respiration load during cold storage:

Calculate Average temperature

Respiration heat load = wt. of the fruit x heat of respiration

Total heat load = Heat transfer through surface + Product cooling + Respiration load

Basket load:

Q = UA (To – Ti) Kcal / hr

Where,

U =Overall heat transfer coefficient (Kcal/m^2hr°C)

A =Surface area through which heat is transferred (m^2)

To=Temperature of outside air (°C)

Ti= Temperature of inside storage space (°C)

Total infiltrated air

Total in filtered air= $\Delta t \times$total in filtered air/$m^3 \times$cubic meter of new air provided

Total Cooling load

Total cooling load= Product load +Respiration load +Basket load +in filtered air

Tonne of refrigeration

Tonne of refrigeration= Total Cooling load/84

CHAPTER THREE
RESEARCH METHODOLOGY

3.1 Theoretical/Conceptual Framework

I have prepared the seminar paper by gathering information and data about cold storage parameters from different sources. The major approaches towards collection of relevant information and data related to Cold storage parameters involve the use of following source

Primary Source

the data were taken from the design and construction process carried out at Nepal Mind Factory. From there we generate the concept.

Secondary Source

we have searched different sites in internet. Moreover, we also got information from journals and research articles which assist to prepare this report.

3.2 Study Design

The research was done in following steps

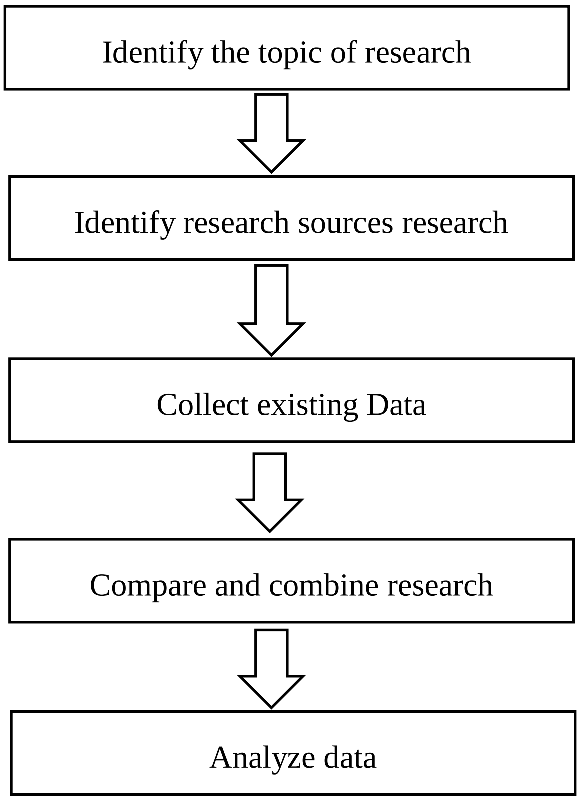

Table 3.1: Study Design

Identify the topic of research: Before beginning Primary and secondary research the topic to research was identified. Once that's done, the research attributes and the purpose was listed down.

Identify research source: Next, the information source that provide most relevant data and information applicable to the research was narrowed down.

Collect existing data: Once the data collection source were narrowed down, we checked foe any previous data that is available which is closely related to the topic. Data related to the research were obtained from primary source and secondary source.

Combine and compare: Once data was collected; we combined and compared the data for any duplication and assemble data into a usable format. Make sure to collect data from authentic sources, incorrect data can hamper research severely.

Analyze data: the collected data was then analyzed and then identified if all question were answered. If not, we repeat the process if there is a need to dwell into actionable insights

CHAPTER FOUR:
CASE STUDY

4.1 Cooling load Calculation

First of all we select the size of cold room. The following dimension is taken:

Table 4.1 : Dimension of cold storage

Dimension of cold storage	
Length(m)	5.2
Width(m)	5.2
Height(m)	4
Total Area(m^2)	27.04
Total volume(m^3)	108.16

The environment condition was taken mean day temperature for every season for Jhapa district.

Table 4.2 : Mean temperature

.	Centigrade	Temp difference	Temperature difference of potato after pre cooling(ºC)
Monsoon(Jun-sept)	28.1	20.1	15
Pre monsoon(mar-may)	25.5	17.5	15
Post monsoon(Oct-Nov)	23.9	15.9	15
Winter(Feb-Dec)	17.5	9.5	15

The room consist of puff panel wall and top and 60 pound concrete bottom. The insulation puff panel heat transfer coefficient for 10cm thickness of wall is $0.22 W/m^2$. The storage is constructed for potato hence 8ºC average optimal storage temperature was taken. Bulk density of potato was taken as $641 kg/m^3$ specific heat capacity as 3.71kJ/KgºC and respiration rate of 3 and relative humidity 93% is to be maintained. Total capacity of cold storage is 5000Kg.

Transmission load through celling and floor

Table 4.3 : Transmission load through walls

Transmission load	Kw/Day
Monsoon	11.75
Pre-monsoon	10.61
Post-monsoon	9.68
Winter	5.95

Product load

Table 4.4 : Product load of vegetables

Product load	Kw/day
Monsoon	77.29
Pre-monsoon	77.29
Post-monsoon	77.29
Winter	77.29

Respiration Rate

Table 4.5 : Respiration Rate

Respiration rate	Kw/day
Monsoon	4.76
Pre-monsoon	4.76
Post-monsoon	4.76
Winter	4.76

Equipment load

Table 4.6 : Equipment load

Equipment load	Kw/day
Light	0.32
Fan	6.00000
Total	6.32

Basket load

Table 4.7 : Basket load

Basket	Kw/Day
Monsoon	0.043
Pre-monsoon	0.038
Post-monsoon	0.034
Winter	0.020

Total infiltrate air

Table 4.8 : Total infiltrate air

Total in filtered air	Kw/Day
Monsoon	0.101
Pre-monsoon	0.088
Post-monsoon	0.080
Winter	0.048

Total heat load

Table 4.9 : Total heat load

Total heat load	Kw/Day
Monsoon	101.350
Pre-monsoon	100.189
Post-monsoon	99.247
Winter	95.476

Total cooling load

Table 4.10 : Cooling load

Tone of refrigeration	Kw/Day
Monsoon	1.21
Pre-monsoon	1.19
Post-monsoon	1.18
Winter	1.14

Calculation is in ANNEX:A

Construction cost

L=5.2m

B=5.2m

H=4m

Puff panel Thickness= 75mm

Door= 1

Material= Puff panel

Cost of construction=NRs. 185947.51

Panel Installation cost=25 per m^2

Total installation cost=NRs.7550

Fitting materials=NRs. 42000

Total construction cost=NRs.233497.51

Components used in cold storage and power required to operate them for cool bot technology

Table 4.11 : Details of LG AC

Refrigeration Unit Model	JW-Q18WUXA1
No. of Refrigeration Units	1 nos
Refrigeration Unit Type	Air-cooled split type
Condenser Type	Copper Condenser
Compressor Make	LG
Compressor Type	LG DUAL Inverter Compressor
Refrigerant	R-32
Power Supply	240 Volt, 50Hz, 1-phase
Defrosting Method	On-cycle

Table 4.12 : Cost and Energy for Cool Bot technology

S.N	Components	Quantity	Cost (NRs)	Energy consumption (Watt)
1.	1.5 ton AC (JW-Q18WUX)	1 nos	60000	1488

2	Cool bot	1 nos	40000	40
3	Light	6 nos	1500	12
4	Fan	1 nos	10000	250
5	Construction cost		233500	
6	Land cost	800 sq ft	300000	
	Total		6465000	1791 Watt

Components used in cold storage and power required to operate them for Conventional refrigeration system

Table 4.13 : Details about refrigeration Unit

Refrigeration Unit Model	ZSI09KQE
No. of Refrigeration Units	2 nos
Refrigeration Unit Type	Air-cooled split type
Condenser Type	Air-cooled aluminum and copper tube type
Compressor Make	Emerson
Compressor Type	Hermetic scroll compressor
Evaporating Coil	Aluminum fin and copper tube type
Refrigerant	R-404a
Power Supply	440 Volt, 50Hz, 3 phase
Defrosting Method	On-cycle

Table 4.14 : Cost and Energy for traditional cool bot technology

	Components	Cost (NRs)	Power (Watt)
Refrigeration unit CR-21 (1ph)	Condensing Unit Refrigeration unit Control Panel	290947	3000
Construction cost	Puff panel (75mm)	233500	
Land cost		300000	
Light	6(12 watt)	1500	72
Fan		10000	250
Total		835947	3322

Electric Consumption of traditional conventional refrigeration system based cold storage per month

Cost of 1kW/Hr. of electricity is NRs. 11

Total power for vapor compression cycle 3322 watt

Total electrical use for a month 2319.84 Kwh

Total electrical uses in a year 27838 Kwh

Annual Cost of operation of vapor compression based cold storage NRs. 361895.04

Electric Consumption of Cool Bot technology per month

Cost of 1kW/Hr. of electricity is NRs. 11

Total power for used by Cool Bot technology1791 watt

Total electrical use for a month 1289Kwh

Total electrical uses in a year 15471.24Kwh

Cost of operation of Cool Bot technology based cold storage NRs. 201165.12

Revenue generated by cold storage

Cost to keep 1kg potato in cold storage for a month= 10Rs

Considering cold storage remains fill every month

Revenue generated in one month =NRS.50000

Revenue generated in a year= NRs. 600000

Payback period and cash flow for traditional cold storage (Product life 15-20 years)

Maintenances cost=10000 per year

$$\text{Payback Period} = \frac{\text{Initial Investment}}{\text{Cash flow period}}$$

Table 4.15 : Pay Back Period Calculation

S.N.	Revenue	Total expense	Net profit
1.	600000	1174146.04	-574146
2.	600000	338199.04	-312345
3.	600000	338199.04	-50544.1
4.	600000	338199.04	211256.8
5.	600000	338199.04	473057.8
6.	600000	338199.04	734858.8
7.	600000	338199.04	996659.7
8.	600000	338199.04	1258461
9.	600000	338199.04	1520262
10.	600000	338199.04	1782063
11.	600000	338199.04	2043864
12.	600000	338199.04	2305665
13.	600000	338199.04	2567465
14.	600000	338199.04	2829266
15.	600000	338199.04	3091067

Payback period=3.193 years which is around 3 Years and 2 month

Payback period and cash flow for cool bot based cold storage (Product life 15-20 years)

Maintenances cost=5000 per year

$$\text{Payback Period} = \frac{\text{Initial Investment}}{\text{Cash flow period}}$$

Table 4.16 : Pay Back Period Calculation

S.N.	Revenue	Total expense	Net profit
1.	600000	852665.12	-252665
2.	600000	333199.04	14135.84
3.	600000	333199.04	280936.8
4.	600000	333199.04	547737.8
5.	600000	333199.04	814538.7
6.	600000	333199.04	1081340
7.	600000	333199.04	1348141
8.	600000	333199.04	1614942
9.	600000	333199.04	1881743
10.	600000	333199.04	2148544
11.	600000	333199.04	2415344
12.	600000	333199.04	2682145
13.	600000	333199.04	2948946
14.	600000	333199.04	3215747
15.	600000	333199.04	3482548

Payback Period=1.15 year which is around 1 Year and 2 month

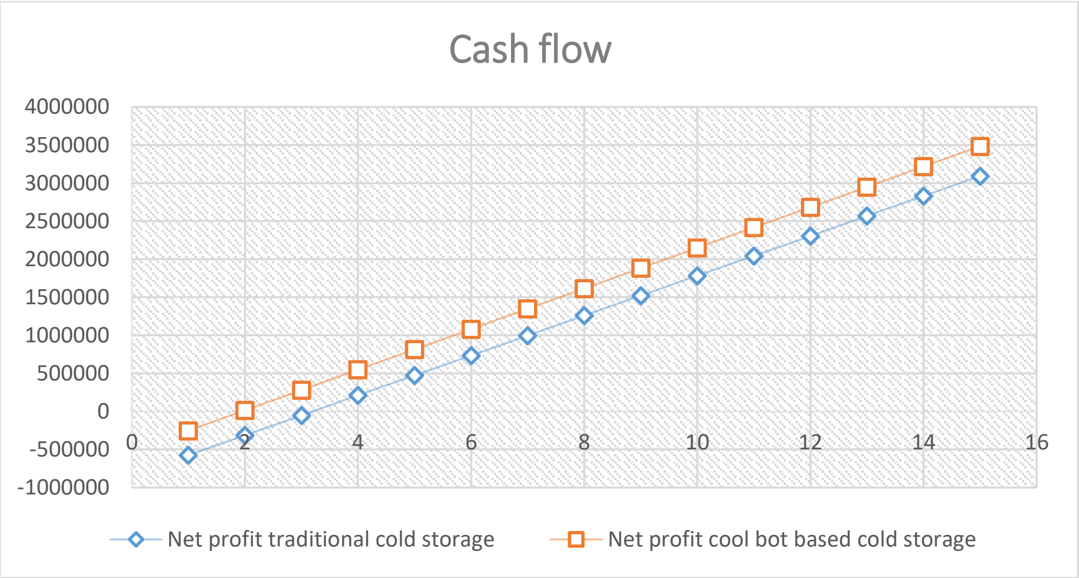

Figure 4.1: Total Cost comparison

CHAPTER FIVE
RESULTS AND DISCUSSION

5.1 Results

After the detail calculation of labour cost, land cost equipment cost and energy cost calculation total cost was high for conventional refrigeration system compared to cool bot.

Calculation of energy uses for both cold storage was calculated and it was found that for 3Kw of energy uses for 1.5 tonne of cooling load with coolbot it was 1.7Kw which is about 44% of energy consumption decrease.

Cost of equipment uses was low for cool bot based cold storage which in return made Payback period of using Cool Bot 1year and 3 months which is 2 years less than Conventional refrigeration system.

5.2 Discussion

The use of cold storage is growing every day yet there isn't sufficient cold storage to fulfil farmer's demands. Investment in Cold storage has contributed in increase in the GDP and overall economy and is forecasted to play even bigger role in the future for farmers and economy of farmers and economy of Nepal.

Cold storage helps to store food and prevent food spoilage. Farmers can also store it in times of low price market and sell their product when their market price is high. Which will have a very important impact. Farmers will go from earning once during time of harvest to having income generation potential any time of year. In order to achieve it cold storage need to construct. Although substantial effort has been seen in recent time to increase the number and volume of cold storage cost of construction and electrical uses has become a big hurdle to clear

Coolbot technology does provides a lifeline to this problem. We can conclude from above data it decrease cost of equipment and cost of electricity consumption nearly to half of what is currently seen in recent time. And Nepal being dependent up to 30% of its total GDP in agriculture and more than 50% of its population a cost effective cold storage is needed and cool bot seems to fill that gap very nicely.

CHAPTER SIX
CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusion:

Cost forecasting for fifteen years its service life which was Nrs.3091067 for conventional refrigeration system and Nrs.3482548 for Cool bot based refrigeration system which is about 11.24% higher net profit for cool bot based cold storage.

Payback period for cool bot and conventional refrigeration system was 1 year and 2 month and 3 year and 2 month respectively. So we can conclude that payback period for cool bot is about 2 year less than that of conventional refrigeration system

6.2 Recommendation:

- Coolbot based cold storage can be used to tackle high cost in building and operating cold storage.
- Coolbot based cold storage has low initial cost of investment, electricity uses and also can be built easily so it can be built by small farmers.

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ANNEX

CALCULATION

Dimensions,

L = 5.2m

B = 5.2m

H= 4m

External temperature Conditions:

Mean Temperature	Centigrade	Temp difference	Temperature difference of potato after pre cooling(ºC)
Monsoon(Jun-sept)	28.1	20.1	15
Pre monsoon(mar-may)	25.5	17.5	15
Post monsoon(Oct-Nov)	23.9	15.9	15
Winter(Feb-Dec)	17.5	9.5	15

Table A.1 : Temperature condition

50% RH

Internal air = 8ºC at 95% RH

Insulation =Puff Panel (0.22 W/m2K)

Ground temperature = 10^0C

General consideration	
Total time of operation (hrs.)	22
No of person	2
Operation time (hrs.)	20
Conversion unit(w to kw)	1000
Mass(kg)	5000
Cp(kJ/kg ºc)	3.71
Respiration rate(for highly perishable vegetables)	3
Heat released by human body per hr.(Joule)	270
Cold storage loading and unloading (hr.)	4
No of light	4

Power of light used (kw)	12
No of fan	1
Power of fan(kw)	250
In filtered air per hr. Per m^2 of door and window(m^3)	5
Total in filtered air(m^3)	9
Cubic meter of new air provides(kJ/ °c)	2
Human body heat load	2.16
1ton of refrigeration(kw)	3.5

Table A.2 : General Consideration

Calculation is carried out for every season using same process: Below the calculation is shown for summer seasons

1) Transmission load,

Q = [U * A * (T0 –TI) * 24]/1000

Opposite two walls will have same area, therefore

2 walls: 5.2 * 4 + 5.2* 4 = 24 +24 = 41.6 m^2

2 walls: 5.2 * 4 + 5.2* 4 = 24 +24 = 41.6 m^2

Roof: 5.2 * 5.2 = 27.04 m^2

Floor: 5.2 * 5.2 = 27.04 m^2

I. Walls,

Q = [0.22 * 83.2 * (20.1)*24]/1000

Q=8.829KW/Day

II. Floor,

Q = [0.22 * 27.04 * (10 – 8) * 24]/1000

Q=0.42KW/Day

III. Roof,

Q = [0.22 * 27.04* (20.1)*24]/1000

Q=2.50 KW/Day

2) Product load,

Q = m * CP * (T0 –TI) / 3600

Q = 5000 * 3.43 * (20.1) / 3600

Q = 77.29 KW/day

3) Respiration load,

Q = m * respiration rate / 3600

Q = 5,000 * 3 / 3600

Q = 4.76 KW/day

4) Internal heat load,

Light,

Q = lamps * time * watts / 1000

Q = 2 * 2 * 40 / 1000

Q = 0.32 KW/ day

People,

Q = people * time * heat / 1000

Q = 2 * 2* 270 / 1000

Q = 1.08 KW/ day

5) Equipment load,

Fan motors,

Q = fan * time * wattage / 1000

Q = 1* 24 * 250/ 1000

Q = 6 KW/ day

6) Infiltrate air

Q= total in filtered air* cubic meter of new air*(T0 –TI) / 3600

Q=9*2*(20.1-8)/3600

Q=0.101KW/ day

7) Total heat load

Q = 101.350KW/ day

8) Tonne of refrigeration

Tonne of refrigeration= Total heat load/ 84

Tonne of refrigeration=1.21