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Investigating the Efficiency of Energy Saving with the Hybrid Solar System Compared to Fossil Fuel Heating

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Abstract: *Among the thermal applications of solar energy, hybrid solar systems have attracted greater attention in the world both technically and economically in comparison with other thermal applications of solar energy. The reason for this preference is that these systems need a medium temperature to provide hot water and solar heat, and this temperature can be provided by using a flat collector which is cheaper than any other collector. Various hybrid solar systems are used in residential buildings whose financial and thermal efficiency depends on different factors. One of the most important factors affecting the performance of a system is the type of fuel used in the building. This study aims to investigate the efficiency of energy-saving by a hybrid solar system compared with the fossil fuel heating and the analysis of the thermal and financial performance of a floor heating system. In this research, a typical building (i.e., a bungalow considering the abundance of this building in Iran) in Tehran has been considered. This building is studied with three systems, and the thermal load, equipment sizing, gas, diesel, and energy consumption and other energy factors are investigated in each case. For this purpose, the typical building was modeled in different configurations by DesignBuilder and Carrier software. Different study states include using a hybrid solar system, fossil fuel heating system using natural gas package, fossil fuel heating system with engine room (powerhouse) and diesel fuel. Finally, the annual savings rate of gas and diesel consumption and Payback period are compared with cases mentioned above and the case of fossil fuels alone. The results show that a combination of the solar system, fossil power system, and natural gas is not very affordable enough for buildings with natural gas pipelines; however, a combination of the solar system is economically feasible for buildings with diesel fuel and central heating. Furthermore, from a global perspective, it is also considered that, if fuel prices, including natural gas and diesel, are considered to be equivalent to their export prices, the payback period will be economically justifiable.*

Keywords: *Solar floor heating system, Energy saving, DesignBuilder software, Carbon dioxide emissions, Payback period.*

INTRODUCTION

According to the crisis of depletion of non-renewable energy resources such as fossil fuels, increased greenhouse gases in the atmosphere, global warming, and climate change show that human beings will be in great danger in the future. A large part of climate change is due to the widespread use of fossil fuels and the resulting CO_2 emissions. To achieve sustainable energy resources, it seems necessary to search for solutions based on non-renewable energy resources.

The sun is the source of different energies that exist in nature. Fossil fuels are one of the most important energies. While other sources of energy such as nuclear energy were used a long time ago, its costly and high technology, as well as its potential risks have contributed to using of solar energy more than other energies.

According to the 2004 energy supply balance, residential buildings consume a large portion of the country's energy (i.e., about 40%). For this reason, in countries like Germany, Sweden, Italy, etc., special mandatory laws have been formulated for building construction and application of thermal insulation, improvement of heating and cooling method, and the general structure of building to optimize energy consumption. The implementation of these cases has resulted in a significant reduction in energy consumption in buildings. In 1991, technical regulations were developed for the building envelope for the first time in Iran (entitled: article 19 of the national building regulations). Although Iran is an energy exporter to different countries, its real value is not being paid by consumers. Therefore, the existing buildings in the country do not have the necessary standards, and mass housebuilders do not pay attention to this issue. All of these factors have led to uncontrolled energy consumption in the country. To prevent this trend, due to different factors, several solar energy utilization methods are considered to be used for building heating, which is referred to in this study.

Problem statement and theoretical literature

Solar systems, which are used both for hot water supply and environment heating, are called hybrid solar systems. These systems are derived from a combination of conventional thermal systems and solar collectors. In residential units in Iran, the contribution of energy to supply hot water and heating is about 54% according to the published statistics (Karbasi, et al., 2005). Accordingly, using these systems can play a decisive role in reducing energy consumption in the building. Thus, regarding an increased amount of investment required for these systems, as well as energy-saving, these systems can be extensively used more than solar water heaters. Solar systems, which are used for hot water supply and environment heating, are called hybrid solar systems. These systems are derived from a combination of conventional thermal systems (floor heating, or solar radiator collector). In these systems, low-temperature (i.e., floor heating) systems are usually used to have more efficiency.

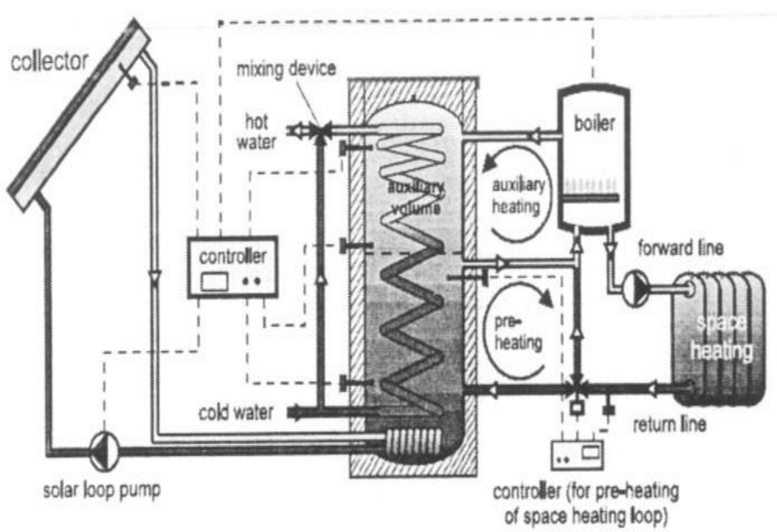


Figure 1. A schematic of a typical hybrid solar system

The components of hybrid solar systems are stored in some cases with solar heaters. Here are some items that should be considered in designing resources:

- Thermal classification in water conservation storage – the collector - designing the depletion system.

The fundamental difference between different hybrid solar systems involves differences in the conservation storage and the principles of thermal load management that are addressed by the system designer:

Selection of produced thermal energy storage from the auxiliary system or lack of thermal energy storage, the number of conservation storages, designing the number of rings or the ring in which the fluid reaches a thermal energy conservation storage, the type of heat exchangers used to transport heat from one medium to another, geometry of the inlet valve to the conservation storage and the fluid flow used which are both effective in mixing sources, the shape of mechanical classifiers used for more comfortable classification, the control algorithm used, and the conservation storage dimensions.

Some of the most important advantages of floor heating using solar energy are the compatibility of this type of energy with the environment, lack of greenhouse gases as a result of using this kind of energy, the conservation of limited energy resources, and the fixed cost of solar energy usage.

There are generally three types of floor heating methods:

1) hot-air floor heating system, 2) electrical floor heating systems, 3) hot-water floor heating system.

The hot-air floor heating system is not cost-effective because the air cannot keep a lot of heat in itself.

The electrical floor heating systems are cost-effective only if the power supply is nuclear energy to reduce the cost of electrical energy. In comparison with the two methods, the hot-water floor heating system can be highly cost-effective. Nowadays, in the floor heating systems, the hot water with a temperature less than the required temperature by the radiator is used. In this system, in the construction stage, Δt of water sweep is determined considering the building thermal load as well as pump and boiler expenditure, etc., designing volume and number of pipes, and discharge of water passing through it. Then, it is carried out by dividing the desired space into several parts to control more easily with zoned spaces, and then the floor is well insulated. In the next step, the walls will be insulated if necessary and finally, depending on the finished floor and the top surface (e.g., ceramics, wood, stone, etc.) the size of the concrete is determined by the mortar placed on the system, and eventually, the system will be designed.

Research background

So far, there have been many developments in the field of water supply and building heating. In conventional heating methods, up to 70% of heat is collected near the ceiling and near the floor has a lower temperature. These environmental conditions do not match human comfort; the experiments have shown that the conditions of desirable human comfort are when the lower part (i.e., the sole) is hot, and the upper part (i.e., the head) is cool, so the heat must be produced where we need more, i.e., on the floor.

In the floor heating system, the hot water flows from the network of special tubes underneath the floor distribute heat slowly. Since the tube covers the entire floor, the heat distribution is completely uniform. In this system, instead of heating the air, the bodies and the inhabitants of the building are warmed. Due to radiation energy and lower water temperatures, the reduction in heat loss is considerable, and energy consumption in this system is 25-35% less than the other methods. Flat plate collectors were first used to provide hot water in areas with suitable radiation intensity. The first design of the solar system for heating was introduced in the early 1970s in France (Solvis Company). In these systems, the flat plate collectors were used to provide the required temperature of heating, but due to the use of conventional heating systems such as the radiator and the need to bleed to relatively high temperature (about$70^{o}c - 80^{o}c$) the need for a large area of solar collectors. In the next designs, the use of vacuum tubes was proposed, but these projects were not met with good reception due to high cost. With the development of hot water systems in the late 1970s and due to low water temperatures required for this system, the discussion of these systems was introduced, and several companies such as SonnenKarft, Solaris, Baltec developed various designs according to different climatic regions and achieved significant results.

Several articles in this regard have been proposed, including:

Comparison of floor heating systems using solar collectors using solar pools: There is a comparison between heating systems with the intake system and the floor heating system with the solar system and powerhouse, and the costs of the two design are compared.

Application of the hybrid solar collector and heating system with the package (in the solar center, 2001): in this paper, the design of the solar system and floor heating system and the thermal package and how the system operates.
Comparative study of some hybrid solar system designs (Druck, Heidemann and Muller-Steinhagen, 2004): in this paper, some hybrid solar systems designs have been studied in different directions such as construction technology, cost and return.
The dimensions and sizes of hybrid solar systems (Lund, 2005). In this paper, some projects of hybrid solar systems that have been installed in different regions of Europe have been compared and illustrated with low efficiency of hybrid solar systems in the colder regions but due to their relatively large savings in fuel consumption, the time of the return of capital in these regions is far less.

- Modeling of floor heating and cooling systems (Strand and Baumgartner, 2005)

In this paper, a model is developed based on a well - known software.

- Sattari and Farhanieh investigated the effect of design parameters on system performance in a parametric study on the performance of the heating system (2006).

Research Method

The research is theoretical - applied. By gathering information and processing them by air conditioning principles, calculation of solar energy and considering the importance of saving energy in buildings and finally using technical and economic principles, a comprehensive analysis was provided. This building has been studied and compared in two different modes with hybrid solar heating and heating with fossil fuel (packages) and diesel (powerhouse). The modeling of the building model has been performed by Design Builder Software.

Steps of conduct survey:

Studying the potential of the country for the use of solar energy
Excavation of a sample structure
The energy modeling of the sample building in the states considering the use of software?
Designing the hybrid solar system for the desired building
8.4 economic review of plan and calculation of payback time with different scenarios
After the above steps, an economic analysis method called the return of capital is estimated to be optimal.

Results and Findings

Thermodynamic model of floor heating

According to the second law of thermodynamics and considering the principle of increasing entropy, always during the processes, some of the work or energy given to systems is wasted due to the existence of irreversibility factors. To optimize energy resources and increase the efficiency of systems, it is necessary to identify the irreversibility factors, as much as possible to correct them., Unlike the first law, which has a very limited look at energy sources, the second law of thermodynamics offers more to the entropy generated during a transformation and waste of work, and thus offers a wide range of fields for modification and development of energy conversion systems. A comparison measure is required to compare the efficiency of the systems with the efficiency of fully integrated systems. Therefore, the definition of the return of the second rule is as follows:

$$\eta_{\mathrm{II}} = \frac{\eta_{th}}{\eta_{rev}} = \frac{COP}{COP_{rev}}$$

Therefore, the return of the second law indicates how closely the performance of the designed systems is closely related to the performance of the ideal and fully integrated systems. To investigate the effect of the thermal structure, the radiation coefficient of the internal surfaces and floor coverage on the irreversibility of heat exchange processes in the hydronic floor heating systems, and comparing the performance of ideal heating devices such as heat pump, is necessary to provide a simple model for these systems. Most of the building heating systems, whether floor heating or hydronic heating, can be likened to heat exchangers. We also use a non-adiabatic heat exchanger with two non-complex flows for modeling heating systems from the hydronic floor. In most of the heating systems, whether in convection or heat, heat enters the building through the flow of hot fluid. It should also be a part of room air with fresh air in all air conditioning processes to provide adequate supplies within the building and to maintain air quality depending on the conditions of the space application. To evaluate the heating systems from the radiation and ceiling, we used the above models for a cubical room of 3 m. In these studies, we have assumed that all the walls and ceiling of the chamber are external. The temperature outside of the room is 5 - and the temperature of an intrusion into the room is 0 ° c. The heat transfer coefficient outside the room is also w / m2k). The radiation emission coefficient of all surfaces was 0.9. In all cases, thermal comfort conditions are calculated for a person in a resting position on a table with typical clothing of 50 % relative humidity. The average velocity of the airflow inside the chamber is considered to be equivalent to 0.15 meters per second in terms of the intensity of the flow of airflow. All calculations are carried out for two different thermal resistance r = 1.5 m2k / w and r = 3 m2k / w for the lateral surfaces of the building.

Sample building selection to investigate hybrid solar heating system

According to the frequency of the use of single-story buildings in Iran, the building is considered as a sample of this type. The sample building is located in Tehran. The plan of the sample building is an example of the following image.

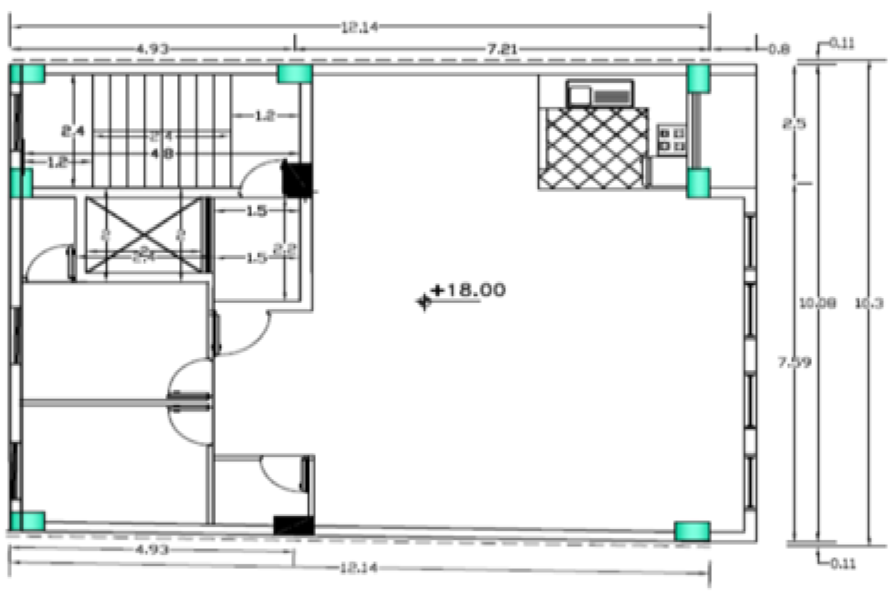


Figure 2. The sample unit typical plan

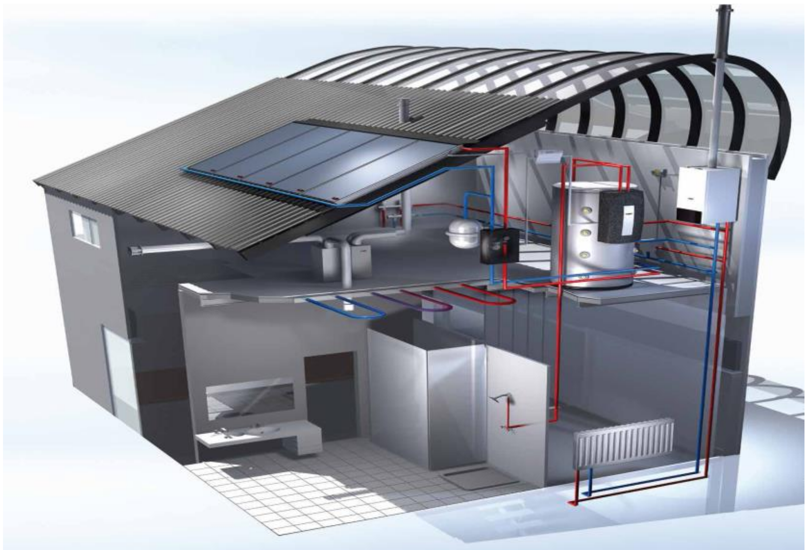


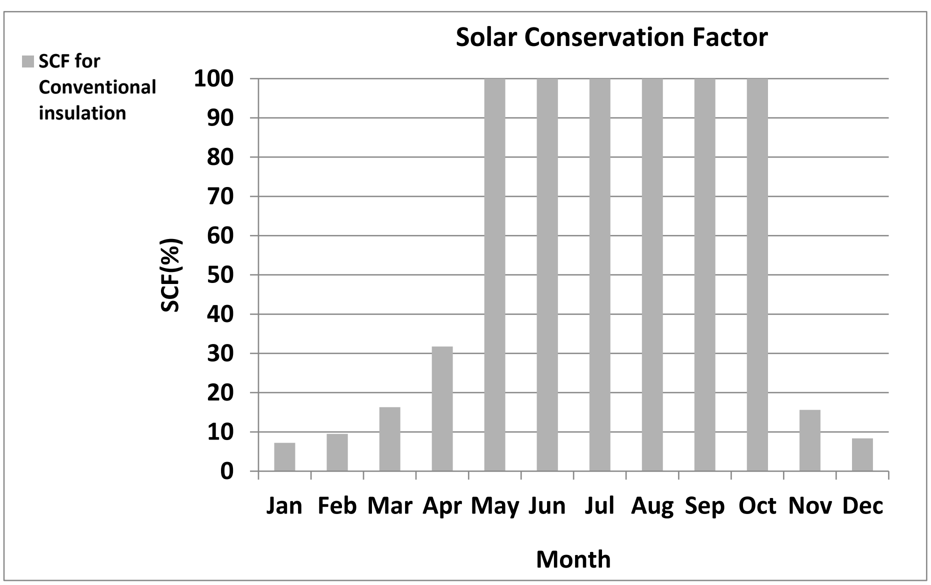
Figure 3. The layout of the hybrid solar system in the villa building

The contribution of solar energy comes from the following equation:

2) $Scf = \frac{e_{co}+E_{win}}{Q_h+Q_{dhw}}$

E_{co}: The energy from the collectors
E_{win}: The energy from windows
Q_h: The thermal energy required for heating the environment
Q_h: The thermal energy required for hot water

The below graph shows the average share of solar energy per year in different building units.



Graph 1: The average solar energy contribution of the sample building in different months

In addition to determining the contribution of solar energy, the amount of energy saved by solar panels is also calculated.

The solar collector which has been studied in this study produces an average of 1700 $\frac{btu}{hr}$ thermal energy per square meter in cold months of the year.
Therefore, with three 2-m panels, about 10,200 $\frac{btu}{hr}$ thermal energy is produced.

The calculation of the cost of implementing the heating system from the combined floor.

The cost of all proposed parameters is calculated to determine the cost of the hybrid solar system. According to the selected hybrid solar system (scheme 4), the use of the water supply source as the conservation storage for heating the environment (CS), the equipment required for each unit is as follows:

A) The collector: The cost of each collector panel is estimated to be approximately 12,000,000 million Rials based on the specifications expressed in Table (8, 6).
B) The floor heating system: description and explanation of this system were mentioned in the previous chapters. The cost estimation of the system for each unit is as follows.
C) Thermal energy conservation storage: The volumetric conservation storage is the amount of consumed energy and the necessary amount of water heating in the ambient heating system.

The volume of water intake (calculated in chapter 5): $v_1 = 90\text{lit}$
Required volume for water heating:
This volume is at least equal to the total volume of water available in the heating pipe, which is calculated as follows:

$$V_2(M^3) = \pi \frac{d^2}{4} l$$

$$3)\ V_2 = \pi \times \frac{0.016^2}{4} \times 470 = 0.094m^3 = 94\text{litres}$$

$$V_t = 94 + 90 = 184 \text{ litres}$$

Therefore, 300-liter conservation storage is chosen for the sample unit, and its cost is estimated at 5.000.000 Rials.

D) The circuit control systems: The cost of control systems are very high as they are not produced inside the country and are estimated at 30.000.000 Rials.

The cost of renewable energy is very high; given that they are not produced domestically. The cost of each one of them is estimated to be 5.400.000 Rials.
Other items: other items are determined exactly after determining the area of the solar collector, and their cost does not contribute significantly to the total cost of the system.
To determine the optimum amount of solar collector at this stage, the number of guessed numbers are estimated.
In light of some empirical results, the areas of 5, 8, 10 are predicted:
According to the stated areas, two decisive factors are calculated for them:
We now compute the amount of energy saved when using the solar system:
The amount of energy required by the building is according to the following table:

Table 1: The amount of energy required by the building

Month	Thermal energy needed in terms of heating (GJ)	The thermal energy required for heating (BTU) * 10^3	Water use energy (BTU) * 10^3	Total thermal energy (BTU)* 10^3
January	16.02	15184.03	1478.5	16671.53
February	13.38	12681.8	1478.5	14169.3
March	9.81	9298.1	1478.5	10785.6
April	5.1	4833.9	1478.5	6321.4
May	1.28	1213.2	1478.5	2700.7

June	0	0	1478.5	1487.5
July	0	0	1478.5	1478.5
August	0	0	1478.5	1478.5
September	0	0	1478.5	1478.5
October	0.257	243.6	1478.5	1731.1
November	7.438	7049.9	1478.5	8537.4
December	13.52	12814.5	1478.5	14302
Total	66.80	63315.03		81168.5

Table 2 shows the amount of energy received by a solar collector based on BTU.

Table 2: The energy received from solar collectors

Month	$Q(\frac{mj}{m^2d})$	$Q(\frac{mj}{m^2d})$* the number of days of the month * collector area.	Q(kbtu)
January	6.1	1134.6=6*31*6.1	1075.4
February	6.67	1160.58=6*29*6.67	1100
March	8.6	1599.6=6*31*8.6	1516.2
April	8.8	1584=6*30*8.8	1501.4
May	9.5	1767=6*31*9.5	1674.8
June	10.4	1872=6*30*10.4	1774.4
July	10.06	1871.6=6*31*10.06	1871.7
August	9.98	1796.4=6*31*9.98	1702.7
September	9.09	1636.2=6*30*9.09	1550.8
October	8.97	1668.42=6*31*8.97	1581.4
November	6.13	1103.4=6*30*6.13	1045.8
December	6.08	1130.88=6*31*6.08	1071.8
Total			17466.4

Now, we observe the amount of energy saving per month if the hybrid system is used in Table 3.

Table 3: The amount of energy-saving per month if the hybrid system is used

Month	Q (kbtu) thermal energy Required:	Q (kbtu) the energy received from the sun	Q (kbtu) the amount of fossil energy required by the hybrid system
January	16671.53	1075.4	
February	14169.3	1100	15596.13
March	10785.6	1516.2	13069.3
April	6321.4	1501.4	9269.4
May	2700.7	1674.8	4820
June	1487.5	1774.4	1025.9
July	1487.5	1871.7	0
August	1487.5	1702.7	0

September	1487.5	1550.8	0
October	1731.1	1581.4	150
November	8537.4	1045.8	7491.6
December	14302	1071.8	13230.2
Total	81169.3	17466.4	64652.53

To determine the cost of investment, the cost of the hybrid solar system must be calculated. Hence:
Since the cost of other items is insignificant, and depending on the number of solar collector for the same sample structure, they are excluded from their calculations at the finished price.
C) Price estimation of hot water pipeline system with super pipeline
In this system, hot water piping is based on the use of the superpipe tube.
The total cost estimation is calculated according to Table 4:

Table 4: The cost estimation of the cost of the hybrid solar system with 6 square meters of solar collector for a sample unit with conventional insulation.

No.	Description	Division.	Value	Unit price	Total price (Rial)
1	Collector panel	Number	3	12.000.000	34.000.000
2	Panel installation	-	2	1.000.000	2.000.000
3	300 - liter storage tank	Number	1	5،000،000	5.000.000
4	Control system	Number	2	10،000،000	20.000.000
5	Electric valve$\frac{3"}{4}$	Number	2	5،400،000	10.800.000
6	Motorized two-way valve	Number	2	2،400،000	4.800.000
14	30 - liter expansion tank	Number	1	3،000،000	3.000.000
15	.$\frac{3"}{4}$ iron pipe	6-m beam	10	250،000	2.500.000
16	Pipe insulation foam	Meter	56	85،000	4.760.000
17	Total solar system cost per unit				86.860.000

Based on the calculation of the investment cost:

Table 5: Estimating the cost of investment in the sample building.

Town	Tehran
Type of insulation in the building	Normal insulation
Fuel type	Gas
The cost of the hybrid solar system (Rial) with 6 square meters of solar collector	59.860.000
Cost of the hybrid solar system (Rial) with 8 square meters of solar collector	98.860.000
Cost of the hybrid solar system (Rial) with 10 square meters of solar collector	11.860.000

The economic survey of the plan
In this section, the usability of the hybrid solar system in each state is investigated.
For this reason, two important economic indices are defined:
1) Net Present Worth 2) Payback Time
Payback time is the time in which the system generates the net present value of the system:

4) $Npw = p - c_o - C_{op}$

5) $\frac{P}{i} = f(i,d,n) = \frac{I}{i-d}[\left(\frac{I+1}{d+1}\right)^N - 1]$

P: equivalent value of all saved fuel

6) $P = i \times f(i,d,n)$

$f(i,d,n)$: Coefficient of longevity combination, discount rate and inflation rate.

I: the value of the fuel stored in the baseline year

I: inflation rate d: discount rate

C_o: Additional investment cost for optimization

C_{op}: Maintenance cost

To compute the operational cost of the system and return it to the present time, the investment is in the following way:

7) $Npw = i \times f(i,d,n) - C_o - C_{op}\frac{(1-d)^N - 1}{d(1+d)^n}$

To compute the payback time of the capital, it is sufficient to solve the NPW = 0 equation in terms of unknown *n*, which is done in an attempt and error method.

Social cost

Heat production is associated with social costs mainly imposed on people who have no role in its production (Saeedi et al., 2005). These costs are formed when the economic activities of one or more groups negatively affect the destruction of environmental impacts such as direct environmental impacts (such as emissions), destruction of ecosystems, and other groups. For calculating the moment of social costs, the value of environmental units must be recognized, and the impact of pollutants on environmental units is estimated.

The social costs associated with the consumption of fossil energy carriers in the country are expressed in 2004 for various pollutants in the annual energy balance sheet. These costs are calculated based on the studies conducted by the World Bank and the Iranian Department of Environment as well as US EPA coefficients. Hence:

Table 6: Social cost resulting from emissions in the domestic, commercial, and public sectors (billions of Rials) (Ministry of Energy, 2004).

Social spending caused by pollutants in the domestic, commercial and public sectors (billions of Rails)	No_2	So_2	Co_2	Co	CH	SPM
According to The Word Bank and the Iranian Department of Environment	491	1289	2574	110	6	376
Based on US EPA coefficients	5281	621	17157	×	×	×

Table 7: The emission rate of pollutants from the domestic, commercial and public sector by fuel type [tones] (Ministry of Energy, 2004)

Fuel / gas	No_x	So_2	Co_2	So_3	Co	Ch	Spm
Fuel oil	13901	21748	4139718	332	5	555	1390
Gas oil	15180	47665	8039328	607	607	911	3036
White oil	3825	18362	18476441	-	5968	-	-
Gasoline	1724	192	296647	-	44695	84045	166

Natural gas	66446	266	70864659	-	8904	1961	6346
Liquid gas	1268	27	5414885	-	12680	857	-
Total	102344	88260	107231678	939	72859	12329	10938

Based on the above tables, each ton of carbon dioxide emissions from the total annual social cost of emissions are produced (Table 6) on the annual total pollutant emissions per unit (Table 7, 2).
Thus, the social cost of each ton of Co_2 emission based on the study of the World Bank and the Iranian Environment Department is 24.004 Rials, and according to the EPA's coefficients is 160.000 Rials.
Since in the investigation of the World Bank some factors include soil erosion and deposition, etc., and in general, some ecosystems services based on Table (8) have been neglected and only the cost of pollution control has been considered, therefore to examine the better, the social costs, its rate is considered to be based on EPA's coefficients.

Table 8: Types of service provided by the World Bank and the environment organization

No.	Services	Example
	Regulation of gases	Regulation of oxygen, nitrogen, and carbon dioxide are available to protect against UV
	Set climate conditions	Controlling the temperature of the world, rainfall, control of greenhouse gases
	Turbulence control (regulating the response of ecosystems to fluctuations)	Flood control, drought compensation
	Water regulation (hydraulic flow regulation)	Agricultural water supply
	Preparation and water supply	Water provision and supply
	Soil erosion control and Sedimentation	Avoiding soil waste by the wind, etc.
	Soil formation	stone and rock outwear
	Nutrient cycling	Fixing nitrates, Phosphates, and other substances
	Pollen	Pollination for reproduction of plants
	Biological control	Population control of different species
	Create a shelter	Creating habitats for immigrant populations
	Food production	Fish production, animals for grain hunting, fruit
	Raw material	Wood, fuel and fodder production
	Genetic resources	Resources, drugs, biological products, medicine, genes,
	Recreation	Ecotourism, entertainment fishing
	Cultural	Creating opportunities for non - commercial, aesthetics, art, and education application

Calculation of carbon dioxide emissions

Carbon dioxide is produced for every fuel by its reaction to oxygen.

$$8)\begin{cases} Ch_4 + 2o_2 \rightarrow Co_2 + 2h_2o \Leftrightarrow 16 + 64 \rightarrow 44 + 36(kg) \\ c_{16}H_{34} + 25(o_2 + 3.76n_2) \rightarrow 16co_2 + 17h_2 + 94n_2 + 0.5o_2 \Leftrightarrow 226 + 800 + 2632 \rightarrow 704 + 306 + 2632 + 16(kg) \end{cases}$$

The equation for calculating the entropy produced in the radiation of the grey object per kilogram of natural gas is estimated to be 2.75 kg Co_2.
For instance, in the sample building:
If you use gas:
The amount of fuel consumed is calculated as follows.
Average torch performance: 75%
(9) Conversion factor * torch performance * thermal value / required heat = annual consumption gas (m^3)

$$\text{gas}(m)^3 = \frac{(\text{btu})}{1055\,\frac{\text{btu}}{\text{ft}^3} \times 0.75 \times 35.31\,\frac{\text{ft}^3}{\text{M}^3}}$$

For example, in the sample building in case of using only the gas fossil fuel:

$$\text{gas}(m)^3 = \frac{81169300(\text{btu})}{1055\,\frac{\text{btu}}{\text{ft}^3} \times 0.75 \times 35.31\,\frac{\text{ft}^3}{\text{M}^3}} = 2905.2$$

The amount of gas consumption in case of using a hybrid solar system in the building:

$$\text{gas}(m)^3 = \frac{64652530(\text{btu})}{1055\,\frac{\text{btu}}{\text{ft}^3} \times 0.75 \times 35.31\,\frac{\text{ft}^3}{\text{M}^3}} = 2314.05$$

As a result, the amount of fuel saved for natural gas is:

$$2905.2 - 2314.05 = 591.15(m)^3$$

Thus, on average per year, the gas fuel consumption is reduced by around 591.15 m^3, depending on $0.66\,\frac{kg}{m^3}$ Co_2natural gas density, its weight is about 400 kg weight, thus CO_2 gas amount is reduced by 1.1 tons.

$$\text{Social cost} = 1.1 \times 160000 = 176000 \text{ rials}$$

Thus, by reducing fuel consumption, the social costs caused by its pollutants is reduced as well.
Now, if the effect of social spending cuts on return of capital is considered:

$$\text{Npw} = (\text{i} + \text{social cost}) \times f(i, d, n) - C_o - C_{op}\,\frac{(1+d)^n - 1}{d(1+d)^n}$$

Cost of fuel consumption reduction

A) The cost of reducing gas fuel consumption can be considered in two ways:
1 - at a domestic rate, 2 – at a global rate.
In this study, the price of each cubic meters of natural gas in the domestic sector in climate 3 of Tehran is considered as 840 Rials in 2015
B) The cost of reducing the consumption of diesel fuel.
In the second case, it is assumed that 100% of the thermal energy required is provided by diesel fuel.

A) Cost of reducing gas fuel consumption

Table 9: Gas tariffs for households in cold months of the year 2014
(November 7, 2014 to April 4, 2015)

consumption domain	1	2	3	4	5	6	7	8	9	10	11	12
Climate 1 (m^3)	Up to 300	301-	401-	501-	601-	701-	801-	901-	1001-	1101-	1201-	Above

		400	500	600	700	800	900	1000	1100	1200	1300	1300
Climate 2 (m^3)	Up to 250	251-350	351-450	451-550	551-650	651-750	751-850	851-950	951-1050	1051-1150	1151-1250	Above 1250
Climate 3 (m^3)	Up to 200	201-300	301-400	401-500	501-600	601-700	701-800	801-900	901-1000	1001-1100	1101-1200	Above 1200
Climate 4 (m^3)	Up to 150	151-250	251-350	351-450	451-550	551-650	651-750	751-850	851-950	951-1050	1051-1150	Above 1150
Gas price per each m^3 (Rials)	**440**	**640**	**840**	**1040**	**1240**	**1740**	**2040**	**2340**	**2640**	**2940**	**3340**	**3640**

The maximum average price per cubic meter is 1800 Rials.
Gas tariffs for households in Climate 1 and 2 are for October 23, 2014 to April 20, 2015 the following year.
In addition to the above-mentioned rates, according to clause (h), note 2 of the single article of the state budget law of 2014, the amount of 130 Rials will be received per cubic meter of natural gas.

Table 10: Comparison of annual fuel costs (domestic rate) in sample units

Annual Gas Cost (Rials)	Conventional Insulation (Rials)
Fossil Fuel heating	2.440.368
Solar radiant floor heating	1.943.802
Amount of money consumed	496.566

And based on the international rate:
Regarding the international rate (export), the price of one cubic meters of natural gas in the domestic sector is considered as equal to 4500 Rials. In Iran, the gas rate dedicated to industries is considered 345 Tomans.

Table 11: Comparison of annual fuel expenditure (international rate) in sample units

Annual Gas Cost (USD)	Conventional Insulation (Rials)
Fossil Fuel heating	13،073،400
Solar radiant floor heating	10،413،225
Amount of money spent	2،660،175

B) Reducing the cost of fuel using diesel fuel:
In the second case, 100% of the thermal energy required is supplied by gasoil; in this case, the fuel consumption is calculated as follows.
Average torch performance: 60%
(Conversion factor * torch performance * thermal value) / Heat required = amount of gasoline consumed annually (m^3)

$$\text{Gas}oil(\text{m})^3 = \frac{(kcal)}{9600\,\frac{kcal}{kg} \times 0.6 \times 835\,\frac{kg}{M^3}}$$

For example, in the sample building, we use only diesel fuel:

$$\text{Gas}oil(\text{m})^3 = \frac{(20292325kcal)}{9600\frac{kcal}{kg}\times 0.6\times 835\frac{kg}{m^3}} = 4.21\text{m}^3$$

The amount of gasoil consumption in case of using solar mixed hybrid systems:

$$\text{Gas}oil(\text{m})^3 = \frac{(16163132kcal)}{9600\frac{kcal}{kg}\times 0.6\times 835\frac{kg}{m^3}} = 3/2\text{m}^3$$

The amount of diesel saved per year is one cubic meter or 1,000 liters per year that considering each liter of diesel at the free price, it will be 60,000 Rials. Therefore, the cost of the saved diesel fuel is estimated in case of using the hybrid solar system per year as = 6000 * 1000 = 6000.000 Rials.

Table 12: Comparison of annual cost saving of diesel fuel in the sample unit

Annual Gas Cost (Rials)	Conventional Insulation (Rials)
Fossil Fuel heating	25‹260‹000
Solar radiant floor heating	19‹200‹000
Amount of money spent	6‹060‹000

Calculating the payback time

Thus, the economic analysis of the solar system is carried out in two cases.

The first scenario: the considered area is equipped with gas pipelines and the system used is working with gas fuel and power house, and the comparison between the fossil system and mixed solar-hybrid system is conducted.

Second scenario: the study area lacks the urban gas pipelines, and the system used is working with gasoil and powerhouse, and the comparison between the fossil system and mixed fossil-solar system is conducted.

In both approaches, the impact of environmental costs on the comparisons has not been considered because, as seen, it has low effect.

Table 13: Typical calculations of the economic analysis of the hybrid solar system in the sample building

Parameters	Unit	Values
Additional investment cost of the combined fossil fuel system with gas fuel	Rial	000‹860‹86
Additional investment cost of a synthetic fuel system with diesel fuel	Rial	000‹860‹81
Subsidiary price of natural gas (m3 / s)	Rial	840
The global price of natural gas (m3 / s)	Cent	33
Interest rate1	Percentage	5/15
Inflation rate2	Percentage	20
Length of system life	Cent	20
Annual savings on the cost of fuel to the fossil system with insulation (at a domestic rate)	Rial	496‹440
The annual saving on gas fuel costs to the fossil system with regular insulation (at a global rate)	Cent	19.503

[1]Information published in Statistical Center of Iran, 2006
[2]Information published in Statistical Center of Iran, 2006

Annual savings on the cost of fuel to the conventional insulation system (at a domestic rate)	Rial	6.060.000
Annual savings in the cost of diesel fuel relative to the hybrid system (at a global rate)	Rial	3.413.520

Conclusion

The heating system of the hybrid solar system for the sample building was investigated in comparison to the two modes of the fossil system with natural gas fuel and the fossil fuel system with diesel fuel. Considering the amount of energy saving on fuel consumption, natural gas conservation is estimated to be about 591 cubic meters per year due to the low price of natural gas in the country (climate 3 of Tehran city about 840 Rials), so that the return of capital will not be possible during the system lifetime. However, compared to the global price of natural gas, the hybrid solar system will find greater economic justification. Regarding the comparison of the hybrid solar system with the fossil fuel with diesel fuel used in areas where gas plumbing does not exist, and the residential house is equipped with the powerhouse. So that 1,000 liters of gasoline are saved annually. So, according to the free price of gasoline prices for the housing units, the initial capital will be compensated for about 11 years. This will increase its impact by considering the international price of fuel. Therefore, due to the increasing sensitivity of energy conservation category and the price of fuel carriers, the global economic justification of the system will be more than ever. The other issue that has to be considered is environmental costs caused by pollutants. The application of this system will reduce the reduction of social costs by reducing fuel consumption. In the meantime, it should be noted that the building is a villa and that in the event of increasing the number of classes, this reduction in thermal loads can save a lot in the costs of equipment and fuel consumption.

Reference

1. Druck, H., Heidemann W., Muller-Steinhagen H., (2004). Comparison Test of Thermal, *EuroSun, 46*, 20-27
2. Karbasi, A., Shafizadeh, et al., (2005). Energy management in the building, *Ministry of Energy*, 6-20.
3. Lund P. D., (2005), Sizing and Applicability Considerations of Solar Combisystems, *Solar Energy, 78*, 59-71
4. Ministry of Energy, energy balance, (2004). 339-341.
5. Saeedi, M., Karbasi, A., et al., (2005). The environmental management of power plants, *Ministry of Energy*, 102-116.
6. Sattari S., Farhanieh B., (2006). A parametric study on radiant floor heating system performance, *Renewable Energy 31*, 1617-626.
7. Strand R. K., Baumgartner K. T., (2005). Modeling radiant heating and cooling systems: integration with a whole-building simulation program, *Energy and Buildings, 37* , 389-397.