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A Novel Policy to Optimize Energy Consumption for Dairy Product Warehouses: A Case Study

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Citation: Almutairi, K.; Esfahani, E.M.; Mostafaeipour, A.; Issakhov, A.; Kaewpraek, C.; Techato, K. A Novel Policy to Optimize Energy Consumption for Dairy Product Warehouses: A Case Study. *Sustainability* **2021**, *13*, 2445. https://doi.org/10.3390/su13052445

Academic Editors: Amir Ebrahimi-Moghadam, Mohammad Hossein Ahmadi and Marc A. Rosen

Received: 27 December 2020
Accepted: 16 February 2021
Published: 24 February 2021

Abstract: Worldwide energy supply is mostly reliant on fossil fuels. Carbon dioxide emissions have caused many negative environmental issues like climate change, air pollution, and energy security. An important alternative to this hazard is substituting the fossil fuel-based carbon energy sources with renewable energy sources. Passive strategies, which are devised to provide thermal comfort in buildings are examples of how to use renewable energies. For this study, a dairy product warehouse in the city of Yazd in Iran was thoroughly investigated. The main goal of this study is to introduce different scenarios, then identifying them based upon optimization of energy consumption. Another main purpose of the present study is to maximize the use of passive energy to meet the cooling needs of a dairy products warehouse in the studied area. Underground temperature is lower than the surface in summer, also it is higher in winter. Therefore, this property of soil is investigated by using nine different scenarios at different heights for constructing underground warehouse for storing dairy products. Clearly, different renewable tools like wind turbine, wind catcher, solar chiller, and different roof designs by Savanah grass, roof pond are also investigated. At first, the cooling load of the warehouse is calculated separately for each season. Then, according to the energy load values obtained, the nominated scenarios are investigated. The results of the comparisons show that the construction of a warehouse at a depth of 3 m from the ground with a green roof covered with Savannah grass helps achieve the best degree of reduction in the cooling power.

Keywords: passive technique; underground warehouse; dairy products; green roof

1. Introduction

Due to the severe energy crisis in developing countries over the past two decades, especially for cooling in summer, energy has become a major issue of concern [1]. With the growing awareness of people and decision makers about the environmental disasters associated with overreliance on fossil fuels, there is a growing concern regarding of renewable and clean energies. Fossil fuel depletion, environmental pollution, and high price of oil are main issues which motivate use of renewable energies [2]. A passive air conditioning system is a key factor in reducing the negative impact of buildings on the environment. Costs incurred in the early years of implementing passive strategies will be offset by reduced fuel or electricity costs in subsequent years, and it is cost-effective [3].

The need to reduce energy costs is one of the priorities of the energy sector when it comes to cooling of food and medicinal products for refrigerators, freezers, and warehouses. This is due to the urgent need for energy to cool the places. By adopting passive cooling approaches, simultaneous improvement of environmental and economic performances is feasible.

Current environmental issues and barriers have forced many countries to pay more attention to implementing different renewable energy sources, hence there has been many research studies in this filed. Overuse of fossil fuels is one of the most important causes of environmental crises. It is necessary to pay more attention to renewable energy sources [4–6]. Using passive techniques that involve no mechanical means to maintain thermal comfort indoors is one of the most effective methods of benefiting from renewable energy. With these techniques, thermal and cooling energy consumption is reduced in residential areas [1]. Reductions also occur in peak load, indoor air temperature fluctuations, fossil fuel consumption, and greenhouse gas emissions. Moreover, the use of such techniques leads to the thermal comfort of buildings [7]. Selection of an inappropriate passive technique may have less effect on the reduction of energy consumption or even result in additional costs [8]. Therefore, to have the most suitable passive technique for a particular building, certain points have to be taken into account [9]. There have been numerous studies related to the use of different renewable energies in order to combat climate change, environmental pollution, and other negative problems that affect the planet [4,10–12].

Among the buildings that require energy for cooling are dairy product warehouses. Depending on their temperature requirements, dairy products should be stored in the temperature range of 0–8 °C [13]. In addition, cooling costs for dairy storage warehouses are high; therefore, the use of passive techniques in this sector is essential.

A warehouse is an expensive structure that consists of a set of buildings and facilities to maintain the quality of a commodity. A warehouse stores perishable products, such as food, at the right temperature and humidity to provide a longer life. It seems necessary to present appropriate solutions or strategies to reduce the energy consumption. Therefore, the present study explores the use of clean energy resources under different scenarios to ensure the required energy for dairy products warehouses.

The purpose of this study is to find suitable passive or active methods for reducing the energy consumption of dairy storage warehouse using passive and renewable energies for selected scenarios.

The novelty of the current research is that the use of passive techniques for storage of dairy products has not been used so far. In addition, the effect of the solar energy on the roof and walls exposed to radiation has been neglected in previous studies. In the present study, the use of passive techniques to provide cooling required for the storage of dairy products with the effect of solar energy on the exposed walls was investigated for the first time.

2. Literature Review

Wind is one of the cleanest and cheapest renewable sources of energy whose advantages over other renewable energies have resulted in the rapid development of its markets in the world [14]. Moghbeli and Nahavandi [15] compared the costs of energy production and evaluated the trend of development in the wind energy technology versus other renewable energies over time in terms of cost-effectiveness. Wind energy technology can lead to sustainable growth in many countries. Since its water demand is low, it is the most appropriate renewable energy technology for investment, particularly in regions suffering from water scarcity, such as Iran. Mostafaeipour and Nasiri [16] studied the use of free sources of energy such as wind and solar, for cooling fruit warehouses in Yazd. Certain economic queries were also performed by using the COMFAR software, value engineering, and AHP method. As the results suggested, solar collectors and solar air conditioners were the most appropriate techniques.

In a comprehensive study for passive cooling methods and the influential parameters such as cooling load and the internal temperature of buildings, Bhamare et al. [17] concluded that these methods had the potential to maintain thermal comfort and were able to reduce the loads on buildings. Ma et al. [18] investigated certain active and passive energy-saving strategies for an office building in Tianjin. The strategies included the use of natural light, external shadows, and green roofs as well as the increase of the open entrance of ceilings in the south. Energy consumption and operating costs were compared before and after the application of these techniques. In order to identify the capacity of passive walls and to use it as a passive technique for improving the efficiency and energy optimization of buildings, Omrany et al. [19] conducted a comprehensive review of various types of systems, such as Trombe walls and Green Walls, and introduced the advantages and disadvantages of each one. The results of the study showed that Trombe walls can greatly contribute to reducing the energy consumption of buildings. Goudarzi and Mostafaeipour [9] investigated the effects of four passive systems on a residential house located in the city of Kerman, Iran. These systems included a green roof with 20 cm of wet soil and Savannah grass, a roof pond with depths of 10 and 20 cm, a wind catcher, and an underground building at a depth of one meter. The house, which required cooling energy, was monitored 14 h a day for a 138-day period. Numerical studies showed the positive effects of all the four systems in reducing the energy consumption. In the hot climactic conditions of the south of Africa, Vorster and Dobson [20] evaluated four passive cooling systems including active mass cooling, night flushing, roof spraying, and a roof pond. They studied various combinations to cool a one-room building. It was performed by a mathematical modeling and computer simulation. The roof spraying system had a better effect than the other options and contributed to energy saving by 59%.

Al Bayyaa et al. [21] analyzed the energy use of a residential building in Sydney, Australia, under an energy efficiency design strategy and a passive solar strategy system. The results of this study showed that these two strategies were able to reduce the thermal energy of buildings up to 36 and 37 percent respectively. Results were verified by real data. Susca [22] found that green roofs had direct and indirect impacts on the energy consumption of buildings, and these impacts depend on the climate as well as the specific design of buildings. Green roofs, especially those with a thick soil cover and well water storage capacity, had a significant role in reducing the need for indoor heating and cooling systems in countries with cold and hot climate respectively. Ghoreyshi and Hami [23] studied the effect of green type of roofs on the reduction of energy consumption and the related costs in buildings. They showed that green roofs reduce heat fluctuations on the outer surface of buildings by preventing solar radiation and, therefore, increasing their thermal capacity. It was found to reduce the cooling load of the space by 1 to 25 percent. It also reduced the energy consumption in multi-story buildings by 10% and in buildings with one or two floors by 20–30%. Yeom and La Roche [24] investigated the cooling potential of green roofs with a radiant cooling system in a warm and dry environment in southern California. In their experiment, the design of the roofs was the only variable that differed from the test cells. The green roofs were tested in seven scenarios and included a non-insulated green roof, a green roof insulated with 140-mm fiberglass, and a green roof insulated with 140-mm INS equipped with a RAD radiant cooler. The green roof with a radiant system had the best cooling performance in all the modes, and the temperature inside that cell was two Celsius degrees lower than that inside of the other cells. Coma et al. [25] conducted a long-term study to evaluate the thermal behavior of large green roofs. They compared recycled rubber crumbs and pozzolana as a lining material for roofs under Mediterranean conditions and during both heating and cooling periods. Water storage capacity, improvement of urban environment, mitigation of the Urban Heat Island effect, and reduction of CO_2 concentration in urban environments were found to be the most important environmental benefits of green roof systems as compared with conventional flat roofs. Sharifi and Yamagata [26] examined 19 roof pond cooling systems and four roof pond heating systems to evaluate their performance and compare them with other passive design techniques. The comparisons showed that, in many cases, the roof cooling systems were more effective in maintaining internal thermal comfort. Carlos J. Esparza et al. [27] compared the experimental and theoretical data to evaluate the potentials of three scenarios including the use of a roof pond, a roof pond with a fabric floating on its surface, and a roof with a wet fabric on it. The results of the study showed that a wet fabric ensures the lowest temperature of enclosed air at any time.

In another study, Sadoughi et al. [28] analyzed the thermal performance of a traditional Shawadan space, which was a basement used to store food at a depth of 6 to 7 m. Such spaces, particularly found in the cities of Dezful and Shushtar in Iran have been constructed through excavating a set of connected rooms under buildings. Based on the ambient air temperature, the thermal behavior of five types of Shawadan located in different parts of Dezful was studied from June to December. The temperature recorded for the Shawadan spaces was 20 to 23 degrees lower than the city, which suggests the high cooling capability of this type of passive system for future buildings.

Mostafaeipour et al. [8] investigated an innovative way of cooling a warehouse for non-fridge drugs so as to minimize the energy costs for the city of Yazd. The results showed that the cost of constructing a wind catcher in a warehouse is less than that of a warehouse with an absorption chiller. In addition, constructing an underground warehouse was more economical than using an absorption chiller system. Ebrahimi-Moghadam et al. [29] investigated the effect of daylight for interior part of a residential building. It was found that optimum conditions for light shelves condition decreased energy consumption. In another study by Ebrahimi-Moghadam et al. [30], they used light shelves (LS) to improve thermal comfort and visual condition of a complex building in Mashahd, Iran. They found that by using the optimal LS conditions, a great improvement of annual 18%, 11%, and 7% in the demand for heating, cooling, and electricity, would be achieved respectively. In an attempt to verify the thermal performance and energy consumption of underground buildings, Shi et al. [31] evaluated an underground office building through dynamic building energy simulation. They concluded that the optimization of U-values, due to the specific weather conditions in China, would have a significant impact on the energy efficiency of that building. The improved thermal performance of the ceiling, in particular, was effective in reducing the energy requirements of the underground building. But it was necessary to study the effect of the apparent factors of the building, such as its shape and size, and the type of performance of the building in U values. Pacheco et al. [32] performed a comprehensive review of the building design criteria that were effective in reducing the energy demand for cooling and heating of residential buildings. It was concluded that the orientation of a building, its shape, and its external surface-to-volume ratio at the design stage had positive and significant effects on the reduction of the final cost and the energy demand of the building.

This paper's work is improved based on existing studies. The literature review is summarized in Table 1 as following:

Table 1. Literature review.

Row	Author	Year	Purpose	Application	Renewable Resources Used	Passive Scenarios Used	Maximum Soil Depth	Sun Effect
1	Moghbeli and Nahavandi [15]	2015	Heating/Cooling	Compare	wind energy compared to other renewable energies	-	Untitled	Not checked
2	Bhamare et al. [17]	2019	Cooling	Building	Solar	✔ heat protection, ✔ heat modulation, ✔ heat dissipation	Untitled	Not checked
3	Al Bayya et al. [21]	2019	Heating/Cooling	Residential building	Solar	Passive solar and energy efficiency design strategies (PSEEDS)	Untitled	Not checked
4	Ghoreyshi and Hami [23]	2014	Cooling	Building	Solar	Green roof		Not checked
5	Yeom and La Roche [24]	2017	Cooling	Residential and Public	Solar	Green roof with radiant cooling system		Not checked
6	Sadoughi et al. [28]	2019	Heating/Cooling	Residential and Public	Wind and Solar	Underground building	10 m	Not checked
7	Coma et al. [25]	2016	Heating/Cooling	Reference room	Solar	Green roof with radiant cooling system	0	Not checked
8	Omrany et al. [19]	2016	Heating/Cooling	Building	Solar	✔ Trombe wall ✔ Autoclaved aerated concrete wall ✔ Double skin wall ✔ Green wall	Untitled	Not checked

Table 1. *Cont.*

Row	Author	Year	Purpose	Application	Renewable Resources Used	Passive Scenarios Used	Maximum Soil Depth	Sun Effect
9	Mostafaeipour and Nasiri [16]	2017	Cooling	Refrigerating fruits	Wind and Solar	✔ Wind catcher ✔ Turbine ✔ Absorbing chiller and solar cooler ✔ Use of soil thermal properties ✔ Use of soil thermal properties ✔ use of the thermal properties of the soil	4	Not checked
10	Mostafaeipour et al. [8]	2014	Cooling	Warehouse	Wind and Solar	✔ Absorbing chiller and solar cooler ✔ Underground warehouse ✔ Underground warehouse with wind catcher	Untitled	Not checked
11	Goudarzi and Mostafaeipour [9]	2017	Cooling	Residential	Wind and Solar	✔ Wind catcher ✔ Underground house ✔ Roof pond with 10 and 20 cm depth ✔ Green roof with 20 cm wet soil and Savana grass	1 m	Not checked
12	Shi et al. [31]	2018	Heating/Cooling	Underground office building	Solar	Related on building envelop	Untitled	Not checked

Table 1. *Cont.*

Row	Author	Year	Purpose	Application	Renewable Resources Used	Passive Scenarios Used	Maximum Soil Depth	Sun Effect
13	Sharifi and Yamagata [26]	2005	Heating/Cooling	Building	Wind and Solar	Different roof ponds	-	Not checked
14	Carlos J. Esparza et al. [27]	2018	Cooling	Building	Solar	✔ Water roof pond ✔ Water roof pond with floating fabric ✔ Wet fabric	-	Not checked
15	Vorster and Dobson [20]	2011	Cooling	One room building	Solar	✔ Active mas cooling ✔ Night flushing ✔ Roof- spraying ✔ Roof- pond	Untitled	Not checked
16	Pacheco et al. [32]	2012	Heating/Cooling	Residential building	Solar	✔ Shading ✔ Glazing ✔ Natural ventilation ✔ Nocturnal convective cooling	Untitled	Not checked

3. Methodology

In order to investigate the cost reduction strategies of a dairy product storage warehouse, several studies and suggested solutions were examined. Since the study area in the present research suffers from very low rainfall and dry climate and has always been affected by water scarcity, the use of water-based methods is not suitable. In contrast, extreme temperature fluctuations allow the use of some other techniques such as wind catchers and soil thermal property. In this regard, there are nine scenarios shown in Table 2.

Table 2. Proposed solutions to reduce the cooling cost of the dairy product storage.

Scenario	Specification
A	Ground level warehouse with solar chiller, wind catcher, and wind turbine
B	1.0 m lower than ground surface with solar chiller and wind catcher
C	2.0 m lower than ground surface with solar chiller and wind catcher
D	3.0 m lower than ground surface with solar chiller and wind catcher
E	3.0 m lower than ground surface with green roof
F	3.0 m lower than ground surface with roof pond
G	4.0 m lower than ground surface and 1 meter free space on the roof
H	5.0 m lower than ground surface and 2 meter free space on the roof
I	6.0 m lower than ground surface and 3 meter free space on the roof

3.1. Peak Heat Loads Calculation

The heat that enters a cooled space mainly classified as [33]:

- Envelope,
- Solar gains,
- Outdoor air (ventilation),
- Internal gains.

3.1.1. Determination of Wall Load Factors

The thermal load that walls put in a cooled space within the unit of time is a function of three factors calculated with Equation (1) as follows [8,33]:

$$Q = AU(T_i - T_o) \quad (1)$$

where Q is the amount of the heat loss (W), A is the surface area where the heat transfer takes place (m^2), U is the overall heat transfer coefficient (W/m^2 °K), and $(T_i - T_o)$ is the temperature difference between the two sides of the wall (°K).

Due to the high thermal resistance of the insulating materials used in the walls, floor, and ceiling of a warehouse, in comparison with the thermal resistance of the air layers and other materials used in that building, the influence of the coefficients of air and other materials in the walls is negligible. Also, to calculate the U-values, only the insulating material used in the walls is often taken into account [34]. In addition, in sun exposure walls, the temperature difference must be corrected before the effect of the sun is evaluated. Depending on the orientation of the wall, the corresponding values are added to the normal wall temperature difference [16].

3.1.2. Air Exchange Load

The required heat to bring in hot air to replace the cold air and reach the temperature and humidity of the internal space is a part of the total cold load of the refrigeration equipment and is called "the air exchange load." In order to calculate this load (in kilowatts), Equation (2) is used, through which the intensity of air penetration (in liters per second) is multiplied by an appropriate enthalpy change coefficient [33].

$$Air\ exchanging\ load\ (\mathrm{kw}) = (air\ penetration\ rate\ (\mathrm{Ls})) \times Enthalpy\ changes(kjL) \quad (2)$$

3.1.3. Product Load

When a product enters a warehouse with a temperature above that place, it is necessary to take some heat from it until it reaches the refrigerated temperature, which is referred to as the product load. The amount of heat that the product should lose when it cools down to the temperature of the space depends on its temperature, mass, and specific heat as well as the time required for cooling it. The product load can be calculated by Equation (3) [16,33,34] as follows:

$$Q = \frac{(m)(C)(\Delta T)}{Time\ to\ cool\ down\ per\ second} \quad (3)$$

3.1.4. Miscellaneous Loads

The heat released from various sources such as people and electrical appliances inside a cooled space is considered as an additional load on refrigeration devices. The heat from lamps [35] and the heat from individuals can be calculated by Equations (4) and (5) respectively [16,33].

$$Q(\mathrm{kw}) = \frac{Daily\ operating\ hours \times power(watt) \times number\ of\ lamps}{24\ \mathrm{h}} \quad (4)$$

$$Q_P(\mathrm{kW}) = noumber\ of\ people \times heat\ equivalent\ per\ person \times \frac{hours\ in\ refrigeration}{24\ \mathrm{h}} \quad (5)$$

4. Case Study Regarding Warehouse Characteristics

As shown in Figure 1, the refrigerated place under study is a space with the capacity of 60 t, and the dimensions of 6 × 6 × 10 m. It is used as a warehouse for storing dairy products. Dairy products are transported to the warehouse in refrigerated trucks and kept there until they are distributed in the market. A warehouse with such dimensions can hold 85 t of dried fruits, 90 t of dates, 18 t of medinas, and 45 t of fruit [36]. The other specifications of the warehouse are as follows:

- Lighting of 3–5 watts per square meter,
- One worker per 100 m^2,
- Daily work of 20 h for the equipment,
- Daily work of 8 h for the workers,
- Sizing factor of 10%.

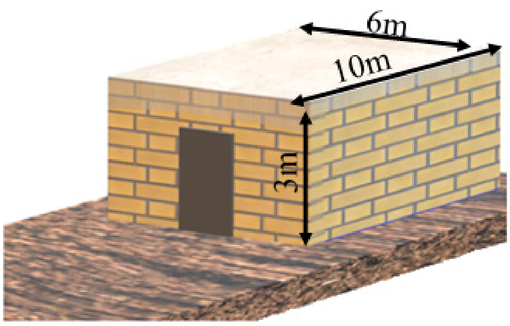

Figure 1. Dairy product warehouse.

4.1. Geographical Characteristics

The study area is located in Yazd Province of Iran. According to the KOPPEN- GEIGER classification [37], climate of Yazd falls into arid category. Climatic characteristics of the area are: drought, dehydration, and severe heat in the summer and extreme cold in the winter. The province is surrounded by the large Lute Desert, the Kavir Desert extending to the Salt Lake of Qom, the Salt Desert of Herat, the Salt Desert of Abarghooh extending to

Marvdasht, and Gavkhuni Swamp [38]. The province is located in a dry and vast valley 54°37′ E and 31°90′ N. The province has an area of 31,539 square kilometers, and is 1200 m above the sea level. Yazd is identified as one of the driest regions in Iran. This is due to such factors like very low precipitation, extreme evaporation, distance from the sea, proximity to dry deserts, low relative humidity with very high temperatures, and extreme temperature fluctuations [16]. Figure 2 shows geographic location of the study area, and Table 3 illustrates the weather data of the city from 2000 and 2018 [39].

Figure 2. Location of Yazd city on the map of Iran.

Table 3. The main meteorological parameters during (2000–2018) for the city of Yazd [40].

Month	Average Rainfall (mm)	Average Wind Speed (km/h)	Relative Humidity (%)	Average Air Temperature (°C)	Sunshine Duration (h)
Jan	10.46	2.25	54	6.79	190.3
Feb	4.83	3.36	46	10.06	210.6
Mar	6.05	2.85	40	15.59	218.9
Apr	4.49	2.87	35	21.24	242.9
May	1.81	3.07	28	26.93	300.7
Jun	0.34	3.00	20	32.30	343.5
Jul	0.07	3.09	19	33.57	345.7
Aug	0.00	2.89	19	31.34	345.0
Sep	0.00	3.37	20	27.58	316.0
Oct	0.76	2.16	28	21.41	386.4
Nov	6.14	2.04	40	12.86	224.2
Dec	10.56	2.08	50	7.60	199.0

Roof of the Warehouse

The roof of the warehouse is a vault made of lathe bricks and gypsum mortar with thickness of 7 to 8 cm. It is covered with a 5 cm layer of stone wool and a 5 cm layer of foam. The roof has a slope so that rainwater can drain. Therefore, brick crumbs were spread over it to form a slope of 5 to 10 percent. Then, 4 to 5 cm of sand and gravel mortar were in top. When the mortar was dried, 0.5 cm of insulating foam and 0.5 cm of ceramic were used to complete the roof. The roof specifications are shown in Figure 3.

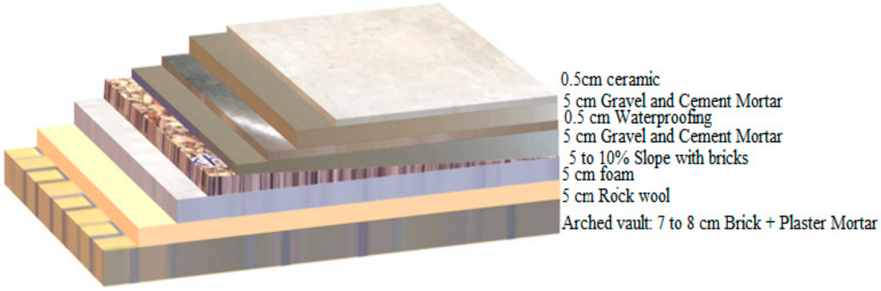

Figure 3. Roof details.

4.2. Walls of the Warehouse

The layers of the wall from outside to inside are as follows: 20 cm of Roberto bricks, 10 cm of foam which greatly prevents the energy exchange, 3 cm of stone wool of the 12-inch type, 15 cm clay wall, 3 mm of cement for polishing the undercoat, 0.5 cm of foil, 0.5 cm of tiles, and 4 cm of slurry (sand and mortar). According to the standards of storing food in a warehouse [41], walls must be covered with tiles at the height of at least two meters. In this case, the walls will be resistant, washable, and impervious to pests. To conform to the standards, as indicated in Figure 4, the walls of the warehouse under study are covered all over with tiles.

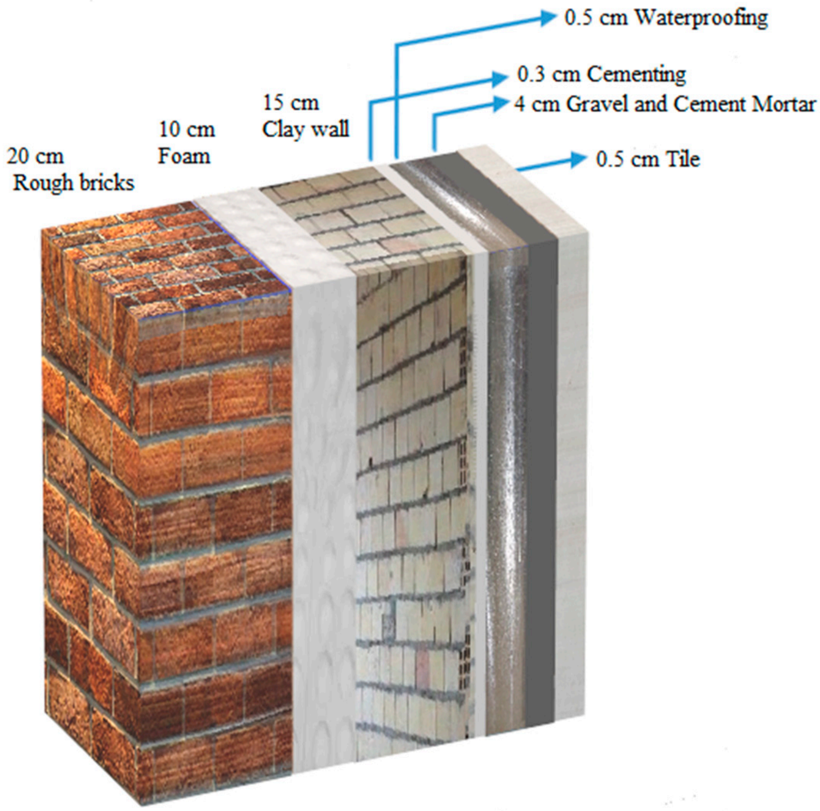

Figure 4. Wall details.

4.3. Floor of the Warehouse

As suggested in Figure 5, it is required for the floor of a warehouse to be built according to the following shown specification.

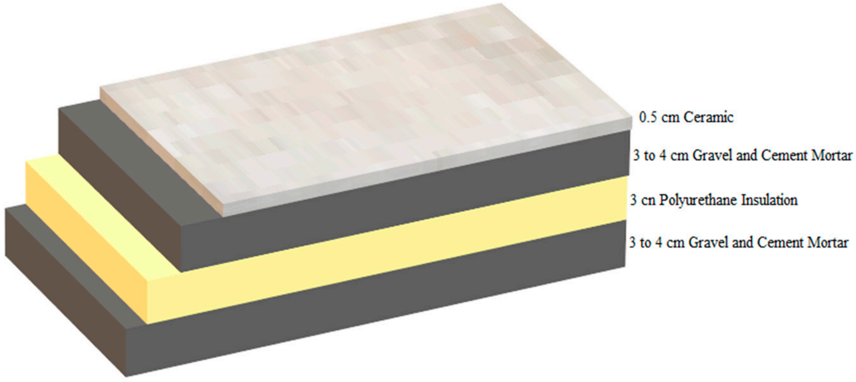

Figure 5. Floor details.

4.4. Specifications of Storage Products

The refrigerated warehouse is intended for storing pasteurized milk, sterilized milk, yogurt, curd, and sterilized cream. The specifications of these products and their amounts to store in the warehouse are given in Table 4. It is important to note that the data on the cooling time of the products have been provided by the food industry specialists.

Table 4. Product specifications [36].

Specifications \ Product Type		Cheese	Sterilized Milk	Pasteurized Milk	Cream	Yogurt	Yogurt Drink
Amount (Tone)		5	10	15	5	10	15
Maintenance standard	Temperature (°C)	2.5 to 3.5	Ambient temperature	1 to 4	1 to 4	2 to 5	1 to 6
	Relative humidity (%)	75 to 80	65 to 75	65 to 75	75 to 80		
	Time	Up to 6 months	Up to 3 months	Up to 3 days	Up to 3 months	Up to 10 days	Up to 3 months
Cool down time		5 days	24 h	10 days in special conditions	24 h	24 h	3 days
Specific heat (kj/kg·K)		2.68	3.77	3.77	3.56	3.66	3.80

The space where the dairy products are kept is a room with the size of 6 m × 10 m and three rows of shelves. According to the standards of food storage in a warehouse [42], these shelves must be set parallel at a distance of 1.2 to 1.5 m from each other and 30 to 40 cm from the walls.

The separation among the shelves has two objectives; one is transportation and the other is to allow the air flow around the products to cool them down.

4.5. Calculation of the Loads from Walls

On the basis of the conduction coefficients (k) of the ceilings, floors and walls of the dairy product warehouse [43], the total heat transfer coefficients or U-values are calculated as given in Table 5. Also, Appendix A is used for Sun effect on different surfaces.

Table 5. Heat transfer coefficient of roof, floor, and wall.

Insulation Location	Insulation Type	Insulation Thickness	Thermal Conductivity (k) [26]	Overall Heat Transfer Coefficient (U) [26]
Roof	Expanded polystyrene	50 mm	0.041	0.617
Floor	Polyurethane	30 mm	0.030	0.765
Wall	Expanded polystyrene	100 mm	0.041	0.346

To calculate the heat load of the walls, the data on the average temperature of Yazd in four seasons were used (Table 2). Table 6 [33] and Table 7 [41,42] respectively present the ground temperature, and summer–winter design conditions. The temperature of the ground is used to determine the temperature variation in the warehouse floor; it is based on the dry bulb temperature of the outside air in winter. According to the data, the temperature of the ground for the city of Yazd is 24 °C.

Table 6. Ground temperature for cold stores (°C).

Outdoor Winter Design Temperature (°C)	Design Ground Temperature (°C)
−40	7
−35	10
−30	12
−25	15
−20	17
−15	20
−10	22
−5	25
0	27

Table 7. Summer and winter design condition of Yazd city.

	Summer	Winter
Dry-bulb temperature (°C)	40.5	−6.7
Wet-bulb temperature (°C)	24.4	-

If refrigerated walls are exposed to the thermal radiation of the sun or any other source of heat, their external surfaces significantly exceed the ambient temperature. Therefore, to account for the effect of the sun, the temperature difference must be corrected in the walls exposed to the sun [44]. The corresponding value should be added to the wall temperature difference between the two sides of the wall, depending on the wall orientation. Table 8 shows the thermal load of the refrigerated walls for each season along with the weather data of Yazd.

Table 8. Thermal load of the roof, floor, and walls for four seasons.

Season	Thermal Load of the Roof, Floor and Walls (W)
Spring	2845.552
Summer	3316.096
autumn	1355.262
Winter	989.131

4.5.1. Air Changing Load Calculation

The walls of the warehouse are about 30-cm thick, and its interior size is $2.7 \times 5.7 \times 9.7 = 149.283$ m^3. So, the load of the intrusive air for different seasons of the year is in accordance with Table 9.

Table 9. Heat loss of air changing for different seasons.

Season	Inside Air Temperature (°C)	Inlet Air Temperature (°C)	Incoming Air Humidity (%)	Enthalpy Change Coefficient (kj/L)	Air Penetration Rate (L/s)	Air Penetration Load (kw)
Spring	4	26.8	50	0.0498	11.8	0.588
Summer	4	30.8	50	0.0557	11.8	0.657
autumn	4	13.9	50	0.0404	11.8	0.477
Winter	4	10.8	50	0.0433	11.8	0.511

4.5.2. Product Load Calculation

The products are transported to the warehouse, reach the intended temperature by refrigerating tools, and stay there until they are transported to the market. Therefore, in this study, the temperature change means the one that occurs when the products are transferred from the trucks into the warehouse. It is assumed that during this transfer, the temperature drops from about 8 °C inside the truck to 4 °C inside the warehouse. This temperature reduction is the same for all the seasons. Table 10 shows the specific heat and time required to cool down the products and provides data on dairy conditions in the warehouse. These data are used in the calculation of the product's load. The total loads of the products are given in the bottom row of the table. The data and the numerical results of this table are the same for all the four seasons.

Table 10. Calculation of the heat loss of products in different seasons.

Product Name	ΔT (°C)	Q (kw)
Cheese	$8 - 4 = 4$	$\frac{(5000)(4)(22.82)}{(5)(24 \times 3600)} = 0.124$
Milk	4	4.363
Cream	4	0.824
Yogurt	4	0.564
Yogurt drink	4	0.88
Total product loads (kw)		6.756

4.5.3. Miscellaneous Loads Calculation

There is a light of 3–5 w for every square meter of space, and the total space is 60 m^2. Thus, 180–300 w is required for the heat load to be calculated according to Equation (4). The result is provided in the first row of Table 10. Also, for every 100 m^2 of space, one worker with 8 h of daily work and the total cooling space of 60 m^2 are taken into account. Hence, there is a need for a worker whose heat load is calculated according to Equation (5). The result is given in the second row of Table 11.

Table 11. Calculate heat loss of lamps and people.

Seasonal Thermal Load of Lamps	Seasonal Thermal Load of People
$Q = \frac{8\text{ h} \times 300\text{ W}}{24\text{ h}} = 100\text{ w} = 0.1\text{kw}$	$Q_P = 1 \times 0.25 \times \frac{8\text{ h}}{24\text{ h}} = 0.083\text{kw}$

4.5.4. Total Refrigeration Load

The total refrigeration load is the sum of the thermal loads of the walls, products, exchange of air, and miscellaneous items.

5. Analysis

In this section, the scenarios mentioned in Table 2 are discussed thoroughly.

5.1. Scenario A

In this scenario, the warehouse is fully assumed to be constructed on the surface of the ground. For the purpose of providing the necessary cooling in the warehouse, a solar absorption chiller, a wind catcher and a wind turbine have been used. The feasibility of using them in Yazd is examined in the following sections.

The total refrigeration load scenario A can be seen in Table 13. A confidence coefficient of 10% is taken into account to compensate for the possible errors.

5.1.1. Solar Absorption Chiller

The relative advancement of the technology, reliability, efficiency, and the economic benefits of cooling systems, as compared to other large-scale air conditioning systems, have made absorption chillers as the most desirable devices which use solar thermal energy [41]. To select a chiller in proportion to the space, two-thirds of the total cooling capacity of the warehouse should be taken into consideration [16]. Therefore, the number of chillers required for cold stores with a capacity of 60 t (≅ 211 kW) of dairy products, and total volume of 180 m^3, are given for each part in Table 14.

5.1.2. Wind Catcher

Under low relative humidity conditions (10–30%), a wind catcher is able to reduce the temperature from 8 to 16 degrees Celsius, but in higher humidity (65–70%), the temperature falls by only 4 to 5 degrees Celsius [16]. Therefore, due to the relative humidity and the temperature of the city of Yazd, the cooling requirements for dairy cold stores cannot be supplied by wind catchers. Also, considering the disadvantages of a wind catcher, it is not suitable for an environment such as a dairy products warehouse that requires the highest levels of hygiene.

5.1.3. Wind Turbine

Based on the data in Table 1, the average monthly wind speed in the city of Yazd is less than 4.5 m/s [45]. So, this location is not suitable for wind turbine installation.

5.2. Scenario B

If a refrigerated room is built under the ground, the thermal dissipation will vary according to its depth. To calculate the soil temperature at depth z and time s, Equation (6) is used [9].

$$t_{s,z} = t_m + A_o \exp\left(-z\sqrt{\frac{\pi}{365\,\alpha}}\right)\sin\left(\frac{2\pi(n-n_0)}{365} - z\sqrt{\frac{\pi}{365\,\alpha}} - \frac{\pi}{2}\right) \quad (6)$$

where t_m is the annual average temperature of soil (°C), A_o is the air temperature fluctuation (°C), z is the depth from the surface (m), α is the heat penetration coefficient (m^2/day), n is the number of days from 31 December, and n_0 is the coldest day of the year from 31 December.

According to Yazd Meteorological Center data for 2000 to 2017, the average annual soil temperature is equal to the average annual air temperature in each season [8,9]. The coldest day of the year is also extracted based on these data. According to [16], the air temperature fluctuation of Yazd is 13.3 °C, and the penetration coefficient of heat for the soil conditions in the city is 0.05 m^2/day. As presented in Table 12, if these data are put in Equation (6) and it is calculated for four seasons of the year from 2000 to 2017 for the depths of 1 to 6 m of soil, the average soil temperature can be obtained in different seasons during this 18-year period.

Table 12. The average soil temperature (°C) in the depths of 1 to 6 m in the years 2000 to 2017.

Season / Depth	Spring	Summer	Autumn	Winter
1 m	13.1	20.1	27.8	19.0
2 m	15.7	19.5	25.5	21.6
3 m	17.9	18.6	23.3	22.5
4 m	19.5	18.7	21.7	22.5
5 m	20.4	19.2	20.8	2.0
6 m	20.9	19.7	20.3	21.5

Scenario B regards the construction of a warehouse at the depth of one meter below the ground level, using a solar chiller, a win catcher, and the thermal properties of the soil. This scenario is different from scenario A in that the soil temperature at the depth of one meter is used as the floor temperature, which is based on the data in the first row of Table 11. In addition, scenario B does not apply the effect of the sun to the part at the height of one meter. The total refrigeration load and the recovery rate in scenario B as compared to scenario A can be seen in Table 13.

Table 13. U value for different green roofs.

Green Roof Types	Overall Heat Transfer Coefficient (U)
Green roofs with insulating	0.282
Green roofs without insulating	2.534
Green ceiling with radiant cooling	0.282

Solar Absorption Chiller

According to Table 14, the number of chillers required for each chapter is consistent with that obtained for scenario A.

Table 14. Total heat gains of different scenarios.

Scenario			A	B	C	D	E	F	G	H	I
Spring	Envelope		2.84	2.06	2.05	2.05	1.4	1.6	164	1.75	1.9
	Products		6.756	6.756	6.756	6.756	6.756	6.756	6.756	6.756	6.756
	Air changing		0.588	0.588	0.588	0	0	0	0	0	0
	Miscellaneous	People	0.083	0.083	0.083	0.083	0.083	0.083	0.083	0.083	0.08
		Lamp	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
	Total		11.41	10..55	10.53	9.88	9.18	9.4	944	9.55	9.72
	Improvement		-	7.52	7.63	13.33	19.54	17.91	17.19	16.22	14.76
Summer	Envelope		3.32	2.69	2.54	2.36	190	1.91	1.91	1.87	1.84
	Products		6.756	6.756	6.756	6.756	6.756	6.756	6.756	6756	6.756
	Air changing		657	0.657	0.657	0	0	0	0	0	0
	Miscellaneous	People	0.083	0.083	0.083	0.083	0.083	0.083	0.083	0.083	0.083
		Lamp	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
	Total		12.004	11.32	11.15	10.23	9.72	9.74	9.84	969	9.66
	Improvement		-	5.65	7.08	14.75	18.96	18.82	18.85	19.22	19.47
Autumn	Envelope		1.36	2.13	2.15	2.15	1.77	1.71	2.49	227	2.1
	Products		6.756	6.756	6.756	6.756	6.756	6.756	6.756	6.756	6.756
	Air changing		0.477	0.477	0.477	0	0	0	0	0	0
	Miscellaneous	people	0.083	0.083	0.083	0.083	0.083	0.083	0.083	0.083	0.083
		Lamp	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
	Total		9.64	10.51	10.53	10	958	9.51	10.37	10.13	9.94
	Improvement		-	−8.94	−9.15	−3.69	0.696	1.83	−7.51	−5.03	-3.07

Table 14. *Cont.*

Scenario			A	B	C	D	E	F	G	H	I
Winter	Envelope		0.98	1.45	1.68	1.85	153	1.41	2.15	2.2	2.16
	Products		6.756	6.756	6.756	6.756	6.756	6.756	6.756	6.756	6.756
	Air changing		0.511	0.511	0.511	0	0	0	0	0	0
	Miscellaneous	people	0.083	0.083	0.083	0.083	0.083	0.083	0.083	0.083	0.083
		Lamp	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
	Total		9.283	9.79	10.05	9.67	932	9.18	10	10.05	10.01
	Improvement		-	−5.50	−8.29	−4.22	−0.43	1.043	−7.81	−8.33	−7.87
	*		42.35	42.182	42.28	39.8	38.18	37.84	39.57	39.44	39.35
	**		-	0.387	1.161	6.006	10.71	10622	6.55	6.846	7.073

* Total heat gains of dairy product storage (KW) + 10% confidence coefficient ** Improvement relative to scenario A (%).

5.3. Scenario C

This part of the study aims at a scenario in which a warehouse is constructed at the depth of two meters with a solar chiller, a wind catcher, and the use of the thermal properties of soil. For the temperature of the floor, the data from the second row of Table 11 have been used. The walls are divided into three 1-m parts. The upper part lies outside the soil and is measured based on the average ambient temperature. The effect of the sun is applied only to this part of the eastern wall. The middle and end parts of each wall are inside the soil at the depths of 1 and 2 m respectively, and they are measured based on the soil temperature at these depths. The total refrigeration loads have been calculated, and the results are given in Table 13. The last column of this table regards the improvement of this scenario as compared to scenario A.

Solar Absorption Chiller

Table 14 shows the number of chillers required for each chapter according to the thermal requirements of that chapter. Despite the reduced refrigeration load, the number of the required chillers remains unchanged.

5.4. Scenario D

The construction of a warehouse at the depth of 3 m under the ground surface and the use of solar chillers, wind catchers, and soil thermal properties are investigated in this section. Different types of temperature have been used in the thermal load calculations. For the floor of the refrigerating room, the soil temperature at the depth of 3 m, for the end and middle parts of the wall, the soil temperature at the depth of 2 and 3 m, for the top part of the wall, the soil temperature at the depth of 1 m, and for the ceiling, the mean weather temperature in different seasons are taken into account. The total refrigeration load and the improvement of the present scenario, as compared to scenario A, are presented in Table 14.

Solar Absorption Chiller

In Table 15, the number of chillers in each chapter is offered according to the thermal requirement of that chapter. The table suggests a decreased number of chillers in spring and summer.

Table 15. Number of chillers required for each season of different scenarios.

Scenario	Spring			Summer			Autumn			Winter		
	Total Heat Gains (kw)	Equivalent Refrigeration ton (kw)	Required Chillers (Number)	Total Heat Gains (kw)	Equivalent Refrigeration ton (kw)	Required Chillers (Number)	Total Heat Gains (kw)	Equivalent Refrigeration ton (kw)	Required Chillers (Number)	Total Heat Gains (kw)	Equivalent Refrigeration ton (kw)	Required Chillers (Number)
A	11.410	3.2	2	12.004	3.4	2	9.64	2.7	1	9.283	2.6	1
B	10.55	2.9	2	11.32	3.2	2	10.51	2.9	1	9.79	2.8	1
C	10.52	2.9	2	11.15	3.2	2	10.53	2.9	1	10.05	2.8	1
D	9.88	2.8	1	10.23	2.9	1	10.00	2.8	1	9.67	2.7	1
E	9.18	2.6	1	9.72	2.8	1	9.58	2.7	1	9.32	2.6	1
F	9.40	2.7	1	9.74	2.8	1	9.51	2.7	1	9.18	2.6	1
G	9.44	2.7	1	9.84	2.8	1	10.37	2.9	1	10.00	2.8	1
H	9.55	2.7	1	9.69	2.7	1	10.13	2.9	1	10.05	2.8	1
I	9.72	2.8	1	9.66	2.7	1	9.94	2.8	1	10.01	2.8	1

5.5. Scenario E

This section of the study deals with the construction of a cold store at a depth of 3 m to utilize the thermal properties of the soil. The building in the present scenario has a roof covered with vegetation. To produce vegetation there, slight changes have to be made in the roof layers. In this case, the ceramic layer is replaced with a 2-layer tar with a thickness of 1 cm, 20 cm of wet soil, and Savannah lawn. The details of this new roof are provided in Figure 6. Savannah lawn is selected in this study because it is resistant to hot and dry climatic conditions, long-term droughts, low rainfall, and poor soil [9].

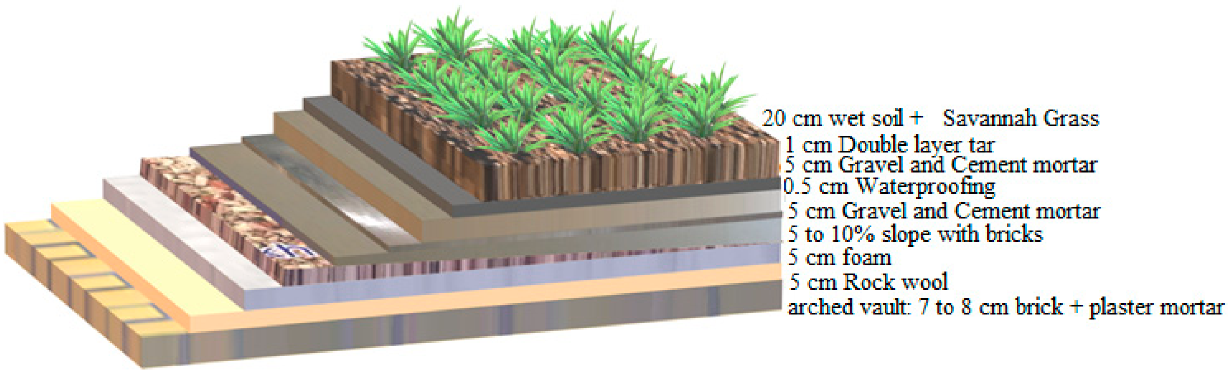

Figure 6. Roof details accordance with Scenario E conditions.

The type of vegetation influences the amount of energy stored [17]. To calculate the cooling energy loss through green roofs, the heat transfer coefficients of two types of green roofs used in tropical regions are given in Table 13 [9]. The energy lost from a green roof with Savannah lawn is calculated for individual seasons of the year (Table 14).

In this scenario, the warehouse is situated at the depth of 3 m; therefore, to do the corresponding calculations, the temperature of the ground at this depth is considered for the floor. There is also a layer of soil and vegetation protecting the roof from the sunlight; with this type of covering, the effect of sunlight is lowered to zero.

Based on the previously offered calculations for the number of absorption chillers required by different chapters, as in Table 14, each chapter emerges to be in need of only one absorbing chiller.

5.6. Scenario F

A review is performed of how refrigeration can be provided for a place built at the depth of 3 m and covered with a roof and a water pond on its surface. This is the best cooling system for areas with low humidity [46]. As shown in Figure 7, the bed of the pond is covered with a layer of wet gunny bag and insulated with polystyrene over it. The thermal properties of soil have also been used to build such an underground refrigerated building.

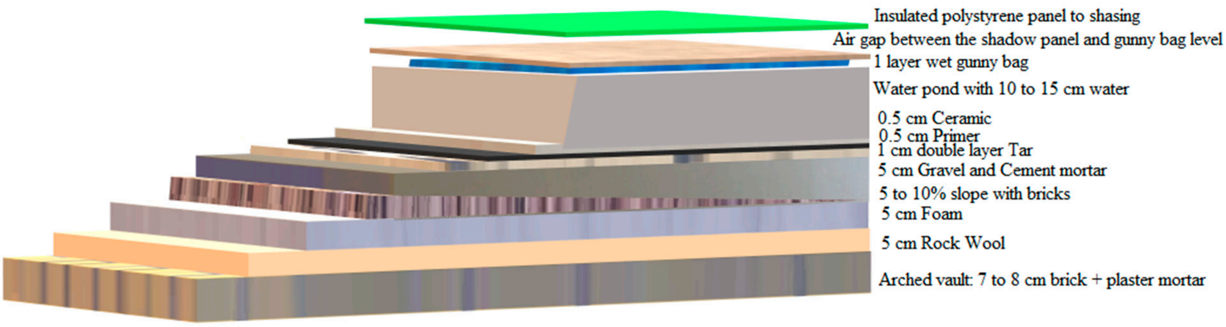

Figure 7. Roof details accordance with Scenario F conditions.

To set up a shaded roof pond with gunny bags (shaded RPWGB), it is necessary first to grade a proper slope for the roof surface using a gravel and cement mortar. Then, a double-layer tar and a primer layer consisting of tar and special mineral powder must be used. This combination is physically like a black solution and is used to make the roof waterproof and anti-humid. Finally, sand and cement mortar and a ceramic layer must be used as the final layer of the roof. According to previous studies [9,28], a depth of 10 to 15 cm of water is suitable for this scenario. Then, a layer of gunny bag or other fabric bags is placed on a lightweight waterproof grid such as a PVC lattice. In addition, a polystyrene insulation panel is used over the gunny bags. As a result, the air can freely move between the shading panel and the surface of the gunny bags, and the polystyrene panel screens the roof of the warehouse from the sun's radiation; part of this radiation is eliminated through evaporation, heat transfer, and night radiation. A shaded roof pond with gunny covering has proved to be colder for 7 °C than a roof without this structure [26]. The refrigeration load for this scenario, as shown in Table 14, is about 11% better than that for scenario A.

Regarding the refrigeration load achieved through scenario F, Table 15 shows the number of the chillers required in each season. The data in this table indicate a decrease in the number of chillers, as compared to those required for the other scenarios.

5.7. Scenario G

This scenario is about the construction of a warehouse at the depth of 4 m under the ground, which has 1 m of free space on the roof and utilizes the thermal properties of soil. The refrigerated warehouse under these conditions is depicted in Figure 8. The temperature at the bottom of this structure is based on the soil temperature at the depth of 4 m. The roof lies at the depth of 1 m, the upper part of the wall at the depth of 2 m, the middle part at the depth of 3 m, and the last part is at the depth of 4 m from the ground surface.

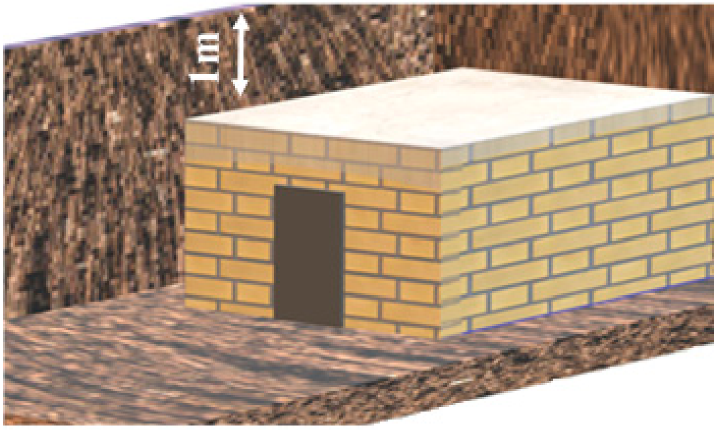

Figure 8. Location of warehouse at 4 m under the ground.

As the distance from the surface of the ground is increased, the effect of the sun on the walls exposed to radiation is gradually diminished. In this scenario, because the walls are completely inside the soil, they are immune to sunlight. However, the roof is still exposed to radiation. At this depth, therefore, a 20-percent reduction is planned for the effect of the sun on the roof. The total refrigeration load for this scenario is shown in Table 14.

According to Table 15, one solar chiller is required for each chapter.

5.8. Scenario H

Using the thermal properties of soil, a warehouse is built at the depth of 5 m under the ground, and 2 m of free space is postulated on the roof. Figure 9 shows the situation of the cold store building. The roof lies at the depth of 2 m.

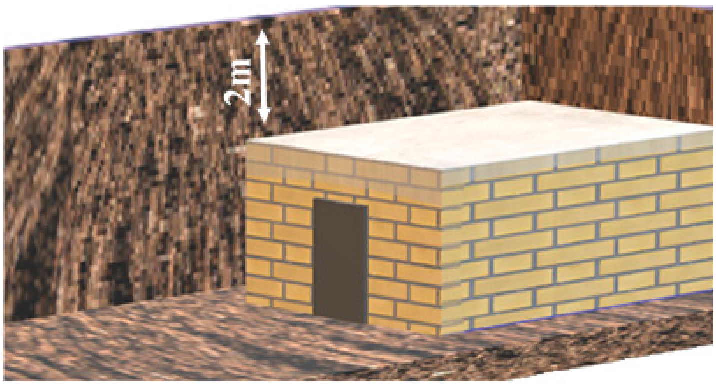

Figure 9. Location of warehouse at 5 m under the ground.

The empty space on the roof reduces the sun's impact by 40%. To calculate the amount of energy lost, the temperature at the depth of 5 m is considered to be the temperature of the refrigerated floor. Also, the temperature of the roof is based on the temperature at the depth of 2 m. The walls are considered in three parts at the depths of 3, 4, and 5 m below the ground surface. The total load factor for scenario H is shown in Table 14.

According to Table 15, one solar absorption chiller is required in each season.

5.9. Scenario I

Scenario I is related to the construction of a warehouse at the depth of 6 m above the ground. As shown in Figure 10, 3 m of free space is created on the roof.

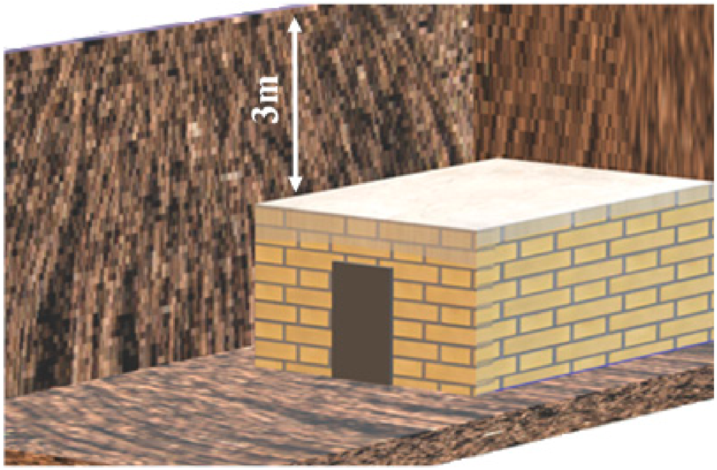

Figure 10. Location of warehouse at 6 m under the ground.

In this case, the effect of the sun on the roof is reduced by 60%. To calculate the amount of the lost energy, it is necessary to use the data in row 6 of Table 11, which relate to different seasons. For the floor and the ceiling of the warehouse, the soil temperature at the depths of 6 and 3 m is required respectively. The top part of the walls is at the depth of 4 m, the middle part lies at the depth of 5, and the last parts situated at the depth of 6 m from the ground. Table 14 shows the total cooling load of this scenario.

According to the data in Table 16, only one chiller is needed for each chapter.

Table 16. Tariff No. 3 for production expenses.

Tariff Code		With a Power Exceeding 30 kW				With a Power of 30 kW or Less			
		Power Price (kw/$)	Energy Price (kwh/$)			Power Price (kw/$)	Energy Price (kwh/$)		
			Mild Load Hour	Peak Load Hour	Base Load Hour		Mild Load Hour	Peak Load Hour	Base Load Hour
3-A		-	0.001	0.002	0.000	-	0.001	0.002	0.000
3-B		0.16	0.002	0.004	0.001	-	0.003	0.005	0.003
3-C	Option 1	0.26	0.003	0.005	0.001	-	0.004	0.008	0.004
	Option 2	-	0.004	0.008	0.002				

5.10. Economic Evaluation

According to the bill enacted by the Ministry of Energy dated 23 November 2018 [47], Tariff No. 3 for production costs is classified as in Table 16, and cold stores are concerned by option 2 of this classification.

According to the specific conditions mentioned in the bill, during summer months, the price of electricity consumed by subscribers rises by 20%. Therefore, considering all the conditions involved in energy production, the price of electricity used by the warehouse in question is calculated on the basis of Table 17.

Table 17. Calculate the price of electricity consumed dairy product storage in spring, autumn, and winter.

Scenarios	Total Heat Gains Spring, Autumn and Winter (kw)	Energy Price (kwh/$)	Total Electricity Price Spring, Autumn and Winter ($)
A	30.342	0.004	0.123
B	41.410	0.004	0.168
C	31.124	0.004	0.126
D	29.569	0.004	0.12
E	28.083	0.004	0.114
F	28.103	0.004	0.114
G	29.831	0.004	0.121
H	29.750	0.004	0.121
I	29685	0.004	0.120

For the summer, 20% should be added to the price of the energy unit. The details are shown in Table 18.

Table 18. Calculate the price of electricity consumed dairy product storage in summer.

Scenarios	Total Summer (kw)	Energy Price (kwh/$)	Total Electricity Price Summer ($)
A	12.004	0.004	0.058
B	11.324	0.004	0.055
C	11.153	0.004	0.054
D	10.233	0.004	0.05
E	9.727	0.004	0.047
F	9.744	0.004	0.047
G	9.741	0.004	0.047
H	9.696	0.004	0.047
I	9.666	0.004	0.047

The total cost of electricity consumption for each scenario in four seasons is as set out in Table 19. As it can be seen, scenarios E and F involve the least costs of all. These two are also in the first rank among the least expensive scenarios.

Table 19. Total electricity consumption of four seasons for each scenario.

Scenarios	Total Electricity Consumption for 4 Seasons ($)
A	0.182
B	0.223
C	0.181
D	0.17
E	0.161
F	0.161
G	0.168
H	0.168
I	0.167

6. Discussion

Dairy warehouses are among the buildings that need energy to generate cooling. Warehouses are divided into two categories according to the latest revision of the National Standard of Iran No. 1899-1 according to the temperature conditions of food, beverage, cosmetic, and sanitary storage. For cold storage or warehouse, the temperature should be between 8 and 15 degrees Celsius, and ordinary storage, the temperature of which should be between 15 and 30 degrees Celsius, depending on the type of product. Depending on the temperature requirements of dairy products, these products need cold temperature conditions for storage. In addition, the cost of providing cooling for dairy warehouses is high. Therefore, the use of passive techniques in this section seems necessary.

The purpose of this study is to find passive methods to reduce energy consumption and cooling costs of dairy storage which could be applied to different regions. The case study for this research is the city of Yazd In Iran.

In this research, for the ground level scenario, solar chiller, wind catcher, and wind turbine are investigated.

Also, for underground warehouse, different depths of 1 to 6 m below surface were investigated by replacing green roof, and pond roof with wind turbine, and wind catcher.

Table 20 summarizes the refrigeration loads of four seasons with regard to the distance from the surface of the ground. The third column relates to the improvement of each scenario in comparison with scenario A. According to the data in this table, scenarios E and F are the most improved ones with the improvement rates of 10.71% and 62.10% respectively.

Table 20. Comparison of total heat gains between scenarios.

Scenarios	Distance from the Ground (m)	Total Heat Gains for 4 Seasons (kw)	Amount of Improvement (%)
A	0 with chiller, turbine and wind catcher	42.35	-
B	−1 with chiller, turbine and wind catcher	42.18	0.39
C	−2 with chiller, turbine and wind catcher	42.28	0.16
D	−3 with chiller, turbine and wind catcher	39.80	6.00
E	−3 and green roof	37.81	10.71
F	−3 and roof pond	37.84	10.62
G	−4	39.57	6.55
H	−5	39.44	6.85
I	−6	39.35	7.07

6.1. Assumptions

1. The amount of energy loss in the storage of dairy products is high.
2. It is possible to use the underground warehouse for cooling the warehouse in the city of Yazd in Iran.

6.2. Novelty

The use of passive techniques for storing dairy products has not been used so far. In addition, in similar studies, the effect of the sun on roofs and walls exposed to radiation has been neglected. In the present study, the use of passive techniques to provide the required cooling for the storage of dairy products with the effect of the sun on the walls exposed to radiation has been investigated. Table 21 shows the new specifications that are used for the current research work.

Table 21. New specifications of current research work.

Purpose	Application	Renewable Resources Used	Passive Scenarios Used	Maximum Soil Depth	Sun Effect
Cooling	Dairy Product Warehouses	Wind and solar	✔ Ground level warehouse with solar chiller, wind catcher, and wind turbine ✔ 1.0 m lower than ground surface with solar chiller and wind catcher ✔ 2.0 m lower than ground surface with solar chiller and wind catcher ✔ 3.0 m lower than ground surface with solar chiller and wind catcher ✔ 3.0 m lower than ground surface with green roof ✔ 3.0 m lower than ground surface with roof pond ✔ 4.0 m lower than ground surface and 1 meter free space on the roof ✔ 5.0 m lower than ground surface and 2 meter free space on the roof ✔ 6.0 m lower than ground surface and 3-meter free space on the roof	6 m	checked

6.3. Limitation

An important limitation for performing this research is the underground water level. The proposed warehouse can be built in areas with high water level.

7. Conclusions

The study was conducted with the aim of reducing the energy consumption and, thus, reducing the costs of refrigerating dairy products in Yazd. Through the evaluation of the costs in this sector, the share of energy consumption to cool down the warehouse was estimated. In order to do this, first, the dimensions of a target warehouse and the type of products that it would store were determined. Then, the thermal loads induced by the walls, air penetration, the products, and the people and equipment in that place were calculated. The calculations were done for individual seasons and under specific scenario conditions. The warehouse was constructed in different depths of the ground on the purpose of utilizing the thermal properties of the soil. Due to the fact that the effect of the sun on the roof of buildings has been neglected in the literature, this study was carried out in detail on an exposed roof and eastern wall exposed to radiation in order to accurately calculate the thermal loads obtained from those surfaces. For scenarios B to D tried in this research, the refrigeration room was somewhere inside the soil while the roof was located on the ground surface.

In scenarios E and F, the roof of the warehouse was covered with vegetation and a water pond respectively. Following previous researchers, Savannah grass, which is compatible with hot and dry areas, was selected as the vegetation. For scenario F, a layer of wet gunny and a sunshade were set up over the pond. In the other scenarios, deeper depths were tried, and an empty space was created at the height of 1 to 3 m on the roof so as to reduce the effect of sun and take the advantage of the thermal balance under the ground.

The scenarios proposed for the construction of a dairy product warehouse were compared in terms of the underground thermal properties for different seasons. The main findings of this study are as followings:

- According to the Table 14, scenario E, which involves the use of a green roof with Savannah vegetation, is the best option for spring. For summer, scenario H, which regards the construction of a warehouse at the depth of 5 m, is the best one. It benefits from the temperature difference between day and night, which has a positive effect on the temperature of the soil. For the fall season, scenario F, which recommends the use of a pond on the roof and a layer of gunny and sunshade over it, is the most appropriate one. This scenario can be used for winter too because it ensures a higher rate of saving than any other scenario.
- According to the Table 20, in terms of energy savings all year round, a warehouse at the depth of 3 m with Savannah grass covering on the roof proved to be the best one; it showed a 10.71% improvement compared to scenario A.
- In terms of energy consumption, according to the Figure 10, scenario E, in which a warehouse is constructed 3 m below the ground surface with a green roof, and scenario F, in which a warehouse is built 3 m under the ground with a roof pond, were found to be the lowest costly scenarios.
- Through calculations, it was found that, if scenarios D-H are implemented, the number of chillers required for the spring and summer will decrease from 2 to 1.
    - A pond with a height of 10 to 15 cm of water covered with a layer of gunny and a PVC sunshade can reduce the cooling consumption of a warehouse by 10.66%, as concluded by Table 19.
    - Also, according to the data, as the depth increases, temperature fluctuation is decreased and the difference between the scenarios in terms of cooling energy consumption begins to fade away.

It is suggested that researchers in the future can choose from the following related areas:

- Because the sun and its radiation have a significant role in increasing the consumption of cooling energy, especially in the tropics, it is suggested to calculate the angle of radiation in different seasons and at different times of the day in order to study the effect more accurately.
- Only one sample of green roof and roof pond was investigated in this study. It is suggested that other examples of this type of roof be examined to find solutions with the greatest reduction in cooling energy consumption of dairy product warehouses.
- The use of these scenarios is suitable for factories, places, and products that do not need to be frozen.
- Performing a robust economic analysis is recommended for selecting cost-effective scenarios.

Author Contributions: A.M.: Conceptualization, Supervision, writing—Reviewing and Editing. K.A.: Writing, Visualization, Investigation, E.M.E.: Methodology, Reviewing, original draft preparation, collecting data, writing. A.I.: Reviewing, editing, methodology. K.T.: Supervision, Writing, Reviewing, Literature Survey and Review, Funding. C.K.: Editing English, reviewing, writing. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: All necessary data are provided in the manuscript.

Acknowledgments: Authors would like to thank Yazd University, and all organizations which supported by providing data. This research was also supported by grant no. ENV6402012N from Prince of Songkla University, Thailand.

Conflicts of Interest: There is no conflict of interest.

Appendix A

Table 1. Sun effect on different surfaces [33].

Type of Surface	East Wall	South Wall	West Wall	Flat Roof
Dark-colored surfaces such as: Slate roofing Tar roofing Black paints	5	3	5	11
Medium-colored surface such as: Unpainted roof Brick Red tile Dark cement Red, gray, or green pant	3	2	3	8
light-colored surface such as: White stone Light-colored cement White paint	2	1	2	5

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