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New Formula for Assessment of Energy Savings in Buildings; Persian Gulf Region

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ABSTRACT

When considering the high costs for providing energy, we notice the importance of energy saving methods in buildings. Many of these methods are simple and can be utilized with little cost. In this study, some of approaches to energy saving, were analyzed in 33 Parsian Gas buildings (complexes), using the ISO 50001 standard. The analyzed criteria are the profit of energy savings and also the amount of conservation based on the volume of considered building. Statistical analysis was carried out on these indexes and considering the results a formula was deduced to calculate the amount of saved energy and the cost of the analyzed methods in this study. The seen error in the formula was acceptable (R^2= 0.905513). This formula can be used for all areas around the Persian Gulf. Finally, the amount of conservation in producing environmental pollutants which come about from applying the methods of energy saving, was analyzed. Comparison of the observed data and the results, obtained from the formula, proves the validation of the formula.

Keywords: *Energy Conservation; ISO 50001; Audited Energy; Energy Saving; Parsian Gas Zone; Persian Gulf.*

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INTRODUCTION

The importance of saving energy was highlighted with the energy crisis in 1970 and has had noticeable progress in different fields up to now. In 1973 the oil producing countries vastly raised the price of oil and this caused countries to become less dependent on oil and other fossil fuels [1]. The energy crisis, forced industrial countries into providing large funds for huge researches and also to put in place policies and standards to reduce the use of fossil fuels. Reducing the use of fossil fuels not only preserves it for future generations it, also helps to reduce environmental pollution [2].

The building sector consumes about 40% of annual energy in Iran and has considerable portion in energy demand [3]. Iran is one of the main producers of oil and is well-known for consuming and producing hydrocarbon fuel resources including Crude Oil and Natural Gas. The distribution of natural gas is among a wide network and several cities of Iran are provided with natural gas. In 2011, Iran was the biggest producer and consumer of natural gas in Middle East countries. According to the statistics, carbon dioxide emission is one of the main environmental issues that Iran faces [4]. Approximately 45% of increase in the combustion of natural gas was occurred between 2005 to 2011. These statistics proves, in recent years the rising trend in natural gas consumption and carbon dioxide emission happened in Iran. Moreover, research shows that world energy consumption was increased by 58% between 2001 and 2005 [5] and the contribution of fossil fuels is approximately 80% [6]. People spend more than 90% of their time inside [7] and more than 70% of building energy consumption is consumed to support cooling systems in Middle East [8]. In US, over 50% of total energy consume in buildings for heating, ventilation and air conditioning [9]. China faces a 10% increase in building energy consumption annually for the past 20 years and in Europe approximately 40% of the energy consumption is represented in residential and commercial buildings [10, 11].

In recent studies the average use of energy in a building for each square meter has been estimated around 170 kw/hr [2]. However, this value in Iran is estimated to be 400 (kw/h) which is 2.5 times the world average [2]. Considering this high usage of energy, paying attention to make efficient use of energy in buildings is one of the necessities in the country. Climate conditions, infrastructure, financial conditions of the family, material used in the building, cultural conditions, insulation techniques used in the building, efficiency of temperature controlling systems (heating and cooling), the type of fuel used and the kind of air conditioning system used are the factors which affect the amount of energy used in building [9, 12].

A suitable approach to analyze the use of energy is auditing energy usage. ISO 50001 standard can be pointed out as one the most used auditing techniques [13]. ISO 50001 was released in June 2011, and is a policy specified by the International Organization for Standardization to monitor and help efficiently reduce and improve the use of energy in organizations. Therefore, it helps to reduce costs of energy consumption and also the amount of greenhouse gases which are released into the atmosphere [14].

A lot of studies have been carried out analyzing the energy consumptions of different building and their auditing. A study carried out in 1982 on the audit of 48 hospitals in four states in the USA. The results caused a 20% reduction on energy consumption (100 kBtu/ft^2 (1.1 GJ/m^2)) [15]. Another energy audit in a pyro-processing unit of a typical dry process cement plant showed a 40% potential saving in energy can be achieved and also a 14% reduction in the production of greenhouse gases steamed out during the processes of the plant [16-18]. Shen et al. evaluated audits that were carried out and studied them to highlight key issues and deduced policy suggestions which could lead to reducing energy consumption [19].

The increased concentration of gases which absorb infrared and trap heat, leads to a temperature increase (Greenhouse Effect). The only way to stop this change is by stabilizing the concentration of greenhouse gases such as carbon dioxide, in the atmosphere. Electricity production, with a proportion of 37.5% is the single largest source of greenhouse gases emissions [20, 21].

When taking in mind that this study is based on the use of electrical energy, considering the environmental side effects of producing electricity will be important. With the rise of worries concerning climate changes, a good understanding about the spread of greenhouse gases produced in electrical power plants with an environmental perspective is necessary. All energy systems are followed with the dispersion of greenhouse gases and are therefore involved in climate change [22].

Moreover, there are some other researches that conducted the various issues in saving energy in the buildings. Boyano et al. (2013) presented key energy use figures and studied the energy saving potentials in office buildings across Europe by simulating several currently available scenarios. They Investigated two aspects including an improvement of the insulation of the windows and the external walls (U -value) and also the orientation of the building. The results showed that the contribution of energy consumption was 46% for lighting, 23% for heating and 20% for cooling. Lighting plays the main role in energy consumption as a result of large operating time. Installing partial or total lighting results in 18% and 36% total energy savings [23].

A literature review of building life-cycle studies are investigated by Beccali et al. (2013), which highlighted that there is a strong interplay among all the phases of a building life-cycle, as each one can affect one or more of the others [24]. Other studies represent the effect of lighting optimization, daylight saving time, geometry factors, double glazing windows, caulking, and using renewable sources such as solar energy, on energy consumption [24-30].

In this study 33 buildings in the Parsian Gas area with different usage, are chosen for analyzing different methods of energy saving. With consideration of the obtained figures from this study regarding the use of energy, methods of conservation in the building, start up cost of these methods and their benefits, the methods are analyzed with a financial perspective. An experimental relationship between the amount of savings and start up costs will be stated afterwards. Taking note of the destructive effects of these gases, such as the thinning of the o-zone layer and increasing of the Earth's temperature studying the environmental effects of reducing the use of energy can highlight the importance of this reduction more than before. Therefore, the environmental aspect will be analyzed too.

2. Methods and material

2-1. Study area

The Parsian Gas area spreads over 2000 hectares, and it was set to develop the largest gas field in the world (the south pars/north dome field). This area is located at the latitude 27° longitude 52°. The lowest and highest temperatures are 5 and 50 degrees centigrade, humidity is 59-89 percent, average annual rainfall is 180mm and the dominant wind is from the north east, overall this area is described as a warm and wet location. The mean wind velocity and monthly mean temperature in the interval of 2012-2014 are shown in Table 1 and 2.

33 buildings with different purposes such as housing, offices, services, workshops, laboratories and storage were studied. The purpose behind choosing this group of buildings is to cover a variety of architecture, building materials and generally different types of building. Different methods of energy conservation were put in place for these buildings and results were obtained in fields such as, amount of consumed energy, costs and overall benefit of saving energy and civil and structural details.

Table 1. Mean wind Velocity

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2012	3	3.7	4.4	2.7	3.2	2.4	2.7	2.4	2.2	2.1	2.3	2.1
2013	2.8	2.8	3.2	3.4	3.5	3.1	2.6	2.4	2.4	2.3	2.4	2.7
2014	2	2.6	2.9	2.8	3.2	2.8	2.6	2.4	2.1	2.4	2.6	2.1

Table 2. Monthly mean temperature

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2012	16.6	18	20.8	25.2	32	32.1	34.2	34.3	31.5	27.9	23.5	19.4
2013	17.8	19.2	22.5	26.4	29.8	32.2	34.9	34.5	32.5	27.6	22.3	18.3
2014	16	17.6	21.7	27.1	30.7	32	35	34.6	32.6	29.1	22.8	19.2

2-1-1. Buildings description

One of the important parameters affecting the amount of energy saved in buildings is the building orientation. To optimize the solar heat gains in the winter and solar heat control in summer for a typical building, the optimized orientation must be considered. Studies conducted by Olgyay et al. showed that in order to optimize the amount of absorbed solar energy, south is the optimum building orientation. In Iran and the Persian Gulf region the buildings' long sides are in the south direction [31].

Moreover, the shape of a building can affect its energy consumption. With a constant area, the exterior wall area of a building with a rectangular shape is less than that of an H-shaped one as the perimeter of the exterior walls of the H-shaped building will be greater. Exterior walls and windows are two important elements for energy loss in a building. The higher the exterior wall area, the higher energy loss will be. In a study conducted by Asadi et al. the impact of building shapes on the amount of building energy consumption was shown. They showed that H-shaped buildings have the highest amount of energy loss compared to buildings with the following shapes: U, L, T, rectangle, rectangle minus corner and triangle. Due to regulations set by municipalities, most buildings in Iran are in rectangular shape [32].

None of the buildings have a basement and the cover between floor and ground in all 33 buildings is a layer of concrete with the thickness of 50 cm. Construction of the buildings dated back to a maximum of 5 years.

The other important parameter that controls energy consumption is the U-Value [32]. While using the U-Value for computing heat loss, many factors come into playing. The thicknesses of separation walls and the materials used for construction can affect the R-Value. In five of the studied buildings, the material used for the exterior walls is Aluminum plates and the material used for the insulation of the roof is bitumen. In the other studied buildings, the exterior walls were constructed with bricks and cement with an approximate thickness of 20 cm and the interior walls' thickness is 10 cm. The studied buildings include office buildings, restaurant, resting room, guard room, warehouse, gym, clinic, laboratory, fire station, and prayer hall. The properties of the studied buildings are shown in Table 3. In addition, the thermal hypotheses of the building envelope are shown in Table 4.

Table 3. Properties of the studied buildings

Variable	Mean	CV	Min	Max
Area (m^2)	508	123.75	29	3193
Number of Floors	1	0	1	1
Height (m)	2.985	29.68	2.2	5.8
Volume (m^3)	1853	166.6	72	16435
Exterior Wall Area (m^2)	388.7	88.5	88.2	1619.2
Window to Wall Area (m^2/m^2)	0.1243	68.91	0	0.3816

Table 4. Thermal hypotheses of the building envelope

Masonry	U-Factor ($W/m^2/K$)
Exterior walls	0.31
Windows	1.22
Roof	0.2
Floor	0.45
Doors	2.6

2-2. Energy audited method

The chosen method for auditing in this area was according to the ISO 50001 method.

ISO 50001 provides certain guidelines which help us to [33]:

- Develop a policy for more efficient use of energy
- Fix targets and objectives to meet the policy
- Use data to better understand and make decisions concerning energy use and consumption
- Measure the results
- Review the effectiveness of the policy and
- Continually improve energy management.

According to ISO 50001, the standard sampling method can be obtained by energy auditing or a course of actions done by the users or the auditing team analyzers in order to collect the required data [34].

The four main stages of energy management using ISO 50001 are simplified as Plan-Do-Check-Act. Plan: Several options can be implemented in order to collect and record the required data. An accounting office can collect the data and it is important to appoint one person as the one responsible for data collection. The required data should be collected with the minimal investment in order to collect the maximum amount of relevant data. Do: In this stage the person responsible should have a clear understanding of what information is necessary and must be collected. The installation of heat metering devices in this stage can assure the collection of the energy consumption data of the building. Check: In this stage the collected data should be analyzed and processed. Act: After analyzing the collected data, the person responsible can choose the best course of actions among those possible, and plan for the implementation of the chosen actions [35,36].

In this case, the analyzers experts evaluate the consumed energy before implementation of the proposed scenarios. Using the energy price of consumed energy, and calculating the total consumed energy, the final cost for energy consumption will be achieved. In the next phase, using EQEST, the simulated model of the buildings was provided. The results of the simulation show the amount of consumed energy in terms of implementing each scenario. Comparing the first (before implementing the scenarios) and final (after implementing the scenarios) will lead to finding the best scenario for saving energy in buildings.

2-3 Analyzing method

To analyze energy conservation methods from a financial perspective, statistical analysis was used. Using Minitab, the collected data analyzed in order to attain the statistical analysis. For comparison, the saved cost/ building volume and saved cost/set up cost proportions were analyzed.

To obtain the relationship between the startup cost and the amount of saved energy, the non-linear regression method was used. Using a curve of amount of saved energy vs. startup cost, resulted in developing of an equation which fits the curve best. This equation provides an estimation of the saved energy regarding the amount of money spent for saving energy. When considering the production of greenhouse gases in the process of electricity production, to analyze environmental effects of conservation methods, Carbon Dioxide was analyzed as the most important greenhouse gas produced in the process of saving energy. In this stage, the amount of emitted Carbon Dioxide was calculated using Carbon Dioxide emission from energy consumption tables.

3. Results and discussion

3-1. Energy saving criteria

In this study which was carried out in the Parsian Gas, 33 buildings are to determine efficient methods of saving energy. Comparison between different methods was done based on the two mentioned criteria which were; the amount of energy conservation based on the volume of the building and the profit of energy saving compared to the set up costs of the methods. The aim of this comparison was to find the most efficient method. 9 methods were compared by the first criterion and 7 by the second. The choices were made based on the quality and quantity of the statistical data at hand. To predict the amount of energy saved, a reliable experimental relationship, or modulus was obtained based on the startup costs for the methods. Finally with consideration of the mutual energy and environmental effects, the best method environmentally, meaning the method with most eco-friendly in terms of the amount of produced carbon dioxide for each kw/h of produced electricity was chosen.

At first, to audit the energy for the buildings, 20 methods were considered. Most of them are the typical methods of energy savings in the most of the countries [37-39]. From these 20 conservation methods, 9 methods were appropriate. Lack of statistical data for analysis of methods was as a result of amounts of energy consumption due to the volume of the building. According to the index, acquired profit saving energy compared to startup cost, 7 methods were suitable. These methods are shown in Table 5. In both criteria to unify the units of the values, the amount of used energy for a certain volume, and the saved money per startup costs were calculated and the analysis was performed for the calculated figures afterwards and results were obtained.

Table 5. The methods of energy saving

Number	The amount of savings per unit volume of the building	Benefit from the (savings/cost)
	Method	**Method**
1	Glazing gasket	Glazing gasket
2	Solar Water Heater	Solar Water Heater
3	Electronic Ballast	Electronic Ballast
4	Compact fluorescent lamp	Compact fluorescent lamp
5	Lack of lighting	Lack of lighting
6	Build Canopy	Build Canopy
7	install socket with timer	install socket with timer
8	Packages	
9	Control the Package timer	

Fig. 1 and 2 show the pattern of changes in the two indexes. In fig. 3 and 4, a box plot for each method is shown. According to this analysis, considering the indexes, the caulking method with a result of $5300 in the unit of volume and 9.4 in the proportion of saved value, compared to setup cost, proved to be the best method according to both indexes. In this case frugality defines as the ratio of the saved money to the implementation cost.

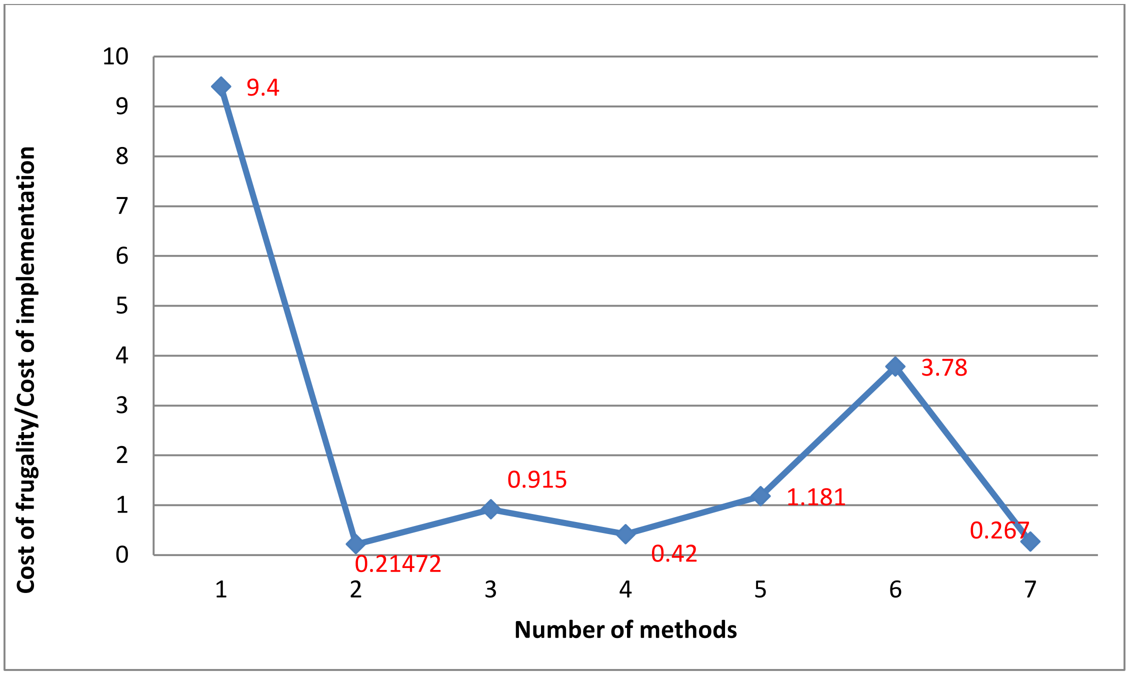

Fig. 1. Changes in the cost savings compared to the cost of running

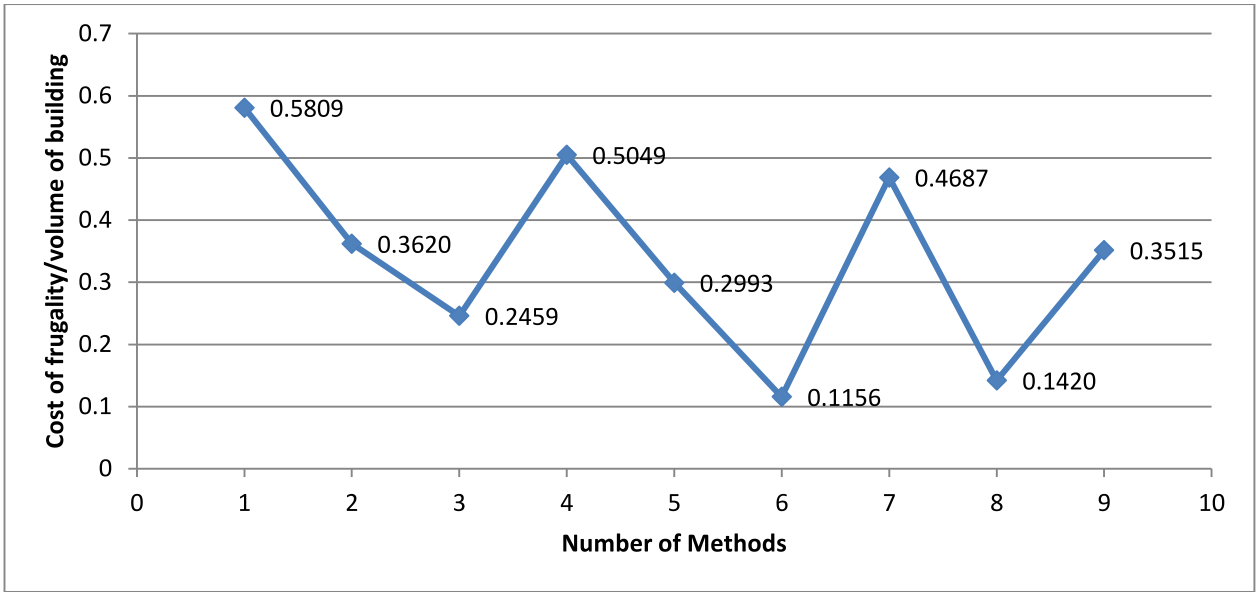

Fig. 2. Changes in the cost of frugality compared to the volume of the building

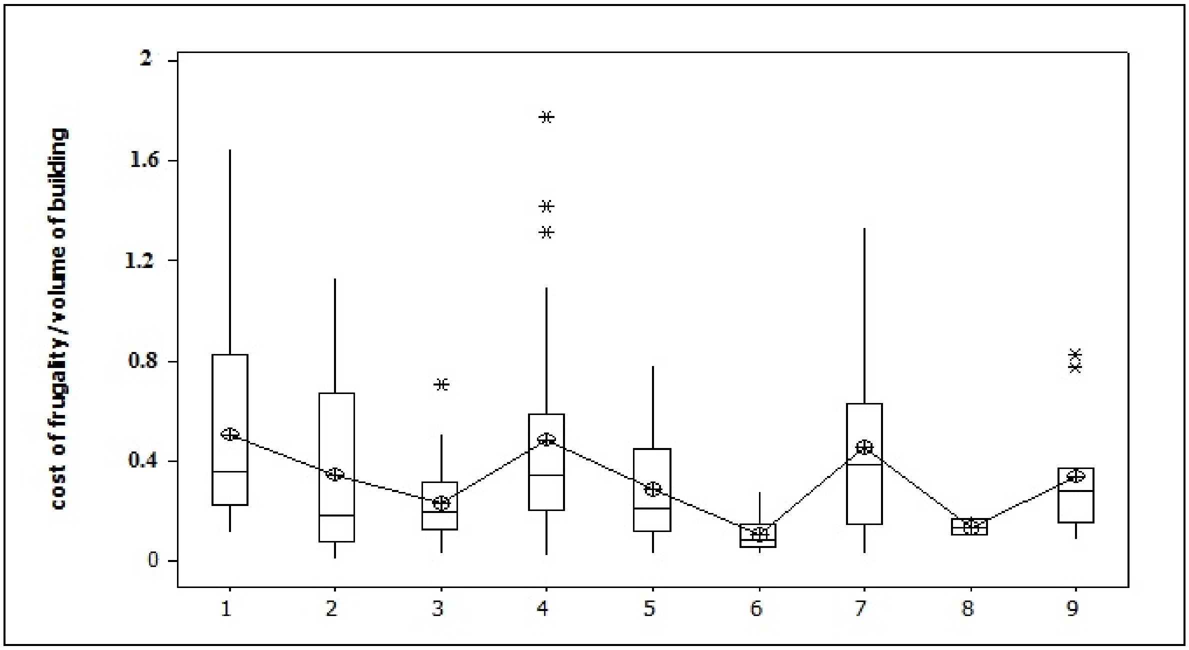

Fig. 3. Box plot of the first Criteria

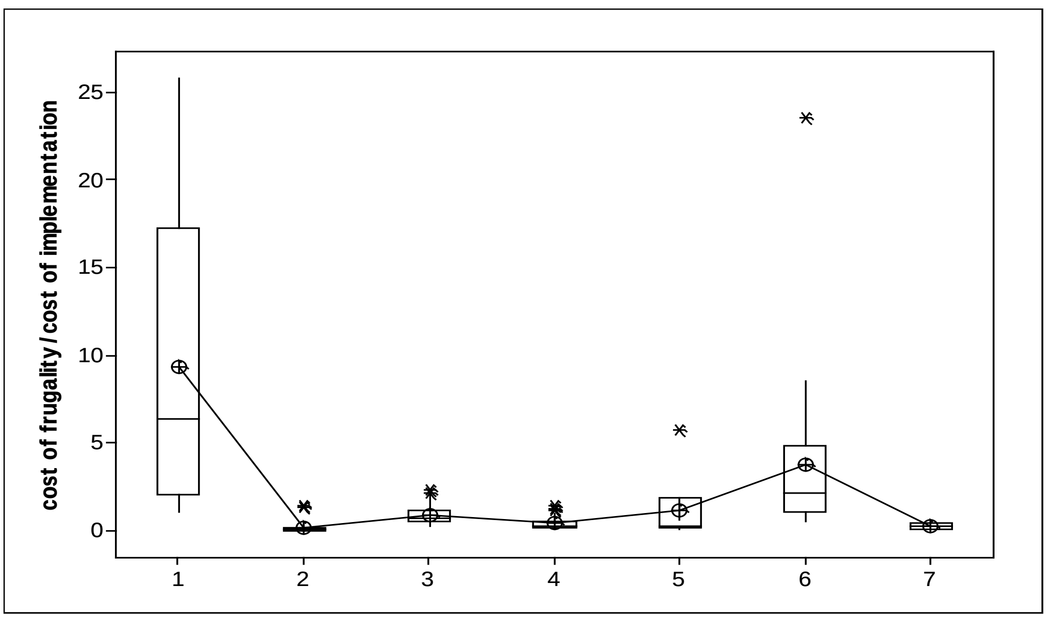

Fig. 4. Box plot of the second Criteria

Considering the spread of data in different methods, the coefficient of variation can also be used to analyze this classification. In Fig. 5 and 6 the values of CV for the methods have been compared according to the mentioned criteria. However, the less value of CV, shows that the data related to that method are less widely spread and are closer to the average and therefore the results are more exact. Therefore, we can claim that a timed outlet according to both indexes with the values 0.07 and 0.11 (consecutively) has the least CV and is the most exact.

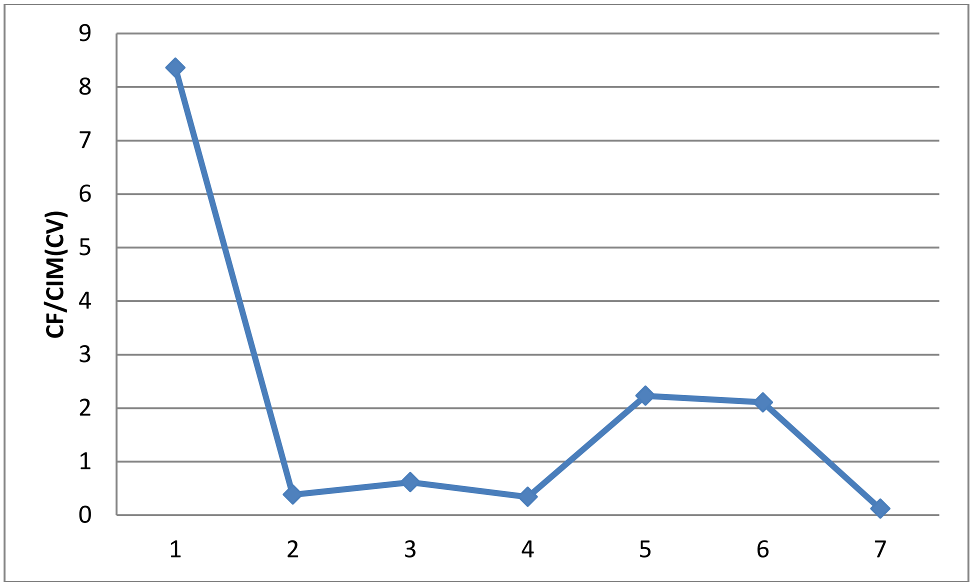

Fig. 5. Implemented cost savings per unit cost based on the dispersion coefficient

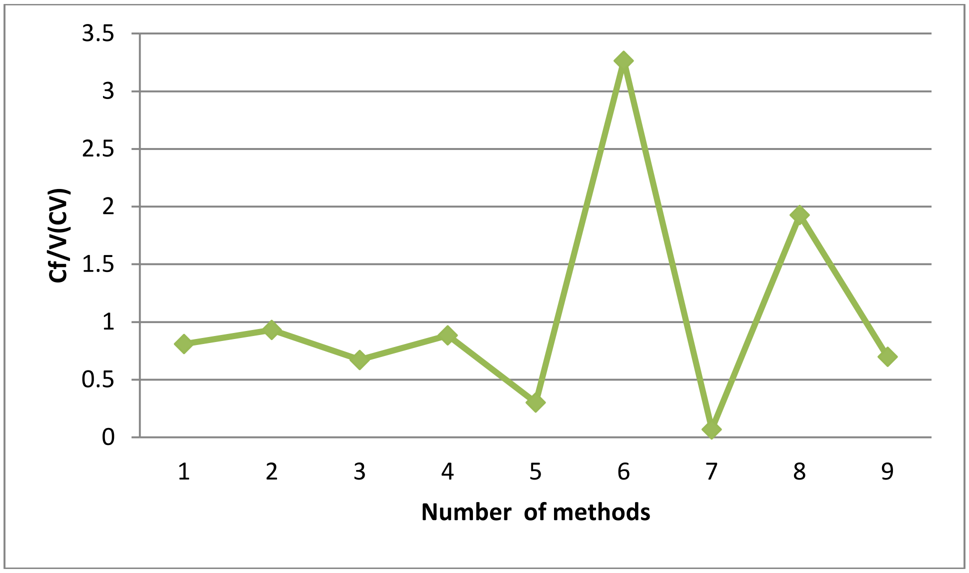

Fig. 6. Implemented cost savings compared to unit volume based on the dispersion coefficient

In recent years energy crisis look more important than before. Energy crisis, limited financial resources, global warming and air pollution clears paying more attention on energy savings. As most of these methods require a large set up fee, predicting these costs regarding energy saving will massively help managing them and give a better picture about spending towards these methods. In this study about the Parsian Gas site, a relationship between the saved energy and the cost for the method was acquired. Therefore, before executing the plan, using one of the other variables can be obtained and give us the chance to analyze the matter. This relationship was acquired experimentally and utilizing the nonlinear regression technique, is stated further on. This relationship was obtained, as based on the collected data; it was the best fitting equation.

$$E/Z = e^{aI^{0.5}+b} \quad (1)$$

In this equation, E is the saved energy; Z is the consumed energy before implementation of the saving scenarios, both in the unit of kwh/m^3. I is the start up cost for the conservation method in the unit of thousand \$/m^3, a and b are the constants which were obtained from the nonlinear regression technique. In total, 104 different scenarios for the 33 buildings were carried out to cover the modeling. The results of this model are shown in Table 6.

$$E/Z = e^{e^{-0.035411 I^{0.5} - 0.49967}} \quad (2)$$

R^2=0.905513 n=104

a= - 0.00035
b= 0.6669

Based on similarities in climate and type of buildings in the Persian Gulf countries, this formula can also be used for calculating the saved energy in their buildings.

3-2. R^2 (R-squared)

The coefficient of determination denoted R^2 represents the fitting of data to the statistical model. In general, the higher the R^2 is obtained, the better the model fits your data. R^2 is always between 0 and 100%. It is also known as the coefficient of determination or multiple determinations (in multiple regression).

The adjusted coefficient of multiple determinations for a multiple regression model, with k regressors, is:

$$R^2_{Adjusted} = 1 - \frac{\frac{SSE}{n-p}}{\frac{SST}{n-1}} \quad (3)$$

It is used in regression, to assess the fit of your model by lack-of-fit tests. If the p-value is less than the selected -level, evidence proves that the model does not accurately fit the data. It is better add terms or transform the data, to acquire more accurate data fitting to model data. Using Minitab, calculations of two types of lack-of-fit tests were obtained:

Pure error lack of fit test: In the case that the data contain replicates (multiple observations with identical x-values) and the goal is to reduce the model, is utilized. Since only random variation can cause differences between the observed response values replicates represent "pure error". If reduction of the model is considered and the resulting p-value for lack-of-fit is less than the selected -level, then the term which is removed from the model should be retained.

Data sub-setting lack of fit test: In the case that data do not contain replicates and the aim is to determine and accurately modeling the curvature. This method identifies curvature in the data and interactions among predictors that may affect the fitting model. Whenever the Data Sub-setting p-value is less than the -level, Minitab displays the message "Possible curvature in variable X (P-Value = 0.006)". Evidence proves that this curvature is not adequately modeled. After examining the raw data in a scatterplot, to model the curvature the try should include a higher-order term.

With the obtained results from the statistical analysis, and considering the involved terms and definitions, the acquired nonlinear regression model, can be checked for its reliability. In the lack-of-fit test, while P-Value>, the model is suitable. When considering the term S (standard error of regression) which indicates the error between the initial and resultant figures from the model, the value of 0.24 was calculated. This is the standard difference between the original values and the shown values in the regression model represents that the error was in an acceptable range. The less the figure is, the more precise the model will fit.

Table 6. Statistical analysis

Method			
Algorithm	Gauss-Newton		
Max iterations	250		
Tolerance	0.00001		
Starting Values for Parameters			
Parameter	Value		
theta1	1		
theta2	1		
Equation			
LN(Energy) = exp(0.06669 - 0.00035411 * 'sqrt(cost)')			
Parameter Estimates			
Parameter	Estimate	SE Estimate	95% CI
Parameter	Estimate	SE Estimate	95% CI
theta1	0.06669	0.122688	(-0.755915; -0.257170)
theta2	-0.00035411	0.039175	(-0.119612; 0.040560)
LN(Energy) = exp(Theta1 + Theta2 * 'sqrt(cost)')			
Correlation Matrix for Parameter Estimates			

theta1					
theta2	-0.894197				
Lack of Fit					
Source	DF	SS	MS	F	P
Error	104	3.71053	0.058897		
Lack of Fit	61	3.46851	0.056861	0.47	0.872
Pure Error	2	0.24202	0.12101111		
Summary					
Iterations	15				
Final SSE	3.71053				
Final SST	39.80				
DFE	104				
MSE	0.0588974				
S	0.242688				

By considering the equation (2) it is obtained that as I = 0, E will be 1.83*Z, which is the least amount of saved energy compared to the spent amount for carrying out the method. In addition, for each $0.04 set up increase in costs, 0.019 watts/m^3 of energy will be saved. This figure can be used in similar studies. The destructive environmental effects of producing electricity have to be taken into consideration when choosing the best method of saving energy. The reduction of carbon dioxide emissions, known as the most important greenhouse gas, in both mentioned criteria, was chosen as the index of environmental effects. The amount of CO2 emission per kilowatt hour of produced electricity is equal to 787 grams [40-44]. According to this the amount of CO2 reduction, each method calculated the emission based on Ton-CO2 per kWh of saved energy. Comparing the averages of these amounts for each method, the best method which is most compatible to environment was determined. The results are shown in Fig. 7 and 8. According to these Figures, which compare the averages of different methods due to the amount of produced CO2, caulking is the best method with an average of 10.9 tons CO2 emission reduction per 1 kWh of saved energy.

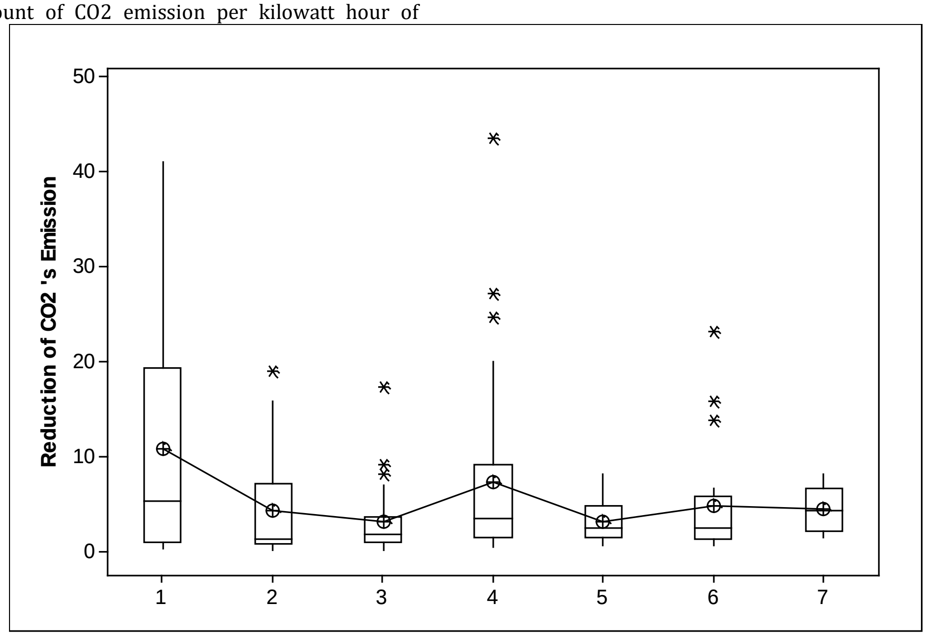

Figure 7. Box plot of CO2 reduction

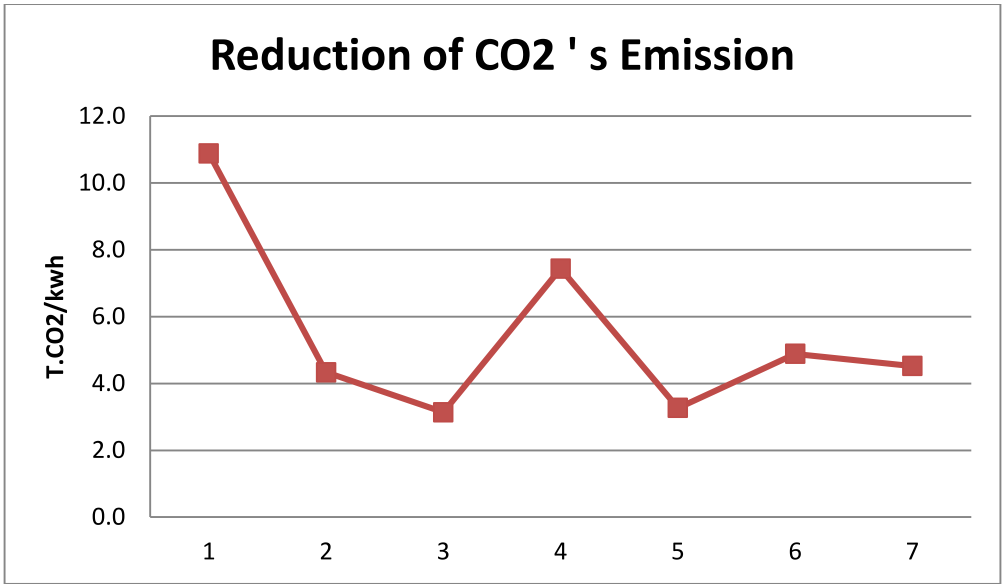

Fig. 8. The amounts of CO2 reduction

3-3. Validation and sensibility analysis

3-3-1. Validation of the proposed formula for energy saving

In addition to studies regarding CO2 emissions and energy savings, the validation process of the proposed formula was also provided. Despite the high obtained value of R^2, the formula was not necessarily guaranteed for validation. In fact, the presence of misspecification functional forms of a relationship or outliers that distort the true relationship can result in high values of R^2. In order to certify the validation of the proposed formula, the paired sample t-test was used. For this purpose, one third of the dataset (34 different scenarios) was used for the paired sample t-test. In this case, the null hypothesis is that the mean of the results from the model and observed are equal. For this purpose, the results of the two sample t-test are given in Table 7. It is found in Table 8 that P-value is not less than 0.05; implying that the null hypothesis is not rejected and the mean of observed data and model data are equal in 95% of confidence interval of the differences. Therefore it can be concluded that the proposed formula contains adequate validation.

Table 7. Paired sample statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Model	7.0120	34	.00314	.00031
	Observed	6.2992	34	6.36688	.62432

Table 8. Paired sample test for validation

		Paired Differences					t	df	P-value
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	Model -Observed	.71278	6.36806	0.62444	-0.52565	1.95121	1.141	103	.256

3-3-2. Sensibility analysis

The data of the 33 buildings with different types was provided from the auditing experts as described in Auditing Method section. Different buildings with different volumes were analyzed in order to define a model for energy saving prediction. As a result, we can conclude that the model can be sensible to the volume of the buildings and the implementation costs. In Table 9, the results of the assessment of different initial assumptions and their impacts of each option are given. Increasing the volume and implementation cost lead to the change in the energy saved. Comparing the results of final saved energy with the average saved energy, as the base input data is the method for sensibility analysis. The analysis shows a little sensitivity to the change of the two parameters of volume and implementation cost. Increasing by %20 in each parameters, leads to an increase of %0.01 in the final saved energy, compared to the average. It can be concluded that the model is not sensible to the changes in the volume and changes in the implementation costs.

Table 9. Sensibility Analysis

Increase in Volume	+20%	+40%	+60%	+80%	Average
	7.012	7.013	7.013	7.013	7.012

Increase in implementation cost	+20%	+40%	+60%	+80%	Average
	7.012	7.011	7.011	7.011	7.012

3-4. Factors affecting the results

One of the factors that can have a significant effect on the amount of energy saving regarding the startup cost is the ratio of windows area to the exterior walls area. In case of using single-glazed windows, the higher the ratio, the lower the amount of energy saved regarding the constant spent money. Also, if the insulation of the roof and materials used for walls change, depending on the materials' thermal conductivity, the amount of energy saving increases or decreases if thermal conductivity decreases or increases, respectively. The number of people working or living in the building can also affect the amount of energy saving. If the number of people or the number of using energy hours increases, the saved energy regarding a certain amount of money will be reduced.

Orientation of the building is another important parameter affecting the amount of energy savings. Studies have shown that south orientation is the best with the highest efficiency in using the sun-light energy. The more the use of sun-light energy, the less the consumption of electrical energy. Changing the orientation from south to east can reduce the amount of energy saved regarding a constant amount of spent money.

The rate of opening and closing the windows, building age, the cover between the floor and the ground, and the color of the roof insulation can also affect the results. Increasing the rate of opening and closing the windows and doors, which mostly occurs in office, clinic and restaurant buildings, increases energy loss. When the roof is insulated with a dark colored material rather than an aluminum layer, the absorption of solar energy by the roof increases leading to less use of heating equipment in winter. The cover between the floor and the ground can be an effective parameter for energy loss, related to the thermal conductivity of the cover. The cover may be of concrete, lime or air- in cases the floor is constructed above the parking.

The shape of buildings can affect the amount of energy consumption. For example, the area of exterior walls in H-shaped buildings is more than that in rectangular shaped ones [32]. As a result, the amount of energy wasted through the walls in H-shaped buildings is more than in rectangular buildings. In this study, all the studied buildings were rectangular and the attained equation was derived with this condition. Changing the shape can decrease the amount of energy savings as the area of exterior walls will increase.

Caulking is found to be the best scenario for increasing the amount of energy savings in terms of spending a constant amount of money. When the building has been caulked, other scenarios will be concluded to be the most efficient scenarios. If the numbers of electrical devices increase, optimizing the efficiency of electrical devices will be the best scenario.

Working schedule is another important parameter which has a direct effect on the amount of energy savings regarding a constant amount of money. If the working schedule changes in order to have the highest use of solar energy, the required energy for lighting will decrease.

Generalizing the attained equation needs additional data reflecting the changes in orientation, shape, thermal conductivity and the ratio of the area of windows to the area of exterior walls. Obtaining additional data can strengthen the precision of the equation which can lead to a general equation. In addition, the usage of the buildings can affect the equation and reduce the R^2 of the validation. In the studied buildings, working hours for the clinic is 24 hours, while it is 8 hours for offices. Also, the area of five of the buildings is more than 1000 m^2 (one more than 3100 m^2) which increases the coefficient of variables in the analysis. The number of occupants, climate and working schedule can also change the results of the analysis. The higher the mean annual temperature, the less energy loss will be. Increasing the number of applicants increases the amount of energy consumption and optimizing working schedule regarding solar energy usage can reduce the amount of energy loss.

The purpose of this study was to develop an equation which can be used for energy saving prediction regardless of the type of usage, area of the building, working schedule and number of occupants. It is only assumed that buildings are located in regions with climate similar to that of the Persian Gulf region, have south orientation, and are rectangular in shape. It is suggested to analyze additional data of buildings located in different climates with other possible orientations and shapes to increase the accuracy of the equation.

4. Conclusion

From the used methods for saving energy in the Parsian Gas site, it is found that the caulking method is the best way in terms of spent money compared to saved money. Using this method will lead to $590000 of money saved per year. In second place, using low consuming light bulbs saves $505000 annually. For each spent dollar, $0.4 are saved. Embedding a canopy-like structure is in the third place, which saves 0.02 dollars per 1 spent cent.

The large difference between caulking and other methods in saved costs, represents proving point that it is the best method. According to the coefficient of variation, installing timed outlets is the most reliable and exact method in terms of predictability, with CV values of 0.07 and 0.11.

The proposed equation provides a good estimation of the amount of energy saved regarding the amount of money spent for energy savings. It can be used for prediction of potential energy savings in regions with similar climates and architectural conditions. As most buildings in the Persian Gulf region have similar architectural conditions and since throughout the region the climate changes very little, and due to the diversity of studied buildings, this equation can be used for all types of buildings located in the Persian Gulf region. The sensitivity analysis proves that the equation is dependent from the changes in volume and implementation costs.

The results were obtained by analyzing all data collected from all 33 studied buildings which had different usages and areas. Changing the parameters usage hours, insulation, orientation, and number of users can change the best scenario for attaining the lowest expenditure on energy costs. As most buildings constructed in the Persian Gulf region face the south, the effect of orientation is negligible.

Changing the materials used for construction can directly affect the amount of energy savings in terms of money spent. The higher the thermal conductivity of construction materials, the lower the energy saved by spending a constant amount of money will be. Working schedule can also affect the results. A clinic operating 24 hours a day will have higher electrical energy consumption than one with less working hours, which can change the best scenario from the caulking method to changing the light bulbs. By changing the working schedule to the time with the highest usage of solar energy, the amount of energy savings can be increased.

Also, taking in mind major areas of Iran have similar climate to the studied area, using the acquired formula for calculation of potential saved energy in other areas, will be financially valuable. Equation (2) has a credibility of 90%, therefore it can be considered a reliable equation and can be used as a basic equation for future studies in similar sites. It can also be found from this equation, that for each $0.04 set up increase in costs, 0.019 watt hour of energy will be saved, which is helpful in prediction of financial and social aspects of such sites.

The caulking method, with a decrease of 10.9 tons in CO_2 emission, is the best compatible environment method.

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