Technical - economic analysis for choosing a solar installation for domestic hot water

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Abstract — **Using renewable energy is a concern that all countries manifests both because of the depletion of natural resources as well as traditional gas emissions greenhouse they produce. The study aims to identify the costs involved in a solar plant for heating domestic hot water for a detached house and choosing the optimal collector of the three categories in the market (flat, vacuum tube and heat pipe). In the first part of the study has analysed the variation of heat over time and solar radiation regarding the characteristics of thermal solar collectors that influence their effectiveness. For each type of collector it was presented the variation in the density flow yield of radiation. Subsequently the global solar radiation intensity was measured over the year and we noticed significant differences that ultimately determine the amount of energy produced. To have a choice of solar DHW system to calculate the heat load necessary the boiler was sized depending on the amount required under storage and other equipment were established: pumping system, automation and expansion vessel. The economic analysis was to establish the purchase of solar installation expenses, income earned as a result of energy products while allowing a return on investment and payback period for a single-family dwelling.**

Keywords— Collectors yield, cost, efficiency, performance

I. INTRODUCTION

In the current concerns for identifying sources of renewable fuels they became very often debated topics at national and international levels [1,2,3].

Due to the reduction of traditional fuels reserves in the world there is a concern of all countries to identify and use of new energy sources for energy security [4,5,6].

Solar energy is considered a renewable energy source, clean and safe and its use for heating domestic hot water (DHW) creates benefits for both consumers and the electrical energy sector by reducing consumption during peak [7,8,9,10] . In 2013 the solar energy used for heating and cooling was produced and successfully exploited in countries such as China (70%), USA (4.5%), Germany (3.3%), Turkey (2.9%), Brazil (1.8%), etc. [1]. Worldwide DHW heating using solar energy reached in 2014 a production of 406 GW by using flat plate collectors and evacuated tube collectors in most of Europe and unglazed collectors to countries like USA, Australia, Brazil, Mexico [11].

Renewable energy as an alternative energy is supported by all countries which results in changes in legislation to facilitate the development of energy infrastructure [12,13].

Using solar energy for heating or cooling is no longer a novelty. Concerns growing specialists are directed towards the choice of technology to achieve the best economic performance (cost - benefit) to reduce consumption at peak times, to reduce emissions Greenhouse gas or other social benefits [14,15,16,17,18,19,20,21]. They have shown in their studies that the use solar energy for heating and cooling buildings can be achieved with low-cost countries such as Brazil, Canada, USA and higher costs in countries like Germany, Austria, etc., due to climatic conditions.

Other experts went further analysing the possibilities for optimizing solar energy by using it in parallel with another type of energy such as geothermal, wind etc. and demonstrated the effectiveness of these systems according to local geographical conditions [22,23]. To design a solar heating installations for domestic hot water Chinese researchers have shown in their studies the existence of several variables such as number of users, cultural characteristics, habits, etc. influencing the sizing of solar as well as geographically dependant variable indicators as the "solar fraction" indicator (ratio of solar heat energy and conventional energy consumption) representing key information to determine the total collector surface [24,25]. They showed that although power consumption is higher for DHW heating with solar energy (2.5 kWh / day) compared to electricity (1 kWh / day) due to the accumulation regime versus instant solar energy has the advantage that it is renewable and therefore a replacement for conventional energy. Effective design of an installation of solar DHW involves correct definition of real needs and how to change them [26,27]. The study found that in general there is a tendency for over sizing in the design phase, leading to higher further operating costs to maintain the water at a certain temperature and water recirculation, this influencing amortization period (payback period) of the investment [28].

The study of the potential for exploitation of solar energy in Cluj-Napoca, Romania highlights the importance given location or location (latitude, longitude, altitude), the orientation of thermal solar collectors on the two angles: the angle of inclination from the horizontal and azimuth i.e. orientation angle to the direction of the south, normal and global radiation, direct and diffuse radiation normal on a slope, etc., the presence or absence of pollution [29]. The efficiency of solar systems for hot water is influenced by both the cold water inlet temperature, average ambient temperature, wind speed and construction features that they hold solar collectors heat (isolation thickness, glazing characteristics, tank painting) [30,31]. Studies in Tunisia have shown that the efficiency of solar collector heat used to heat domestic hot water can be affected up to 30% due to variations in ambient temperature up to 40% of cold water temperature and up to 9% wind speed [30].

II. Material And Methods

In the study it started from the premise that technical and economic efficiency of energy is determined by the correlation between outcomes as a result of the efforts made.

Technical-economic study is a comparative study conducted which allowed choosing an installation of solar DHW for single-family dwelling by analysing the behaviour of the thermal solar collectors. It started from the technical data of solar collectors by choosing how many of two collectors of each type collectors in the market: flat plate collectors, evacuated tube collectors and collectors with thermal tubes from two major manufacturers Bosch and Viessmann Termotechnology (Table I).

TABLE I. Global solar radiation flux density

No.	Name solar collectors	Key	Name of the company
1	Collector flate plate Vitosol 100-F SH1B	A	Viessmann
2	Collector flate plate Buderus 4.0	B	Bosch Termotechnology
3	Collector vaccum tube Vitosol 300 SP3	C	Viessmann
4	Collector vaccum tube Buderus Vaciosol CPC 12	D	Bosch Termotechnology
5	Heat pipe solar collector Vitosol 200-T tip SP2 de 2 m^2	E	Viessmann
6	Heat pipe solar collector Vitosol 200-T tip SP2 de 3 m^2	F	Viessmann

The main objectives that have been considered are:

Objective 1: Create a comparative analysis on the types of collectors (global solar radiation intensity and heat);

Objective 2: Identify the best choice for collectors and solar installations based on cost-benefit criteria.

It started from the analysis of data on types of collectors using measurements obtained by two pyranometers CMP3 type from Kipp & Zonen Company in the Netherlands. The measured data were recorded in a database with a transfer rate of 60 seconds at the Technical University of Cluj-Napoca, Romania. The data corresponds to measurements made in Cluj-Napoca at the following location: Latitude, Longitude: 46 47.758 N 23 37 563. A pyranometer was used to determine the total solar radiation intensity and the other for determining the intensity of diffuse solar radiation. These measurements were stored in a database that can be accessed through programs that support: storing, reading, and graphical display of the monitored values. Using the technical data specific to each solar collector: correction factor for heat loss k_1 correction factor heat loss k_2, optical return for collectors in the study were obtained values of global solar radiation intensity and corresponding time points.

The mathematical model that was the basis for achieving this software considered for solar panels tilt at an angle of 45^0 and a height angle sun in the sky giving 7^0 (angle of the sun to the earth's surface) [4].

To see the differences resulting from structural characteristics of collectors it was realized an analysis of their view of transmittance, absorption factor, yield optical and global coefficient of heat transfer for the three types of collectors (flat, vacuum tube and heat pipe solar).

The yield of the solar collectors is the efficiency with which solar radiation can be transformed into heat, and it is calculated by computing the relationship (1):

$$\eta = \eta_0 - k_1 \frac{\Delta t}{I_g} - k_2 \frac{\Delta t^2}{I_g} \quad (1)$$

Where:
- η [%] is the efficiency of solar collectors;
- η_0 [%] is optical efficiency, which takes into account the efficiency with which energy is absorbed solar radiation;
- k1 şi k2 [Wm^{2}K] are factored heat loss characteristics (overall heat transfer coefficient);
- Δt [^{0}C] is the difference between the average temperature of the heat collector and the ambient temperature;

Optical yield may be determined by the properties of the materials used in the construction of thermal solar collectors, with the relationship (2):

$$\eta_0 = \tau \times \alpha \quad (2)$$

Where:
- τ - is the transmittance, the transparent material (usually glass), which covers and seals the collector and ensuring the mechanical strength thereof;
- α is the absorption factor of absorbing material.

It was studied the variation in the output of each collector values of solar radiation flux density (Ig) between 200-1000 W/m^2 and temperature difference (Δt)) with values between 0-100^{0}C.

For the collectors in the study there were identified the following technical data factored yield and heat loss characteristics (Table II):

TABLE II. Technical data on every type of collector

	Units	Collector flate plate	Collector vaccum tube	Heat pipe solar collector
η_0	%	0.84	0.84	0.825
k1	W/m^{2}K	3.36	1.75	1.19
k2	W/m^{2}K^2	0.013	0.008	0.009

For heating DHW heating load (Q_{DHW}) was calculated using the following equation calculation (3):

$$\dot{Q}_{DHW} = \frac{n \times m \times c_w \times (t_b - t_r)}{\tau \times 3600} \quad (3)$$

Where:
- Q_{DHW} [kW] is the thermal load of hot water;
- n is the number of persons;
- m [kg] is the amount of hot water daily consumption considered as;
- c_w [kJ/kgK] is the specific heat of water quantity which varies with temperature, but which can be considered value c_w = 4,186kJ/kgK;
- t_b [°C] is the temperature of the cylinder;
- t_r [°C] is the cold water temperature, inlet temperature;
- τ [h] is the period during heating hot water considered of particular importance for the amount of heat load.

To store the hot water boiler is necessary to estimate the volume (V_b), knowing that the hot water accumulation regime occurs. Boiler volume was determined by the following relationship (4):

$$V_b = f \times V_{b\min} = f \times n \times C_{zn}\frac{t_{acm} - t_{ar}}{t_b - t_{ar}} \qquad (4)$$

Where:

- V_b [l] is the volume of the cylinder;
- f is the excessive factor with values between 1.5 ÷ 2 for solar energy, the role of increased to no temperature difference is felt to refill due to consumption;
- n is the number of people;
- C_{zn} [l/person/day] is the normal daily consumption per person;
- t_{DHW} [°C] is the water temperature at the point of use;
- t_{ar} [°C] is the temperature of the cold water inlet temperature;
- t_b [°C] is the temperature of the hot water boiler;

Area needed for sizing solar thermal collectors using the following equation (5):

$$S = \frac{\dot{Q}_{DHW}}{\dot{Q}_{DHW1}} \qquad (5)$$

Where:

S [m^2] is the area of solar collectors;

Q_{DHW1} [kW] is the task of the particular unit thermal solar collectors;

Total expenditure DHW solar system for heating comprises both fixed costs and variable costs, according to (6):

$$C_T = CF + CV \qquad (6)$$

Where:

CT [Euro] is total expenditure;

CF [Euro] is fixed costs;

CV [Euro] is variable expenses.

We have considered the following relationship:

1 kWh = 3.6 MJ

Starting from this relationship has been calculated transformation of an MJ kWh respectively for each month of the year after the following process:

- For January:

1 kWh = 0.10 RON = 0.02 Euro

(as the price for natural gas used by national distributor SC EON GAZ S.A. and exchange rate of the National Bank of Romania for January).

Given the quantity produced by each collector and an MJ value has been calculated monthly and total energy produced by collectors.

Revenues are considered to be equal to the energy produced by the solar DHW heating. The monthly income was calculated according to (7):

$$V_i = Amount \;\; of \;\; heat \;\; produced \times price \;\; per \;\; unit \qquad (7)$$

Total revenues for the year were calculated with the following equation (8):

$$V_T = \sum_{i=1}^{12} V_i \qquad (8)$$

Where:

VT [Euro] is total revenue;

V_i [Euro] are income for each month of a year.

Duration payback of solar thermal heating DHW is calculated by the relationship:

$$D_r = \frac{\dot{C}T}{\dot{V}T} \qquad (9)$$

Where:

D_r [Years] is the length of payback;

In the conducted study six models of collectors were used in three categories: flat plate collectors, evacuated tube collectors and heat pipe solar collectors, which were identified technical parameters and construction to Table III.

TABLE III. TECHNICAL FEATURES COLLECTORS

Features technical	Unit	Type collectors					
		Flat plate collectors		Vacuum tube collectors		Heat pipe solar collectors	
		A	B	C	D	E	F
Number of tubes	buc	-	-	20	12	20	30
Optical Yield	%	75,4	85,1	81,5	66,5	76,6	76,6
Correction factor for heat loss k_1	W/m^{2}k	4,15	4,036	1,43	0,721	1,42	1,42
Correction factor for heat loss k_2	W/m^{2}k^2	0,0114	0,0108	0,0076	0,006	0,005	0,005
Area capture	m^2	2,32	2,1	2,05	2,56	2,00	3,02

III. RESULTS AND DISCUSSIONS

Following the calculation of optical performance, the results were obtained on types of collectors, shown in Figures 1-3 where the behavioural changes of each solar thermal collector from varying the temperature of the heat in the collector and the environment can be observed.

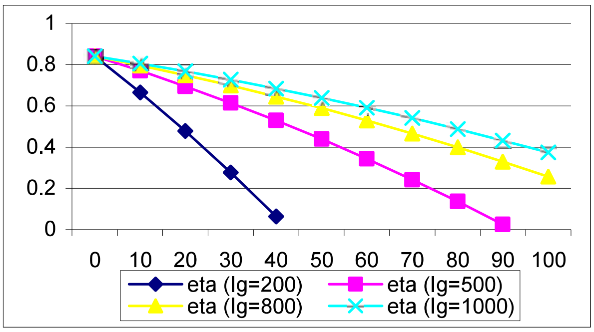

Fig. 1. Variation efficiency of solar collectors plan

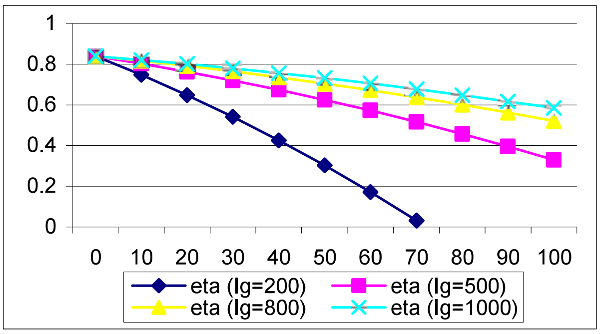

Fig. 2. Variation efficiency vacuum tube solar collectors

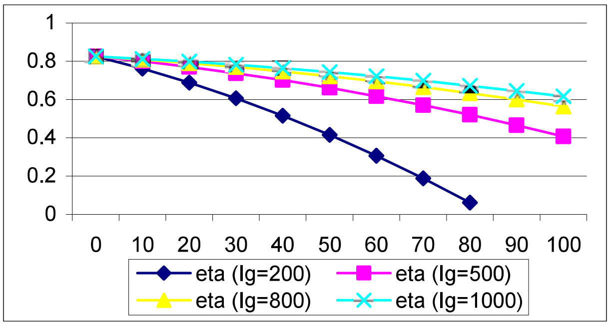

Fig. 3. Variation efficiency heat pipe solar collectors

Figures 1-3 also show the variation of efficiency to the change in temperature and global solar radiation flux density, as follows:

- this collection ranges differently, creating different optical performance efficiency both on the global solar radiation flux density on the yield and optical absorbing material;
- as the difference between the average temperature of the heat collector and the ambient temperature is higher the optical efficiency decreases;
- flat plate collectors are the most sensitive to temperature differences between heating collector and the environment, they can not cope with these differences due to the technology used (a difference of 40, return optic is close to the value 0 for Ig = 200, while vacuum tube solar collector that difference of 40 to 0,5 and the heat pipe takes the value of 0.6);
- they also found that regardless of the collector between the Ig = 800 at Ig = 1000 performance differences are small (close).

Although the yield optical collectors plan is the most sensitive affected by this temperature difference is considered that the benefits of costs and the related conditions of use in winter make this be considered the most accessible if desired heating DHW throughout the year.

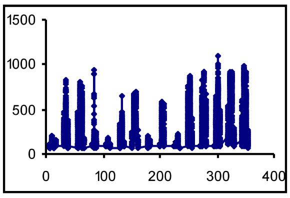

Fig. 4. Global solar radiation intensity during March 1 to 15

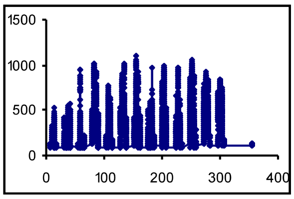

Fig. 5. Global solar radiation intensity during March 16 to 31

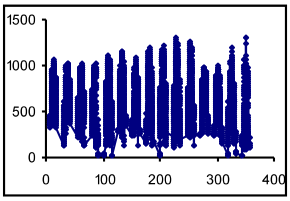

Fig. 6. Global solar radiation intensity during July 1 to 15

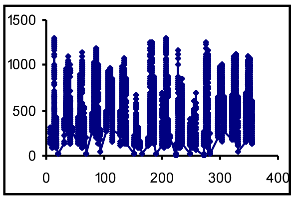

Fig. 7. Global solar radiation intensity during 16 to 31 July

Subsequently, based on data from the database, the global solar radiation intensity for the whole year was studied. For comparison we have the results shown in Figure 4-7 March and July, where on the abscissa we have time (from 0 hour of every day) and we ordinate the global solar radiation intensity (W/m^2). In the month of July (Fig. 6-7), the values are maximum 1309 W/m^2, very good values of global solar radiation intensity compared with March (Fig. 4-5) where the maximum value reaches 1096 W/m^2.

To determine the number and type of solar thermal collectors was performing calculations necessary for determining the thermal load and volume heating boiler knowing that DHW is in accumulation mode. Following the calculation resulted heat load required to heat domestic hot water is presented in Table IV.

TABLE IV. VARIABLE SIZING SOLAR INSTALLATIONS

Elements of calculation	Symbol	Units	Data value
Number of persons	n	no. pers	4
Normal daily consumption per person	C_{zn}	l/pers/day	50
The specific heat of water	c_w	kJ/kgK	4.186
Water density	ρ	kg/m^3	1000
Boiler water temperature	t_b	^{0}C	45
Cold water temperature	t_{ar}	^{0}C	10
Water temperature at the point of consumption	T_{DHW}	^{0}C	32
Time	τ	h	8
Cover factor	f		1.5
The thermal load required for DHM	Q_{DHW}	W/4 pers	1,017.43
Boiler volume	V_b	l	188.57

From the above calculations it required about 190 l boiler to provide enough hot water for 4 people, for 8 hours / day. Considering the particular values of thermal loads Q_{DHW1} unit according to the type of the collector used in the calculations were carried out for dimensioning the number of collectors is shown in Table V.

TABLE V. SIZING NUMBER SOLAR COLLECTORS

Elements of calculation	Units	Type solar collectors					
		A	B	C	D	E	F
Uniform thermal load	W/m^2	200	200	250	250	250	250
Collector area needed	m^2/4 pers	5.09	5.09	4.07	4.07	4.07	4.07
Area capture every collector	m^2/collector	2.32	2.1	2.05	2.56	2	3
Number collectors	number of pieces	2.19	2.42	1.99	1.59	2.03	1.36

To identify the best collector it was conducted an analysis of solar radiation global and heat produced by the three categories of collectors in the study: flat plate collectors, vacuum tube collector and collector heat pipe having in mind that they different technical performance (Table VI) and different rates.

TABLE VI. ANNUAL HEAT TYPE SOLAR COLLECTORS

Solar collector type	Collector aperture area [m^2]	The annual heat [MJ/colector]	Specific annual heat [MJ/m^2]	Price / Collector [Euro]	Annual heat /m^2 collector [MJ/m^2/Euro]
0	1	2	3=2/1	4	5=(2/4)/1
A	2.32	2,014.76	868.43	656.86	1.32
B	2.1	2,590.03	1,233.35	931.13	1.32
C	2.05	3,655.09	1,782.97	1,417.64	1.26
D	2.56	3,248.47	1,268.93	1,593.00	0.80
E	2	3,395.83	1,697.92	2,520.87	0.67
F	3	3,395.83	1,131.94	3,770.82	0.30

It appears that the best price per m^2 collector plane is given by 1.32 MJ/m^2 for 1 Euro spent; although they recorded annual heat is lower compared to other types of collectors. Table VII is expressed monthly value heat produced every type of collector, as measured.

TABLE VII. HEAT AMOUNT MONTHLY BY TYPE SOLAR COLLECTORS

Months of the year	Type solar collectors A	B	C	D	E	F
January	5.77	7.99	14.07	13.12	12.99	12.99
February	10.06	13.41	20.86	18.91	19.33	19.33
March	9.06	11.95	18.63	17.02	17.25	17.25
April	13.71	17.63	25.34	22.70	23.52	23.52
May	20.21	25.59	34.61	30.41	32.20	32.20
June	19.67	25.00	33.63	29.47	31.30	31.30
July	20.01	25.11	32.57	28.36	30.34	30.34
August	23.78	29.50	36.98	32.01	34.48	34.48
September	13.81	17.49	23.73	21.00	22.07	22.07
October	11.86	15.37	21.93	19.50	20.37	20.37
November	7.48	10.25	17.05	15.51	15.79	15.79
December	5.66	7.87	13.34	12.25	12.34	12.34
TOTAL	161.07	207.15	292.75	260.28	271.98	271.98

The analysis of this table is found that the highest values we record collector vacuum tube (B), followed by collectors with thermal tubes (D and E) and collector vacuum tube (C), last topping collector plan (A).

In Figure 8 presents the monthly heat accumulated by each collector (MJ / collector). It appears that the values are different from one month to another, being influenced by the technical features of collectors and solar radiation.

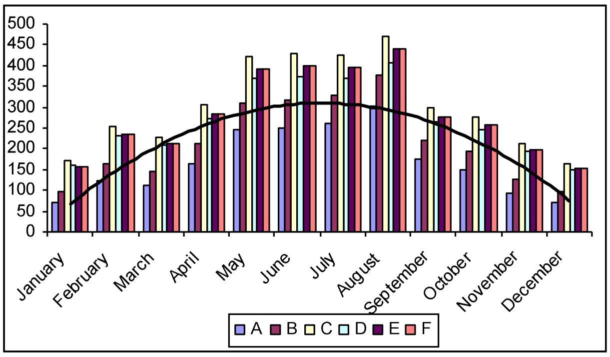

Fig. 8. The annual heat produced by solar collectors

The trend since the beginning of this development is increased, the maximum value recorded in August, before falling thereafter until the end. The lowest values recorded in January and December, natural values taking into account lower temperatures.

TABLE VIII. FIXED COSTS OF SOLAR INSTALLATIONS

No.	Name elements of cost	Units	Quantity	Unit cost including VAT	Value including VAT
1	Bivalent boiler Buderus Logalux SM 300	buc	1	1,213.00	1,213.00
2	Solar pump group Bosch AGS 5	buc	1	431.15	431.15
3	Automation Bosch B-sol 100	buc	1	215	215.00
4	Expansion vessel for hot water Aquasystem VR8/8	buc	1	21	21.00
5	Total fixed costs of solar system (1÷4)				1,880.15

To achieve solar installations with solar thermal collectors for heating DHW were considered fixed costs acquisition of materials, according to results from sizing hot water needs: tank, the solar pumping automation system and the expansion vessel (Table VIII). No installation charges were included considering that they are constant regardless of the type of collectors.

The variable costs necessary to the investment were added to the fixed costs. It is added to the fixed costs the variable costs necessary to the investment that are given by the type and amount of collectors dimensioned according to the amount required for heating the tank. After determining the value of the investment cost was calculated with and without the subsidy from the state to Table IX.

TABLE IX. COST SOLAR SYSTEM

No.	Elements of calculation	A	B	C	D	E	F
1	Quantity solar collectors	2	2	2	2	2	1
2	Variable expenses per unit / type collector	656.86	931.13	1,417.64	1,593.00	2,520.87	3,770.82
3	Total variable costs for solar collectors (3=1x2)	1,313.72	1,862.26	2,835.28	3,186	5,041.74	3,770.82
4	Fixed expenses	1,880.15	1,880.15	1,880.15	1,880.15	1,880.15	1,880.15
5	Total expenditure without any subsidies from the State (5=3+4)	3,193.87	3,742.41	4,715.43	5,066.15	6,921.89	5,650.97
6	State subsidy value*	1,339.25	1,339.25	1,339.25	1,339.25	1,339.25	1,339.25
7	Total expenses subsidized by the State (7=5-6)	1,854.62	2,403.16	3,376.18	3,726.90	5,582.64	4,311.72

* State Subsidy Programme "Green House" was calculated: 6,000 RON: 4.4801 Ron/Euro = 1,339.25 Euro) [32,33]

Duration payback was obtained by dividing total expenses to revenues as a result of using solar energy to heat DHW. Following the calculations made annual solar energy value expressed representing annual revenue due to the use of solar energy, shown in table X.

TABLE X. SOLAR ENERGY PRODUCT AND INVESTMENT RECOVERY PERIOD

No.	Elements of calculation	A	B	C	D	E	F
1	Yearly income derived from solar energy [Euro]	161.07	207.15	292.75	260.28	271.98	271.98
2	Duration payback with State Subsidy [Years]	11.51	11.60	11.53	14.32	20.53	15.85
3	Duration payback without State Subsidy [Years]	19.83	18.07	16.11	19.46	25.45	20.78

Analysing the table above it is found that when using the subsidy from the state through the "Green House" [32, 33], the number of years payback is reduced by about one third.

The way of assigning each solar installation using technical and economic criteria of differentiation is shown in Table XI.

TABLE XI. INVESTMENT PROJECT SELECTION

Type solar heating / differentiation criteria	Selection criteria			
	Economic (investment cost)	Technical (annual energy produced)	Payback time	Total score
DHW solar installation using flate plate collectors Vitosol 100 (A)	1	1	1	3
DHW solar installation using flate plate collectors Buderus 4.0 (B)	2	2	3	7
DHW solar installation using evacuated tube collectors Vitosol 300 SP3 (C)	3	3	2	8
DHW solar installation using evacuated tube collectors Buderus Vaciosol CPC 12 (D)	4	4	4	12
DHW solar installation using heat pipe solar collectors Vitosol 200-T (2 m^2) (E)	6	5	6	17
DHW solar installation using heat pipe solar collectors Vitosol 200-T (3 m^2) (F)	5	5	5	15

For technical and economic evaluation of the best solar heating installations DHW was chosen using a 1-6 scale of importance by assigning number 1 for the best option and number six last possible alternative choices to Table XI.

In this selection they were given equal weight to the importance of differentiating criteria chosen. After calculating the score was achieved studying alternatives for DHW heating installations where the lowest score corresponds to the best investment and the highest score given the less favourable cost-benefit ratio. For each investment project has achieved a ranking which is shown in Table XII:

TABLE XII. RANKING SYSTEM SOLAR INVESTMENT

Type solar heating	Ranking
DHW solar installation using flate plate collectors Vitosol 100 (A)	I
DHW solar installation using flate plate collectors Buderus 4.0 (B)	II
DHW solar installation using evacuated tube collectors Vitosol 300 SP3 (C)	III
DHW solar installation using evacuated tube collectors Buderus Vaciosol CPC 12 (D)	IV
DHW solar installation using heat pipe solar collectors Vitosol 200-T (2 m^2) (E)	VI
DHW solar installation using heat pipe solar collectors Vitosol 200-T (3 m^2) (F)	V

The economically most advantageous project is project 1 because it involves the lowest total cost of installation.

IV. CONCLUSIONS

It appears from the study that when choosing a solar heating installation DHW is important to know the consumer behaviour and the regional characteristics of the location of the site in order to design effective type and amount of required thermal solar collectors.

Under the first objective it was achieved a comparative analysis of the types of collectors could be seen that they carry different performance optical efficiency both on the global solar radiation flux density on the yield and optical absorbing material. Vacuum tube collector „Vitosol 300 SP3" from manufacturer Viessmann has recorded the highest values both in summer and in winter.

Objective 2 was to identify the best choice for collectors and solar installations based on cost-benefit criteria. Under this objective it chose the „Plan collector Vitosol 100" from manufacturer Viessmann because it has sufficiently high thermal efficiency if the solar radiation is intense and acquisition costs are relatively low. As a result of the cost-benefit, the plan collector records also the lowest payback period. Instead it presents the disadvantage that convection losses are relatively high at high temperature differences between the heating and the environment.

The investment is influenced by the amount of energy required to be produced which leads to increased variable expenses reflected in the number of collectors, fixed costs remain constant up to a certain level they changed only if necessary increase storage capacity and storage tank. Total expenditure on investment DHW heating are relatively high but can become accessible when there is subsidization from the state. It appears that the decrease in total expenditure subsidy produce a substantial reduction in overall recovery which results in a shorter period of investment expenses made.

An installation of solar DHW must be adapted to the needs of operation and the period of a year in which it is desired. Although in this study it considered that the period of operation the whole year as a debt characteristics specific area (Cluj-Napoca, Romania) is more effective operation only in the summer or spring - summer - autumn, leading to reduced costs due to downsizing influences and the duration of payback.

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