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Economic Evaluation of Cooling Storage Warehouses in Hot and Dry Regions for Fruits Using Different Renewable Energies

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ABSTRACT

In hot and dry regions, air conditioning is used for many different applications like residential, industry, and agriculture and dairy products. This research studies the applicability of wind and solar energies for cooling fruit storage warehouse in the hot and dry region of Yazd in Iran. The studied case is a fruit warehouse with an area of 4240 m^2 resulting in a storage capacity of about 1000 tons. For this purpose, the heat gain of the warehouse is determined, and the obtained cooling load is then used to examine the solar and wind energy to power a conventional warehouse system. Different scenarios are examined for this research such as solar air conditioner, solar absorption chiller, wind catcher, and a combination of solar air conditioners and solar absorption chiller for cooling the fruit warehouse. Comparison and economic evaluation of different scenarios show that the solar air conditioning ranks first for this purpose. Results are then validated using value engineering methodology. Solar air conditioning with the highest net present value (NPV) of 4,865,040,418 Rials and the best internal rate of return (IRR) value of 182.98 % was determined to be the best approach among the studied methods. The results of this research can be applied to other regions with similar climatic conditions too.

1. INTRODUCTION

Fossil fuels such as oil and gas are nonrenewable sources of energy with detrimental pollution outputs. In addition, the depleting reserves of fossil fuels ensure that they will get more expensive in the future. These issues highlight the importance of the constant search for clean, permanent and cost-effective methods of energy supply. One such method is the effective use of renewable energy sources such as wind or the sun [1].

Today, fossil fuels are the main sources of energy in the world, but adverse global consequences like environmental pollution, global warming, and sea-level rise are considered as a common cause of these problems [2]. There have been numerous renewable energy researches in the literature, but solar and wind energies share more than other sources [3-6]. Global warming, adverse environmental impact, and limited resources of fossil fuel have resulted in discovering the importance of implementing alternative systems of energy [7-11]. Nowadays, many countries decided to begin paying more attention to replacing fossil fuels with different renewable energy sources [12]. Economic aspects of using electricity and high consumption have become an important concern of Iran for many years [8]. An important role of renewable energy technologies is its share in the energy production field, which must energy demands of industries [13, 14].

Iran is located on the radiation belt [15] which provides great potential for the use of solar power and is also positioned in a low pressure area relative to high pressure areas in north and northwest, which causes many winds in both winter and summer [16].

Distribution of water energy, wind energy, solar energy, and other resources in the world are illustrated in Table1. It shows that Asia shares 25 % of wind resource, and also 25 % of solar energy in the world and therefore provide good wind and solar energy potential [17]. Clearly, Africa has the highest capacity of wind and solar in the world.

Consumption of fossil fuel can be reduced by heating and cooling the buildings by renewable energies such as wind and solar which are not only permanent and clean but also cost effective. In recent years, engineers and architects have paid unparalleled attention to the use of these renewable energies to provide heating and cooling [18].

Solar radiation reaching unevenly to the earth’s rough surface results in temperature and pressure variations that produce massive air flows known as wind. The wind is also a product of the earth’s rotation, which causes heat transfer in the earth’s atmosphere from warm regions to polar areas [19].

Wind energy can be used to produce electricity and provide cooling. One of the most basic cooling systems is air conditioning by drawing fresh air into the building and using the airflow to discharge the warm and polluted air out of it. The traditional system used for this purpose is known as wind catcher [18].

Wind catcher is an architectural element traditionally used for cooling and air conditioning in warm and dry regions [20]. A wind catcher causes the fresh air to flow into the building, which results in negative pressure on the other side pushing the warm air out of the building. Some wind catchers have a shelf with a wooden door to control airflow and works as a container like today’s fridges. Based on the outer shape, wind catchers are divided into several groups: one-sided, two-sided, three-sided, four-sided, eight-sided, and double [21]. Figure 1 shows a typical four-sided wind catcher in Yazd, Iran [22].

Solar energy is a promising source of energy for the future needs of many sectors in different parts of the world. The earth relies on the sun to provide a majority of its required

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energy. Wind energy, sea waves, and even fossil fuels stored within the earth are the results of the solar energy received by the earth. Solar energy can be converted into other forms of energy directly or via indirect measures. For example, solar energy can be converted to electricity using solar panels [23, 24].

Table 1. Distribution of water energy, wind energy, solar energy and other resources in the world [17].

Region	Water energy		Wind energy		Solar energy	
	Theoretical reserves (trillion of kwh/year)	Proportion (%)	Theoretical reserves (trillion of kwh/year)	Proportion (%)	Theoretical reserves (trillion of kwh/year)	Proportion (%)
North America	6	15	400	20	16500	11
South America	8	21	200	10	10500	7
Europe	2	5	150	8	3000	2
Asia	18	46	500	25	37500	25
Africa	4	10	650	32	60000	40
Oceania	1	3	100	5	22500	15
Total	39	100	2000	100	150000	100

Figure 1. A typical wind catcher in Yazd [22].

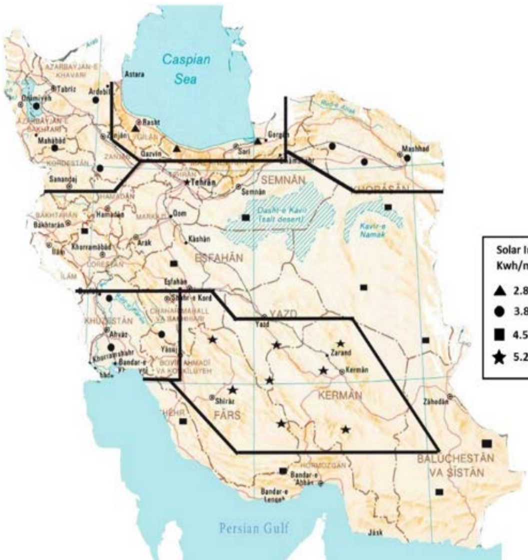

Figure 2. Solar energy map of Iran [25].

The solar energy map of the world is illustrated in Figure 2. In this map, the areas with a high solar energy potential are colored orange, and as can be seen, Iran falls in this category [25].

Figure 3 displays the solar energy map of Iran. In this map, the areas with a high solar energy potential are marked with a star. As this figure shows, Yazd is one of these areas [26].

This paper is structured as follows: In the next section, the literature review is presented in detail. Section 3 describes methodology. Section 4 presents the value engineering methodology. Case study is presented in section 5. Analysis is discussed in section 6. The economic evaluation is presented in section 7, and economic comparison is presented in section 8. Section 9 presents the validation, and finally conclusion is brought in section 10.

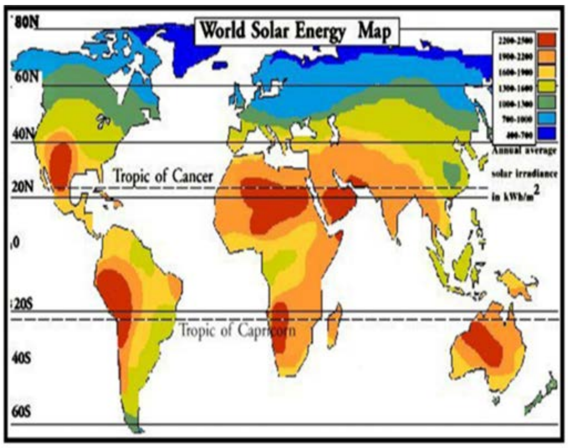

Figure 3. World solar energy map [26].

2. LITERATURE REVIEW

In this section, we will review the literature on the subject of study. There have been numerous research works which showed Iran is capable of using different sources of renewable energies [5,6,26-30].

Clark et al. [30] assessed the efficiency of a building's energy in two types of systems: standard and renewable. The building's required energy for cooling and heating was measured by two systems and the results showed that using solar energy and photovoltaic system increases the building's energy efficiency.

In a study by Hua and Shiu [31], where they investigated the use of renewable energies in Wangan Island of Taiwan, they found that using a wind-solar hybrid system can result in more than 50 % reduction in CO_2 emission and 23-27 % reduction in the cost of electricity consumed.

In an article by Danish and Wang [32] titled the "Role of renewable energy and non-renewable energy consumption on EKC: Evidence from Pakistan", it was reported that the use of renewable energies can play a main in reducing CO_2 emissions and non-renewable energies use and that there is a bi-directional causality relationship between renewable energy use and CO_2 emission. It was also stated that to promote renewable energy use, the government has to increase investment in renewable energy projects.

Shahsavari and Akbari [33] studied the potential of developing countries in using solar energy to reduce greenhouse gas emissions. This study found that given the significant solar energy potential of many developing countries, the promotion of solar energy generation in these countries can be an effective strategy for reducing their greenhouse gas emissions. They added that to achieve this goal, governments of developing countries have to adopt a set of measures to support solar energy development and reduce dependence on fossil fuels and biomass resources; measures that may include restrictive laws and regulations, financial incentives, tax incentives, research and development programs, reduction or elimination of fossil fuel subsidies, and creation of a support program for investment in solar energy sector.

In an article by Lang et al. [34], they carried out a technical and economic analysis on the use of a grid-connected PV system for power generation in a residential unit. They also studied the geographical, technical and economical parameters of the study area and concluded that the PV system can be an attractive option in many areas; but the low cost of power (and fossil fuel subsidies) is a strong obstacle for further use of PV systems.

In an article by Askari et al. [35] titled “Energy management and economy of the system, solar PV, solar collector and fuel cost”, they assessed the effect of solar panel, solar collector and fuel cost on the optimization of a cooler. The system was considered for supplying cooling and heating energy and power of a 5-story residential building. In the end, they concluded that removing the fuel subsidy would result in the PV system and generally all solar energy systems to become more attractive.

Daneshvar et al. [36] assessed the economic potential of using a solar air conditioner for reducing the peak loads in Gilan. They concluded that the allocation of government subsidies for the use of hybrid solar conditioners can be effective in all areas even in the clouded northern region of the country. Some of the mentioned effects included: reduced production costs, reduced peak load, reduced loss, increased reliability, reduced consumer cost, job creation, increased equipment lifetime, increased efficiency due to high efficiency of solar cells, environmental merits, etc.

Abdullah et al. [37] assessed the use of solar absorption chiller in three cities of Italy. They used the software TRNSYS17 for modeling and the software GenOpt for optimization. They concluded that using a solar chiller in these three cities increases energy efficiency and reduces power consumption.

In an article by Saffar [38], the author assessed the use of cooling apparatus such solar panels, wind catcher and solar chiller in a residential building in Bahrain, and concluded that using this cooling measures is significantly effective and results in reduced power consumption, reduced energy bill, and increased thermal comfort for residents.

In an article by Mostafaeipour & Bardel [22] titled “economic evaluation of surface and subsurface warehouses cooled with wind catcher: a case study”, the authors assessed the use of cooling systems based on free natural energies such as wind and underground temperature gradient and carried out an economic analysis on the use of these measure in a medicine warehouse. The medicine warehouse with an absorption chiller was compared first with the one with a wind catcher and then with a warehouse built underground. For this purpose, heat gain and the costs associated with each project were calculated and then economic evaluation was carried out with the uniform annual cost method. The results showed that the warehouse with wind catcher is far more economical than the one with an absorption chiller, and in case of needing a new warehouse, constructing the facility underground would result in lower energy loss and would be more economical than constructing an ordinary warehouse with an absorption chiller.

3. METHODOLOGY

This study examines the use of free natural energies, wind and solar, for cooling a warehouse dedicated to fruit storage. For this purpose, first, the heat gain of facility is calculated; then the resulting cooling load is used to examine the utility of solar panels (to power a conventional warehouse), solar air conditioners, solar absorption chiller, wind catcher, and a combination of solar air conditioner and solar absorption chiller for cooling a typical fruit warehouse in Yazd. Finally, the method is evaluated economically by the software COMFAR as well as the value engineering technique.

3.1. Warehouse

Warehouses are stationary or mobile refrigerated spaces for storage of foodstuffs and operate with a mechanism similar to conventional refrigerators. A typical warehouse generally consists of a motor, compressor, condenser, nitrogen store, expansion valve, blower (fan) and connecting tubes [39].

3.2. Calculation of cooling load

The first step is to obtain the cooling load of the warehouse. To simplify the calculations, the total cooling load is divided by the heat source. Thus, the total cooling load is the sum of:

1. Wall, roof and floor gain load
2. Air change load
3. Product load
4. Respiration load
5. Miscellaneous load

The Equations used for calculation of these loads are described in the following:

3.2.1. Wall, roof, and floor gain load

The energy loss due to heat exchange through a wall is calculated by Equation (1) [22]:

$$Q = AU(T_i - T_0) \quad (1)$$

where A is the area of the wall, U is the overall heat transfer coefficient, T_0 is the temperature of the outer layer and T_i is the temperature of the inner layer.

Overall heat transfer coefficient (U) is obtained from Equation (2) [22, 40]:

$$U = \frac{1}{\frac{1}{f_i}+R_1+R_2+R_3+R_4+\cdots+\frac{1}{f_O}} \quad (2)$$

where R_i is the thermal resistance of the different layers of the wall, and is obtained by the following Equation [22]:

$$R = \frac{X}{K} \quad (3)$$

where X is the wall thickness, k_i is the wall conduction coefficient, $\frac{1}{f_i}$ is the surface conductance of the outside conductance of the inside wall, floor, or ceiling and $\frac{1}{f_o}$ is the surface conductance of the outside wall, floor, or ceiling. k_i depends on the material of the wall and is obtained from Table A (Appendix).

3.2.2. Air change load

Air change load is calculated by Equation (4) [40]:

$$\text{Air change load (KW)=Air infiltration rate } \left(\frac{l}{s}\right) \times (h_0\text{-}h_i)\ \frac{kJ}{s} \quad (4)$$

where h_0 is the enthalpy of outside air and h_i is the enthalpy of the inside air. The enthalpy change coefficient for the incoming air is obtained from Table D (Appendix) according to its temperature and temperature and humidity of the warehouse. The approximate air infiltration rate is obtained from Table E (Appendix) according to the size of the warehouse.

3.2.3. Product load

The amount of heat released by the product is calculated by Equation (5) [40]:

$$Q\ (W) = \frac{(m)(c)(T_i - T_0)}{\text{chilling rate factor} \times \text{cooling time(s)}} \quad (5)$$

where m is the product weight, c is the specific heat above freezing (kj/kg/K), T_0 is the entering temperature (K), and T_i is the space temperature (K).

Space temperature refers to the temperature of the room where products are to be stored, entering temperature refers to the temperature of the space from which products are transferred to the warehouse, and chilling rate factor and c are obtained from Table F (Appendix) according to product type and storage temperature.

3.2.4. Respiration load

Respiration load is calculated by Equation (6) [40]:

$$Q\ (W) = \text{Weight of product (kg)} \times \text{Respiration heat } (W/kg) \quad (6)$$

where respiration heat is obtained from Table G (Appendix) according to product storage temperature. Respiration heat means oxidizing the six carbohydrates and converting them to carbon dioxide and water with the help of enzymes that release energy.

3.2.5. Miscellaneous load

The heat load due to lighting is obtained from Equation (7) [40]:

$$Q = \frac{P \times t}{24hr} \quad (7)$$

where P is the power of lights and t is the working time (hr).

Heat load due to the presence of people is calculated by Equation (8) [40]:

$$Q = \frac{n \times ph \times T}{24hr} \quad (8)$$

where n is the number of people, ph is the person's heat and T is working time (hr). hp is obtained from Table H (Appendix) according to the temperature of the point where the person stands.

Heat load due to operation of forklifts is obtained using Equation (9) [40]:

$$Q = \frac{n \times P \times t}{24hr} \quad (9)$$

where n is the number of forklifts and P is the Power of forklift and t is working time(hr).

Heat load due to boxes is obtained from Equation (10) [40]:

$$Q\ (kj) = \text{number of boxes} \times \text{Weight of each box (kg)} \times \text{Specific heat of each box} \times (T_i - T_0)(K) \quad (10)$$

where T_0 is the entering temperature (K) and T_i is the space temperature (K). Again, entering temperature refers to the temperature of the space from which products are transferred to the warehouse, and space temperature is the temperature of the room where products are to be stored.

3.3. Comfar software

Comfar is a software program developed by the United Nations Industrial Development Organization (UNIDO) for designing and evaluation economic development plans in developing countries [41]. This software can be used for estimating the revenue and cost of industrial, mining, agriculture, infrastructure, maritime, and many other types of projects [42].

3.4. Net Present Value (NPV)

Net Present Value (NPV) is a measure for the evaluation of returns of an investment with the time-variant value of the money taken into account. The present value of future cash flows can be determined by Equation (11):

$$NPV = NFC_0 + \frac{NFC_1}{(1+i)^1} + \frac{NFC_2}{(1+i)^2} + \ldots + \frac{NFC_t}{(1+i)^t} \quad (11)$$

where NPV is the net present value, i is the discount rate, and t is the time period. NPV may be positive, negative, or zero. The higher the discount rate is, the lower the present value of the future cash will be.

- IF: NPV> 0 → the project can be considered.
- IF: NPV = 0 → the project can also be considered.
- IF: NPV <0 → the project must be disregarded.

If, after applying a certain discount rate as the minimum rate to attract investment and taking into account the effect of inflation, calculations show that NPV of a project is positive, that project will have economic feasibility. Also, the larger the calculated NPV is the more attractive will be the investment [43].

3.5. Internal Rate of Return (IRR)

Internal rate of return (IRR) is another criterion for economics evaluation of projects and is commonly used to assess the desirability of an investment. In the NPV-discount rate plot, IRR of a project is the point where the curve intersects with the horizontal axis. For a project to be more desirable, the value of IRR, which is obtained by equating the project's NPV to zero, has to be greater than IRR of alternatives [44].

4. VALUE ENGINEERING METHODOLOGY

Value engineering is a systematic method of organizing creativity and teamwork to solve problems, reduce costs, and improve the performance and quality of projects, products and processes. Value engineering utilizes a wide range of expert knowledge and experience with a focus on the functions of the project, product or process to quickly provide applicable solutions for improving the results. The main procedure of value engineering consists of several phases: information phases, function analysis phase creativity phase, and evaluation phase, which are briefly described in the following.

4.1. Information phase

The purpose of this phase is to understand and define the current status of the project and the constraints affecting its outcomes as well as the objective of the effort. The activities to be done this phase include:

- Acquiring key data, information and documents, such as project scope and definitions, plans, specifications, reports, detailed project costs, and qualitative data.
- Provision of a main plan or design/product/process concepts by the project team.
- Defining the scope, schedule, budget, expenses, and non-financial performance criteria of the project.

4.2. Function analysis phase

The purpose of this phase is to understand the project from the functional perspective, in the sense that what functions the project should have rather than how it is now. The activities this phase include:

1. Determining the project functions by means such as random determination.
2. Classification of project functions.
3. Scaling the model with the parameters of cost, performance characteristics and user behavior in order to identify the value-incompatible functions and focus the creativity phase. The tools used in this phase include cost/function analysis (function matrix), and performance/function analysis.

4.3. Creativity phase

The objective of this phase is to produce a number of ideas regarding other methods of achieving the desired functions. In this stage, a group of usually 4 to 6 people with different specialties use techniques such as brainstorming to express their thoughts and ideas. In these sessions, people are encouraged to provide diverse views and no idea is criticized.

4.4. Evaluation phase

The purpose of this phase is to reduce the number of ideas to produce a shortlist of solutions with the highest potential for fulfilling the desired functions subject to quality requirements and resource constraints [45]. Some of the activities that should be carried out in this phase include:

1. Explaining and categorizing every idea to create a common understanding.
2. Discussing the impact of ideas on performance parameters and project cost with the help of tools such as T-Chart.
3. Prioritizing ideas for further development with the help of tools such as lifetime cost calculations.

In this paper, validation is performed by using Value Engineering (VE) technique. In VE, the criteria by which alternatives are to be evaluated are determined by brainstorming. Then options to reduce product prices to maintain its quality are obtained via creative analysis. The relative importance of the criteria is determined by pairwise comparison and the weight of each criterion equals the sum of all of the preference scores relative to other criteria. Finally, the weight of the criterion is multiplied by the normalized decision matrix to obtain the final score of each alternative, and the alternative with the highest score is determined to be as the best option [27].

5. CASE STUDY

5.1. Geoghraphic characteristics

The studied warehouse is located in the city of Yazd in Iran. This city is located at 37˚54' E and 31˚90' N on a desert valley between the mountains of Shirkooh and Kharanaq. The city has an area of 31539 m^2 and a mean height of 1200 meters above the sea level [46]. Figure 4 illustrates the location of Yazd [47].

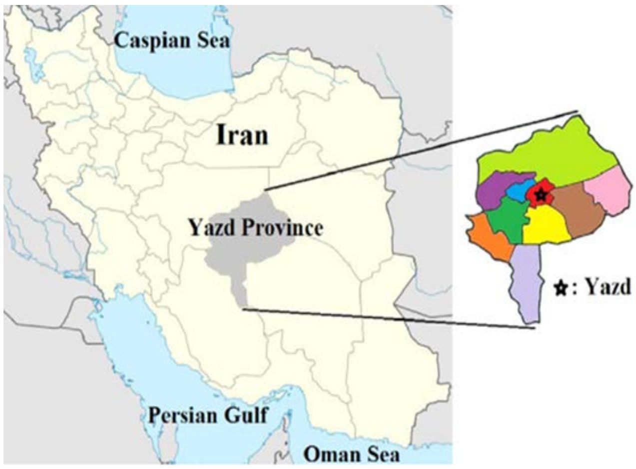

Figure 4. Location of Yazd [47].

Based on the information provided by the Meteorological Organization of Yazd, climatic conditions of the city are as follows (the following are the averages of previous years):

In Yazd, the average temperature is 18.9 °C; during warm months, the average temperatures is 30 °C and the diurnal temperature difference is 12 °C; strongest winds blow in spring and summer from the northwest; the average annual relative humidity is 30 %; the average sunshine hours is 3025 hours per year with the maximum of 345 hours in June and the minimum of 134 hours in January [22]. Table 2 shows the weather data of Yazd including Relative Humidity (%), Maximum Temperature (℃), Average Temperature (℃), Minimum Temperature (℃) and Sunlight Duration (hours) [47].

5.2. Specification of warehouse

The studied case is a fruit warehouse with an area of 4240 m^2

resulting in a storage capacity of about1000 tons. In this study, all calculations are performed for the summer.

5.2.1. Ceiling

The roof of all rooms is made of the 150 mm thick Reinforced Concrete (RC) slab covered with two layers of traditional waterproof (traditional tarpaper) with a total thickness of 60 mm. This floor is also coated with a layer of polyurethane insulation with a thickness of 150 mm.

Table 2. Average weather data of Yazd [47].

Monthly average	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Relative humidity (%)	44.5	30.3	20.6	20.5	13.1	9.7	9.0	9.5	11.6	18.7	34.2	45.6
Maximum temperature (℃)	12.8	17.1	22.8	27.6	33.5	38.4	40.5	38.8	35.0	29.3	20.2	14.2
Average temperature (℃)	6.8	11.2	15.7	20.7	26.4	31.1	33.4	31.2	27.1	21.6	13.5	8.0
Minimum temperature (℃)	0.8	4.0	8.6	13.8	19.3	23.8	26.2	23.7	19.2	14.0	6.9	1.9
Sunlight duration (hours)	215.4	919.3	257.4	258.9	316.0	345.7	352.8	353.1	320.4	296.5	229.5	213.9

5.2.2. Walls

All walls, both exterior and interior, are made of ordinary 500 mm thick brick walls covered with two layers of cement with a total thickness of 100 mm layer and coated on both sides with one layer of traditional tarpaper with a thickness of 30 mm. External walls are coated with polyurethane insulation with a thickness of 200 mm while internal walls are coated on both sides with polyurethane insulation with a thickness of 100 mm.

5.2.3. Floor

The floor of the warehouse is constructed with a 200 mm concrete slab (light pumice, cement) covered with 200 mm thick polyurethane insulation and coated with a 400 mm thick RC slab.

5.3. Warehouse size

The warehouse consists of six 25 m ×10 m rooms and a total area of 200 m^2 and a 30 m × 8 m corridor, all with a height of 4 meters. Each room can hold about 180 tons of fruits. The type, amount, and storage temperature of each fruit are shown in Table 3 [40].

Table 3. Type, amount, and storage temperature of fruits.

Room	Fruit	Ton (Quantity)	Degree (℃)
1	Peach	180	1
2	Plum	180	1
3	Apple	180	1
4	Watermelon	180	10
5	Melon	180	10
6	Cantaloupe	180	10

5.4. Miscellaneous specifications

1. The power required to light the room is considered to be 3-5 Watts per 1 m^2.
2. The workforce required to operate the warehouse is considered to be 1 person per 100 m^2.
3. Warehouse's equipment is considered to work 20 hours a day.
4. The temperature of the corridor is considered to be 25 °C.
5. Warehouse personnel are considered to work 8 hours a day.
6. The safety factor is 10 %.
7. Each room is equipped with an electric 4.17 KW forklift working 4 hours a day.
8. The cooling load due to products is calculated based on the amount entering the warehouse per day [29].
9. Fruits are stored in 0.5 m×0.3 m×0.25 m wooden boxes each holding about 15-20 kg of product. Given the amount of useful storage space, each room can store 34 boxes in the longitudinal direction, 12 boxes in the transverse direction and 11 rows in height, which amount to a total of 8976 boxes per room.
10. Total room space is 20 m×10 m. As shown in Figure 5, the useful storing space is divided into two 7 m×16 m rectangles.

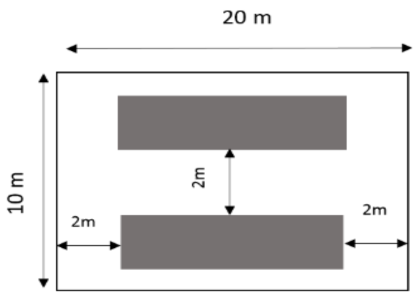

Figure 5. Useful storing space.

6. ANALYSIS

In this section, first, the cooling load of the described warehouse is calculated and then the cooling methods are evaluated with this cooling load acting as the basis of calculations.

6.1. Calculation of cooling load

As mentioned, the total cooling load is considered to be the sum of a number of separate cooling loads originating from different heat sources:

1. Wall, roof and floor gain load
2. Air change load
3. Product load
4. Respiration load
5. Miscellaneous loads

6.1.1. Wall, roof, and floor gain load

When calculating U for a warehouse, it is customary to only consider the effect of insulations and ignore the layers of air and other materials constituting the wall because of their considerably lower thermal resistance. Table 4 shows the parameter U based on the thickness of polyurethane insulation in walls, ceiling and floor of the warehouse [22]:

Table 4. Rate of U [22].

Title	Insulation thickness (mm)	U (m^2/k)
Outside walls	200	0.119
Inside walls	100	0.227
Roof	150	0.153
Floor	200	0.119

If the exterior walls of the refrigerator are exposed to direct sunlight, the temperature will rise as a result of this radiation, and this extra amount can depend on the color of the walls. Sun correction factor is presented in Table B of the Appendix.

The heat load of the wall, roof and floor is obtained from Equation (1). According to Table B (Appendix), the sun correction factor that is to be added to ΔT of the roof is 5. Using Table C (Appendix), the ground temperature is determined to be 24.4 °C. Since the overall heat transfer coefficient of the doors is much lower than the walls, all walls are considered to be monolithic (doors are disregarded). The outside temperature is 30 °C. Thus:

The heat load of the walls, roof and floor of the room dedicated to storing Peach at the temperature of 1 °C is shown in Table 5. According to this table, solar radiation has caused the heat load of the roof to be greater than all other surfaces.

Table 6 shows the heat load of the walls, roof and floor of the room dedicated to storing Plum at the temperature of 1 °C. As can be seen, the south and east walls have zero heat load.

The heat load of the walls, roof and floor of the room dedicated to storing Apple at the temperature of 1 °C is shown in Table 7. As shown in this table, only the east wall has zero heat load and the highest heat load is obtained for the roof (because of the sun).

Table 5. Heat load of the walls, roof and floor of room 1 dedicated to storing peach.

Title	A (m^2)	ΔT (°C)	U (m^2/K)	Solar correction factor	Q (w)
North wall	40	29	0.119	0	138.04
South wall	80	0	0.227	0	0
East wall	80	29	0.119	0	276.08
West wall	40	24	0.227	0	217.92
Roof	200	34	0.153	5	1040.4
Floor	200	23.4	0.119	0	556.92
Q_{total}	-	-	-	-	2229.36

Table 6. Heat load of the walls, roof and floor of room 2 dedicated to storing plum.

Title	A (m^2)	ΔT (°C)	U (m^2/K)	Solar correction factor	Q (w)
North wall	40	29	0.119	0	138.04
South wall	80	0	0.227	0	0
East wall	80	0	0.227	0	0
West wall	40	24	0.227	0	217.92
Roof	200	34	0.153	5	1040.4
Floor	200	23.4	0.119	0	556.92
Q_{total}	-	-	-	-	1953.28

Table 7. Heat load of the walls, roof and floor of room 3 dedicated to storing apple.

Title	A (m^2)	ΔT (°C)	U (m^2/K)	Solar correction factor	Q (w)
North wall	40	29	0.119	0	138.04
South wall	80	29	0.119	0	276.08
East wall	80	0	0.227	0	0
West wall	40	24	0.227	0	217.92
Roof	200	34	0.153	5	1040.4
Floor	200	23.4	0.119	0	556.92
Q_{total}	-	-	-	-	2091.32

Table 8 shows the heat load of the walls, roof and floor of the room dedicated to storing Watermelon at the temperature of 10 °C. Again, the east wall has zero and the roof has the highest heat load.

Table 9 shows the heat load of the walls, roof and floor of the room dedicated to storing Melon at the temperature of 10 °C. As can be seen, the east and south walls show the lowest and the roof shows the highest heat load.

The heat load of the walls, roof and floor of the room dedicated to storing Cantaloupe is shown in Table 10. As shown in this table, only the south wall has a heat load of zero and the heat load of the floor is lower than the walls.

Table 11 shows the heat load of the walls, roof and floor of the corridor with a temperature of 25 °C. As can be seen, heat loads of the floor, east wall, west wall and north wall are negative, and only the south wall has a positive heat load.

Table 8. Heat load of the walls, roof and floor of room 4 dedicated to storing watermelon.

Title	A (m^2)	ΔT (°C)	U (m^2/K)	Solar correction factor	Q (w)
North wall	40	15	0.227	0	136.2
South wall	80	20	0.119	0	190.4
East wall	80	0	0.227	0	0
West wall	40	20	0.119	0	95.2
Roof	200	25	0.153	5	765
Floor	200	14.4	0.119	0	342.72
Q_{total}	-	-	-	-	1529.52

Table 9. Heat load of the walls, roof and floor of room 5 dedicated to storing melon.

Title	A (m^2)	ΔT (°C)	U (m^2/K)	Solar correction factor	Q (w)
North wall	40	15	0.227	0	136.2
South wall	80	0	0.227	0	0
East wall	80	0	0.227	0	0
West wall	40	20	0.119	0	95.2
Roof	200	25	0.153	5	765
Floor	200	14.4	0.119	0	342.72
Q_{total}	-	-	-	-	1339.12

Table 10. Heat load of the walls, roof and floor of room 6 dedicated to storing cantaloupe.

Title	A (m^2)	ΔT (°C)	U (m^2/K)	Solar correction factor	Q (w)
North wall	40	15	0.227	0	136.2
South wall	80	0	0.227	0	0
East wall	80	20	0.119	0	190.4
West wall	40	20	0.119	0	95.2
Roof	200	25	0.153	5	765
Floor	200	14.4	0.119	0	342.72
Q_{total}	-	-	-	-	1529.52

Table 11. Heat load of the walls, roof and floor of the corridor.

Title	A (m^2)	ΔT (°C)	U (m^2/K)	Solar correction factor	Q (w)
North wall	24	-24	0.227	0	-136.2
South wall	160	5	0.119	0	95.2
East wall	160	-20	0.119	0	-26.4
West wall	24	-15	0.227	0	-81.72
Roof	240	-15	0.153	5	-550.8
Floor	240	-0.6	0.119	0	-17.13
Q_{total}	-	-	-	-	-717.05

6.1.2. Air change load

To calculate the air change load, the enthalpy coefficient is obtained based on the temperature and humidity of the room and the entering temperature. For this purpose, temperature of the rooms 1, 2, and 3 is determined to be 1 °C, temperature of the room 4, 5, and 6 is determined to be 10 °C; humidity is determined to be 50 %; entering temperature is determined to be 25 °C for the rooms and 30 °C for the corridor (using Table D (Appendix)). Air infiltration rate is then obtained from Table E and these values are substituted into Equation (4). The results of these calculations are shown in Table 12.

6.1.3. Product load

To calculate the product load, first, the c-value and chilling rate factor of each fruit are obtained from Table F (Appendix), according to the type of fruit and its storage temperature, and the resulting values are then substituted into Equation (5). The results of these calculations are presented in Table 13.

6.1.4. Respiration load

To calculate the respiration load, the respiration temperature corresponding to each fruit is obtained from Table G (Appendix), according to the type of fruit and its storage temperature; then the resulting value and the weight of fruit stored in each room are substituted into Equation (6). Table 14 shows the results of these calculations.

6.1.5. Miscellaneous loads

Since the power required for lighting is considered to be 3-5 watts per 1 m^2, each room with an area of 200 m^2 needs about 1000 Watt and the corridor with the area of 240 m^2 needs about 1200 Watt of power for lighting. These values are substituted into Equation (7) to calculate the required power to provide 8 hours of lighting a day.

The workforce required for the warehouse is considered to be 1 person per 100 m^2, so each room with an area of 200 m^2 needs 2 workers and the corridor with the area of 240 m^2 needs 3 workers to be properly operated. The workers' heat in each room is determined using Table H (Appendix) and then the workers' heat load is obtained from Equation (8).

Each room is equipped with an electric 4.17 KW forklift working 4 hours a day, so substituting these values into Equation (9) gives the heat load generated by forklifts.

Calculations showed that each room can store 8976 boxes, each weighing 3 kg, and for each box c=2.5 [40]. Substituting these values into Equation (10) gives the heat load due to boxes. The final results of the above calculations are shown in Table 15.

The cooling load of each room is obtained by summing loads of walls, roof and floor, air exchange load, product load, respiration load, and miscellaneous loads using a safety factor of 10 % [40]. The cooling loads obtained for the room are shown in Table 16.

6.2. Valuation of cooling methods

Having the cooling load of the studied warehouse, we evaluate the performance of different methods for cooling this facility.

6.2.1. Cooling with solar panels

The average daily power consumption of the warehouse is 300 kW, so in this scenario, the cooling system is considered to consist of 300 KW solar panels and two 12 V 800 AH batteries and two 200 kW inverters.

Table 12. Air change load obtained for the studied warehouse.

Title	Room 1	Room 2	Room 3	Room 4	Room 5	Room 6	Corridor
Air infiltration rate (L/S)	24.7	24.68	24.7	24.7	24.68	24.7	26.57
Enthalpy rate (KJ/L)	0.0266	0.0266	0.0266	0.0472	0.0472	0.0472	0.0341
Air change load (KW)	1.165	0.252	1.165	0.788	0.787	0.787	0.908

Table 13. The product loads obtained for the studied warehouse.

Title	Peach	Plum	Apple	Watermelon	Melon	Cantaloupe
(kj/kg/k)C	3.81	3.68	3.72	3.81	3.81	3.81
Chilling rate factor	0.62	0.67	0.62	0.9	0.9	0.9
Product load (kw)	0.446	0.398	0.403	0.212	0.212	0.212

Table 14. The respiration loads obtained for the studied warehouse.

Title	Peach	Plum	Apple	Watermelon	Melon	Cantaloupe
(kj/kg/k)C	0.0166	0.021	0.0166	0.0656	0.0656	0.0656
Chilling rate factor	2.988	3.760	2.412	11.808	11.808	11.808

Table 15. Miscellaneous loads obtained for the studied warehouse.

Load	Room 1	Room 2	Room 3	Room 4	Room 5	Room 6	Corridor
Lights	0.333	0.333	0.333	0.333	0.333	0.333	0.4
People	0.179	0.179	0.179	0.141	0.141	0.141	0.181
Forklift	0.695	0.695	0.695	0.695	0.695	0.695	0.695
Box	18.7	18.7	18.7	27.115	27.115	27.115	-

Table 16. the Cooling load of the warehouse.

Room	Kw	TR	Btu/h
1	38.66	10.99	131880
2	39.24	11.16	133920
3	37.81	10.75	129000
4	37.62	10.69	128280
5	37.44	10.64	127680
6	37.62	10.69	128280
Corridor	2.206	0.627	7524

6.2.2. Cooling with solar air conditioner

Considering the calculated cooling load, in this scenario, the rooms 1, 2, 3, 4, 5 and 6 are considered to be cooled with twelve 60000 Btu/h solar air conditioners (2 per each) and the corridor is considered to be cooled with one 9000 Btu/h solar air conditioner.

6.2.3. Cooling with solar absorption chiller

The choice of chiller is usually based on two-thirds of the total cooling capacity. Therefore, in this scenario, rooms 1, 2, 3, 4, 5 and 6 are cooled with six 7-ton solar absorption chillers (1 per each) and the corridor is cooled with one 1-ton solar absorption chiller.

6.2.4. Cooling with solar air conditioner and solar absorption chiller

In this scenario, the rooms 1, 2, and 3 are considered to be cooled with three 7-ton solar absorption chillers (1 per each) while the rooms 4, 5, and 6, are cooled with six 60000 Btu/h solar air conditioners (2 per each) the corridor is cooled with one 9000 Btu/h solar air conditioner.

6.2.5. Cooling with wind catcher

A wind catcher can reduce the temperature by 8-16 °C at low relative humidity (10 %-30 %) and by 4-5 °C when relative humidity is higher (65 %-70 %) [42]. Thus, wind catcher by itself cannot meet the fruit storage cooling requirements. The other issue of this method is the discharge of cold air through outlet vents, which make the wind catcher completely unsuitable for this application.

7. ECONOMIC EVALUATION

In the economic evaluation, the NPV of every project is obtained and the project with the greatest positive NPV is identified. In the economic analysis:

1. All projects are evaluated with the software Comfar.
2. The discount rate is considered to be 18 % [48].
3. The inflation rate is considered to be 9 % [48].
4. The lifetime of solar energy systems is considered to be 20 years [27].
5. The fixed investment cost is considered to be the system price plus the cost of installation [43].

7.1. Cost of cooling warehouse by fossil power

Here, fossil power refers to the electricity provided by the conventional power grid. According to the Ministry of Energy, the cost per kilowatt-hour of fossil power for the warehouse is 208, 416, and 832 respectively for low, medium, and high peak hours [49].

Thus, the annual cost of electricity and NPV of fossil power consumed by the warehouse with an average daily consumption of 300 kw is calculated according to Table 21. The results of this calculation shown that annual electricity cost and NPV are 1,114,214,400 Rials (Iranian currency unit) and 9,538,837,442 Rials respectively.

7.2. Revenue by solar power

Assuming that the state purchases the solar electricity with a price of 4900 Rials [50], annual revenue and NPV of the solar power system are calculated to be 546,840,000 Rials and 15,276,856,284 Rials respectively.

7.3. Economic evaluation of cooling methods

Table 17 shows the list of costs associated with solar power systems.

7.3.1. Economic evaluation of cooling by solar panels

As mentioned, in this scenario, the warehouse is considered to be cooled with the power produced by 300 KW solar panels, supported by two batteries and two inverters. Thus, the initial cost of this method is 2,837,409,600 Rials, maintenance and repair cost of 500,000 Rials, and NPV of 2,513,794,655 Rials. The internal rate of return would then be 29.34 %.

Table 17. List of costs associated with solar power systems.

Title	Capacity	Price (Rials)	Installation cost (Rials)	Annual maintenance & repair costs (Rials)
Solar panel	300 kw	9357 (per watt)	10,000,000	500,000
Battery	12 V 800 AH	7,592,880		
Inverter	200 kw	5,061,920		
Solar air conditioner	60000 (Btu/h)	24,727,200	2,000,000	800,000
	9000(Btu/h)	13,343,400		
Solar absorption chiller	7 TR (Ton of Refrigeration)	97,785,500	100,000,000	10,000,000
	1 TR	60,190,300		

7.3.2. Economic evaluation by solar air conditioner

In this scenario, the warehouse is cooled with twelve 60000 Btu/h solar air conditioners (2 per room) and one 9000 Btu/h solar air conditioner for the corridor. Thus, the initial cost of this method is 336,069,800 Rials, maintenance and repair cost of 10,400,000 Rials, and NPV of 4,865,040,418 Rials. The internal rate of return would then be 182.98 %.

7.3.3. Economic evaluation by solar absorption chiller

In this scenario, the warehouse is cooled with six 7-ton solar absorption chillers (1 per room) and one 1-ton solar absorption chiller for the corridor. Therefore, the initial cost of this method is 1,351,903,300 Rials, materials, maintenance and repair cost of 70,000,000 Rials, and NPV of 3,433,476,659 Rials. The internal rate of return would then be 47.42 %.

7.3.4. Economic evaluation by solar air conditioner and solar absorption chiller

In this scenario, the rooms 1, 2, and 3, are cooled with three 7-ton solar absorption chillers (1 per room), the rooms 4, 5, and 6, are cooled with six 60000 Btu/h solar air conditioners (2 per room), and the corridor is cooled with one 9000 Btu/h solar air conditioner. Therefore, the initial cost of this method is 694,881,500 Rials, materials, maintenance and repair cost of 35,600,000 Rials and NPV of 4,327,869,138 Rials. The internal rate of return would then be 89.19 %.

8. ECONOMIC COMPARISON OF METHODS

The total cost and NPV and IRR of the methods evaluated in this study are shown in Table 18. According to Table 18, all methods have a positive NPV and thus economic justification, but among these methods, the ones with the highest NPV and IRR would be the most desirable. As can be seen, the method that is based on solar air conditioner has yielded the highest NPV and IRR among the evaluated methods, so it can be considered as the most economically desirable method.

Table 18. Economic comparison of evaluated methods.

Method	NPV (Rials)	IRR (%)
Solar panel	2,513,794,655	29.34
Solar air conditioner	4,865,040,418	182.98
Solar absorption chiller	3,433,476,659	53.70
Solar air conditioner & Solar absorption chiller	4,327,869,138	89.19

Also, the NPV of cost of solar air conditioning, 402,815,886 Rials, is lower than the NPV of the cost of fossil power, which indicates that the use of solar air conditioning is more economically feasible than the use of fossil power.

9. VALIDATION BY VALUE ENGINEERING

The results obtained in previous sections are validated by the use of value engineering. As mentioned, the procedure of value engineering consists of several phases: information phase, function analysis phase, creativity phase, and evaluation phase.

9.1. Information phase

The studied case is a warehouse with the capacity to store 1000 tons of fruit in six rooms. The cooling method considered for this warehouse includes solar panels (to power conventional cooling), solar air conditioner, solar absorption chiller, and combined use of solar air conditioner and a solar absorption chiller. We show methods with M (method). Thus, there are 4 M values as shown in Table 19.

Table 19. Information phase.

Methods	M
Solar panel	M1
Solar air conditioner	M2
Solar absorption chiller	M3
Solar air conditioner & Solar absorption chiller	M4

9.2. Function analysis phase

The parameters considered important include cooling power, ease of installation, ease of maintenance, ease of implementation, low weight, low space usage, availability, climatic limitations, low power consumption, low emissions, and low price.

9.3. Creativity phase

In this phase, the methods are shown in Table (23) are considered for cooling the warehouse.

9.4. Evaluation phase

In this phase, M is selected and prioritized, the evaluation criteria of alternatives are obtained by brainstorming, and then options for selecting the best cooling method are determined by creative analysis. The description and categorization of each idea developed to create a common understanding are shown in Table 20.

Table 20. Desired criteria.

A = Cooling power
B = Ease of installation
C = Ease of maintenance
D = Ease of implementation
E = Low weight
F = Low space usage
G = Availability
H = Climatic limitations
I = Low power consumption
J = Low emissions
K = Low price

The ideas were then compared with the help of a matrix known as a pairwise comparison matrix. For this comparison, the ideas of Table 20 were placed in the top row of the matrix, and then pairwise comparison was made by brainstorming and the total score points of every row were obtained in the corresponding column. All these operations are illustrated in Table 21.

The weight of ideas of Table 21 was written in the top row of the decision matrix and then each M was given a score by the analyst in view of the associated parameters. These scores were then multiplied by each weight, and the values obtained for each M were summed together. The method with the highest score was selected as the best method for cooling the warehouse. The above calculations are presented in Table 22.

As can be seen, cooling with solar air conditioner has earned the highest score among the studied methods, so it is the best method for this particular application.

Table 21. Matrix of pairwise comparisons.

	B	C	D	E	F	G	H	I	J	k	SCORE
A	A3	A1	A1	A3	A3	A2	A3	A1	A1	A1	**19**
B		C2	D3	B3	B3	G1	B3	I2	J1	K1	**9**
C			D1	C3	C3	C1	C2	I1	C1	K1	**12**
D				D3	D3	D3	D2	D1	D1	D1	**19**
E					E1	G2	H1	I3	J3	K3	**1**
F						G2	F1	I3	J3	K3	**1**
G							G2	I3	J2	K3	**7**
H								H1	J3	K3	**2**
I									I1	K1	**12**
J										K1	**12**
k											**16**

Comparison	**Pts.**
Major Difference	3
Minor Difference	2
Minor Difference	1
No Difference	0

Table 22. Decision matrix.

Value Engineering Analysis **Excellent=5** **Very Good=4** **Good=3** **Fair=2** **Poor=1**	**Desired criteria**	**Cooling power**	**Ease of installation**	**Ease of maintenance**	**Ease of implementation**	**Low weight**	**Low space usage**	**Availability**	**Climatic limitations**	**Low power consumption**	**Low emissions**	**Low price**	
Proposal	Weightage for criteria	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**	**K**	**Total Score**
		19	9	12	19	1	1	7	2	12	12	16	
Solar panel		5	5	5	5	5	3	5	4	5	5	1	**482**
		95	45	60	95	5	3	35	8	60	60	16	
Solar air conditioner		5	4	4	4	4	2	3	3	5	5	4	**472**
		95	36	48	76	4	2	21	6	60	60	64	
Solar absorption chiller		5	3	3	4	2	2	5	3	5	5	2	**431**
		95	27	36	76	2	2	35	6	60	60	32	
Solar air conditioner & Solar absorption chiller		5	3	3	4	2	1	3	3	5	5	3	**432**
		95	27	36	76	2	1	21	6	60	60	48	

10. CONCLUSIONS

Today, the rising prices of fossil power and the resulting increase in the energy costs of business operations, and more importantly, the environmental pollution resulting from fossil fuels motivate the efforts toward cheaper and cleaner energy solutions like the use of renewable energy such as solar and wind. The good potential of Iran for the exploitation of wind and solar energy provide ample opportunities for such efforts, one example of which could be in cooling applications based on renewable energies. In this paper, the use of wind and solar energies via solar panels (to power a conventional cooling system), solar air conditioner, solar absorption chiller, wind catcher, and a combination of solar air conditioners and solar absorption chillers was subjected to techno-economic study. In the economic analysis, as shown in Table 18, solar air conditioning with the highest NPV of 4,865,040,418 Rials, and the best IRR value of 182.98 % was determined to be the best approach among the studied methods. Above result was validated using value engineering technique, as shown in Table 22, cooling with solar air conditioner earned the highest score of 489, and is found to be the best option in this respect. Considering the rising price of fossil power in Iran, the availability of less expensive solar cooling equipment such as solar chillers and solar air conditioners and better incentives for the use of solar power can make these systems more economically attractive.

The approach of this paper can be used in the examination of cooling systems for any other similar applications in other regions.

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APPENDIX

Table A. Thermal conductivity of the materials used in the walls of warehouse [40].

Material	Thermal conductivity (k) (w/m k)	Thermal conductance (c) (w/m^2 k)
Polyurethane	0.025	-
Cement	0.72	-
Brick, common	0.72	-
Brick, face	1.30	-
Tile	-	5.11

Table B. Sun radiation correction factor [40].

Type of surface	East wall	South wall	West wall	Flat roof
Dark-colored surfaces such as: Slate roofing, Tar roofing, Black paint	5	3	5	11
Medium-colored surfaces such as: Unpainted wood, Brick, Red title, Dark cement, Red, gray or green paint	3	2	3	8
Light-colored surfaces such as: White stone, Light-colored, Cement, White paint	2	1	2	5

Table C. Ground temperature for warehouse [40].

Design outside temperature for winter	Design ground temperature
-40	7
-35	10
-30	
-25	15
-20	17
-15	20
-10	22
-5	25
0	27

Table D. Heat due to one liter of air (kJ) for above zero warehouse [40].

Storage room temperature (℃)	Inlet air temperature (℃)					
	25 ℃			30 ℃		
	50	60	70	50	60	70
15	0.0441	0.0357	0.0281	0.0246	0.186	0.0128
10	0.0574	0.0491	0.0319	0.0382	0.0323	0.0266
5	0.0693	0.0610	0.0536	0.0502	0.0445	0.0388
0	0.0794	0.0713	0.0639	0.0606	0.0550	0.0493

Table E. Air infiltration rate (in liters per second) due to opening and closing of door [40].

Infiltration rate (L/S)	
Room volume (m^3)	Room (℃)
700	24.3
800	25.9
900	27.1
1000	28.9

Table F. Design data for storing vegetables [40].

Fruits	Rate factor	Special heat
Apple	0.62	3.72
Plum	0.67	3.68
Peach	0.62	3.81
Watermelon	0.90	3.81
Melon	0.90	3.81
Cantaloupe	0.90	3.81

Table G. Respiration temperature of fruits and vegetables [40].

Commodity	Temperature (℃)	Watts per kilogram
Apples	0 5 10	0.012 0.019 0.075
Pulm	0 16	0.010 0.149
Peach	0 5 16	0.015 0.023 0.110
Watermelon Melon Cantaloupe	0 5 16	0.016 0.026 0.113

Table H. Heat due to people [40].

Cooler temperature (℃)	Heat equivalent/Person Kw
10	0.211
5	0.242
0	0.275
-5	0.305
-10	0.347
-15	0.378
-20	0.407

REFERENCES

1. Huang, Y., "Drivers of rising global energy demand: The importance of spatial lag and error dependence", ***Energy***, Vol. 76, (2014), 254-263. (DOI: 10.1016/j. Energy. 2014.07.093).
2. Ramazankhani, M., Mostafaeipour, A., Hosseininasab, H. and Fakhrzad, M., "Feasibility of geothermal power assisted hydrogen production in Iran", ***International Journal of Hydrogen Energy***, Vol. 41, (2016), 18351-18369. (DOI: 10.1016/j.ijhydene.2016.08.150).
3. Sedaghat, A., Hassanzadeh, A., Jamali, J., Mostafaeipour, A. and Chen, W.H., "Determination of rated wind speed for maximum annual energy production of variable speed wind turbines", ***Applied Energy***, Vol. 205, (2017), 781-789. (DOI: 10.1016/j.apenergy.2017.08.079).
4. Goudarzi, H. and Mostafaeipour, A., "Energy saving evaluation of passive systems for residential buildings in hot and dry regions", ***Renewable and Sustainable Energy Reviews***, Vol. 68, (2017), 432-446. (DOI: 10.1016/j.rser.2016.10.002).
5. Fereidooni, M., Mostafaeipour, A., Kalantar, V. and Goudarzi, H., "A comprehensive evaluation of hydrogen production from photovoltaic

power station", ***Renewable and Sustainable Energy Reviews***, Vol. 82, (2018), 415-423. (DOI: 10.1016/j.rser.2017.09.060).

6. Zarezade, M. and Mostafaeipour, A., "Identifying the effective factors on implementing the solar dryers for Yazd province, Iran", ***Renewable and Sustainable Energy Reviews***, Vol. 57, (2016), 765-775. (DOI: 10.1016/j.rser.2015.12.060).

7. Jahangiri, M., Haghani, A., Alidadi Shamsabadi, A., Mostafaeipour, A. and Pomares, L.M., "Feasibility study on the provision of electricity and hydrogen for domestic purposes in the south of Iran using grid-connected renewable energy plants", ***Energy Strategy Reviews***, Vol. 23, (2019), 23-32. (DOI: 10.1016/j.esr.2018.12.003).

8. Moein, M., Pahlavan, S., Jahangiri, M. and Alidadi Shamsabadi, A., "Finding the minimum distance from the national electricity grid for the cost-effective use of diesel generator-based hybrid renewable systems in Iran", ***Journal of Renewable Energy and Environment (JREE)***, Vol. 5, (2018), 8-22.

9. Jahangiri, M., Rizi, R.A. and Alidadi Shamsabadi, A., "Feasibility study on simultaneous generation of electricity and heat using renewable energies in Zarrin Shahr, Iran", ***Sustainable Cities and Society***, Vol. 38, (2018), 647-661. (DOI: 10.1016/j.scs.2018.01.043).

10. Jahangiri, M., Haghani, A., Mostafaeipour, A., Khosravi, A. and Raeisi, H.A., "Assessment of solar-wind power plants in Afghanistan: A review", ***Renewable and Sustainable Energy Reviews***, Vol. 99, (2019), 169-190. (DOI: 10.1016/j.rser.2018.10.003).

11. Ebrahimi, S., Jahangiri, M., Raiesi, H.A. and Rahimi Ariae, A., "Optimal planning of on-grid hybrid microgrid for remote island using HOMER software, Kish in Iran", ***International Journal of Energetica***, Vol. 3, (2018), 13-21.

12. Mostafaeipour, A., Saidi Mehrabad, M., Qolipour, M., Basirati, M., Rezaei, M. and Golmohammadi, A., "Ranking locations based on hydrogen production from geothermal in Iran using the Fuzzy Moora hybrid approach and expanded entropy weighting method", ***Journal of Renewable Energy and Environment (JREE)***, Vol. 4, (2017), 9-21.

13. Kuhe, A., Terhemba Achirgbenda, V. and Agada, M., "Global solar radiation prediction for Makurdi, Nigeria using feed forward backward propagation neural network", ***Journal of Renewable Energy and Environment (JREE)***, Vol. 5, (2018) 51-55.

14. Ameri, M. and Salimi, K., "Techno-economic and life-cycle cost assessment of the CCHP/PV hybrid system application", ***Journal of Renewable Energy and Environment (JREE)***, Vol. 4, (2017), 1-8.

15. Najafi, G., Ghobadian, B., Mamat, R., Yusaf, T. and Azmi, W.H., "Solar energy in Iran: Current state and outlook", ***Renewable and Sustainable Energy Reviews***, Vol. 49, (2015), 931-942.) DOI: 10.1016/j.rser.2015.04.056).

16. Alamdari, P., Nematollahi, O. and Mirhosseini, M., "Assessment of wind energy in Iran: A review", ***Renewable and Sustainable Energy Reviews***, Vol. 16, (2012), 836-860. (DOI: 10.1016/j.rser.2011.09.007).

17. Yang, B., Yao, L., Yan, S., Li, N., Cao, Y., Cui, H. and Ge, X., "Comprehensive benefits assessment of different new energy generation technologies for global energy Internet development", ***Materials Science and Engineering***, Vol. 452, (2018), 2-3. (DOI: 0.1088/1757-899X/452/3/032036).

18. Kalantar, V., "Numerical simulation of cooling performance of wind tower in hot and arid region", ***Renewable Energy***, Vol. 34, (2009), 246-254. (DOI: 10.1016/j.renene.2008.03.007).

19. http://moe.gov.ir, (Accessed 14-03-2019), In Farsi language.

20. Bahadori, M.N., "Passive cooling systems in Iranian architecture", ***Scientific American***, Vol. 10, (1978), 144-278. (DOI: 10.1038/scientificamerican0278-144).

21. Mahdinejad, M.J. and Javanrudi, K., "Comparative examination of effects of air flow on Yazdi and Kermani wind catchers", ***The Journal of Fine Arts - Architecture***, Vol. 48, (2012), 69-76. (In Farsi language).

22. Mostafaeipour, A., Bardel, B., Mohammadi, K., Sedaghat, A. and Dinpashoh, Y., "Economic evaluation for cooling and ventilation of medicine storage warehouses utilizing wind catchers", ***Renewable and Sustainable Energy Reviews***, Vol. 38, (2014), 12-19. (DOI: 10.1016/j.rser.2014.05.087).

23. Mostafaeipour, A. and Sadeghi Sedeh, A., "Investigation of solar energy utilization for production of hydrogen and sustainable chemical fertilizer: A case study", ***International Journal of Energy Research***, Vol. 43, No. 14, (2019), 1-23. (DOI: 10. 1002/er.4829).

24. Qasemifard, M., "Prioritization of the cities of Yazd province for the use of solar energy", Dissertation for the master's degree in Industrial Engineering, Yazd University, (2013), In Farsi language.

25. http://www.satba.gov.ir/br/sun/potential, (Accessed 6-3-2019), In Farsi language.

26. https://www.google.com/search?sxsrf=ACYBGNTJ3rqJQqebL8vBFK20QNHW7hFv8Q:1569678467076&q=The-world-solar-energy-map-Zhang-et-al-2013&tbm=isch&source=univ&client=firefox-b-d&sxsrf=ACYBGNTJ3rqJQqebL8vBFK20QNHW7hFv8Q:1569678467076&sa=X&ved=2ahUKEwiI5sP70_PkAhWEJFAKHThzCJwQsAR6BAgJEAE; 2019, (Accessed 5-3-2019).

27. Rezaei-Shouroki, M., Mostafaeipour, A. and Qolipour, M., "Prioritizing of wind farm locations for hydrogen production: A case study", ***International Journal of Hydrogen Energy***, Vol. 42, No. 15, (2017), 9500-9510.

28. Mostafaeipour, A., Qolipour, M. and Goudarzi, H., "Feasibility of using wind turbines for renewable hydrogen production in Firuzkuh, Iran", ***Frontiers in Energy***, Vol. 13, No. 3, (2019), 494-505.

29. Mostafaeipour, A. and Sadeghi Sedeh., A., "Investigation of solar energy utilization for production of hydrogen and sustainable chemical fertilizer: A case study", ***International Journal of Energy Research***, Vol. 43, No. 14, (2019), 8314-8336.

30. Clark, J.A. and Stachan, P.A., "Simulation of conventional and renewable building energy systems, Energy systems research unit University of Strathclyde", ***Renewable Energy***, Vol. 5, (2009), 1178-1189. (DOI: 10.1016/0960-1481(94)90148-1).

31. Hua, J. and Shiu, H.-G., "Sustainable development of renewable energy on Wangan Island, Taiwan", ***Utilities Policy***, Vol. 55, No. C, (2018), 200-208. (DOI: 10.1016/j.jup.2018.10.003).

32. Danish, Zhang, B., Wang, B. and Wang, Z., "Role of renewable energy and non-renewable energy consumption on EKC: Evidence from Pakistan", ***Journal of Cleaner Production***, Vol. 156, (2017), 855-864. (DOI: 10.1016/j.jclepro.2017.03.203).

33. Shahsavari, A. and Akbari, M., "Potential of solar energy in developing countries for reducing energy-related emissions", ***Renewable and Sustainable Energy Reviews***, Vol. 19, (2018), 275-291. (DOI: 10.1016/j.rser.2018.03.065).

34. Lang, T., Gloerfeld, E. and Girod, B., "Don't just follow the sun – A global assessment of economic performance for residential building photovoltaics", ***Renewable and Sustainable Energy Reviews***, Vol. 42, (2015), 932-951. (DOI: 10.1016/j.rser.2014.10.077).

35. Askari, I., Sadegh, M. and Ameri, M., "Energy management and economics of a trigeneration system considering the effect of solar PV, solar collector and fuel price", ***Energy for Sustainable Development***, Vol. 26, (2015), 43-55. (DOI: 10.1016/j.esd.2015.03.002).

36. Daneshvar, H., Honarmand, M.I. and Talebi, J., "The potential of hybrid solar air conditioners to reduce peak load", ***Proceedings of The 25th International Conference on Electricity***, Gilan, Iran, (2011), Source file is in Farsi.

37. Abdullah, G., Saman, W. and Whaley, D., "Optimization of standalone solar heat fired absorption chiller for typical Australian homes", ***Energy Procedia***, Vol. 91, (2016), 692-701, (DOI: 10.1016/j.egypro.2016.06.232).

38. Saffar, A.," Passive cooling strategies in greening existing residential building in hot dry climate: Case study in Bahrain", ***Journal of Environmental Science and Engineering***, Vol. 4, (2015), 233-240. (DOI: 10.17265/2162-5298/2015.05.003).

39. Gholamnejad, N., "Economic and feasibility analysis of a solar cold room in desert regions", Dissertation for the bachelor's degree in Mechanical Engineering, Yazd University, (2013), Source file is in Farsi.

40. Dossat R.J. and Horan T.J., Principles of refrigeration, 5th Edition, published by Pearson, (2001).

41. https://fa.wikipedia.org/w/index.php?search=%2F%E2%80%8E%E2%80%8Fcomfar&title=%D9%88%DB%8C%DA%98%D9%87%3A%D8%AC%D8%B3%D8%AA%D8%AC%D9%88&go=%D8%A8%D8%B1%D9%88&ns0=1, (Accessed 09-11-2018).

42. Valipour, M., A practical guide to COMFAR, Daneshparvar Publications, Tehran, (2014), Source file is in Farsi.

43. Oskunejad, M.M., Engineering economics, Amirkabir University of Technology Publications, Tehran, (1997), Source file is in Farsi.

44. Pazhuyan, J., Money, currency, and banking (for the students of Accounting and Business Administration), Payam Noor University Press, (2015), Source file is in Farsi.

45. PourReza, M., Zolforian, M.H. and Atri, I., Introduction to value engineering, Training unit of Iran's value engineering comprehensive reference, Tehran, (2014), Source file is in Farsi.

46. Labs, K., Regional analysis of ground and above-ground climate, Oak Ridge National Laboratory,)1981).

47. Mostafaeipour, A., Zarezade, M., Goudarzi, H., Rezaei-Shouroki, M. and Qolipour, M., "Investigating the factors on using the solar water heaters for dry arid regions: A case study", ***Renewable and Sustainable Energy Reviews***, Vol. 78, (2017), 157-166. (DOI: 10.1016/j.rser.2017.04.102).

48. https://www.cbi.ir, (Accessed 30-12-2018), Source file is in Farsi.

49. http://barghnews.com/fa/news/8305, (Accessed 30-12-2019), Source file is in Farsi.

50. http://www.satba.gov.ir/fa/guidances, (Accessed 30-12-2019), Source file is in Farsi.