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Economic Analysis of Solar Energy Used for Supplying Heating Load and Electricity Required for a Poultry House

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ABSTRACT

In this study, the economic analysis of the architectural part of the building, the use of both the solar thermal and solar electric systems in a poultry farm were discussed. In this economic analysis, the implementation of architectural solutions as well as the utilization of the solar thermal system considering the global gas price and the current gas rates in the country and finally the use of solar electric system with different subsidies were analyzed. Economic analysis was conducted using RETSCREEN software. The results showed that the internal rate of return (IRR) for the architectural solutions of using double-glazed windows and wall insulation, considering the global gas price, was estimated as 53.1% and, the investment return, taking into account the inflation and discount rates, was equal to 2.6 years, which is the break-even point of investing in this solution. Utilizing the solar thermal system and without considering the cost of the underfloor heating system, the IRR value is equal to 34.1%, and considering the cost of the underfloor heating system, the IRR value is equal to 27.9%, which is economic in terms of these solutions. This option proves to be cost-effective. When employing the solar electric system with an IRR of 4.4%, this solution proves uneconomical under all circumstances due to the IRR falling below the bank rate and yielding a negative Net Present Value (NPV). However, when considering a 50% government subsidy and a 1.5-fold increase in the electricity purchase tariff for the solar electric system, this solution approaches the threshold of economic viability.

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INTRODUCTION

Poultry farming is one of the energy-intensive industries that consumes a lot of energy to provide a suitable indoor environment for the health and production of chickens such as meat and eggs. Currently, there are extensive researches and practices to apply renewable and sustainable energy technologies in poultry farming to achieve energy savings and reduce carbon dioxide emissions. Major technologies include photovoltaic (PV), solar collectors, PV/thermal hybrids, thermal energy storage, ground/water/air source heat pumps, lighting and radiant heating. It has been determined that by using these advanced technologies, energy savings of up to 85% can be achieved compared to traditional poultry farms with a payback time of 3 to 8 years (Cui et al., 2020). The livestock sector is the main source of greenhouse gas emissions and other effects. Poultry (meat and eggs) is the fastest growing livestock sector in the world. Poultry housing, including infrastructure and operational energy, may account for up to 50% of total non-renewable energy consumption and 20–35% of some life cycle impacts of poultry production (Lee et al., 2022) In Iran, poultry farms, as one of the subsets of the agricultural sector, are among the most energy-consuming sectors, and the main part of their consumption is related to the heating of breeding halls (Shahini et al., 2018). Thermal simulations can accurately predict possible problems in poultry systems and lead to appropriate strategies for energy saving (Wang et al., 2020). In a numerical study, a hybrid strategy was proposed for photovoltaic panels to increase heat transfer. In that study, it was shown that by using a new heat collector and phase change materials, space heating or hot water heating can be provided quickly. In that study, the best performance of the system was reported in the panel angle mode of 35 degrees and the wind angle of 45 degrees (Jurčević et al., 2021). In a study, the impact of using solar energy and climate control systems on the performance of a poultry farm was evaluated with an economic approach (Gad et al., 2020). In a study, it was found that the design strategies of a poultry farm should emphasize a combination of aspects including (1) reducing direct energy consumption (DE) through structural design, (2) improving the energy efficiency of active technology systems, and (3) installing renewable energy production systems (Lee et al., 2022). Electricity supply systems in poultry need to be optimized using renewable energy sources. In research, the optimal power and connection location of the photovoltaic system as an additional power source to reduce power losses in the power line with a uniformly distributed load was studied (Bogdan et al., 2018). In that study, a comparison was made between the performance of the poultry power supply system with and without an additional energy source, and it was concluded that the maximum power loss of the optimal photovoltaic system is almost equal to the average power consumption of the line without considering it. In another study, a new and renewable heating system was carried out to evaluate the energy demand and improve the indoor environment temperature of a poultry farm (Cui et al., 2022). In a research, three different photovoltaic systems were used to heat and control the temperature of a poultry farm (Moehlecke et al., 2019). In a research, various aspects of using a solar photovoltaic system in the poultry industry were identified with regard to economic and technical capability (Habib et al., 2019). In that study, it was shown that the poultry industry can not only meet its own local energy needs, but can also export electricity to the grid using solar photovoltaics. The results of that study showed that the implementation of solar photovoltaic reduces the cost of electricity production by reducing diesel consumption. Since the poultry industry requires a large space to operate, the on-grid PV system can not only supply the domestic load, but also earn significant income by exporting electricity. In one study, an energy and cost saving strategy was proposed for commercial poultry farms (Elahi et al., 2022). In that study, data were collected from 192 farmers in environmentally controlled poultry farms in Pakistan, and a well-structured questionnaire was used to conduct face-to-face interviews with the respondents. In that study, using the method of artificial neural networks, optimization was done for energy inputs. The results showed that 958.84 $can be saved in each chicken farm annually. Also, the findings of that study showed that energy output is very sensitive to changes in feed, electricity and diesel energy. In a study, two different models of cooling systems namely, direct evaporation and mixed direct evaporative desiccant rotatory wheel, were identified in a greenhouse in Tehran. The results of these models have been evaluated, compared, and modeled in TRNSYS (Kamrani et al., 2023). The results showed that despite the 10% increase in radiation intensity and 7% increase in temperature in the case of evaluating the mixed evaporative desiccant rotatory wheel system, the temperature changes of greenhouse in this system followed a similar behavior, and 8% reduction in functional expenses was also confirmed. In research, the design of a solar thermal system was discussed with the aim of reducing energy consumption in a poultry farm (Jalali et al., 2022).

In that study, it was shown that in order to establish a balance (That is, 50% energy from the auxiliary system and the rest from the solar system) between the use of solar energy and the use of the auxiliary system, a collector surface equal to 16 m^2 is needed. According to the review of the research records, it can be seen that most of the studies emphasize on improving the energy efficiency by using renewable energy production systems, however, the study about the economic analysis of solar energy used in providing the heating load and electricity required for the poultry house has not been investigated so far, in this research, the economic analysis of the implementation of architectural solutions, the use of solar thermal system with the global gas price and the actual gas rate in the country, and finally the use of solar electric system with different subsidies have been analyzed.

MATERIALS AND METHODS

Statement of the problem

The problem under study is the thermal simulation of a meat poultry farm in Ardestan city of Isfahan province. Ardestan city is located in the north of Isfahan province, in the south of the salt desert, with latitude 33 degrees 23 minutes 47 seconds north and longitude 52 degrees 22 minutes 21 seconds east. The highest temperature is in July and August, the lowest temperature is in January and February, and there is a temperature difference of about 5 ℃between the warm northern areas and the colder southern highlands. The floor dimensions of the poultry hall are 5 m by 8 m and, the height is 2.5 m with a capacity to house 300 chickens. Figure 1 shows the scheme of poultry farming (Jalali et al., 2022).

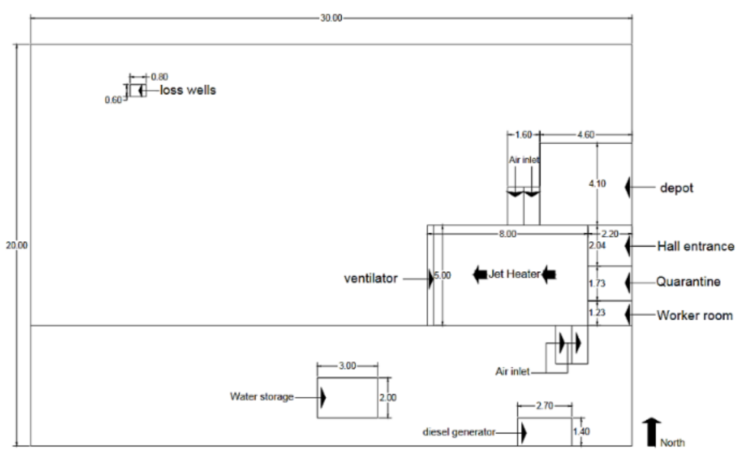


Figure 1. The schematic of the present problem.

Assumptions and physics of poultry farming studied

There are 2 air inlets (windows) with dimensions of 1.90 ×1.6 m. The average height of the roof is 2.5 m and the roof is gable and is a combination of plastic cardboard, glass wool and metal sheet. Due to the wind, the hall area is built east-west and the ventilators are located on the west side. The type of window is single-paned, and the entrance door is metal. The thickness of the wall is 20 cm and it was covered with gray cement on both sides. Table 1 shows the characteristics of the different parts of poultry farming under investigation.

Table 1. Specifications of different parts of poultry

Property	Length (m)	Width (m)	Height (m)	Surface (m^2)	Number	Area (m^2)
Walls	9	5	2.5	65	-	65
Windows	1.9	1.6	-	3.04	2	6.08
Doors	2	2	-	4	1	4

Hourly weather conditions in Ardestan city were modeled using geographical data and information gathered from the Meteorological Organization, employing Meteonorm software. For the purposes of this study, it is assumed that poultry farming commences at the beginning of January. Poultry cycle takes place once every 56 days. Considering that the time between both cycles is 15 to 20 days, in this research, the average interval between two cycles is considered to be 17 days. Table 2 displays the climatic characteristics of the area.

Table 2. Characteristics of climate and solar radiation in the area based on the data of Metronorm software

	Temperature	Relative humidity (%)	Wind velocity (m/s)	Wind direction angle
Minimum	-8.88	9.89	0	7.62
Maximum	44.33	98.45	7.9	358.15
	Intensity of sunlight on the horizon	**The angle of the solar horizon**	**Solar elevation angle**	**Solar angle**
Minimum	378.15	10.06	59.72	10.03
Maximum	639.3	89.82	116.047	98.98

In addition, the specifications of the collectors are presented in Table 3.

Table 3. Collector specifications

Property	Value/Description
Type of collector	Tube plate
Plate material	Aluminum
Cover color of plate	Matte black
Emission coefficient of the plate	0.9
Thermal conductivity of the plate	211 W/m .K
Collector dimensions	m^2 2×1 m^2 3×2 m^2 3.2×2.5
Emission coefficient of the cover	0.85
Insulation thickness around	0.02 m
Thermal conductivity of insulators	0.05 W/m .K
Working fluid	Water
The material of the reflectors	Steel 304
Slope of the collector	45°

Figure 2 shows the modeling of the poultry building in the existing conditions using TRNSYS software (Jalali et al.,2023).

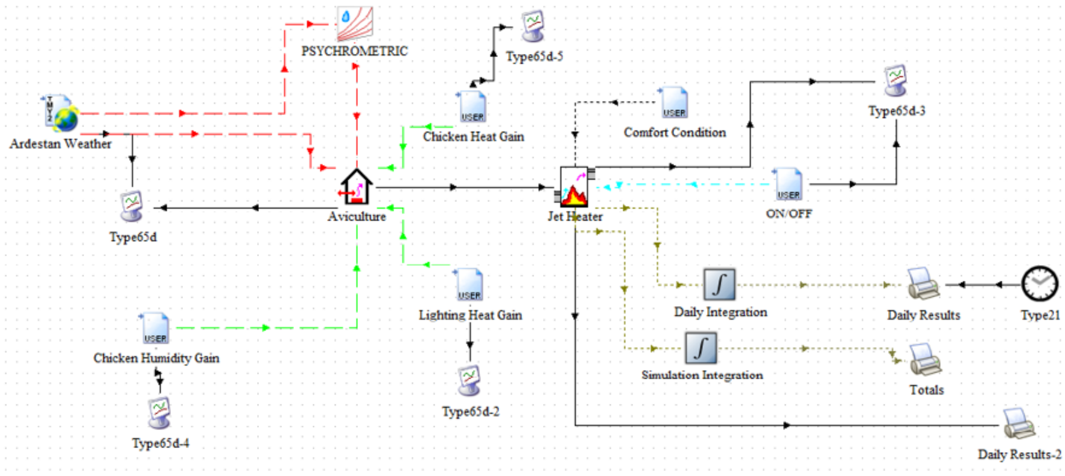


Figure 2. Simulated model in TRNSYS software for existing conditions (Jalali et al.,2023).

In order to simulate weather conditions, TYPE109 software, which is a COMPONENT with the ability to read simulated weather conditions with TMY2 extension, has been used. Type 88 in this software deals with the calculations related to the thermal load of the building. In Figure 2, this TYPE is displayed under the name Aviculture.

This research includes two main parts. Thermal modeling department and building electrical modeling department. In the thermal modeling section, first, the amount of heat required by the building was modeled using TRNSYS 16 software, taking into account the building physics and the conditions of the building's internal environment, as well as the effect of the building's weather conditions, the building was modeled and it was determined that for the examined hall, the amount of 137462334 kJ/h (137.462334 GJ/h) is required for heating during the year. This amount is equal to 17180 m^3 of natural gas. This amount was compared with the total annual consumption bills of the same poultry farm and it had a deviation of 8%, and the reasons for the deviation can be pointed to the lack of accurate adjustment of the comfort temperature of the chickens. In the following, two important solutions were presented in the architectural department of the building, during which the amount of energy consumed was greatly reduced. These two solutions are the use of double-glazed windows and insulation for the external walls of the building. In this way, the required annual gas consumption was equal to 11833 m^3. As part of the ongoing efforts to optimize energy consumption in the studied poultry hall, one proposed measure is the utilization of a solar water heater to facilitate heating via a floor heating system. For this purpose, a comprehensive optimization of the required cross-sectional area has been done. The results showed that an area 26 m^2 of solar collector with an optimal slope of 47 degrees and taking into account the tank volume of 440 L and the pump flow rate of 1700 kg/h, represent the most effective configuration for attaining 100% energy provision. The economic calculations of this solution are evaluated in two ways. The first part assumes that the hall is equipped with an underfloor heating system and only the cost of the solar system is added to the hall, and in the second part, in addition to the cost of the solar system, the cost of the underfloor heating system is also considered. Another measure that was mentioned in this research and was optimized in detail was the use of a photovoltaic system for the collection. Due to the fact that the rate of electricity purchase was much lower than the rate of sale of renewable electricity to the grid, therefore, the scenario of selling the entire electricity to the grid and buying electricity separately was proposed. Based on this, the optimal configuration identified was 60 solar panels arranged in 6 parallel sections, with each section comprising 10 panels in series. The economic analysis of this solution has been done using RETSCREEN software. It is important to mention that in this case the inflation rate is zero because the purchase guarantee contract is set at the beginning. The step rate of price increase in this contract is equal to 5%.

RESULTS AND DISCUSSION:

In the following, a more detailed economic analysis of the calculations in the RETSCREEN software was discussed. Table 4 shows the economic parameters considered in the calculation.

Table 4. Economic parameters in RETSCREEN analysis

Financial parameters		
General	Unit	Value
Fuel cost escalation rate	%	2
Inflation rate	%	15
Discount rate	%	18
Reinvestment rate	%	0
project life	Year	20

The investment cost for these solutions is listed in Table 5.

Table 5. Investment cost necessary to reduce energy wastage in architecture sector

Initial costs	Value (%)	Cost ($)
Double glazed window	68.8	265
Wall insulation	31.2	120
Total initial costs	100	385

The income generated from employing these solutions is also specified in Table 6.

Table 6. Annual normal implementation of architecture sector solutions

Annual saving and revenue	Unit	Cost
User-defined	$	107
GHG reduction revenue	$	0
Other revenue(cost)	$	0
Total annual saving and revenue	$	107

Based on the information provided above, the cash flow diagram for implementing these solutions is generated using the specified software, and the outcome is depicted in Figure 3.

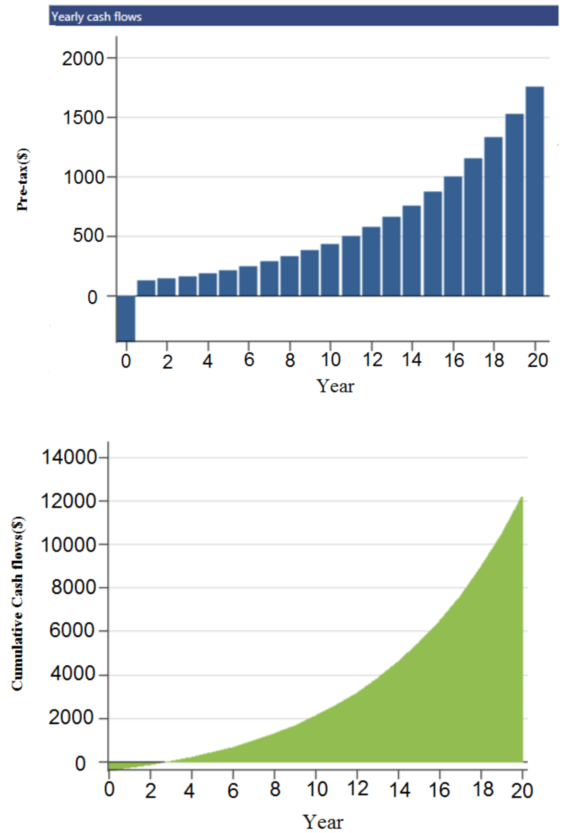


Figure 3. Cash flow diagram and capital accumulation using double-glazed window and wall insulation

According to the above diagram and the calculations presented in this software, other influential economic parameters are presented in Table 7. As shown in the table, the IRR value is equal to 53.1% and since this value is more than the bank interest of 18%; therefore, this solution is economically viable. The payback period for this investment, factoring in inflation and discount rates, is estimated at 2.6 years, signifying the break-even point.

Table 7. The results of the economic analysis of the implementation of architectural solutions

(Financial Viability)	Unit	Value
Pre-tax IRR-equity	%	53.1
Pre-tax MIRR-equity	%	23
Pre-tax IRR-assets	%	53.1
Pre-tax MIRR-assets	%	23
Simple payback	year	3.6
Equity payback	year	2.6
Net Present Value (NPV)	$	2180
Annual life cycle saving	$/year	407
Benefit-Cost(B-C) ratio		6.7

In order to investigate more precisely the application of these solutions, a sensitivity analysis was conducted, the result of which is presented in Table 8. This analysis has been done on the total cost compared to the IRR. This sensitivity analysis is done on the initial investment cost with a change range of 100%.

Table 8. Sensitivity analysis of the implementation of architectural solutions

(Initial costs)($)				
0	193	385	578	770
-100%	-50%	0.0%	50%	100.0%
Positive	86.7%	**53.1%**	41.4%	35.1%

As it is clear in the figure, as long as the total cost reaches 770 $ this solution is economically profitable. As mentioned, in these calculations, the gas purchase rate is assumed to be equal to 2 cents (equivalent to 492 Tomans) of the world price. For a more detailed investigation, the gas price of 100 Tomans, which in reality reaches the sales of such trade units, will also be analyzed and evaluated. In this case, the cash flow diagram drawn in Rat Screen software is reported as Figure 4.

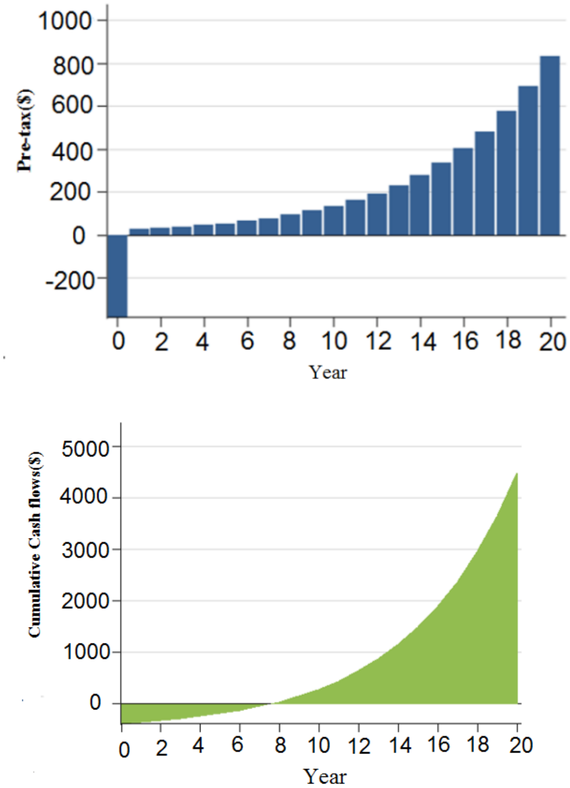


Figure 4. Cash flow diagram and capital accumulation using double-glazed window and wall insulation using real gas rate.

The results of engineering economics are also presented in Table 9. As it is clear in this table, this solution will be exactly on the border of economic conditions.

Table 9- The results of the economic analysis of the implementation of architectural solutions with the actual fuel price

Financial Viability	Unit	Value
Pre-tax IRR-equity	%	21.4
Pre-tax MIRR-equity	%	13.5
Pre-tax IRR-assets	%	21.4
Pre-tax MIRR- assets	%	13.5
Simple payback	year	17.7
Equity payback	year	7.5
Net Present Value (NPV)	$	136
Annual life cycle saving	$/year	25.44
Benefit-Cost(B-C) ratio		1.4

The investment cost for using a solar water heater to heat the hall without considering the cost of underfloor heating is listed in Table 10.

Table 10- The investment cost required to reduce the energy wastage of using the solar thermal system

Initial costs	Value (%)	Cost ($)
Initial cost	0	0
Solar Flat Plate Collector	100	1788
Total initial costs	100	1788

The annual income of using these solutions is also specified in Table 11.

Table 11. The annual income of using the solar thermal system

Annual saving and revenue	Unit	Value
NG Saving	$	236
GHG reduction revenue	$	0
Customer Premium Income(rebate)	$	0
Total annual saving and revenue	$	236

According to the information provided above, the cash flow diagram of the application of these solutions is drawn in Rat Screen software and the result is presented in Figure 5.

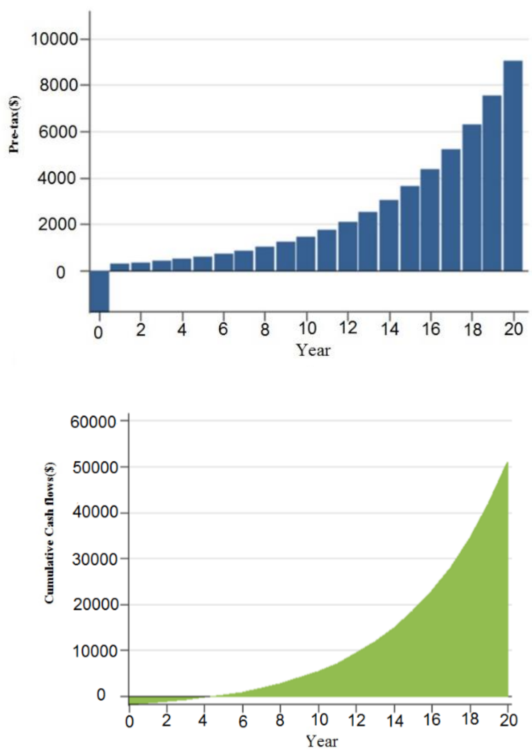


Figure 5. Cash flow diagram of using solar system without considering the cost of underfloor heating system

According to the diagram in Figure 5 and the calculations provided in this software, other influential economic parameters are presented in Table 12. As shown in the table, the IRR value is equal to 34.1% and since this value is more than the bank interest of 18%; Therefore, this solution is economically very affordable. The return on investment is equal to 4.5 years, taking into account inflation and discount rates.

Table 12. The results of the economic analysis of the implementation of the solar thermal system

Financial Viability	Unit	Value
Pre-tax IRR-equity	%	34.1
Pre-tax MIRR-equity	%	18.5
Pre-tax IRR-assets	%	34.1
Pre-tax MIRR- assets	%	18.5
Simple payback	year	7.6
Equity payback	year	4.5
Net Present Value (NPV)	$	3870
Annual life cycle saving	$/year	723
Benefit-Cost(B-C) ratio		3.2

In addition, a sensitivity analysis has been done for this solution, and the investment cost has been investigated to decrease and increase by 50%. 50% decrease can be possible government subsidies and 50% increase can be the change in exchange rate and the system becomes more expensive. The result of these calculations is listed in Table 13.

Table 13. Sensitivity analysis of the implementation of solar thermal system implementation solutions

Initial costs ($)				
894	1341	1788	2235	2682
-50%	-25.0	0.0%	25.0%	50.0%
51.4%	40.2%	**34.1%**	30.2%	27.3%

As mentioned, the calculations in the previous section are without considering the cost of the underfloor heating system. By adding the necessary investment cost for the underfloor heating system, the calculations are renewed as follows and we will continue to examine it. In this case, Table 14 shows the investment costs of using this solution with the mentioned conditions

Table 14. The investment cost required to reduce the energy wastage of using the solar thermal system and considering the cost of the underfloor heating system

Initial costs	Value (%)	Cost ($)
Initial cost	0	0
Solar Flat Plate Collector	69.1	1788
Under Floor Heating	30.9	800
Total initial costs	**100**	**2588**

The amount of rial saving in energy has not changed and remains the same as before. According to the change in the investment cost, the cash flow diagram of the application of these solutions has been drawn in the Rat Screen software, and the result is presented in Figure 6.

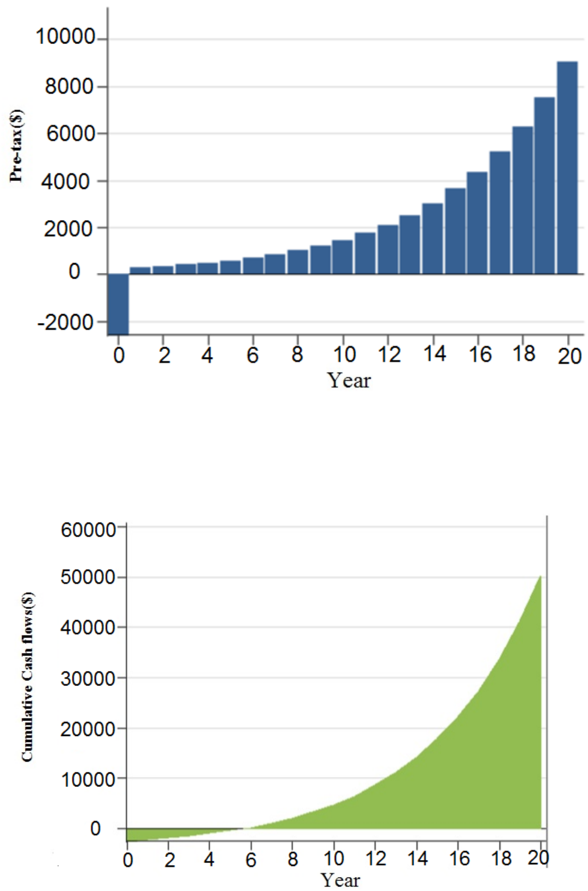


Figure 6. Cash flow diagram of using solar system considering the cost of underfloor heating system

According to the above chart and the calculations presented in this software, other influential economic parameters are presented in the table below. As shown in Table 15, the IRR value is equal to 27.9% and since this value is more than the bank interest of 18%, this solution can be economical in terms of these conditions. The return on investment is equal to 5.7 years, taking into account inflation and discount rates. In this case, this solution comes with various risks. For example, the lifetime of the solution is considered to be 20 years, and the break-even point is equal to 5.7 years. This system must work for 5.7 years without failure and have no side costs so that this solution can continue to be economical.

Table 15. The results of the economic analysis of the implementation of the solar thermal system and underfloor heating system

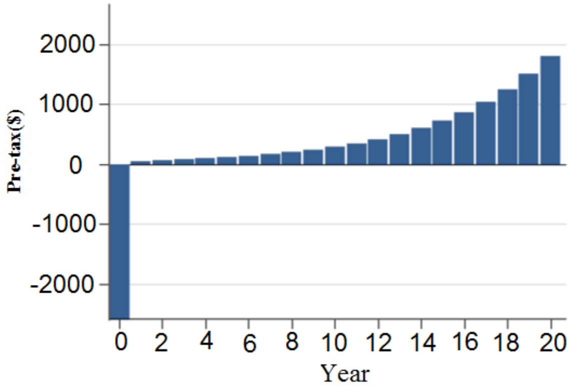
Financial Viability	Unit	Value
Pre-tax IRR-equity	%	27.9
Pre-tax MIRR-equity	%	16.3
Pre-tax IRR-assets	%	27.9
Pre-tax MIRR- assets	%	16.3
Simple payback	year	11
Equity payback	year	5.7
Net Present Value (NPV)	$	3070
Annual life cycle saving	$/year	574
Benefit-Cost(B-C) ratio		2.2

In order to pay more attention to this issue, a sensitivity analysis is performed in this solution. Investment cost up to 50% reduction and increase have been investigated, and the results are listed in Table 16.

Table 16. Sensitivity analysis of the implementation of solar thermal system and floor heating system

Initial costs ($)				
1294	1941	2588	3235	3882
-50%	-25.0%	0.0%	25.0%	50.0%
41.0%	32.6%	**27.9%**	24.7%	22.3%

As mentioned, in these calculations, the gas purchase rate is assumed to be equal to 2 cents (equivalent to 492 Tomans) of the world price. For a more detailed investigation, the gas price of 100 Tomans, which in reality reaches the sales of such trade units, will also be analyzed and evaluated. In this case, the cash flow diagram drawn in Rat Screen software is reported as Figure 7.



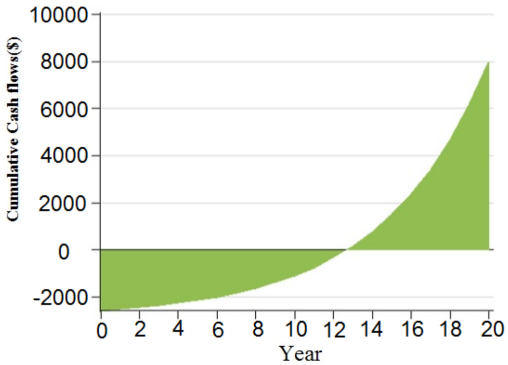


Figure 7. Chart of cash flow and capital accumulation of using the solar system, taking into account the actual fuel rate.

The results of engineering economics are also presented in the table below. As it is clear in table 17, this solution is not economic under any heading.

Table 17. The results of the economic analysis of the implementation of the solar thermal system solution considering the actual fuel price

Financial Viability	Unit	Value
Pre-tax IRR-equity	%	10.2
Pre-tax MIRR-equity	%	7.3
Pre-tax IRR-assets	%	10.2
Pre-tax MIRR- assets	%	7.3
Simple payback	year	54.8
Equity payback	year	12.7
Net Present Value (NPV)	$	-1456
Annual life cycle saving	$/year	-272
Benefit-Cost(B-C) ratio		0.44

Table 18 is considered regarding the economic parameters that are given as input to the problem in the RETSCREEN analysis of the photovoltaic system.

Table 18. Economic parameters in the rat screen analysis of the photovoltaic system

Financial parameters		
General	Unit	Value
Fuel cost escalation rate	%	5
Inflation rate	%	0
Discount rate	%	18
Reinvestment rate	%	0
project life	Year	20

The required investment cost is presented in Table 19.

Table 19. The investment cost required to reduce the energy wastage of using the solar electric system

Initial costs	Value (%)	Cost ($)
Initial cost	0	0
Photovoltaic Panel Invertor	100	6408
Total initial costs	100	6408

The income resulting from the application of this solution is also presented in Table 20.

Table 20. Normal annual use of solar electric system

Annual saving and revenue	Unit	Value
NG Saving	$	490
GHG reduction revenue	$	0
Customer Premium Income(rebate)	$	0
Other revenue (Cost)	$	0
Total annual saving and revenue	$	490

The cash flow diagram for this solution is shown in Figure 8.

Table 21. The results of the economic analysis of the implementation of the solar electric system

Financial Viability	Unit	Value
Pre-tax IRR-equity	%	4.4
Pre-tax MIRR-equity	%	2.2
Pre-tax IRR-assets	%	4.4
Pre-tax MIRR- assets	%	2.2
Simple payback	year	13.1
Equity payback	year	13.1
Net Present Value (NPV)	$	-3786
Annual life cycle saving	$/year	-707
Benefit-Cost(B-C) ratio		0.41

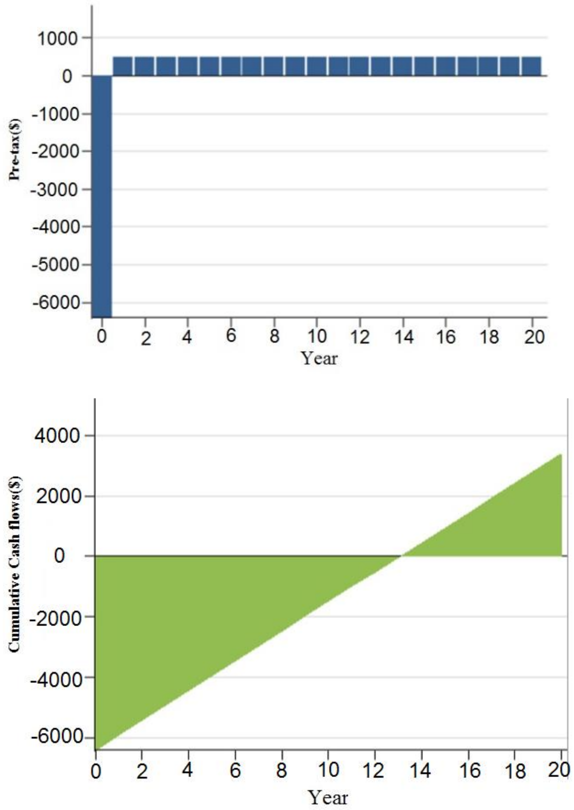


Figure 8. Chart of cash flow and capital accumulation of using solar electric system

The results of economic calculations are also presented in Table 21.

As it is clear in Table 21, this solution is not economical under any economic terms due to the IRR below the bank rate and negative NPV. In this next stage of calculations, a subsidy rate of 50% from the government is considered for this solution. Therefore, the investment cost is assumed to be 3200 $. Based on this, the table of economic calculations is presented in Table 22.

Table 22. The results of the economic analysis of the implementation of the solution of using the solar electric system with a 50% subsidy

Financial Viability	Unit	Value
Pre-tax IRR-equity	%	14.2
Pre-tax MIRR-equity	%	5.8
Pre-tax IRR-assets	%	14.2
Pre-tax MIRR- assets	%	5.8
Simple payback	year	6.5
Equity payback	year	6.5
Net Present Value (NPV)	$	-578
Annual life cycle saving	$/year	-108
Benefit-Cost(B-C) ratio		0.82

As it is clear in table 22, even with this subsidy, this solution is not economical in any way due to the IRR below the bank rate and negative NPV. By doubling the electricity purchase price by 1.5 by the Ministry of Energy and without subsidy, economic calculations have been made again for this solution, and the result is presented in Table 23.

Table 23. The results of the economic analysis of the implementation of the solution of using the solar electric system with an increase of 1.5 times the electricity purchase tariff

Financial Viability	Unit	Value
Pre-tax IRR-equity	%	10.2
Pre-tax MIRR-equity	%	4.4
Pre-tax IRR-assets	%	10.2
Pre-tax MIRR- assets	%	4.4
Simple payback	year	8.4
Equity payback	year	8.4
Net Present Value (NPV)	$	-2319
Annual life cycle saving	$/year	-433
Benefit-Cost(B-C) ratio		0.64

As it is clear in Table 23, even with the increase in the purchase price, this solution is not economically viable due to the IRR below the bank rate and the negative NPV. Now, with a 50% subsidy and a purchase price of 1.5 times, this solution is evaluated. The result of this task is presented in Table 24.

Table 24. The results of the economic analysis of the implementation of the solution of using the solar electric system with an increase of 1.5 times the electricity purchase tariff and 50% subsidy

Financial Viability	Unit	Value
Pre-tax IRR-equity	%	23.5
Pre-tax MIRR-equity	%	8.1
Pre-tax IRR-assets	%	23.5
Pre-tax MIRR- assets	%	8.1
Simple payback	year	4.2
Equity payback	year	4.2
Net Present Value (NPV)	$	889
Annual life cycle saving	$/year	166
Benefit-Cost(B-C) ratio		1.3

As it is clear in table 24, with the increase in the electricity purchase price by the Ministry of Energy and also the 50% subsidy, this solution is on the border of being economical.

CONCLUSION

In this research, an economic analysis was conducted on various aspects of a broiler farm in Ardestan city, located in the Isfahan province. This included the architectural considerations, as well as the utilization of both solar thermal and solar electric systems. The study then proceeded to evaluate the economic feasibility of implementing architectural solutions in comparison to the global gas prices and the actual gas rates within the country. Additionally, the economic viability of adopting the solar thermal system was examined, both with and without factoring in the cost of an underfloor heating system, considering the global gas prices and the domestic gas rates. Furthermore, the research delved into the application of the solar electric system under different scenarios, such as with a 50% government subsidy, an increase of 1.5 times the electricity purchase tariff, and without any subsidy. All of these analyses were carried out using the RETSCREEN software. The outcomes of this research are outlined as follows: The internal rate of return in architectural solutions using double-glazed windows and wall insulation was estimated to be 53.1% considering the global gas price. Since this amount is more than the bank profit of 18%; Therefore, this solution is economically viable. The return on investment is equal to 2.6 years, taking into account inflation and discount rates. This marks the break-even point for investing in this solution. Moreover, when accounting for the domestic gas price, the internal rate of return was calculated to be 21.4%. This suggests that the solution lies at the threshold of economic feasibility under local conditions.

1- By using the solar heating system and without considering the cost of the floor heating system, the IRR value is equal to 34.1% and since this value is more than the bank interest of 18%; Therefore, this solution is economically very affordable. The return on investment is equal to 4.5 years, taking into account inflation and discount rates. Using the solar system, taking into account the cost of the underfloor heating system, the IRR value is equal to 27.9%, and since this value is more than the bank interest of 18%, this solution can be economical in terms of these conditions. The return on investment is equal to 5.7 years, taking into account inflation and discount rates. In this case, this solution comes with various risks. For example, the lifetime of the solution is considered to be 20 years, and the break-even point is equal to 5.7 years. This system must work for 5.7 years without failure and have no side costs so that this solution can continue to be economical. Using the solar thermal system, taking into account the real price of fuel, taking into account the real price of fuel in the country, the IRR value is equal to 10.2%, which means that this solution is not economical under any circumstances.

3- In using solar electric system with IRR equal to 4.4%, this solution is not economical under any circumstances due to IRR below the bank rate and negative NPV. In using the solar electric system with a 50% subsidy from the government, because the IRR is equal to 14.2% below the bank rate and the negative NPV is not economically under any circumstances. In using the solar electric system with a 50% subsidy from the government and a 1.5-fold increase in the electricity purchase tariff; this solution is on the border of being economical.

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