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Economic guideline about financial utilization of flat-plate solar collectors (FPSCs) for the consumer segment in the city of Eskisehir

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ABSTRACT

Solar energy systems yield energy savings relative to conventional systems by considering the ecological balance. Although, it still has barriers, the most commonly used system of this type is FPSC in Turkey, which produces hot water by absorbing solar energy through FPSCs. This study is a kind of guidance about utilization of FPSCs in Eskisehir that, concentrates on a consumer segment. The aim of the study is; displaying the necessity of transition to renewable energy systems in the local free markets where the place of domestic resources. The data is supplied from an original hand collected survey and Turkish governmental institutions such as the Central Bank of the Republic of Turkey (CBRT) and the Turkish Statistical Institute (TurkStat) that is used for a possible scenario to show how these systems can become an extensive investment and financed in the city. The most significant finding is purchasing a FPSC device which is a rational and profitable investment decision for households in the economic conditions of Eskisehir. This type of energy system has certain costs, including installation, credit and annual maintenance costs. However, after they have been set up, FPSC systems yield many ecological advantages that more than offset the associated costs, such as fuel savings over the long term and exemptions from tax payments that apply to other types of fuels. These advantages benefit both the environment on a global scale and the region in which the system is constructed. Therefore, the global and local economy can improve its structure by utilizing FPSCs.

1. Introduction

The increase in the usage of solar energy systems brings many positive environmental and economic gains. These helpful changes can be told as; a solution to the problem of obtaining energy, usage of energy without any interruption and avoiding foreign dependency in supplying energy, creating new employment opportunities, and a decrease on environmental pollution. There are some positive externalities for markets in the solar water heating systems deployment. These renewable energy systems lead to reduced environmental pollution and greenhouse emissions [1–6]. However, there is a main principle related with these systems for their acceptance as a part of life. This principle is; production costs and once the production happens after that, repair and maintenance costs should not be above the energy savings which is supplied by these systems. This decision is nothing more than a long term investment projection or planning. Taking this decision, which heavily depends on time and money is closely related to knowing the key points during this time interval. This can be achieved by the help of serious planning and following the basic points of a sensitive economic analysis. The countries that satisfy this basic principle and go along with on the path of using renewable energy resources will make their economies better off. According to our minds, the sustainable development can be achieved this way for a region or a country.

Technically, producing and utilizing these renewable solar energy systems is one of the effective ways of the sustainable development. Following this development strategy, it has a potential that might give Eskisehir a leadership position in the region. Production of FPSCs and supplying energy needs with these devices, will automatically create employment opportunities during this transformation, and also will indirectly provide benefits by solving unemployment problems in the city. In this regard, the investments that will be made on these renewable energy systems should be considered within the above mentioned principle, and in the concept of time-money dimensions. It is crucial to mention that, consumers will have an important effect on contribution for their city and as well as for their country along with the time of giving their decisions on these investments.

This study performs an economic analysis of FPSCs. The objective

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of the study is the cultivation of the consumer segment for much better market transactions. By doing this, we believe that, both the buyers and sellers will be more conscious and informed about using renewable energy systems. Once FPSCs are produced by domestic possibilities, our paper then concentrates on the investments by the consumer segment. As a result of these analyses, a guideline for consumers has been supplied. By this way, the household residences who live in Eskisehir will make their decisions on investments about FPSCs, more healthy and strongly. The demographic features of the city of Eskisehir, the currently used energy type and its amount and also the cost of this amount, the tax benefits and credits after transition to this energy type, the resale income (if consumers are not satisfied with these systems), mortgage costs, some miscellaneous costs and initial investment costs are taken in consideration. The data belonging to these factors is obtained from a survey that was conducted in Eskisehir and from Turkish Governmental Institutions such as CBRT and TurkStat. The findings showed that, for many reasons a FPSC device is a rational and profitable investment decision for consumers in these economic conditions of Eskisehir. The Turkish Government should immediately give the necessary importance to this investment and organize some tariff and subsidy reforms for both consumers and producers. At this point, we can refer to some studies taken from some literature. Yurtsev & Jenkins [7] show the solar water heating systems (SWHS) are financially attractive in Northern Cyprus. The reason for this is it can design and build SWHS with highly price competitively by the help of tariff (tax) and subsidy advantages. Goess et al. [8] display while proactive support from local governments are the strong drivers for the emergence of Shandong's (China) innovation system for SWHS, the lack of adequate personnel and an overreliance on government policies are the main barriers. The contribution of their work is a comprehensive analysis of SWHS' technologies in the Chinese province of Shandong, and more specifically its cities Rizhao, Jinan and Dezhou, all of which have an international reputation in the entire world. Their analysis showed that the improvements on SWHS technology heavily depend on the strong networks of organizations and governments at the national level. In line with the above-mentioned concept but in more general form, Thapar et al. [9], identify innovative renewable energy practices with minimal financial obligations in India. Their findings show that, the financial impact of the applied instruments has a high environmental effect, which may be followed by in other emerging markets and economies with local demands.

If we continue to give study samples from literature, we understand that, there are very limited number of papers that focused on the sustainability of households, environmental issues and solar energy hot water systems. These studies are [10–12];, in Greece, United Kingdom and New Zealand, respectively. Besides these, we observe that, there are studies close to ours' that investigate the domestic SWHS for households. Bell [13], can be given as the earliest study of our literature which explains the economics of the solar heating energy systems. An example is shown in Bell's paper that evaluates an annual cost of capital investment at a given interest rate of a water heating energy system for a single family house. Wei et al. [14] conducted a survey in Xi'an city with 96 samples, and they made a 25 year lifetime cost-benefit analyses in urban China. Ma et al. [15] analyzed the financial attractiveness for consumers' investment in solar water heaters with a panel data cost model and proposed a new incentive subsidy policy program for rural areas of China. Gill et al. [16] examine household responses from those who adopted the energy saving solar hot water energy systems in Australia. They try to investigate how SWHS can be integrated into everyday life. With their investigation their study can be taken as guidance for consumer segment for installation and pre-purchase decision of SWHS.

It is important to mention that, the FPSCs are needed not only for water heating they can also be used for environmental reasons such as; reduction of carbon dioxide emissions. This concept is discussed in detail in [17] for cities in Brazil and the Brazilian Government who created public policies to encourage the use of solar energy system technologies primarily among the low-income population. Silva et al. [18] showed that, in Portugal, for a typical residence building, it is possible to supply all of the energy needs for domestic hot water by the integration of solar energy systems. In addition to this they indicate that, during its life time of 30 years with attractive reimbursements and cost-effective scenarios decrease a significant amount of energy and carbon emissions which are avoided by using these solar energy systems. Saxena & Deval [19], show the advantages of a high rated solar water distillation unit for households in India and they indicated that solar energy systems are also used for purposes other than cooking or heating by considering the limited amount of fossil fuels. In parallel with these usage styles of FPSCs, one of the indirect but important objective or future visions of the study is to utilize FPSCs in different geographical regions. Ayompe & Duffy [20], tested the characteristic features of a FPSC and recorded the collector outlet fluid temperature at around 70 °C that gives an idea for consumers and producers for deployment opportunities of these systems in Dublin, Ireland. In addition to this and stated in Shrivastava et al. [21], there is a rapidly growing market structure of SWHS worldwide. SWHS is transient in nature and its performance depends on dynamic parameters varying from geography to geography or location to location. Simulations about its technical features, report a generation capability for sales & marketing, assessment of subsidy, life cycle savings, life cycle cost earnings, reimbursement periods, economy, finance, environmental aspects etc. were excellent and are also tried as an objective in our study. In addition to this, for covering the literature from a general aspect; on one hand the studies that financially explain the solar energy systems can be given as [22–28] and on the other hand the studies of [29–37] can be referenced as a guidance or explaining some scenarios related to these solar energy systems.

The organization of the remainder of this paper is as follows: In Section 2, we discuss economics and utilization of FPSC investment; the structure of FPSCs market, renewable energy support policies by government, barriers that affect production and consumption of FPSCs and technical aspects, optimization properties, efficiency calculations about FPSC in Eskisehir and in all of Turkey. Section 3 presents data and methods. Section 4 displays results and discussion. In the discussion part, we consider a possible scenario for Eskisehir. In Section 5, the conclusions are given and some policy implications are suggested.

2. Economics of FPSC investment and utilization of FPSC equipment

The investment and utilization of FPSC equipment in Eskisehir and Turkey cannot be analyzed without considering the renewable energy developments in other countries, because, Turkey is an important global actor in todays' world. We can understand this issue from the significant and positive relationship between per capita carbon emissions and openness (the ratio of foreign trade to GDP) [38], high young population ratio (with 16.4% or 12,899,677 young (15–24 year old) individuals in the whole population of 78,741,053) [39] and the geographical location advantage of the country (Turkey has a very strategic locational position between Asia and the continent of Europe.).

In this part of the study we will look at the structure of the FPSCs market, factors affecting consumption of FPSCs, renewable energy support policies, and technical aspects about FPSC equipment and its investment in Eskisehir and Turkey, consequently in the perspective of the interaction with and influence of the other countries' global renewable energy policies.

2.1. The structure of FPSCs market in Eskisehir and in Turkey

Eskisehir which has a population of 781,247 consumed a total of

1950,433 kWh of energy in 2011, and this corresponds to 1.13% of Turkey's consumption [40]. With solar radiation at 3.6 kWh/m^2 per day, total solar radiation for 2011 is approximately 2640 h on average for a year in Turkey. This amount is appropriate enough to provide solar energy both in the city and country [41]. The appropriate way for this, is to adopt solar energy systems for energy needs.

The types of solar energy systems on the market are very crucial with taking investment decisions and to be more rational and cost effective. Markets need to be perfect competitive but they are far away from their ideals. As a result, the investors may easily find the sector risky and cannot take investment decisions with assurance. The solution to this problem can be; balancing the public sector with private. Therefore, some institutions become very important and are needed to control and orient the markets such as; Republic of Turkey Energy Market Regulatory Authority (EPDK).

Solar water heating and its equipment FPSCs are now a mature technology in the world, and internationally, the market for solar water heaters has grown significantly during the last decade [42,43]. Turkey is now consciousness about the necessity of solar energy. Right now, there is a support mechanism for the production of electricity by using solar energy, but there is still a lack of policy implications for producers of solar collectors and consumers. Solar energy systems are used for generally hot water production by households in Turkey. The southern regions of Turkey, installed FPSCs which is more than both the northern and the western parts combined for the simple reason of better solar conditions. In addition to this, a financial incentive program was conducted. The manufactures were positively affected, so this program led to an increase in the number of installations. Before 1990, the installed capacity was not more than 150,000 m^2 per year. Lower household income and higher installation cost could be the factors that influenced this number. After the situation changed with the introduction of incentives during the period between 1990 and 2010, local markets increased its capacity and approached 800,000 m^2 installation per year. The increase in the installation continued during the period of 2005–2010 and, this development can be attributed to technological progress in solar thermal systems, economic growth in the country, and increases in the disposable income of households [44].

2.2. Financial strategies for efficient renewable energy production and consumption

Technological development is the key factor that helps to raise the standards of living from generation to generation. This can be achieved by giving enough attention to renewable energy issues together with producers, consumers and some government interventions as well as, necessary precautions. Technological policy is the term that is used for government intervention and, aims to promote technology-enhancing industries in the economy. Strategic government intervention may be a significant method to encourage solar energy systems in Turkey. This subject is shown and concluded in a study of [45] the cities in United States (US). Public intervention can be supplied at regional, national or local level to regulate the market failures. The methods for these interventions can be given as; local aid to specific sectors or firms in the form of grants or exemptions from value added taxes (VAT) and charges. However, they need to be well designed. Otherwise, some extra market distortions may arise [46]. In addition to this, it is important to take into account that, the government can set the incentive feed-in tariff according to the actual average cost of solar energy system, so that the feed-in tariff amount and current average costs of systems are significantly correlated [14]. So if the costs can be optimized, this will also help to adjust the feed-in tariff in an appropriate way.

Besides these issues, if producing and consuming FPSCs yields spillovers we believe it leads, then the government should use the tax laws to encourage the production of solar energy systems. A successful technology policy requires measurable size of spillovers from different markets. Without exact measurements, the subsidizing policies cannot reach its goals. One of the technological policies, which works with the equity principle, and precise enough, is the patent protection. The investors are protected by having the exclusive use of their inventions in a definite time period. When an individual or a firm makes an invention or experience a technological breakthrough, a family member can patent the idea and capture much of the economic benefit for her or himself. The externality is internalized by the patent and by this way the individual or firm gets a property right over their invention. If other individuals or firms want to use the new explored technology, they would have to obtain permission from the property owner. Thus, the patent system gives individuals or firms a greater incentive to engage in research and other activities that progress technology [47]. This cycle will automatically develop the markets and country. Therefore, the Turkish Government should quickly take precautions on investments and financial subjects. And also, Turkey should make arrangements for solar energy markets by following advanced, and developed countries which use densely renewable energy such as; Germany, China, USA and Spain.

The good news for financing is some development and national banks supply financial sources for renewable energy projects. The International Finance Corporation, European Bank for Reconstruction and Development, European Investment Bank, and French Development Agency provide loans for renewable energy investments and these banks corporate with Turkish banks. In addition to this, The Industrial Development Bank of Turkey has a leadership in renewable energy project financing [48].

2.3. Renewable energy support policies by Turkish Government

The application purpose of the renewable energy policies in Turkey is finding a solution to energy demands for the rising population through a growing economy in a secure and sustainable way. Environmental issues with social developments and targeted growth ratios are the main objectives in this regard [49]. The applied renewable energy support policies in Turkey are indicated with the symbol **"O"** in Table 1 below. It can be inferred that, if the development level of countries increases, more policy items in this table can be implemented in a specific time horizon. Table 1 is obtained from [50]. The original table consists of countries that are classified by development

Table 1
Renewable energy support policies.
Source [50]*: Renewables* 2015- Global Status Report, (p.100).

Country	Regulatory Policies						Fiscal Incentives and Public Financing				
	Feed-in tariff/ premium payment	Electric utility quota obligation/ RPS	Net metering	Biofuels obligation/ mandate	Tradable REC	Tendering	Capital subsidy, grant, or rebate	Investment or production tax credits	Reductions in sales, energy, CO2, VAT, or other taxes	Energy production payment	Public investment, loans, or grants
Turkey	**O**			**O**			**O**				**O**

O - existing national (could also include state/provincial).

levels.[1] Turkey exists in the class of upper-middle income countries, and is separated and is shown in Table 1.

It is important to mention that, the choice of the support mechanism depends on the market technology, its scale, the time horizon and geographic location, therefore changes from country to country.

2.3.1. Feed-in tariff mechanism

The support mechanism on renewable energy in Turkey is placed within the Law, No. 5346. Power plants which started to operate on 18 May 2005 or, started before 31 December 2015 are able to receive the following feed-in tariffs that are stated in Table 2 below shows a ten year production. The definition of the feed-in tariff mechanism can be made as; a policy that: (1) sets a constant, guaranteed price over a indicated fixed-term period at which various generators can sell renewable energy power into the electricity network, (2) having a grid access to renewable electricity generators. Some procedures supply a fixed tariff while others support fixed premium payments that are added to wholesale market and feed-in tariffs for heat, are evolving [48]. As it is understood from the definitions this mechanism has a low risk, because it encourages to produce energy power and pays as long as this cycle is carried out or accomplished.

From Table 2 we see that the feed-in tariff value is 13.3 cents for 1 kWh electric or heat energy production. This information is used for our calculations in the scenarios for households living in Eskisehir for the following sections.

2.3.2. Mandate/obligation

Mandate or obligation can be defined as a measurement of a minimum and incrementally increasing goal for a definite amount of capacity or a ratio of total supply. They can include obligations which require the set up or installation of renewable energy systems [48].

2.3.3. Capital subsidy, grant or rebate mechanism

According to one definition a subsidy is; ‘any government assistance, in cash or in kind, to private sector producers or consumers for which the government receives no equivalent compensation in return, but conditions the assistance on a particular performance by the recipient’ [49,51]. For FPSCs the above mentioned definition can be indicated as; one-time payments or utility to cover a percentage of the capital cost of an investment by the government [48].

2.3.4. Public investment, loans and grants mechanism

Instead of growing bigger energy markets to reach enough energy access, political stability needs to be ensured by the public sector, which means a positive investment signal to investors. Public finance mechanisms (for example: preferential loans, grants and, loan guarantees) can be effective in an uncertain private sector investment by prevailing the lack of private financial instruments, promoting market development, and reducing risks. Financial tools can be performed on both the demand and supply sides, supporting energy users and project developers to commute the assessment of projects to a high capacity classification. Furthermore, achieving financing and buy-in, necessitates trust in the technology, which needs the development of certification, standards, etc. to guarantee quality. This is likewise crucial for developing domestic industries and the functioning of exporting renewable energy goods and products [50].

In the earliest part of 2015, a predicted 126 countries around the world had affirmed some arrangements with financial support, consisting of grants, low interest loans and tax reductions [50]. Turkey announced improvements to its investment incentive program with the objective of encouraging energy efficiency in industrial skills in 2014, and some fiscal incentives are used in this industry sector [50].

[1] Countries are classified according to their gross national income (GNI) per capita levels. For example; “high” is $12,746 or more, “upper-middle” is $4125 to $12,745, “lower-middle” is $1046 to $4125, and “low” is $1045 or less. It is important to note that, per capita income levels and group organizations from World Bank, “Country and Lending Groups”, accessed in March 2015.

Table 2
Feed-in tariff mechanism in Turkey.
Source [48]: *Turkey's Renewable Energy Sector from a Global Perspective 2012.*

Type of power plant facility	Feed-in tariff	Maximum local production premium	Maximum possible tariff
Solar PV PP	$13.3 cents/kWh	$6.7 cents/kWh	$20 cents/kWh
Concentration Solar PP	$13.3 cents/kWh	$9.2 cents/kWh	$22.5 cents/kWh

2.4. Barriers affecting renewable energy and utilization of FPSCs in Eskisehir and Turkey

The potential utility of solar energy systems in Eskisehir and Turkey is not wholly recognized and understood. One of its reasons is, there exist coordination faults between agencies, ministries, institutes and consumers. In recent times, bureaucracy seems a crucial handicap or disadvantage for the foreign entrepreneurs and investors. Besides, operation, management and initial capital costs are higher than its expected values. This situation creates problems for investors. As a result, technology transfers cannot be made. The solution to these barriers is encouraging local production and developing renewable energy technology. The other examples of barriers can be given as; inadequate market transactions and conditions, lack of private sector contributions, risky renewable energy investments depending on fiscal policy implications and the handicaps in financing renewable energy projects [49]. It is known that, the 2008 global crisis affected whole the world and Turkey, also felt some negative influences. Volatile market conditions are unwanted situations for both investors and buyers on the demand side. Sponsors were not able to get non-recourse loans, even before the crisis, which are conserved by the project assets and paid back by the project's money gain itself. However, during the time of crisis, financing conditions became stricter [48].

In addition to market failures about renewable energy, the technical barriers directly related to the utilization of FPSCs can be given as; energy storage system issues, thermal losses, diverse consumer demand profiles in the design of solar water heaters, lack of integration with typical building materials, small revenue streams and lengthy payback periods raises creditworthiness risks, the low financial viability of domestic water heating system, backup heater systems adds to the cost, the additional cost of copper makes water heating and its distribution costly, lack of building integrated systems and limited rooftop area prevent widespread applications [52].

2.5. Technical aspects, optimization properties and efficiency matters about FPSC and its usage

Technical features of the FPSC device can be found in [53]. In addition to this, the concept about FPSCs can be shown in Fig. 1. Its environment friendly usage makes this investment a rational decision for consumers. Banos et al. [54] state that, solar radiation is converted into energy by active solar design. According to them, a solar design, which is also related to our subject, is based on the optimal design of buildings. The solar energy is captured and is used for the reduction in fossil fuels for light and heating. In this case, the researchers focus on solar energy in relation to the optimization and design of solar energy homes. Energy efficiency of buildings is the crucial factor for these systems. It depends on energy consumption, financial costs, environmental factors and performance.

However, the optimal level of FPSCs cannot be provided by the market unless public intervention is successfully made or in the lack of an intervention. This situation is possibly the cause for the reason of

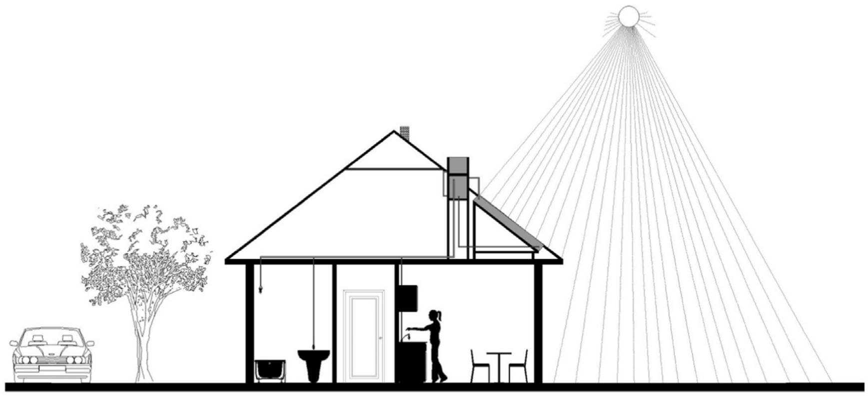

Fig. 1. FPSC Device and Its Usage **Note:** This figure is obtained by the authors of this manuscript with Autocad software. The entire concept is designed imaginary.

Table 3
Survey questions and the related given answers to these questions.
***Source*:** From author's first handed collected survey, 2013.

Questions
1) What is the typology of the staying residences of household individuals?
2) What kind of system is used for heating in your residence?
3) What are you using instead of heating fuel in your residence?
4) What kind of energy do you cook with in your residence?
Given Answers to Questions

Options	The number of individuals staying in a detached house		The number of individuals staying in an apartment	
1)...	17		138	
Options	combi boiler	central heating system	heating with electricity	heating with others
2)...	74	65	3	3
Options	natural gas	coal	electricity	other heating fuel
3)...	126	13	4	2
Options	natural gas	LPG cylinder	electricity	
4)...	131	8	6	

low level and unfair competition with other fuels (for example; subsidies for fossil fuels and nuclear energy), existence of external costs such as; air pollution an energy security, and for the structural defect of electricity system designs [46].

3. Data and methods

3.1. The survey and the data

The data used in this study is obtained from a survey that was conducted in 2013. This survey, which is designed as a regional study, is distributed to people who are residents in the city of Eskisehir. The average number of residents provides a general idea about family size for households. The seasonal effects are considered for precise estimation of total energy consumption each month in Eskisehir. The questions that are asked in this survey can be classified into two categories: First; the questions are related with household's water and electricity consumption. In this case, the hot water consumption of household's is determined by the information of how many times a week they are taking a shower and how much water is used during these showers. Second; households are questioned about the type of residence they live in and electric equipment they have. There are also additional questions on monthly usage amount of energy on lighting, heating, cooling, cleaning and cooking facilities.

Multiple-choice questions with filling gap techniques are preferred to gather information for the survey. 154 individuals are included who are resident in the city of Eskisehir. The individuals are selected randomly. 145 respondent's answers are considered, because the remaining nine individuals gave meaningless information, but these nine are also used for the general and for non-specific information. We give importance to respondents from different earning incomes and residential areas. The reports of this survey reflect a different variety of occupations. While some of them are academics and teachers, the remaining of them are engineers and workers from both public and private institutions. This survey is favored because we believe that the actual data will shed light on theoretical knowledge. In other words, if this survey hadn’t been conducted, and used, we believe that our predictions would still be reliable. However, the calculations and predictions will be made more robust with actual data.

In the following paragraphs, the findings about the conducted survey are first evaluated generally and followed by an analysis. The first series of questions that were asked of households addressed definitions regarding the features of their residences. From the answers given, it is clear that the average population per residence is 3.19. According to this finding, a nuclear family is present if there are at least three individuals. According to the answers that were given regarding the types of residences in Eskisehir, the number of individuals living in stand-alone houses was 17, and the number of individuals living in apartments was 138. Thus, 12% of the survey respondents lived in a stand-alone house, whereas 88% lived in an apartment. Some of the survey questions and the given answers to these questions are presented in Table 3 and the statistical explanation is made below the Table 3.

The answers to the question, "What type of system is used to heat your residence?" were as follows: 74 individuals indicated a combi boiler, 65 individuals indicated a central heating system, 3 individuals said heating with electricity and 3 individuals said heating by other means. According to these answers, 51% of households are heated with individual combi boilers, 45% are heated with central heating systems, 3% are heated with electricity and 3% are heated by other means.

In response to the question, "What do you use as heating fuel in your residence?" – 126 residences indicated that they used natural gas, 13 residences used coal, 4 residences used electricity and 2 residences used another type of heating fuel. Based on these answers, 87% of households are heated with natural gas, 9% of households are heated with coal, 3% of households are heated with electricity, and 1% of households are heated by other means. In response to the question, "What type of energy do you cook with in your residence?” 131 individuals said they cooked with natural gas, 8 individuals said they used propane cylinders, and 6 individuals said they used electricity. According to these answers, 90% of households cook with natural gas, 6% cook with LPG cylinders and 4% cook with electricity.

Thus, approximately 90% of the households who answered this survey used natural gas for heating and cooking in their residences in Eskisehir. For this reason, a comparison is made between natural gas and solar energy in this study. Energy from coal and propane, in addition to electrical energy, can also be compared with solar energy, but these comparisons are beyond the scope of this study.

3.2. Time effect on the investment of money amount for FPSCs

The most important parts or components of having a solar energy system (FPSC) from the consumers' perspective are; the aggregate evaluation of positive and negative contributions to total savings life-cycle time (TSLT) that is shown in Eq. (1). In Eq. (1), while there is total savings life-cycle time variable on the left side, (+) life cycle savings (LCS) of natural gas, (+) life cycle savings of tax encouragement, (+) life cycle savings of resale income, (+) life cycle savings of tax credits, (-) life cycle cost (LCC) of mortgage costs and (-) life cycle cost of initial investment variables are placed on the right side, respectively.

$$\begin{aligned}\text{TSLT} &= \text{LCS of natural gas} + \text{LCS of tax encouragement} \\ &\quad + \text{LCS of resale income} + \text{LCS of tax credits} \\ &\quad - \text{LCC of mortgage costs} - \text{LCC of some costs} - \text{LCC of initial investment}\end{aligned} \tag{1}$$

Since there exists compound interest or discount rate[2] in an economy, an amount of investment will have a higher value in the future depends on the present value, time, and interest or discount rate. This relationship can be given by Eq. (2). In Eq. (2), the term "FV" represents the amount of future value of the investment. The term "PW" refers to the present worth of this money, "d" represents the discount rate and "n" represents the investment period.

$$\text{FV} = \text{PW}(1 + d)^{n} \tag{2}$$

If we rearrange Eq. (2), "PW" can be expressed as in Eq. (3);

$$\text{PW} = \text{FV}/(1 + d)^{n} \tag{3}$$

with compound inflation, the future value is given by Eq. (4). Here, the term "PC" is the present cost and "i" represents the general inflation rate of the country.

$$\text{FV} = \text{PC}(1 + i)^{n} \tag{4}$$

If we arrange Eqs. (3) and (4) and combine them (note: put "FV" term in Eq. (3)), then we obtain Eq. (5);

$$\text{PW} = \text{PC}\left(\frac{1+i}{1+d}\right)^{n} = \text{PC}\left(\frac{1}{1+D_r}\right)^{n} \tag{5}$$

Here, *"D_r"* is the inflation-adjusted discount rate and it is shown in Eq. (6).

$$D_r = \frac{1 + d}{1 + i} - 1 \tag{6}$$

Businesses eventually have an idea about their minimum acceptable discount rate. This situation depends not only on the investment philosophy of the business but also depends on the general conditions of the country and future expectations on financial markets. But this percentage corresponds to 0–30% more than the prevailing general inflation rate [55]. This situation is a critical clue for home owners or residential applications. If the homeowners can obtain discount rates which exceed the general inflation rate in their country then we can highly encourage the homeowners to invest in this equipment. Otherwise, the present worth of their investment would be much higher which is an unwanted case for homeowners. Both the general inflation rates and, discount rates for Turkey are given in Table 4 and, Fig. 2 consequently, below. This data helps us to figure out the possible scenarios for consumers of Eskisehir about FPSCs investment in Turkey. Table 4 shows year to year and month to month average percentage changes of CPI for the period between 2010 and 2016 in Turkey.

[2] Generally speaking, discount rate is the percentage that is used when a future receivable amount is purchased during the present time. Normally, this term is used while funding against bills with a credit period. On the other hand, interest applies where the customer pays the interest after a certain period of time for the loan, benefitted from being charged at monthly or annual rests.

Table 4
Consumer price index (CPI) (2003=100), monthly and annual average inflation rates announced by TurkStat.
Source [56,57]: *CBRT and TurkStat.*

Year	CPI (Year to Year Average % Changes)	CPI (Month to Month Average % Changes)
2016	7.91	0.68
2015	7.67	0.71
2014	8.85	0.66
2013	7.49	0.60
2012	8.94	0.50
2011	6.45	0.84
2010	8.58	0.52

Table 4 is originally derived from Table A2 which can be found in the Appendix A and, the CPI values are determined by taking the averages of various years year to year and month to month, respectively. It is understood from Table 4 that, the annual general inflation rate can be taken as 8% or 9% in Turkey.[3] Fig. 2 shows the three kinds of interest rates that, all of them are taken from the CBRT at specific dates which is given in the X axis. The logic behind Fig. 2 is to give a reference for interest rates in Turkey. The detailed information and data about three types of interest rates can be found in Table A1, in the Appendix A.

4. Results and discussion

4.1. Results

4.1.1. A guideline with possible scenarios for consumers of FPSCs investment in Turkey

Let's discuss two possible scenarios which are closely related with Turkey's economy and the financial situation in the country. First, let's take the inflation rate as 9%,[4] and discount rate as 10%.[5] In order to purchase in thirty years[6] equipment which currently costs 1500 TL at an inflation rate 9% and discount rate 10%, the present worth of the item is then calculated as 1140 TL from Eq. (5). The numerical calculations are shown in Table 5 below.

Second lets, take the inflation rate again at 9% but this time take the discount rate as 6% which is lower than the general inflation rate. In order to purchase in thirty years a device which currently costs 1500 TL at an inflation rate of 9% and discount rate of 6% the present worth of the device is then calculated as 3465 TL which is 2325 TL more expensive[7] than the first case! The numerical calculations are shown in Table 5 at below.

Therefore, it is important to note that, if the discount rate is higher than the general inflation rate, this condition is a very critical clue for consumers in taking their investment decisions. Robust investment decisions need more specific and clear information by mathematical approaches. Table 6 and Fig. 3 are a kind of guidance for both producers and consumers who will buy or sell a FPSC with a market price of 1500 TL. The extended form of Table 6 can be found in the Appendix A with Table A3. Table 6 and Table A3 are the input values of Fig. 3, and they are simultaneously designed. Each point in Table A3

[3] For detail information about CPI values considering specific date, please look at Table A2 in Appendix. The 9% annual general inflation rate will be used for the calculations for the possible scenarios in the following sections.

[4] This inflation rate is the indicated CPI in 2014, and it is taken from Table 4.

[5] This interest rate is taken from Fig. 2, and can also be checked from the indicated interest rate corridor.

[6] Thirty years life time and 1500 TL device cost are not chosen randomly! A reference for that choices can be found in [53]. Another reference for the prices of equipment can be [58], who developed a prototype of a solar water heater in Algeria and determined the total cost of this prototype as €548 (€548 ~1808 TL (€1 = 3.3 TL, September 10/2016) with current prices in Turkey).

[7] from 3465 TL – 1140 TL = 2325 TL.

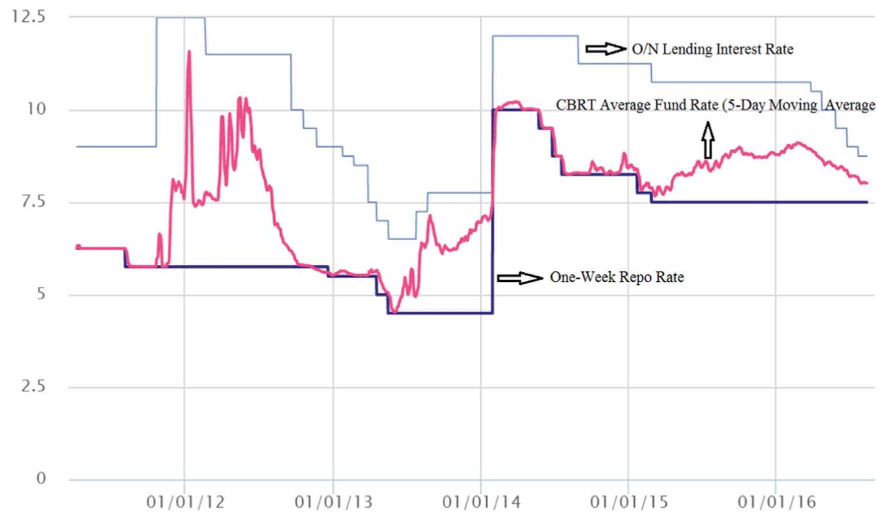

Fig. 2. Central Bank of the Republic of Turkey (CBRT) policy rates and interest rate corridor (%).
Source [56]: Latest Observation: August 10, 2016.

Table 5
The numerical calculations of PW values by executing Eq. (5).

$$PW = PC\left(\frac{1+i}{1+d}\right)^n \rightarrow 1500\left(\frac{1+0.09}{1+0.10}\right)^{30} \sim 1140\text{ TL}$$

$$PW = PC\left(\frac{1+i}{1+d}\right)^n \rightarrow 1500\left(\frac{1+0.09}{1+0.06}\right)^{30} \sim 3465\text{ TL}$$

Table 6
The values of actual costs and present worth of an annual incurred cost or savings in 30 years life span (TL) (Short form: shortened by periodically 5 consecutive years.).

Years	1.year	5.year	10.year	15.year	20.year	25.year	30.year
Actual cost or saving	1635	2308	3551	5464	8407	12,935	19,902
Years	1.year	5.year	10.year	15.year	20.year	25.year	30.year
Present worth	1339	851	483	274	156	88	50

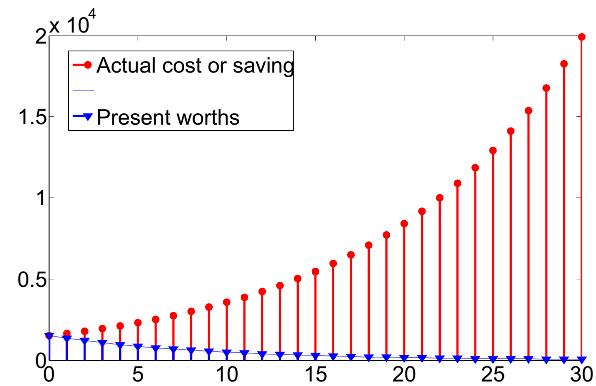

Fig. 3. **:** Actual Costs and Present Worth of an Annual Incurred Cost or Savings. ***Note:*** This figure is obtained by our data however, it is inspired from the figure in [55]. Notice that, the initial value starts from origin that means; the costs are known and payable at the beginning of the first time period. If the costs are payable at the end of first time period, the present worth calculation of the equipment should be made by a different formula. This formula is explicitly introduced and used in [59].

corresponds to both red circles for actual cost or saving values, and also corresponds to blue triangles for present worth of the initial 1500 TL. The values are arranged according to a 5 year period over 30 years for practical checking[8] in Table 6.

From Fig. 3 by summing up all the present worth values of regularly occurring savings over the economic lifetime, the life-cycle savings (LCS) can be obtained by:

$$LCS = A\sum_{j=1}^{n}\left(\frac{1}{1+D}\right)^j = A\ PWF(D,\ n) \tag{7}$$

Where A; is the present value of the first year's savings. After some arrangements the PWF(D, n) function can be given and calculated from:

$$PWF(D, n) = \begin{cases} \frac{1-(1+D)^{-n}}{D} \ when\ D \neq 0 \\ n\ when\ D = 0 \end{cases} \tag{8}$$

PWF(D, n) is known as the present-worth factor. It can be thought as, the consumers give a decision to invest in these systems with an effective discount rate "D", this quantity corresponds to a return ratio of first year natural gas savings for the next n years. As a result, we can obtain life cycle savings by multiplying the present value of first year's savings with this ratio (PWF(D, n)). Table 7 displays the present versus worth factors in each 7 year lifetime and discount rates for 30 year lifetime and between 1% and 50% discount rates. This table is the shortened form of Table A4 in the Appendix A. The values in Table 7 and Table A4 are determined by the algorithm indicated in Eq. (8), and it is expected to give a practical lifetime investment decision guideline for FPSCs' consumers.

4.1.2. The crucial information and findings about FPSCs investment in Turkey

According to our calculations we found that, the energy savings of a FPSC device for one year corresponds to 700 TL on average. In other words a household will pay less than that amount of money in a year.[9] It is known that, 1 m^3 natural gas is 1TL in Istanbul and it is 1.2 TL in Ankara [60]. Therefore, we reach a conclusion[10] that, each household or a residence will consume 600 m^3 less natural gas, in this case. Currently, 69 cities in Turkey are using natural gas. Also, there exists

[8] The Matlab codes for any year's lifetime can be supplied and given upon request for both producers and consumers. This study takes the lifetime year period as 30 years. However, this duration might be different due to the conditions of location, economy (subsidies, tax incentives, inflation and saving rates) and future expectations.

[9] Based on the survey interrogations and related calculations in Eskisehir, and it can be assumed that Eskisehir reflects Turkey's average because its geographical location places it in the center of the country, the contribution of these energy savings are calculated as 700 TL per a household in a year. This way the amount of natural gas used will be less.

[10] From 700 TL / 1.2 TL = 583.3 TL, since 1 TL = 1m^3→ 583.3 TL ~ 600m^3.

Table 7
Present-worth factors for various (in each 7 years) lifetimes and discount rates for 30 years life time and %1–50 discount rate.

Discount Rate (%)	Lifetime (years)				
	1.year	8.year	15.year	22.year	29.year
%1	0.990	7.652	13.865	19.660	25.066
%8	0.926	5.747	8.559	10.201	11.158
%15	0.870	4.487	5.847	6.359	6.551
%22	0.820	3.619	4.315	4.488	4.531
%29	0.775	2.999	3.373	3.436	3.446
%36	0.735	2.540	2.750	2.775	2.777
%43	0.699	2.193	2.315	2.325	2.326
%50	0.667	1.922	1.995	2.000	2.000

Note: Table 7 which is the shortened form of Table A4 in Appendix presents the present-worth factors of a given life time and discount rates and it can be used for practical checking by consumers.

9.5 million residences which use natural gas in Turkey [61]. As it is consumed 600 m^3 natural gas per residence[11]; 5.7 billion m^3 of natural gas will be saved in a year. As it is known that, 9.5 million residences are consuming 9 billion m^3 of natural gas [61] from our calculations, 45%[12] of this amount will be supplied by FPSCs. Thus, Turkey will save[13] 4.05 billion m^3 natural gas.

This amount corresponds to[14] 48.6 billion TL in a year.[15] Our import will be much less than this amount and also, for the reason of this situation, that amount will be supplied by domestic resources, therefore some production and new employment opportunities will arise. Turkey will save 14.7 billion dollars from this investment. It is important to note that, this amount is a minimum for the needs of the residences that will be supplied by FPSCs. Potentially, there exists an additional contribution of this device. As an example; the hot water systems can be improved for cooking meals, and it can be utilized by the savings of natural gas in the kitchens. When this modification is applied in restaurants it will create saving opportunities with an increasing rate.

An interesting question arises at this point. This question is: Once this energy system is set up, in how many years' time will a FPSC device pay for itself? The cost of a FPSC device for a residence can be calculated[16] as 3500 TL with additional 500 TL maintenance and repair cost. So, if we consider that, a FPSC device will save 700 TL of natural gas for each year,[17] it will pay its amount back in 5 years' time. Our finding is also mentioned in the Cicek Bezir et al.'s study with a reimbursement period of around 4.5 years in Turkey [62]. If we assume that this device is used for 30 years[18]; 21,000 TL saving opportunity will arise for a family. If we subtract the cost of 3500 TL, then[19] 17,500 TL remains and if there would be doubled the maintenance and repair costs,[20][21], 16,500 TL will be contributed for a family at present value[22] in a 30 year life time.

In addition to this, we can say that, if the numbers of cities which use natural gas increase in Turkey, this amount will increase rapidly. Currently, the amount of 156.75 billion TL will be saved for natural gas in Turkey's budget. The saving amount by FPSCs in 30 years with the present value is 4.7 times[23] more than its cost. For that reason this investment should immediately be implemented into daily life without any doubt.

4.1.3. A guideline with a possible scenario for consumers to calculate the TSLT of FPSCs investment Eskisehir

Three answers from consumers as a guideline for the calculation about TSLT of FPSCs investment in Eskisehir. It is important to mention that, these events are designed for Eskisehir and the solutions for them are calculated by Eskisehir's data. However, they can be applied to the other regions of the country.

It has been already discussed that, 3000 TL[24] is needed to purchase a FPSC system in Eskisehir that will save 700 TL in natural gas during the first year with a discount rate of 15% and a general inflation rate of 9%. Let's consider and estimate the first event as the question of; what will the actual cash value of natural gas saving be in the tenth year? The second event is the question of; what will the natural gas LCS for a 30-year period be? The third event is a question of; what will the TSLT for a 30-year period be? Let's calculate D_r, the first case, the second case and the third case in the first, second and third row of Table 8, respectively.

Over the 30 years, this renewable energy system investment is worth 7173.621 TL in current Turkish Liras with an inflation rate of 9% and a discount rate of 15%.

4.1.4. Natural gas savings

In this part of the study, LCS_n (Annual Incremental Natural Gas Savings) is calculated. The type of fuel can be different from region to region and country to country based on the types of buildings and their structure. However, our survey gives an explicit answer of what kind of fuel is used in our sample case. Based on answers from the survey questions that are indicated in Table 3, approximately 90% of households are using natural gas for heating and cooking purposes. Thus, we take natural gas as a fuel in our calculations.

LCS_n can be calculated from annual solar fraction (f), the unit cost of replaced energy (C_n), annual energy requirement (Q) and, anticipated energy inflation rate (PWF). D_r is the effective discount rate adjusted for the inflation rate and, n had already defined. So, Eq. (9) can be written as;

$$LCS_n = fC_nQPWF(D_r,\ n) \tag{9}$$

The conventional natural gas unit costs normally have volatile price values depending on time and location. The natural gas for residential heating purposes is calculated from households' bills that are obtained from our survey and have a value between 40 TL/month and 244 TL/month and the average value for a month is 134 TL (see Table 2 in [53]). If we calculate for one year[25] then 1608 TL will be needed for heating purposes.

LCS_n changes from system to system depending on the efficiency. Our device has an efficiency of up to 85% (see [53]). The data about annual natural gas-inflation rate can be found in Table A2 in the Appendix A. For a possible scenario let's calculate the LCS_n of natural gas saved for a household residence that uses a FPSC system. From the data of our calculations this system can save 4320 MJ annually,[26] in other words; one collector produces 4320 MJ per year. Solar energy

[11] From 9.5 million * 600m^3 = 5.7 billion m^3.

[12] This percentage is calculated by a detailed observation and measurements for Eskisehir, and can be supplied upon a request.

[13] From 9 billion m^3 * 0.45 = 4.05 billion m^3.

[14] From 4.05 billion m^3 * 12 = 48.6 billion TL.

[15] This amount corresponds to; (from 48.6 billion TL / 3.3 ~ $14.7 billion) 14.7 billion dollar per year.

[16] From 1500 TL * 2= 3000 TL + 500 TL maintenance and repair cost = 3500 TL.

[17] From 3500 TL / 700 TL / year = 5 year.

[18] From 700 TL * 30 years = 21,000 TL.

[19] From 21,000 TL – 3500 TL = 17,500 TL.

[20] From 500 TL + 500 TL = 1000 TL.

[21] From17,500 TL – 1000 TL = 16,500 TL.

[22] According to this calculations; from 9.5 million * 16,500 TL = 156.75 billion TL will be saved in the country with present value. And this amount will have a present worth of (from $PW = PC\left(\frac{1+i}{1+d}\right)^n \rightarrow 156.75$ billion TL$*\left(\frac{1+0.09}{1+0.06}\right)^{30} \sim 362.09$ billion TL) 362.09 billion TL after 30 years duration with 9% inflation rate and 6% discount rate.

[23] That can be calculated as; 16,500 TL / 3500 TL = 4.7.

[24] Since 1 collector's price is 1500 TL, 2 collectors' price is from 1500 TL * 2 = 3000 TL.

[25] From 134 TL * 12 = 1608 TL.

[26] From 8 months * 30 days = 240 days, one collector produces 5 kWh per day so 240 * 5kWh =1200kWh per year. 1kWh = 3600,013.307J so (1200kWh * 3600,013.307J) / 1000,000 = 4320Mega Joule (MJ)).

Table 8
Numerical calculations of above-mentioned four questions.

1st row: from Eq. (6) $\left(D_r = \frac{1+d}{1+i} - 1\right) \rightarrow D_r = \frac{1+0.15}{1+0.09} - 1 = 0.055 = 5.5\%$

2nd row: from Eq. (4) (FV = PC $(1+i)^n$) → FV = 700 * $(1.09)^{10}$ = 1657.154 TL

3rd row: from Eq. (7) (LCS = A $\sum_{j=1}^{n} \left(\frac{1}{1+D}\right)^j$ = A PWF(D, n)) →700 * $\left(\frac{1-(1+0.055)^{-30}}{0.055}\right)$ = 10,173.621 TL

4th row: from Eq. (1) (TSLT = LCS of natural gas – LCC of initial investment) → TSLT = 10,173.621 TL −3000 TL → TSLT = 7173.621 TL

replaces natural gas which is adjusted to a unit cost of 1 TL/m^3 [53] which has an inflation rate of 10% per year (see Table A2). We have already known and calculated that the economic life of the system is 30 years [53] and let's take the discount rate as 12%[27]and, if 4320 MJ corresponds to 1608 TL then the amount of 1 MJ is[28] 0.4 TL/MJ, so if we turn back to our calculations; D_r, LCS_n and PWF(18%, 30) are calculated as it is shown in the first, second and third row of Table 9, respectively.

So, with an inflation rate of 10%, discount rate of 12% the LCS_n of natural gas saved for a residence that uses FPSCs for heating space, in 30 year life time, is 9531.648 TL.

4.2. Discussion: considering a possible scenario for Eskisehir

In this section of the study, we calculated the annual payment, the LCC of these payments, the LCC of the interest portion of these payments, and the TSLT, including income tax benefits and tax credits for a 30-year life span. The theoretical background had already been given in the methods part and the additional related formulas can be followed from the Section 5.1. The following results are obtained by the help of survey data and second hand data collected from CBRT and TurkStat.

Let's consider a possible scenario which goes along with the economic facts of Turkey. A consumer is planning to buy a FPSC energy system that has a cost of 3000 TL[29] (a high quality evacuated tube absorber water heater model has a selling price of approximately[30] €900 or 2970 TL with current prices, for a 150 l equipment in Turkey [62], for both heating and cooking purposes (1128 TL[31] is more expensive than a conventional energy system). It will be financed with a 20% down payment[32] which is supplied as a grant or a rebate from the Turkish Government. 14% interest (mortgage) rate[33] and 30 year loan that is a part of the house mortgage. The average tax bracket which is referenced by the Turkish Government as 18% VAT, and also eligible for a 32%[34] energy tax credit, and the discount rate is 10% which is discussed in Section 4.1.1. and is taken from Fig. 2.

[27] This discount rate changes business to business and determined by competition rules in a free market conditions.

[28] ffom 1608 TL / 4320MJ = 0.372 ~ 0.4 TL / MJ.

[29] Since 1 collector's price is 1500 TL 2 collector's price is 3000 TL.

[30] From €1 = 3.3 TL so €900 ~ 2970 TL.

[31] The average annual cost for both heating and cooking purposes is calculated as 133.8 TL + 21.8 TL = 155.6 TL ~ 156 TL [53] for one month. If we multiply this with 12 months we get 156 TL * 12 = 1872 TL annual cost for a household with a conventional system. If we subtract this amount from 3000 TL, (3000 TL – 1872 TL = 1128 TL) then 1128 TL is found as the difference amount that is given to FPSC system.

[32] In the US, down payments for home and home systems vary up to 20% of the purchase cost [63]. Turkish Government should immediately consider and apply down payments on renewable energy systems. Therefore, we take the 20% down payment and wanted to gain an idea on this subject.

[33] This interest rate is different from effective discount rate in Turkey. It depends on a mortgage market which is a few points greater than effective discount rate in Turkey, since Eskisehir is an attractive living place by means of mortgage markets.

[34] A FPSC system produces 1200kWh per year that is discussed in section 4.1.2. and 13.3 cents is given for 1kWh as a feed-in tariff [64]. Therefore 13.3 cents * 1200 = 15,960kWh cents, and 15,960 kWh cents / 100 cents ~$160 (since $1 is 3 TL, thus $160 * 3 = 480 TL is given to this system as a feed-in tariff by Turkish Government for one year. (480 TL / 1500 TL) * 100 ~ 32% is calculated as the energy tax credit for one year.

Table 9
Numerical calculations of LCS_n.

1st row : $D_r = \frac{1+d}{1+i} - 1 \rightarrow \frac{1+0.12}{1+0.10} - 1 = 0.018 \rightarrow 18\%$

2nd row: so, LCS_n = 0.4 * 4320 * PWF(18%, 30), therefore we need to calculate PWF(18%, 30)

3rd row : PWF(18%, 30) = $\left(\frac{1-(1+0.18)^{-30}}{0.18}\right)$ = 5.516, if we substitute this value in LCS_n

4th row : LCS_n = 0.4 * 4320 * 5.516 = 9531.648 TL is found.

Table 10
Numerical calculations of A_p, LCC_p, LCC_{ip} and TSLT.

1st row : from Eq. (10) → $A_p = P_a$ / (PWF(i, n_i) → A_p = 1632 / PWF*(14%,30) = 1632 / 7 ~ 233 TL per year

2nd row: from Eq. (11)→ LCC_p = 233 PWF** (10%, 30) → 233 * 9.43 = 2197 TL

3rd row: P_a* i = 1632 * 0.14 ~ 229 TL

4th row: D^* = ((1+d) / (1 + i)) − 1 = (1.1 / 1.14) − 1 ~ −0.035

5th row: $LCC_{ip} = P_a$ * i * [((1+ i)$^n{}_i$ PWF(d, n_{min}) – PWF(D^*, n_{min}) / (1+i)) / (1+i)$^n{}_i$ – 1] → LCC_{ip} = 1632 * 0.14*[((1 + 0.14)^{30} PWF(10%, 30) – (PWF(−3.5%, 30)) / 1.14)) / ((1.14)^{30} − 1) ~ 2290 TL

6th row: TSLT = 960 TL + 0.18 * 2290 TL – 408 TL – 2197 TL ~ −1231 TL

Note: *PWF(14%, 30) = 1 – (1 + 0.14)$^{-30}$ / 0.14 ~ 7 and ** PWF(10%, 30) = 1 – (1 + 0.1) $^{-30}$ ~ 9.43.

According to this information, we can determine the annual mortgage payment, the LCC of these payments,[35] the LCC of the interest portion of these payments, and the TSLT, including income tax benefits and tax credits for a 30-year life time[36] as followed below.

Now we can solve the above-mentioned scenario as a guideline for a consumer living in Eskisehir. 32% tax credit leads[37] for 3000 TL is equal to 960 TL. If we subtract this term from two units of FPSC equipment[38] the price comes to 3000 TL, we reach[39] a 2040 TL payment. If we multiply this amount with a 20% down payment rate we obtain[40] 408 TL. If we subtract this from 2040 TL we reach[41] 1632 TL which is the amount of borrowed capital. According to Eq. (10); A_p is found as 233 TL per year, the LCC of the payments are given in Eq. (11) and LCC_p is found to be at 2197 TL, by the way, P_a is also found to be at 229 TL, D^* is calculated at −0.035, according to Eq. (12) and Eq. (13), LCC_{ip} is 2290 TL, the energy tax credit, which is applied to the purchase price[42] is 960 TL, the incremental down payment[43] of 408 TL and the TSLT, including the down payment, tax credit mortgage payment, and income tax benefits is therefore; −1231 TL as it is shown in the first, second, third, fourth, fifth and sixth row of Table 10, respectively.

The net present worth of this purchase is −1231 TL. Note that this is a cost of 1231 TL, and not a saving. Also notice that, the TSLT would have been −2290 TL without the energy tax credit. A very critical finding is that 1231 TL < 1872 TL which shows the meaning behind the FPSC. This means that, buying FPSC equipment is a profitable investment for homeowners or consumers for not only it supplying clean energy but also, it has a significant cost advantage against conventional systems during a life time of investment.

Besides our calculations as [15], mentioned in their study and we agree with them for FPSCs, the costs of FPSCs are much lower than those of solar

[35] Please follow the formulas that are stated in Section 5.1.

[36] These two variables have not been taken consideration in Turkey yet (Please check the Table 1. However, we believe that they will be applied in a soon time period for the reason of rapid developments in renewable energy markets, therefore we add them in our calculations.

[37] From 3000 TL * (32 / 100) = 960 TL.

[38] From 1500 TL * 2 = 3000 TL; two units of collector price.

[39] From 3000 TL − 960 TL = 2040 TL.

[40] From 2040 TL * (20 / 100) = 408 TL.

[41] From 2040 TL − 408 TL = 1632 TL.

[42] From 3000 TL * 0.32 = 960 TL.

[43] From 3000 TL * (32 / 100) = 960 TL and 3000 TL – 960 TL = 2040 TL and 2040 TL * (20 / 100) = 408 TL.

PV, wind and biomass power. Therefore, policymakers should pay more attention to the diffusion of FPSCs to minimize total costs to reach renewable energy objectives. When consumers treat FPSCs as an investment, the financial attractiveness is below the effective amounts. So, an incentive program is needed to make FPSC consumption more attractive. Some practical information due to energy saving performance for FPSCs investment will be an important issue for consumers when taking their investment decisions, because the usage of FPSCs has some benefits to consumers. These are; 1) They can be used for both domestic and for larger systems such as; in restaurants, guest houses, canteens, hotels and hospitals etc… 2) A FPSC can prevent a considerable amount of CO_2 emission, some harmful pollution, and can lower various amounts of fuel and energy consumption such as; firewood, charcoal, kerosene, lpg and electricity. 3) It needs less maintenance in comparison to other electrical devices. 4) It is user friendly and no need to require a highly skilled person to operate it. 5) It has a sound economic reimbursement period 6) Usage of it is safer than its electrical substitutions. 7) It has some extra features that can also function in bad climatic conditions [43]. In addition to these advantages, if the consumers invest in FPSCs' technology, this will provide extra employment alternatives in the case of production for the city and country.

5. Conclusions

The utilization feature of FPSCs in households makes this study is a kind of a guideline for a segment of residents who are living in Eskisehir, Turkey. The basic objective of the study was the cultivation and the informing of the consumer segment for better market transactions. We obtained scientifically satisfying findings and the aim is achieved by different aspects both in the frame of economics and finance. Specifically, we showed that transition to renewable energy systems thorough a FPSC equipment is a rational and powerful decision for both consumers and producers of local markets.

In the economic and financial analysis we firstly considered two possible scenarios purchasing a FPSC device for a 30 year lifetime with inputs of 9% inflation rate and 10% discount rate and then we changed only the discount rate to 6% and observed that the present worth of the equipment became 2375 TL more costly than the first case which is a heavy and an unwanted situation for consumers. Therefore, the case of the discount rate is higher than the general inflation rate in the country, is a very critical clue but negative for consumers in making their investment decisions. Table A3 (Fig. 3 is the analytical form of Table A3) shows the values of actual costs and the present worth of an annual incurred cost or saving 1500 TL in a 30 year life span and it is a guideline for consumers with Turkish economy indicators for their long term investment decisions. In addition to this, it is important to note that, for different economic inputs or the application for the financial situations of other countries and the algorithms for calculations are available. They can be supplied upon request. Secondly, we took into account some possible cases and answered some of the questions for consumers to calculate the TSLT of FPSCs investment in Eskisehir. With a purchase of 3000 TL, 15% discount rate, 9% inflation rate and 700 TL saving in natural gas for the first year the actual cash values of natural gas saving in the tenth year will be 1657.154 TL. The LCS of the natural gas for a 30-year period will be 10,173.621 TL. Thirdly we calculated the TSLT over 30 years. Therefore, this renewable energy system investment is worth 7173.621 TL (TSLT) in current Turkish Liras with an inflation rate of 9% and a discount rate of 15%. In addition to this, with an inflation rate at 10% per year and an economic life of 30 years and a discount rate of 12% LCS_n is calculated at; 9531.648 TL annually.

We end up with the calculation of the annual payment, the LCC of these payments, the LCC of the interest portion of these payments and the TSLT including income tax benefits and tax credits for a 30-year life time investment of FPSC in condition of a 20% down payment, 14% mortgage rate, %18 tax bracket, 32% tax credit and 10% discount rate for a consumer who buys two units of FPSC equipment for heating and cooking purposes. These calculations showed that buying a FPSC device is a rational and profitable investment decision for households in the economic conditions of Eskisehir because the present worth of this investment is less (1231 TL) than the value amount of conventional fuel (natural gas) (1872 TL) that is used for the indicated needs above.

This study also showed that, the amount saved by FPSCs in 30 years with present value is 4.7 times more than its cost. So we came to a consensus that there is no doubt about using FPSC energy systems for the reason of both their cost advantage and environmentally friendly structure. However, there still exists some application barriers especially in developing countries such as Turkey. As it is stated in the earlier parts of the study, there are some solar energy system applications in both technical and financially developed countries such as; United Kingdom, Australia, New Zealand, Ireland, China, India and Greece. Turkey may follow these countries for a fast growing market structure and technological improvements. Controversially, those countries may take this study as a reference and guideline on for consuming and producing FPSCs. FPSCs can be accepted as a part of life only if the condition of production costs is not much more than their present values or energy saving performances along with repair and maintenance costs. If this condition is satisfied, which we displayed in this research, the investment decision is nothing more than a rational and logical time plan. Besides, the Turkish government should give enough and needed importance for implementing public policies between consumers and producers by adjusting, renewable and sustainable energy support policies. Feed-in tariff, mandate, subsidies, grant and investment mechanisms exist but some other energy policies should also be included such as; specific regulatory policies, fiscal incentives and public financing policies. Transition to renewable energy systems will bring many advantages. Producing our own energy without any interdependence, creating new employment opportunities and living in a clean environment are top priority. Sustainable development can be achieved by giving the decision of choosing these environmentally friendly systems for Eskisehir and Turkey.

5.1. Borrowed-loan costs

Annual payments on borrowed-loan consists both the interest rate and the borrowed loan amount. The annual payment to borrowed amount ratio for n_i years at an annual interest (mortgage) rate "i" is;

$$A_p/P_a = i/1-(1+i)_i^{-n} = 1/\mathrm{PWF}(i, n_i) \tag{10}$$

where P_a is the borrowed loan amount and A_p is the annual payment. One can calculate the life cycle cost for all loans in the duration of whole economic life from;

$$\mathrm{LCC_p} = P_a*(\mathrm{PWF}(d,\ n_{min})/\mathrm{PWF}(i, n_i)) \tag{11}$$

where n_{min} is the minimum amount of the economic life n. While loan payments are determined by contract, therefore they can be taken as fixed and independent from inflation rate.

The annual interest cost can be calculated in the jth year of the loan as;

$$A_j = P_a*i*[(1+i)_i^n-(1+(i)^{j-1}/(1+i)_i^n-1] \tag{12}$$

The LCC of interest payments can be found from;

$$\mathrm{LCC_{ip}} = P_a*i*[((1+i)_i^n\mathrm{PWF}(d, n_{min})-\mathrm{PWF}(D^*,n_{min})/(1+i))/(1+i)_i^n-1] \tag{13}$$

Here, the mortgage adjusted is introduced as[44];

$$D^* = (1+d)/(1+i)-1 \tag{14}$$

[44] The indicated formulas above is inspired by and followed from [55].

Appendix A

See appendix Tables A1-A4 here.

Table A1
Central Bank of the Republic of Turkey (CBRT) policy rates and interest rate (%).
Source [56]: *CBRT, Latest* Observation: August 10/2016.

CBRT Policy Rates CBRT Interest Rates (%) Overnight (O/N)		CBRT Policy Rates CBRT Interest Rates (%) Late Liquidity Window (LON)		CBRT Policy Rates	
CBRT Interest Rates (%)		CBRT Interest Rates (%)		1 Week Repo	
Overnight (O/N)		Late Liquidity Window (LON)			
Date	**Lending**	**Date**	**Lending**	**Date**	**Lending**
15.10.2010	8.75	15.10.2010	11.75	20.05.2010	7
12.11.2010	8.75	12.11.2010	11.75	17.12.2010	6.5
17.12.2010	9	17.12.2010	12	21.01.2011	6.25
21.10.2011	12.5	21.10.2011	15.5	05.08.2011	5.75
22.02.2012	11.5	22.02.2012	14.5	19.12.2012	5.5
19.09.2012	10	19.09.2012	13	17.04.2013	5
19.10.2012	9.5	19.10.2012	12.5	17.05.2013	4.5
21.11.2012	9	21.11.2012	12	29.01.2014	10
23.01.2013	8.75	23.01.2013	11.75	23.05.2014	9.5
20.02.2013	8.5	20.02.2013	11.5	25.06.2014	8.75
27.03.2013	7.5	27.03.2013	10.5	18.07.2014	8.25
17.04.2013	7	17.04.2013	10	21.01.2015	7.75
17.05.2013	6.5	17.05.2013	9.5	25.02.2015	7.5
24.07.2013	7.25	24.07.2013	10.25		
29.01.2014	7.75	29.01.2014	15		
28.08.2014	12	28.08.2014	12.75		
25.02.2015	12	25.02.2015	12.25		
25.03.2016	11.25	25.03.2016	12		
21.04.2016	10.75	21.04.2016	11.5		
25.05.2016	10.5	25.05.2016	11		
22.06.2016	10	22.06.2016	10.5		
20.07.2016	9.5	20.07.2016	10.25		

***Note*:** Table A1 is the extended and detailed form of Fig. 2.

Table A2
Consumer Price Index (CPI) (2003=100). Monthly and annual inflation rates were announced by TurkStat.
Source [56,57]: *CBTR and TurkStat.*

Date	**CPI (Year to Year % Changes)**	**CPI (Month to Month % Changes)**
01.07.2016	8.79	1.16
01.06.2016	7.64	0.47
01.05.2016	6.58	0.58
01.04.2016	6.57	0.78
01.03.2016	7.46	−0.04
01.02.2016	8.78	−0.02
01.01.2016	9.58	1.82
01.12.2015	8.81	0.21
01.11.2015	8.1	0.67
01.10.2015	7.58	1.55
01.09.2015	7.95	0.89
01.08.2015	7.14	0.4
01.07.2015	6.81	0.09
01.06.2015	7.2	−0.51
01.05.2015	8.09	0.56
01.04.2015	7.91	1.63
01.03.2015	7.61	1.19
01.02.2015	7.55	0.71
01.01.2015	7.24	1.1
01.12.2014	8.17	−0.44
01.11.2014	9.15	0.18
01.10.2014	8.96	1.9

(continued on next page)

Table A2 *(continued)*

Date	CPI (Year to Year % Changes)	CPI (Month to Month % Changes)
01.09.2014	8.86	0.14
01.08.2014	9.54	0.09
01.07.2014	9.32	0.45
01.06.2014	9.16	0.31
01.05.2014	9.66	0.4
01.04.2014	9.38	1.34
01.03.2014	8.39	1.13
01.02.2014	7.89	0.43
01.01.2014	7.75	1.98
01.12.2013	7.4	0.46
01.11.2013	7.32	0.01
01.10.2013	7.71	1.8
01.09.2013	7.88	0.77
01.08.2013	8.17	−0.1
01.07.2013	8.88	0.31
01.06.2013	8.3	0.76
01.05.2013	6.51	0.15
01.04.2013	6.13	0.42
01.03.2013	7.29	0.66
01.02.2013	7.03	0.3
01.01.2013	7.31	1.65
01.12.2012	6.16	0.38
01.11.2012	6.37	0.38
01.10.2012	7.8	1.96
01.09.2012	9.19	1.03
01.08.2012	8.88	0.56
01.07.2012	9.07	−0.23
01.06.2012	8.87	−0.9
01.05.2012	8.28	−0.21
01.04.2012	11.14	1.52
01.03.2012	10.43	0.41
01.02.2012	10.43	0.56
01.01.2012	10.61	0.56
01.12.2011	10.45	0.58
01.11.2011	9.48	1.73
01.10.2011	7.66	3.27
01.09.2011	6.15	0.75
01.08.2011	6.65	0.73
01.07.2011	6.31	−0.41
01.06.2011	6.24	−1.43
01.05.2011	7.17	2.42
01.04.2011	4.26	0.87
01.03.2011	3.99	0.42
01.02.2011	4.16	0.73
01.01.2011	4.9	0.41
01.12.2010	6.4	−0.3
01.11.2010	7.29	0.03
01.10.2010	8.62	1.83
01.09.2010	9.24	1.23
01.08.2010	8.33	0.4
01.07.2010	7.58	−0.48
01.06.2010	8.37	−0.56
01.05.2010	9.1	−0.36
01.04.2010	10.19	0.6
01.03.2010	9.56	0.58
01.02.2010	10.13	1.45
01.01.2010	8.19	1.85

Table A3
The values of actual costs and present worth of an annual incurred cost or savings in 30 years life span (TL) (Extended form).

Years (1–10 years)	1.year	2.year	3.year	4.year	5.year	6.year	7.year	8.year	9.year	10.year
Actual cost or saving	1635	1782	1943	2117	2308	2516	2742	2989	3258	3551
Years (11–20 years)	**11.year**	**12.year**	**13.year**	**14.year**	**15.year**	**16.year**	**17.year**	**18.year**	**19.year**	**20.year**
Actual cost or saving	3871	4219	4599	5013	5464	5955	6491	7076	7712	8407
Years (21–30 years)	**21.year**	**22.year**	**23.year**	**24.year**	**25.year**	**26.year**	**27.year**	**28.year**	**29.year**	**30.year**
Actual cost or saving	9163	9988	10,887	11,867	12,935	14,099	15,368	16,751	18,258	19,902
Years (1–10 years)	**1.year**	**2.year**	**3.year**	**4.year**	**5.year**	**6.year**	**7.year**	**8.year**	**9.year**	**10.year**
Present worth	1339	1196	1068	953	851	760	679	606	541	483
Years (11–20 years)	**11.year**	**12.year**	**13.year**	**14.year**	**15.year**	**16.year**	**17.year**	**18.year**	**19.year**	**20.year**
Present worth	431	385	344	307	274	245	218	195	174	156
Years (21–30)	**21.year**	**22.year**	**23.year**	**24.year**	**25.year**	**26.year**	**27.year**	**28.year**	**29.year**	**30.year**
Present worth	139	124	111	99	88	79	70	63	56	50

Table A4
Present-worth factors for various (2 years) lifetimes and discount rates for 30 years life time and %1–50 discount rate.

Lifetime (years)															
Discount Rate (%)	**1**	**3**	**5**	**7**	**9**	**11**	**13**	**15**	**17**	**19**	**21**	**23**	**25**	**27**	**29**
1	0.99	2.94	4.85	6.73	8.57	10.37	12.13	13.87	15.56	17.23	18.86	20.46	22.02	23.56	25.07
3	0.97	2.83	4.58	6.23	7.79	9.25	10.63	11.94	13.17	14.32	15.42	16.44	17.41	18.33	19.19
5	0.95	2.72	4.33	5.79	7.11	8.31	9.39	10.38	11.27	12.09	12.82	13.49	14.09	14.64	15.14
7	0.93	2.62	4.10	5.39	6.52	7.50	8.36	9.11	9.76	10.34	10.84	11.27	11.65	11.99	12.28
9	0.92	2.53	3.89	5.03	6.00	6.81	7.49	8.06	8.54	8.95	9.29	9.58	9.82	10.03	10.20
11	0.90	2.44	3.70	4.71	5.54	6.21	6.75	7.19	7.55	7.84	8.08	8.27	8.42	8.55	8.65
13	0.88	2.36	3.52	4.42	5.13	5.69	6.12	6.46	6.73	6.94	7.10	7.23	7.33	7.41	7.47
15	0.87	2.28	3.35	4.16	4.77	5.23	5.58	5.85	6.05	6.20	6.31	6.40	6.46	6.51	6.55
17	0.85	2.21	3.20	3.92	4.45	4.84	5.12	5.32	5.47	5.58	5.66	5.72	5.77	5.80	5.82
19	0.84	2.14	3.06	3.71	4.16	4.49	4.71	4.88	4.99	5.07	5.13	5.17	5.20	5.22	5.23
21	0.83	2.07	2.93	3.51	3.91	4.18	4.36	4.49	4.58	4.63	4.67	4.70	4.72	4.73	4.74
23	0.81	2.01	2.80	3.33	3.67	3.90	4.05	4.15	4.22	4.26	4.29	4.31	4.32	4.33	4.34
25	0.80	1.95	2.69	3.16	3.46	3.66	3.78	3.86	3.91	3.94	3.96	3.98	3.98	3.99	3.99
27	0.79	1.90	2.58	3.01	3.27	3.44	3.54	3.60	3.64	3.66	3.68	3.69	3.69	3.70	3.70
29	0.78	1.84	2.48	2.87	3.10	3.24	3.32	3.37	3.40	3.42	3.43	3.44	3.44	3.44	3.45
31	0.76	1.79	2.39	2.74	2.94	3.06	3.13	3.17	3.19	3.21	3.21	3.22	3.22	3.22	3.22
33	0.75	1.74	2.30	2.62	2.80	2.90	2.96	2.99	3.01	3.02	3.02	3.03	3.03	3.03	3.03
35	0.74	1.70	2.22	2.51	2.67	2.75	2.80	2.83	2.84	2.85	2.85	2.85	2.86	2.86	2.86
37	0.73	1.65	2.14	2.40	2.54	2.62	2.66	2.68	2.69	2.70	2.70	2.70	2.70	2.70	2.70
39	0.72	1.61	2.07	2.31	2.43	2.50	2.53	2.55	2.55	2.56	2.56	2.56	2.56	2.56	2.56
41	0.71	1.57	2.00	2.22	2.33	2.38	2.41	2.42	2.43	2.44	2.44	2.44	2.44	2.44	2.44
43	0.70	1.53	1.94	2.14	2.23	2.28	2.30	2.31	2.32	2.32	2.32	2.32	2.33	2.33	2.33
45	0.69	1.49	1.88	2.06	2.14	2.18	2.20	2.21	2.22	2.22	2.22	2.22	2.22	2.22	2.22
47	0.68	1.46	1.82	1.98	2.06	2.10	2.11	2.12	2.12	2.13	2.13	2.13	2.13	2.13	2.13
49	0.67	1.42	1.76	1.92	1.98	2.02	2.03	2.04	2.04	2.04	2.04	2.04	2.04	2.04	2.04

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